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Mobile apps for supporting healthy parental food provision: a user-centred approach informing a digital health intervention concept

by

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LIST OF PUBLICATIONS, GRANTS AND CONFERENCE ABSTRACTS

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THESIS SUMMARY

Background

The dietary intake of Australians is suboptimal and a risk factor for overweight, obesity and non-communicable diseases. Intake of discretionary choices are of concern due to their excessive consumption, direct contribution to diet-related disease, and potential to displace healthy foods. Intervening early in life may promote positive dietary habits that persist into adulthood. Dietary interventions targeting early childhood have been of limited effectiveness and tend to target sugar-sweetened beverages and snack foods. Furthermore, interventions have been largely education-based, focusing on children's nutrition needs and parental feeding practices. Enhanced approaches are required that aim to reduce young children's discretionary choice intake across the day and prioritise parent's needs.

Mobile apps offer a practical way to deliver behavioural support for healthy parental food provision in real time. App-based interventions are effective in improving the dietary intake of adults, however are focused on diet monitoring and weight loss and are not suitable in a family context. Furthermore, limited engagement with health apps remains a challenge to their effectiveness. Reviews of commercially available apps shows a similar focus on weight loss in adults and a lack of evidence-based content. There is an opportunity to explore apps for addressing parental food provision behaviour, with the development of evidence and theory informed apps that are engaging, usable and effective in modifying the health behaviour of children and families, being a priority.

Aim

This thesis aimed to develop an evidence-based app concept targeting the parental provision of discretionary choices to young children.

Methods

The program of research included three studies that sought to provide a deeper understanding of the what, when and why of young children's discretionary choice intake, and to determine the feasibility of apps and app features to support parental food provision behaviour. <u>Chapter 2</u> describes a secondary analysis of young Australian children's discretionary choice intake across eating occasions, including an investigation of time and money as determinants of intake; <u>Chapter</u>

3 describes a systematic assessment of commercially available food provision apps; and Chapter 4 describes user-testing of apps with working parents, incorporating mixed methods to assess app utility and acceptability.

Main findings

The secondary analyses demonstrated that discretionary choices consumed by young children at main meals contributed substantially to energy, fat, saturated fat and sodium intake. Foods such as processed meat and fried potato were common and are yet to be targeted in early dietary interventions. Time, money, and parent and child factors explained more variation in discretionary choice intake at main meals than at snacks. The systematic assessment and user-testing of commercial apps found that apps and app features supporting meal planning were feasible solutions for supporting healthy parental food provision in real time. They addressed parents self-identified need for support regarding the time and mental burden of food provision. However the effort involved in using the apps, their lack of relevant evidence-based content and content addressing money as a barrier, limited the utility of apps in their present state.

Conclusion

Findings demonstrate the need to prioritise intervention strategies addressing the time, financial and mental burden of parental food provision, in order to promote a reduction in young children's intake of discretionary choices at main meals. The thesis discussion draws on the existing literature, user perspectives of commercial technology and behaviour change theory to develop an app concept addressing these barriers to healthy food provision. The proposed app concept provides real time behavioural support and skill development regarding healthy and cost-effective meal planning, whilst automating food provision behaviours to reduce their time and mental burden. The integration of such an app-based tool with daily life may address engagement-related challenges that have limited the realisation of the full potential of digital health to date.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and
2. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed by Chelsea Emma Mauch on the 18th of September 2020

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ABBREVIATIONS

ABS	Australian Bureau of Statistics
ADGs	Australian Dietary Guidelines
AGHE	Australian Guide to Healthy Eating
AHS	Australian Health Survey
AUD	Australian dollar
BCTs	Behaviour change techniques
BCTTv1	Behaviour change technique taxonomy version 1
BCW	Behaviour Change Wheel
BMI	Body mass index
CEBQ	Child Eating Behaviour Questionnaire
COM-B	Capability, Opportunity, Motivation – Behaviour system
FFQ	Food frequency questionnaire
FPSQ	Feeding Practices and Structure Questionnaire
IQR	Interquartile range
kJ	Kilojoules
NCDs	Non-communicable diseases
PhD	Doctor of Philosophy
RCT	Randomised controlled trial
SAIDI	South Australian Infants Dietary Intake study
SD	Standard deviation
SE	Standard error
SES	Socioeconomic status
SUS	System Usability Scale
SSBs	Sugar-sweetened beverages
TAFE	Technical and Further Education
UTAUT2	Unified Theory of Acceptance and Use of Technology 2

GLOSSARY

Digital behaviour change intervention	Digitally delivered interventions designed to promote behaviour change. Includes digital technology such as websites, apps, text messaging and wearables. Digital health refers specifically to those interventions designed to target health related behaviour.
Discretionary choices	Foods and beverages that are unnecessary to meet nutrient requirements, and are generally high in saturated fat, added sugars, sodium and/or alcohol, and low in fibre. Also termed unhealthy foods.
Early dietary interventions	Interventions targeting the dietary intake of young children up to but not including 5 years of age.
Food provision	The planning, purchasing and preparation processes associated with providing food to a family or child
Healthy food	Foods and beverages from the five food groups, namely 1 - grain or cereal foods; 2 - vegetables and legumes/beans; 3 - fruit; 4 - dairy and/or alternatives; and 5 - lean meats, poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans.
In-time	When behaviour is occurring.
Mobile app or app	Software application for mobile devices.
Maternal	Mother or mother-figure.
Paternal	Father or father-figure.
Young children	Children aged up to but not including 5 years of age.

CHAPTER 1: INTRODUCTION

1.1 Health and dietary intake

1.1.1 Non-communicable disease, and overweight and obesity

Non-communicable diseases (NCDs) such as cardiovascular disease, cancer and diabetes are responsible for around 70% of global deaths annually (1). Suboptimal nutrition is a major risk factor for these diseases (1). Lifestyle changes and food system shifts due to industrialisation and urbanisation in the latter half of the 20th century have given rise to the modern dietary habits that contribute to NCDs (1, 2). Improving dietary intake is a key strategy toward addressing the risk of NCDs.

Low diet quality and energy intake in excess of expenditure are associated with an increased risk of NCDs. Excess sodium intake is associated with elevated blood pressure (3) and saturated and trans fat with dyslipidaemia (4, 5), both key risk factors for cardiovascular disease. Energy intake in excess of expenditure is associated with overweight and obesity, which in turn contribute to insulin resistance and the development of diabetes (6). Overweight and obesity are also risk factors for other NCDs such as cardiovascular disease and cancer and are therefore key targets of global NCD policy (1).

Overweight and obesity have significant health and economic implications. In 2015, there were an estimated 107.7 million children and 603.7 million adults with obesity worldwide (7). Overweight and obesity were shown to account for 4 million deaths and 120 million disability-adjusted life-years globally during that same year (7). Cardiovascular disease and diabetes were the leading causes of death associated with overweight and obesity (7). Estimates in 2005 showed that the direct cost of overweight and obesity in Australia was $21 billion Australian dollars (AUD) (8). Addressing the dietary causes of overweight, obesity and non-communicable diseases will reduce their impact on health and the economy.

Overweight and obesity starts young and tracks into adulthood. One in five Australian children aged 2 to 4 years are overweight or obese (9), while 14% of 2 to 5-year-old children in the United States (US) have obesity (10). Around 40% of children with obesity maintain the condition into adulthood (11). The tendency to remain overweight or obese into adulthood is strongest in those that are older, more overweight, or have parents with obesity (11). Overweight and obesity is therefore a health problem across the life course.

There are health and psychological consequences associated with overweight and obesity in childhood. Health consequences include cardiovascular disease risk factors such as hypertension, dyslipidemia and atherosclerosis, impaired glucose tolerance and early-onset Type 2 Diabetes Mellitus, metabolic syndrome, obstructive sleep apnoea, gastrointestinal problems such as fatty liver and gallstones, and joint and muscular problems (11). Children with overweight and obesity also experience greater psychological problems than those of a healthy weight (12). Depression, emotional and behavioural disorders, and lower self-esteem are all associated with overweight and obesity in childhood (12). Children with overweight or obesity also experience greater stigma and bullying, which may further exacerbate these psychological problems (12).

The economic implications of overweight and obesity in childhood are substantial. Brown et al. (13) estimated that in the preschool years alone, the direct cost of overweight and obesity to the Australian health care system is $17 million AUD per annum. Compared with children of a healthy weight, those with overweight or obesity cost an additional $367 per child, per year (13). Even in childhood, overweight and obesity has impacts beyond health.

NCDs and associated risk factors such as overweight and obesity, are public health challenges with substantial consequences. Energy intake in excess of expenditure and low dietary quality are key causes of these health problems, and important targets for intervention. The early establishment of overweight and obesity suggests that such unhealthy dietary patterns are established early in life. Thus, dietary interventions in childhood may be important in reducing the health and economic impacts of these public health problems.

1.1.2 Dietary intake in Australia: falling short of dietary guidelines

The Australian Dietary Guidelines (ADGs) offer guidance regarding the optimal diet for wellbeing across all stages of life (14). It is recommended that the following five food groups form the majority of all Australians diets: 1 - grain or cereal foods; 2 - vegetables and legumes/beans; 3 - fruit; 4 - dairy and/or alternatives; and 5 - lean meats, poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans (14). Discretionary choices are those that are unnecessary to meet nutrient requirements, and are generally high in saturated fat, added sugars, sodium and/or alcohol, and low in fibre (14). They include food and beverages such as cakes, biscuits, chocolate, confectionary, pastries, processed meats, sugar-sweetened beverages (SSBs), ice-cream, fried potatoes, crisps and alcohol (14). It is recommended that discretionary choices be consumed only sometimes and in small amounts. In children under 8 years of age it is recommended that they be avoided or allowed in small amounts, particularly where children are small or less active (15).

The dietary intake of Australian adults

Australian's are failing to meet national dietary guidelines (16). The most recent national survey to collect nutrition data from a representative sample of the Australian population was the Australian Health Survey (AHS) 2011-12 (17). The survey included the National Nutrition and Physical Activity Survey and collected 24-hour dietary recalls from more than 12,000 Australians aged from 2 years (17). For Australian adults aged between 19 and 50 years, average intakes of all five food groups were below recommendations (16). Only one in 10 and one in five adults met the recommended daily servings of vegetables and fruits respectively (16, 17). By comparison, intakes of discretionary choices were well in excess of recommendations, contributing just over a third of daily energy intake for adults in every age bracket (16). This intake of discretionary choices contributed to average intakes of added sugars, saturated fat and sodium being above recommended limits (16). The shortfalls of the dietary intake of Australian adults, including low dietary quality and excess energy intake, is contributing to the development of overweight, obesity and early NCD risk factors.

The dietary intake of Australian children

The suboptimal dietary intake patterns of Australian adults are mirrored in children (16). Vegetable intakes are the farthest from meeting recommendations, with 99% of children aged between 2 and 18 years not meeting recommendations (16). AHS data show that children aged 2 to 3 years were most likely to meet recommendations for vegetable intake, with around 50% meeting the recommendation (17). This is partly due to the relatively low number of recommended servings in this age group (2.5 serves) compared to older children (4.5 – 5 serves) (14). In the 4 to 8 year age group, less than 10% of children met the recommendation (17). AHS data do not include children aged less than 2 years, however in a separate sample of children from Queensland and South Australia, only 77% of children aged 12 to 16 months consumed vegetables on the recall day (18).

Fruit intakes tend to be somewhat better, with population-based figures suggesting that intake of this group is the closest to meeting the guidelines of any of the food groups (16). The average intake of 2 to 3 and 4 to 8-year-olds exceeded the minimum daily recommendations (16).

Unfortunately there is a decline in fruit intake with age, with 70% of teenage children aged 14 to 18 years not meeting the guidelines, compared to only 22% of children aged between 2 to 3 years (16). Similar patterns are observed for grain foods and lean meats and alternatives (16). Overall, the mean dietary intake of most age groups across childhood are not aligned with recommendations for the five food groups, with the proportion of children meeting recommendations declining with age.

1.1.3 Discretionary choice intake in Australian children: a target for intervention

Children's intake of discretionary choices is similarly failing to meet recommendations, being in excess of recommendations from early childhood. Guidelines recommend no or minimal intake of discretionary choices for children under the age of 8 years (14). Data from a sample of children across two states of Australia showed that almost all (91%) children aged 12 to 16 months consumed discretionary choices on the day of the recall (18). In a similar Australian sample of mean age 18 months (standard deviation (SD) 1.5 months), discretionary choices contributed 14% of total daily energy intake (19). Nationally representative data show that at 2 to 3 years of age, the proportion of total daily energy intake from discretionary choices consumed by children is around 30% (17). Intake of discretionary choices in excess of recommendations begins early in life, with intake increasing with age.

There is increasing and tracking of discretionary choice intake across childhood. Spence et al. (19) in a longitudinal analysis of data for 467 children from 9 months to 5 years of age showed that discretionary choice intake tracked strongly over time. Discretionary choice intake as a proportion of total daily energy intake exceeds adult intakes by 4 to 8 years, peaking at 40% in the teenage years (16). The high intake of discretionary choices in Australia is established during childhood, suggesting a need to intervene in the first few years of life before intakes reach that of adults.

Discretionary choices as a priority for intervention

Excess intake of discretionary choices in childhood has direct impacts on health (20). Sugar consumption is associated with dental caries, whilst intake of saturated fat is associated with cardiovascular disease risk factors such as dyslipidemia, and salt intake with blood pressure (3-5). Weight management studies in preschoolers have shown that reductions in discretionary choices are more strongly associated with weight-related changes than modifications to healthy food intake, highlighting the key role of discretionary choices in the development of overweight and obesity (21). Discretionary choice intake in childhood therefore directly contributes to the risk of overweight, obesity and NCDs.

Discretionary choice intake also has an indirect impact on health through the displacement of healthy foods. The preferential consumption of discretionary choices over food groups such as fruit, vegetables and wholegrains can have negative effects on laxation, satiety, cholesterol and blood glucose in the short-term (22). The low energy density, and high fibre and antioxidant content of fruit, vegetables and wholegrains has been linked to weight management and disease prevention (14, 23, 24). The direct and indirect impact of discretionary choices on health make them a priority for intervention.

Food and beverage contributors to discretionary choice intake amongst children

Nationally representative data also provides insights into the food and beverages contributing to children's excess intake of discretionary choices. The most commonly consumed discretionary choices across all children aged 2 to 18 years are sweet biscuits, potato crisps and similar savoury snacks, and sugar-sweetened carbonated beverages, all of which are consumed by more than a quarter of children (25). Whereas the largest contributors to energy, saturated fat, sodium and added sugars intake per consumer are somewhat different. The top four contributors to discretionary energy intake per consumer were cereal-based takeaway foods such as pizza, burgers, and spring rolls; sweet baked goods; meat pies and similar savoury pastries; and dishes containing processed meats such as sausages, rissoles or chicken nuggets (25). These same foods were among the top contributors to saturated fat and sodium intake, while SSBs and cakes, muffins and slices were the largest contributors to added sugars intake (25). The most commonly consumed discretionary choices are therefore not necessarily the same as the largest contributors to energy and nutrient intake.

There are differences in the types of discretionary choices consumed across age groups. Sweet biscuits were the most commonly consumed discretionary choice in the younger age groups (25). Almost 40% of 2 to 3-year-olds and 25% of 4 to 8-year-olds consumed sweet biscuits on the day of the recall (25). Whereas 9 to 13-year-olds were more likely to consume potato crisps and similar snacks, and 14 to 18-year-olds more commonly consumed sugar-sweetened carbonated beverages (25). Although sweet biscuits and processed meats were commonly consumed by children across all age groups. This demonstrates that different foods and beverages may need be targeted at different stages across childhood.

Improvements in discretionary choice intake over time

There have been some improvements in the intake of discretionary choices in children over time. A comparison between nationally representative data from 1995 and 2007 showed that energy consumed in the form of discretionary choices reduced significantly across all age groups (26). Children consumed around 600 kilojoules (kJ) less energy from discretionary choices in 2007 compared to 1995, a reduction equivalent to around one serve of discretionary choices according to the ADGs (26). This reduction in discretionary energy intake may be due to changes in the intake of added sugars and SSBs in recent decades.

There has been a reduction in the intake of added sugars and SSBs between 1995 and 2011-12 (27). Australian children's intake of added sugars fell between 24 and 36% from the 1995 to the 2011-12 national nutrition surveys (27). This may be due to a reduction in the intake of sweet biscuits, icecream and iceblocks, and SSBs between the 1995 and 2007 national surveys (26). In 1995 82% of Australian children aged 2 to 16 years consumed SSBs, compared with 70% in 2007 (26). These reductions suggest that public health messaging and dietary interventions targeting sugar and SSB intake have been successful to some extent.

The greatest reduction in SSB intake has been seen in younger children. The proportion of 2 to 3-year-old children consuming SSBs has reduced from 85 to 63% between 1995 and 2007 (26). Whereas the proportion of 9 to 13 and 14 to 16-year-old children consuming SSBs reduced from 80% to 74 and 73% respectively during the same time period. This suggests that the impact of public health messaging and dietary interventions on intake may be greater in the younger age groups.

The focus on SSBs and added sugars in public health messaging and dietary interventions means that other sources of excessive energy intake may have been overlooked (27). While most other discretionary choices have reduced over time, there has been no change in the number of children consuming pizza, and meat pies and other savoury pastries between 1995 and 2007 (26). This indicates that more needs to be done to address discretionary choice intake beyond added sugars and SSBs (27).

1.1.4 Summary: health and dietary intake

Australian adults and children do not consume enough of the five food groups, and consume discretionary choices in excess of recommendations. This suboptimal dietary intake is a key risk factor for overweight, obesity and NCDs. Discretionary choice intake contributes both directly and indirectly to the risk of NCDs through their contribution to energy, added sugars, saturated fat and sodium intake, and their displacement of healthy food intake. Discretionary choice intake should therefore be a priority for intervention.

Discretionary choice intake in excess of recommendations is established early in life and tracks over time. Dietary patterns that track across the life course are established as early as 4 to 8 years of age. Early intervention in childhood may be an effective strategy in the prevention of excess intakes in adulthood. A reduction in the consumption of added sugars and SSBs between 1995 and 2007 demonstrates the positive impact of public health messaging and dietary interventions, particularly amongst younger age groups. However, the lack of change in other discretionary choice intake indicates that more must be done to address this public health issue.

1.2 Early childhood development of food preferences, eating behaviours, and dietary patterns

Section 1.1 highlighted the importance of establishing lifelong dietary habits to support health and wellbeing. Early childhood is a particularly important period in the establishment of dietary habits that track into adulthood. Eating behaviours and food preferences are established during this time, with early food exposure in the home environment playing a key role in shaping the development of these behaviours and preferences. Infants and young children up to school age (i.e. up to but not including 5 years) will henceforth be termed 'young children' (except where specified otherwise).

This section will explore the individual level determinants of young children's dietary intake, which are represented by the inner two circles of the socioecological model pictured in Figure 1.1 below (28). These include child level determinants, such as child physiological and developmental attributes, food preferences and eating behaviours, and parent level determinants, such as parental knowledge, attitudes and behaviour. Child and parent level determinants have been the main targets of recent dietary interventions in early childhood. This section will also introduce the context of the home environment in which these determinants exist. Although external influences at the educational institution, workplace, community and public policy level have been acknowledged in Figure 1.1, these are out of scope of the present work.

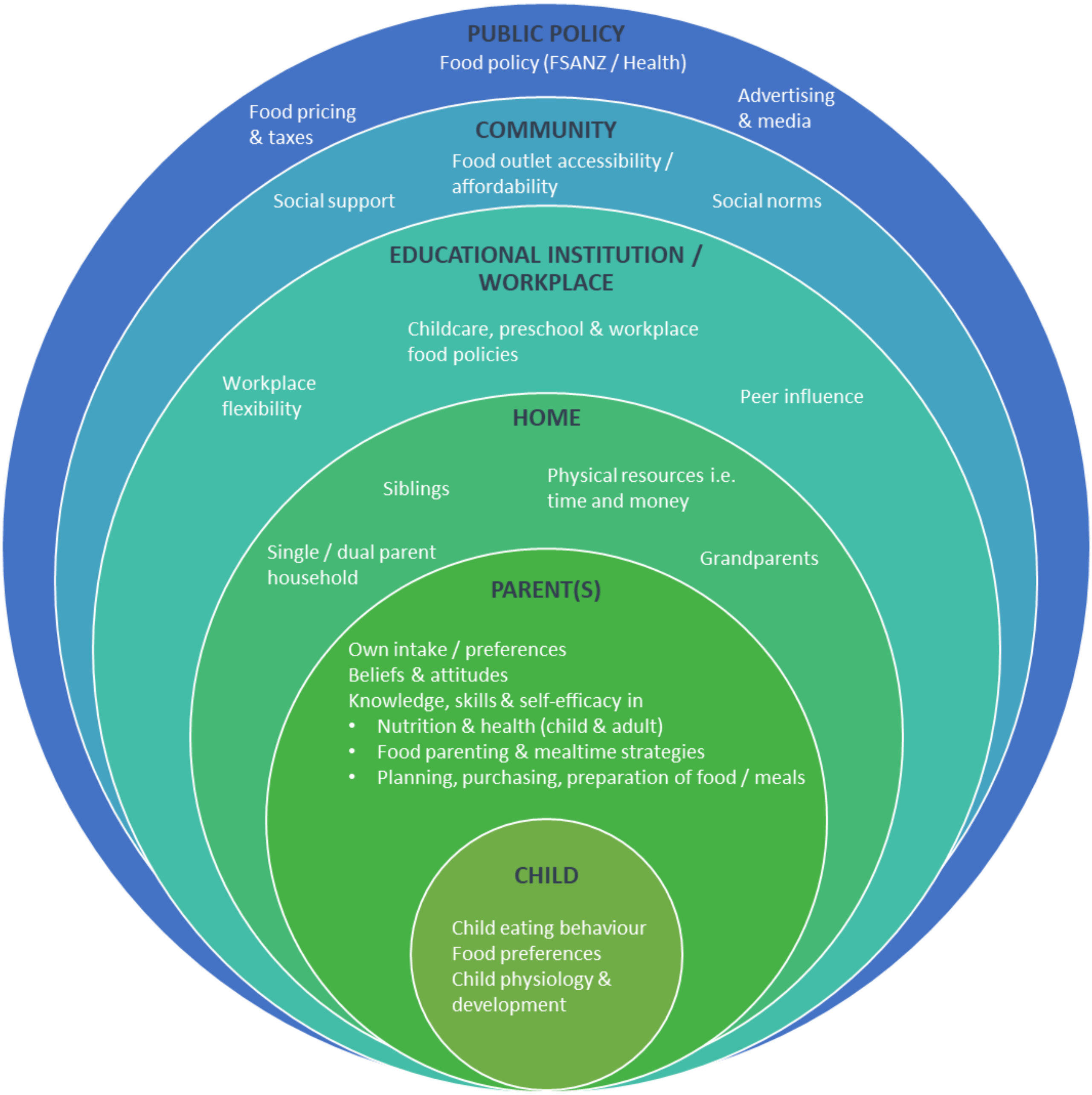


Figure 1-1: A socioecological model describing the key intra- and interpersonal factors influencing child dietary intake, adapted from Bronfenbrenner (28)

1.2.1 Food preference development

Dietary preferences are made up of both learned and innate preferences. The food that infants are exposed to in early life largely shape their preferences and therefore dietary intake in the future. However innate predispositions are not conducive to the development of healthy food preferences in the current food environment.

Early flavour learning

Early flavour learning begins in utero, with flavours such as garlic found to be present in amniotic fluid (29, 30). Learning continues during breastfeeding, where flavours can be tasted via the breastmilk (30). The introduction of solid foods, also termed 'weaning' or 'complementary' foods, then paves the way for the development of food preferences in line with family intake and culture (31). This exposure to the maternal and family diet plays a crucial role in ensuring the acceptance of and preference for the food environment within which infants will grow and develop.

In an ideal world, early exposure would be to healthy foods. This would support the development of healthy food preferences and eating habits into the future. Foods introduced to infants during the first year of life are typically geared toward healthy foods, such as plain vegetables and fruits (32). However as children age, a rapid transition towards less healthy dietary habits is observed as they begin to be exposed to the dietary habits of their family (31).

As previously discussed, population-based data demonstrate that adults and children alike are consuming inadequate healthy foods and excess discretionary choices. Infants are increasingly exposed to these dietary patterns in their parents and siblings over time, thus mirroring their intake by 4 to 8 years. Data from the Feeding Infants and Toddlers Study (FITS) in the United States demonstrated that infants aged 9 to 11 months consumed a mean of 25% of their energy intake in the form of table foods (32). Table foods were defined as foods other than infant foods and breastmilk or formula. By the time they reached 19 to 24 months, this had increased to 63% (32). With this was a concurrent increase in the proportion of children consuming discretionary choices such as desserts, confectionary, SSBs, chips and other salty snacks (32).

An Australian study also demonstrated this same transition toward the dietary patterns of older children and adults. The number of discretionary choices being consumed by at least 10% of a sample of toddlers almost doubled between 14 and 24 months, with sweet foods being particularly favoured (33). This early and increasing exposure to discretionary choices poses a threat to the development of healthy food preferences (31).

Innate predispositions and tendencies

Children's innate predispositions regarding flavour challenge the development of healthy food preferences (34). Infants are born with a tendency to prefer sweet and salty flavours (34). This is thought to be an evolutionary response promoting the intake of foods which provided important nutrients in an environment where these nutrients were scarce (34). In the current food environment which is saturated with foods high in added sugars and salt, this predisposition only serves to encourage the intake of discretionary choices over healthy foods.

Young children are also innately food neophobic, that is they are fearful or tentative toward new or novel foods (31, 35). When new foods are introduced that do not satisfy their innate preference for sweet and salt, they may be rejected or refused. This response is developmentally normal and throughout evolution was important in preventing the consumption of food that was harmful, for example poisonous or spoilt foods (35, 36). This food neophobia can lead to the rejection of foods that are particularly sour or bitter, with these flavours being overrepresented in plant-based foods such as vegetables (34, 37).

Food neophobia has been shown to impact the development of healthy dietary intake. An Australian study found that neophobia, measured by the 6-item Child Food Neophobia Scale (38), was associated with lower fruit and vegetable variety and greater discretionary choices intake (measured as a proportion of total energy intake) in 24-month-old children (39). Furthermore, Cooke et al. (40) found that neophobia in 2 to 6-year-olds, measured by the same scale, was associated with a lower frequency of fruit and vegetable consumption. Although food neophobia cannot be prevented, early experience with food can allow children to overcome this predisposition.

Repeated early exposure to flavour and texture

Exposure to a variety of flavours, particularly the more challenging flavours such as bitter and sour, can promote the acceptance of other new foods (37, 41-43). However exposure to foods from one food group, such as fruit, does not necessarily promote acceptance of foods from another group, such as vegetables (44). A varied diet in terms of flavour and food group is therefore important in promoting overall acceptance of healthy foods in young children.

Repeated early exposure to foods may also be important in improving children's acceptance of novel foods (44). Up to 10 tastes of a single vegetable may be required to promote acceptance, although less exposure may be required for foods with more preferable flavour qualities such as fruits (43, 44). Greater exposure is needed to promote acceptance in older children, with preschool aged children needing up to 15 exposures for acceptance (45). However mothers tend to only offer infants new foods less than 5 times, an inadequate number to promote healthy preference development (43).

The development of a preference for healthy foods is not just associated with flavour, but also with the texture. Healthier food tends to be associated with more challenging textural properties. For example, raw fruit and vegetables, wholegrain bread and pure cuts of meat have tougher, more challenging textures than fried potato, white bread, and processed meats. Repeated exposure to textured foods before 10 months of age has been shown to improve acceptance of these foods and lead to a greater consumption of fruit and vegetables in later childhood (44, 46). Therefore, encouraging early exposure to textured food may also be supportive of healthy food preference development.

Summary: food preference development

The development of healthy food preferences is characterised by the early, frequent and increasing exposure of young children to a variety of flavours and textures. Healthier foods and beverages tend to have properties more conducive to rejection such as a bitter or sour flavour, or tougher texture. Whereas the higher sugar and salt content of discretionary choices make them more palatable and therefore acceptable to young children. Furthermore, as children transition toward the family diet their exposure to discretionary choices increases, only bolstering their preference for these less healthy foods and beverages. This highlights the need for early and frequent exposure to a wide variety of healthy foods, with limited exposure to discretionary choices in order to best support healthy food preference development and intake into the future.

1.2.2 Child eating behaviour and parental feeding practices

Child eating behaviour traits appearing during toddlerhood can also pose challenges to the development of healthy food preferences. Parental response to child eating behaviour can act as a precursor or response to these behaviours, and therefore also have a role to play in healthy food preference development and dietary intake.

The development of independence and child eating behaviours

The transition to toddlerhood marks the development of independence with food and eating. Toddlers begin exploring food on their own terms, exerting some control over what they consume and what they do not. This behaviour is developmentally appropriate, occurring at a time when they are developing a sense of self and desire control over their own actions (47). These behavioural traits related to food and eating that emerge during toddlerhood have been termed child eating behaviours and can vary from child to child depending upon genetics, child development and temperament (37, 41, 48). Some of these child eating behaviours are thought to be associated with dietary intake (40, 49) and weight (37).

Child eating behaviour traits such as food fussiness and contrasting behaviours such as eating in the absence of hunger, appear to be associated with both dietary intake and weight status (50, 51). It has been demonstrated that *enjoyment of food*, a subscale of the Child Eating Behaviour Questionnaire (CEBQ) by Wardle et al. (51), is associated with greater frequency of vegetable consumption in 2 to 6-year-olds (40). Similarly, a study from the Netherlands using the Dutch Eating Behaviour Questionnaire found that external eating and emotional eating traits such as eating in the absence of hunger were associated with sweet food consumption (49). The eating behaviour traits of children therefore play a role in their dietary intake.

To further add complexity to this challenging stage of development, the growth rate in the second year of life is slower than during the first. Average weight gain in the second year of life is similar to that of the first three months of life (52). Coupled with emerging child eating behaviour traits, reduced energy needs and a smaller appetite can therefore result in the rejection and refusal of food. This food refusal can be the catalyst to a cycle of parental feeding practices that only exacerbate the problem, such as pressuring to eat, rewarding for eating and ceasing to offer refused foods.

Parental feeding practices

The emergence of child eating behaviour traits in the second year of life may present significant challenges to parents' ability to maintain positive and healthy food exposure. Parental feeding practices describe those strategies, rules and limits that parents use to manage food and feeding in their children. These strategies are thought to be associated with the development of healthy child eating behaviours (53). Parental feeding practices may occur at the table, with encouragement or pressure to eat. They may also occur at the broader household or environmental level, for example with the restriction of food entering the household (54, 55).

Parental feeding practices thought to support the development of healthy child eating behaviours are those that are responsive to a child's cues, promote self-regulation and provide limits and structure around the food environment (53). Jansen et al. (53) found that the non-responsive feeding practices in their newly validated Feeding Practices and Structure Questionnaire were positively associated with the CEBQ measures *fussiness*, *food responsiveness*, *emotional eating* and *desire to drink* (53). Whereas structure-related measures were associated with greater *enjoyment of food* and lower levels of *emotional eating*. Being that some of these child eating behaviours have been associated with child dietary intake, parental feeding practices may influence the development of healthy eating habits. Although the association may not be causal, with parental feeding practices also occurring in response to child eating behaviour.

Parental feeding practices have been shown to have a bi-directional relationship with child eating behaviours, with the use of non-responsive feeding practices occurring in response to children's eating behaviour and weight status (56, 57). A longitudinal study showed that fussy eating in 3-year-olds was associated with higher levels of parental pressure to eat one year later (56). Furthermore, a mixed methods review found that maternal feeding practices such as restriction and pressure to eat tended to be in response to child weight status (57). Heavier children tended to experience less pressure to eat and more restriction. The study demonstrated that the relationship from child eating behaviour to parental feeding practice was stronger than the reverse. This perpetuating cycle of problematic child eating behaviours and non-responsive parental feeding practices can challenge the establishment of healthy dietary intake.

Summary: child eating behaviour and parental feeding practices

Child eating behaviours that emerge in toddlerhood are largely the result of genetics, child development and temperament. Various child eating behaviours have been associated with both dietary intake and weight. Parental feeding practices occurring as a response to and catalyst for child eating behaviour are also important determinants of intake during this stage of child development. Positive and responsive parental feeding practices combined with healthy food exposure may promote child eating behaviour that supports healthy dietary intake.

1.2.3 Parental food provision and the home food environment

Parental feeding practices and child eating behaviour are ultimately set amongst the broader context of the home food environment. The home food environment includes the resources, structures and behaviours responsible for the food provided to and consumed by children (58). Parents are largely responsible for curating the home food environment, particularly during early childhood when children are almost entirely dependent upon their parents (58). In shaping the home food environment, parents create opportunity for the development of healthy food preferences and thus intake in their children.

Parental knowledge and attitudes

Parent's own nutrition knowledge and attitudes have been shown to influence child dietary intake (59-61), particularly in young children. Low dietary adequacy and high intake of discretionary choices in preschool aged children have been associated with lower maternal nutrition knowledge and health related attitudes in cross-sectional studies (61). The association between maternal nutrition knowledge and child dietary intake appears to weaken with child age (62). Furthermore, general nutrition knowledge has been shown to be a more important predictor of preschool aged children's intake of discretionary choices, than their intake of healthy foods (63). These studies demonstrate the important influence of parental nutrition knowledge on the discretionary choice intake of children in early life.

Parental dietary intake and modelling

Parent's own dietary intake has also been linked with child dietary intake in several systematic reviews (64-67). Parental intake of vegetables and fruit (64-67), and fat and soft drinks (65) have been shown to predict child dietary intake. Furthermore, parental intake is one of the only correlates demonstrating consistency between childhood and adolescence (64). Parental dietary intake is therefore an important correlate of child intake, across all age groups.

Parental modelling of intake also appears to be important (64-66), with experiments in young children demonstrating that they accept and consume more when adults are modelling consumption of the same food (68). Despite its importance, parental modelling has been inconsistently conceptualized in research, with studies frequently using parental intake as a proxy (66). Where it may be distinct from intake is in the modelling of eating behaviour and attitudes (66). Frazier et al. (69) presented preschoolers with a series of images of adults consuming an unidentified snack, and asked them to choose which snack they would like to eat the most. They found that preschoolers consistently chose the snack associated with images displaying positive facial expressions (69). This work demonstrates that it is not just parent role modelling of consumption itself, but their behaviour and attitude toward food consumption that is important in shaping children's food acceptance and intake. Although, it could be argued that parent intake and role modelling are simply proxies for the food that is available within home.

Home food availability and accessibility

Home food availability describes the food that is available within a household. It has been shown to be positively associated with children's vegetable and fruit intake (64-67, 70). Food accessibility, referring to the direct access children have to food, is a similarly important predictor of fruit and vegetable intake in children (64-67). Accessibility can operate independently to food availability in influencing dietary quality, such that food may be available within a household but not necessarily accessible. For example, vegetables may be available in a household but not in a form or location that is accessible to young children. Having healthy food available and accessible to young children may encourage intake, while the reverse may be true for discretionary choices.

Reducing discretionary choice availability at the household level or restricting young children's access to discretionary choices has been shown to promote a reduction in intake. In their study of mothers of 2 to 7-year-old children, Boots et al. (55) found that a higher intake of seven discretionary foods and beverages was predicted by a lower level of 'covert' restriction. Covert parental feeding practices are those that restrict the availability of and access to food without a child's knowledge and include strategies such as avoiding purchasing discretionary choices at the supermarket or storing them out of sight. Covert restriction is more effective at limiting intake of discretionary choices than overt restriction (54). In fact overt restriction, which includes restriction of the quantity and type of food children consume during interactions between parent and child, may even promote greater intake of discretionary choices in the long term (54). This suggests that forms of restriction that modify the home food environment may be the best strategies for reducing child exposure to and intake of discretionary choices.

The shared home food environment

The relationship between parent's own knowledge and intake, and their child's intake may be due to the shared food environment of the household. Campbell et al. (59) found that maternal nutrition knowledge was a weak predictor of child intake of a number of healthy and discretionary choices, whereas home food availability was strongly associated with all dietary measures and mediated the relationship with maternal knowledge. Similarly, a mediation analysis of a randomised controlled trial (RCT) targeting the home food environment of preschool aged children provides further evidence of the importance of this shared food environment on children's intake of discretionary choices (71). They found that a combined measure of the availability and accessibility of discretionary food in the home was a key mediator of the relationship between the intervention condition and children's intake of discretionary choices (71). These studies demonstrate that the main parental determinants of child dietary intake may be in fact be markers of the shared food environment in which children learn and develop. This highlights the importance of considering broader factors that may impact on parental curation of the home food environment.

External influences on the shared home food environment

Life stage plays a key role in determining the home food environment in which children grow and develop. Returning to the socioecological model of children's dietary intake, parents' knowledge, attitudes and behaviour with regards to food are set amongst the opportunity that the household environment affords them (see Figure 1-1). The household environment in which parents exist changes over the course of a lifetime, with employment, relationships, residence, social support and family structure varying with life stage.

Early parenthood in particular is a time of significant change, with the birth of a child disrupting the family and household environment. Changes in employment status, the division of household labour and caring responsibilities can impact upon the availability of resources such as time and income. These changes can impact upon parents' ability to maintain a healthy home food environment amongst competing demands and priorities. Although these factors may be outside the parents' locus of control, they nonetheless play a key role in influencing parental food-related behaviour and therefore the home food environment.

Summary: parental food provision and the home food environment

Maintaining and curating the home food environment is a key responsibility borne by parents, and shapes children's exposure to and experience with healthy food. Parents own knowledge, attitudes and behaviours developed over the course of their own lifetime are important determinants of the food environment in which children grow, learn and develop. However external influences on the household environment occurring as a result of life stage and transitions may compromise parents' ability to maintain a healthy home food environment.

1.2.4 Summary: early childhood development of food preferences, eating behaviours, and dietary patterns

The early years of life are critical to the formation of healthy food preferences. These early years encompass child learning and developmental stages that ultimately shape future dietary behaviour and intake. Children's innate predisposition towards sweet and salty food, and rejection of flavours and textures synonymous with healthy food make it difficult to establish healthy food preferences in early life. Child eating behaviours such as food refusal and emotional eating may further threaten the success of healthy food preference development. Positive and responsive parental feeding practices may help to overcome these developmental and behavioural challenges. Yet these must be set amongst a healthy home food environment in order to promote healthy food intake and discourage discretionary choice intake.

Early and frequent exposure to healthy food and beverages, and limited exposure to discretionary choices can support the development of healthy food preferences and patterns that track into adulthood. Parents' largely control and curate the home food environment in which children learn and develop these food preferences and dietary patterns. Parents own intake and behaviours established over their own lifetime largely predict the foods that are made available in the household. This shared food environment thus influences the development of children's dietary habits. External influences on the home food environment that are outside of parents' locus of control may be particularly relevant during early parenthood. Parents as agents of change in the development of healthy dietary habits in early childhood should be the priority of early dietary interventions.

1.3 Dietary interventions addressing discretionary choice intake in early childhood: a review of the evidence

Section 1.2 introduced the individual child and parent level factors set amongst the home environment which influence the establishment of healthy food preferences and dietary behaviour in young children. It was demonstrated that parents play a pivotal role in the establishment of the early dietary habits of their children and thus should be targeted as agents of change in intervention efforts to address the excess intake of discretionary choices in young children. This section will therefore explore the published literature regarding dietary interventions targeting parents of young children, with a focus on discretionary choices as intervention targets and outcomes. Interventions targeting the intake of young children will henceforth be termed early dietary interventions.

Systematic reviews of interventions addressing discretionary choice intake in young children under the age of 5 years remain sparse. Reviews have generally focused on preschool or school-aged children, specific styles of interventions, or specific discretionary choice targets. Two recent reviews synthesised evidence regarding interventions targeting children aged from 3 to 8 years (72, 73). The most recent review (73) spans the largest age range (3 to 8 years, compared with 4 to 8 years) and includes a review of the outcomes of early dietary interventions.

Johnson et al. (73) identified 18 papers describing 17 interventions with discretionary choices as one of multiple dietary targets (73). Discretionary choice targets and outcome measures varied from discrete measures such as SSBs to measures of total or overall intake. Interventions had a small effect on discretionary choice intake, with Cohen's d mostly ranging from -0.2 and -0.4 (73). The review concluded that more targeted interventions specifically focusing on reducing discretionary choice intake are required. It was suggested that the focus on SSBs as a target and outcome measure limits our understanding of intervention effect on a wide range of discretionary choices and therefore should be addressed in future interventions (73).

The only review identified that specifically considered interventions targeting the discretionary choice intake of young children was focused on SSB intake outcomes only (74). The review of studies targeting the SSB intake of young children under 5 years of age identified 27 studies conducted in high income countries published from 2000 to 2017 (74). Nine of the studies included children with a mean age at or below 2 years. Seven of these nine studies targeted dietary intake, with three also targeting other obesity-related behaviours such as physical activity and screen use (74). Two studies were focused exclusively on addressing oral hygiene related behaviours, including the intake of SSBs. Interventions were all education-based targeting primarily mothers. Five incorporated individual (face-to-face) education or counselling, two group education, and one each incorporated written materials only or a combination of online material and individual counselling (74).

Five of the nine studies targeting children aged up to 2 years were considered successful in reducing the intake of SSBs at one or more follow-up time points, only one of which was long-term (74). The studies showing positive intervention outcomes regarding SSB intake represented the individual education-based studies only, two being focused on oral hygiene (74). Comparatively, 12 of the remaining 18 studies including children with a mean age between 2 and 5 years were considered successful. The paucity of evidence and mixed success of studies in the younger age group may be because of the discretionary target of the review. SSB intake tends to be greater with age and thus may have a greater propensity to change in older age groups. Furthermore, juice intake tends to be more of a concern in the early years and yet is not generally grouped or targeted with SSBs (75, 76).

Matvienko-Sikar et al. (77) conducted a systematic review of healthcare professional-delivered early interventions targeting feeding practices and dietary intake in children up to 2 years of age. Three of the 10 trials reviewed reported on discretionary choice outcomes. They found limited evidence regarding the impact of early interventions on the intake of discretionary beverages, with the only trial reporting discretionary food outcomes not having an effect on intake (77). Other reviews in this space have tended to focus on the impact of interventions on weight-related outcomes of early dietary interventions, or on healthy rather than discretionary choice intake (42, 78, 79).

There is a paucity of reviews investigating the efficacy of early dietary interventions to reduce discretionary choice intake of young children. The limited reviews available have a narrow discretionary choice focus, such as on SSB intake only, or are limited to certain types of interventions such as those delivered by healthcare professionals. Therefore, the following section will systematically review the published literature investigating the effect of interventions to reduce discretionary food and/or beverage intake in young children.

1.3.1 Methods

Publications were identified through a 2019 search of Ovid Medline. Search terms included those relating to the target population (i.e. infant, child(ren), parent, mother, father) and target behaviour (i.e. diet, nutrition, discretionary, healthy, unhealthy, intake). Cross-referencing of reference lists of the aforementioned reviews took place, while reference lists of included studies were also checked. The search was limited to literature published within the last 10 years (between 2009 and 2019), as the vast majority of early dietary interventions identified in the aforementioned reviews and similar review have been published in the last decade (42, 73, 74). Included publications were also limited to those published in English.

Studies were included in the present review that targeted the dietary intake of children up to 3 years of age at baseline. This age group was selected in order to capture literature not covered by prior reviews (73). Studies were included where the intervention started from the antenatal period or beyond; targeted parents as agents of change; reported on a measure of child discretionary choice intake or a marker of intake as primary or secondary outcomes; and were controlled trials and not pilot studies. Studies were excluded where they addressed dietary intake from an oral hygiene perspective (i.e. targeting SSBs and/or 'cariogenic' foods for reducing the risk of dental caries) to prevent overlap with the prior review which included these studies (74).

Data were extracted regarding the study sample, design and characteristics, intervention and control condition, intervention setting, discretionary choice outcome/s and key results. Where necessary, study protocols were used to cross-check and complete data extraction. Cohen's d effect sizes were calculated for those studies with adequate reporting of results and sample sizes. Study quality was assessed using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies (80). The tool assesses quality on six domains including selection bias, study design, confounders, blinding, data collection method and withdrawals and drop-outs, with studies given a rating of weak, moderate or strong (80). Studies with a weak rating on two or more domains were considered to be of weak study quality, while studies with no or one weak domain ratings were considered to be of strong or moderate quality respectively (80).

1.3.2 Results

Fourteen publications describing 12 independent interventions were identified that met the inclusion criteria (81-94). A summary of these studies is provided in Table 1-1, with more comprehensive data tables included in Appendix 1. Four studies were conducted in Australia (82, 87, 90, 93, 94), one in New Zealand (84) and three in Scandinavia (81, 83, 85), with the remaining studies from Europe (88, 91, 92) and the Americas (86, 89). All studies were randomised controlled trials, four of which used cluster-based randomisation (82, 83, 89, 91). Sample sizes were large, with eight studies including 500 or more participants (82-87, 91, 93, 94). Studies were mostly assessed as weak (81, 84, 85, 89, 90) and moderate (82, 83, 87, 91) quality, with key sources of bias including participant selection, and a lack of blinding in outcome assessors.

Table 1-1: Summary of early interventions addressing discretionary choice intake in children aged up to 3 years

Study	Intervention name	Country	Design	Child age at BL (M±SD/range)	Int type	Parental target	Measurement tool	Discretionary choice outcomes[a]			Quality score[c]
								Food	Bev	Comb[b]	
Beinert et al, 2017 (81)	N/A	NOR	RCT	4 – 6 mo	G	Parents	FFQ		Ø		W
Campbell et al, 2013 (82)	Infant Feeding, Activity & Nutrition Trial (INFANT)	AUS	CRCT	3.9±1.6 mo	G	Mother	2-3 x 24hr recalls	**+ MI, PI**	**+ MI**		M
Doring et al, 2016 (83)	PRIMROSE	SWE	CRCT	6.7±1.1 mo	I, T, G	Mother	FFQ	**+ PI**	**+ PI**	**+ PI**	M
Fangupo et al, 2015 (84)	Prevention of Overweight in Infancy (POI)	NZ	RCT	NR (antenatal)	I, G	Mother	FFQ	Ø	Ø	Ø	W
Helle et al, 2019 (85)	Early Food for Future Health	NOR	RCT	5.5 mo	O	Mother	FFQ			Ø	W
Louzada et al, 2012 (86)	N/A	BRA	RCT	NR (birth)	I	Mother	1-2 x 24hr recalls	**+ PI, 2-3y FU**		**+ PI, 2-3y FU**	S
Magarey et al, 2016 (87)	NOURISH	AUS	RCT	4.3±1.0 mo	G	Mother	1 x 24hr recall	Ø	Ø		M
Schroeder et al, 2015 (89)	N/A	US	CRCT	NR (birth)	I	Parents	FFQ		**+ PI**		W
Skouteris et al, 2014 (90)	N/A	AUS	RCT	2.7±0.6 y	G	Parents	FFQ	**+ PI**	Ø		W
van Griecken et al, 2017 (91)	E-Health4Uth	NL	CRCT	~14 mo	O, I	Mother	Q item		Ø		M
Watt et al, 2009 (92); Scheiwe et al, 2010 (88)	Infant Feeding Peer Support Trial	UK	RCT	~10 w	I	Mother	Q item		**+ 4-5y FU**		S
Wen et al, 2012 (93); Wen et al, 2015 (94)	Healthy Beginnings Trial (HBT)	AUS	RCT	NR (antenatal)	I	Mother	FFQ	Ø	Ø		S

a Bold indicates measures demonstrating a significant between group difference
b Combined target – including both discretionary food and beverages
c Assessed using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies (80): W = weak; M = moderate; S = strong
AUS = Australia; BRA = Brazil; NL = Netherlands; NOR = Norway; NZ = New Zealand; SWE = Sweden; UK = United Kingdom; US = United States
CRCT = cluster randomised controlled trial; RCT = randomised controlled trial
mo = months; NR = not reported; w = weeks; y = years
G = group; I = individual (face-to-face counselling/sessions); O = online; T = telephone
FFQ = food frequency questionnaire; Q = questionnaire
+ = between group differences in favour of intervention (i.e. lower intake of discretionary choices in intervention group); Ø = no between group differences at PI, MI or FU
FU = follow-up; MI = mid-intervention; PI = post-intervention

Intervention types

Intervention duration varied widely, with the shortest intervention lasting two consecutive days (81), and the longest spanning almost three years (83). Interventions generally started very early in life with four beginning antenatally or around the birth of the child (84, 86, 89, 93, 94), six during infancy, between approximately 3 and 7 months of age (81-83, 85, 87, 88, 92), and two in toddlerhood at around 14 months and 2.7 years of age (90, 91). Mothers were primarily the target of intervention content (82-88, 91-94). Only one study incorporated the children directly in a component of the intervention, this being the study that included the oldest children (90). Interventions were mainly focused on overweight and obesity prevention (82-84, 87, 89-91, 93, 94), with a strong focus on infant and child feeding behaviour and nutrition, or parental feeding practices such as responsive feeding, and mealtime structure. Seven studies addressed other weight-related targets such as physical activity and screen time in addition to dietary targets (82-84, 89-91, 93, 94). Interventions were mostly education-based, delivering information to participants via face-to-face or telephone counselling sessions (84, 86, 88, 89, 92-94), groups (81-84, 87, 90), or online (85, 91). One study uniquely focused on parental food provision processes such as food preparation, spending much of the two intervention days delivering skills training in the form of cooking classes regarding the preparation of infant food at different eating occasions (e.g. breakfast and dinner) (81). Other than this study, the remaining studies were relatively homogenous in design, with some variation in content and method of delivery.

Outcome measures

With respect to outcomes, only three studies (82, 86, 87) used at least one 24-hour dietary recall to assess discretionary choice outcomes, with the remainder of the sample using food frequency questionnaires (FFQ) or single questionnaire items. Discretionary choice outcomes were varied, with seven studies including discretionary food outcomes (82-84, 86, 87, 90, 93, 94), 10 including discretionary beverage outcomes (81-84, 87-94) and four reporting on a combined measure of discretionary food and beverage intake (83-86). Food targets included sweet and salty snacks (74, 82, 93, 94), fried potato (83, 84, 93, 94), confectionary (93, 94), lipid dense foods (86) and a broader measure of all discretionary foods consumed (87). Beverage targets included seven different definitions, with some including juice as a sweet beverage, and some including sweetened milks. Combined terms in two cases encompassed all discretionary choice consumption (83, 85), while one combined sweet foods and beverages as ‘sugar dense foods’ (86). In 10 of the 12 studies, fruit and vegetable intake was also under investigation (81-88, 90, 92-94).

Eight studies included follow-up beyond post-intervention, with the longest follow-up period being 6 years post-intervention (81, 84, 86-88, 90-94).

Intervention effect on discretionary choice outcomes

Six of the 12 studies reported between-group differences post-intervention in favour of the intervention group (82, 83, 86, 89, 90). A further two found group differences at long-term follow-up in favour of the intervention group (86, 88, 92). There were no clear commonalities between studies reporting positive intervention findings, and findings were across a variety of food, beverage and combined discretionary choice targets. Cohen's d effect sizes were mostly of small to moderate magnitude (range 0.13 - 0.46, see Appendix 1).

Two studies reported moderate effect sizes of around 0.4 for some of their discretionary choice outcomes (86, 90). Louzada et al. (86) found that their intervention providing new mothers with nine x 40 minute counselling sessions regarding infant feeding, parental feeding practices and child nutrition, compared with a usual care control, resulted in a significantly lower intake of lipid-dense foods (kJ/day mean (SD) for boys: I = 95 (201), C = 196 (375), p<0.05, Cohen's d = 0.34; and girls: PI: I = 52 (152), C = 181 (369), p<0.05, Cohen's d = 0.46) and sugar-dense foods (including SSBs) (kJ/day mean (SD) for girls only: PI: I = 52 (152), C = 181 (367), p<0.05, Cohen's d 0.30). Changes were sustained at follow-up 2 to 3 years later in boys only (kJ/day mean (SD) of lipid dense foods: I = 605 (770), C = 818 (923), p<0.05 and sugar dense foods: I = 52 (152), C = 181 (367), p<0.05, Cohen's d = 0.40). Skouteris et al. (90), a community based intervention comprising of 10 weekly education and skills based groups, found a significant post-intervention effect on high energy snack foods of a similar magnitude favouring the intervention group (mean(SD) serves yesterday; I = 0.9 (0.8), C = 1.3 (1.4), p=0.02, Cohen's d = 0.35).

Only one other intervention reported a longer-term intervention effect on discretionary choice intake. Watt et al. (92) and Scheiwe et al. (88) found that their intervention incorporating nine monthly home visits from trained local mothers resulted in a long-term intervention effect on the number of children who, at 4 to 5 years of age, had never consumed 'squash' (a SSB, also termed cordial) (n(%) I = 40 (73), C = 19 (41), p=0.001).

In terms of post-intervention differences, one study found that their clinic-based intervention resulted in group differences in favour of the intervention children for serves of various discretionary beverages. Although the study was poorly reported, with the method of randomisation not being reported, the outcome measures unclear and only the p-values reported, making the results difficult to interpret (89). Campbell et al. (82), in their Dietitian-delivered group-based intervention addressing infant and child nutrition, family meals and parental modelling found that intake of sweet snacks and discretionary beverages, measured by 24-hour recall, was lower in the intervention group at mid-intervention and post-intervention (for sweet snacks only), compared with usual care controls (intake g/day mean (SD) of sweet snacks: mid-intervention I = 11.0 (14.1), C = 14.7 (15.7), p=0.01 & post-intervention I = 11.0 (14.1), C = 14.7 (15.7), p=0.01; and discretionary beverages mid-intervention: I = 2.1 (13.2), C = 6.6 (26.8), p=0.008). Döring et al. (83) incorporated motivational interviewing with messages regarding nutrition for both infants/children and parents where necessary. The intervention had an inverse effect on the frequency of consumption of French fries (times/month mean (standard error (SE)): I = 1.5 (0.07), C = 1.8 (0.07), p<0.001), SSBs (times/week mean (SE): I = 2.2 (0.18), C = 2.7 (0.15), p=0.04), and overall discretionary calories (times/week mean (SE): I = 5.3 (0.17), C = 5.9 (0.12), p=0.01) whilst additionally impacting positively upon maternal intake, although effect sizes were small (83). The intervention was also carried out over the longest period of all the studies, being conducted over 39-months starting from infant age 9 months (83).

Conversely, three obesity prevention trials conducted in Australia (n=2) and New Zealand (n=1) reported no significant group differences post-intervention or at long-term follow-up, despite their strong infant and child nutrition focus (84, 87, 93, 94). Similarly, neither interventions incorporating an online component were successful in modifying children's discretionary choice intake (85, 91), nor was the only practical, skills based intervention (81).

1.3.3 Discussion

Outcomes of these early interventions focusing predominately on obesity prevention were mixed, with half demonstrating between-group differences in favour of the intervention at post-intervention or follow-up. This finding is consistent with reviews of interventions in preschool and school-aged children (73) and those targeting SSBs (74). Also consistent with past reviews was the heterogeneity of outcome measures. Although some discretionary choice targets were highly specific such as squash and sweetened tea, others were broad, such as 'discretionary food' or 'discretionary calories'. This raises some issues regarding the interpretation of the findings. For example, even where the effect size is large, a change in intake of a single type of discretionary food or beverage (e.g. squash) may have little overall impact upon diet quality or weight status.

Alternatively, the use of a very broad discretionary choice target may reduce the likelihood of seeing an intervention effect.

SSBs were the most commonly reported discretionary outcome, despite the young age of the target group. Discretionary food targets were variable and did not represent the breadth of discretionary foods consumed by children up to 3 years of age. It is therefore important for future research to consider which discretionary choice targets are most impactful in this age group in terms of popularity and contribution to energy intake. This would help to ensure that discretionary choice targets have the maximum possible impact from a diet quality perspective. Intervention content could be tailored to such targets, and outcomes measures selected to best represent these targets. Although outcome measures should be broad enough to capture dietary changes that may occur in compensation for the reduction in discretionary choices.

Of the early dietary interventions reviewed here, most delivered the intervention to mothers rather than parents or primary caregivers more generally. It is unlikely that the goal of these studies was to exclusively target mothers per se, however research in early childhood tends to bias itself towards involving the mother as they are typically the primary carer during these years. The intervention delivery mode was mostly face-to-face, which may be a barrier to the involvement of other caregivers who are employed. Future interventions may need to consider how to involve more family members than just the mother, as other parents or caregivers may play an important role in child dietary intake (95, 96).

The early dietary interventions reviewed were mostly individual or group education-based, aiming to influence parent behaviour through enhancing their knowledge of the nutritional, behavioural and parenting needs of children. This is consistent with prior reviews of early dietary interventions (73, 74). Johnson et al. (73) suggested that this focus on education, without consideration of the necessary skills, physical access to healthy food and social supports, may be partly the reason for the lack of efficacy seen in interventions thus far. The similar lack of efficacy seen in these early dietary interventions targeting the intake of children up to 3 years of age suggests a need to consider interventions that go beyond enhancing knowledge through education.

The interventions reviewed mostly targeted the nutritional, behavioural and parenting needs of children, with a focus on the first year of life. Conversely, very few studies incorporated practical information or advice supporting parents to make healthy food available in the home. Only one study delivered a unique skill-based intervention focusing on the preparation of infant food, although the study was weak in terms of quality and found no between group differences post-intervention or at long-term follow-up (81). Fangupo et al. (84) included a healthy food shopping and label reading component, however this was only a small part of a more comprehensive intervention, and the intervention had no effect on children's intake. Intervention content regarding home food availability or parental provision of healthy food may have been included in other studies, however reporting did not generally describe such content. It may be that this content was implicit, rather than being an overt component of the intervention. Future research could investigate how early dietary interventions could be more parent centred.

1.3.4 Summary: dietary interventions addressing discretionary choice intake in early childhood

Published interventions targeting the discretionary choice intake of children up to 3 years of age were mixed in terms of outcomes. Intervention content primarily addressed the nutritional, behavioural and parenting needs of children. They were largely education-based and delivered face-to-face, with mothers primarily targeted as agents of change. Furthermore, there was heterogeneity in discretionary choice targets and outcome measures, with discretionary beverages such as SSBs being favoured. There is a need for interventions targeting young children's intake of discretionary choices that consider the most appropriate and impactful targets. Future early dietary interventions should also consider parents needs in the context of food provision, and address enablers of healthy food provision behaviour beyond knowledge alone.

1.4 Opportunities for enhancing early dietary interventions

In Section 1.3 it was demonstrated that early dietary interventions addressing the discretionary choice intake of young children have so far been inconsistent in their outcomes. Thus more work is required in this area to better understand how young children's intake of discretionary choices can be reduced. The focus of these interventions on increasing parental knowledge of the nutritional, behavioural and parenting needs of young children means that parents needs have been largely overlooked. Davison et al. (97) similarly found that obesity prevention interventions in children have tended to be child rather than family-centred. There is a need for future early dietary interventions to be more family-centred, by considering family and household factors that play a key role in determining child dietary intake (97).

Returning to the socioecological model of child dietary intake, the previously reviewed early dietary intervention studies place children at the centre of the model, with parents being a key interpersonal influencer of child intake (see Figure 1-2). A shift in focus will now be explored, placing parents at the centre of this socioecological model to consider their role as primary food providers and curators of the home food environment. Placing parents at the centre of this model means that their needs are also prioritised. This family-centred approach may have a wider impact than on child dietary intake alone.

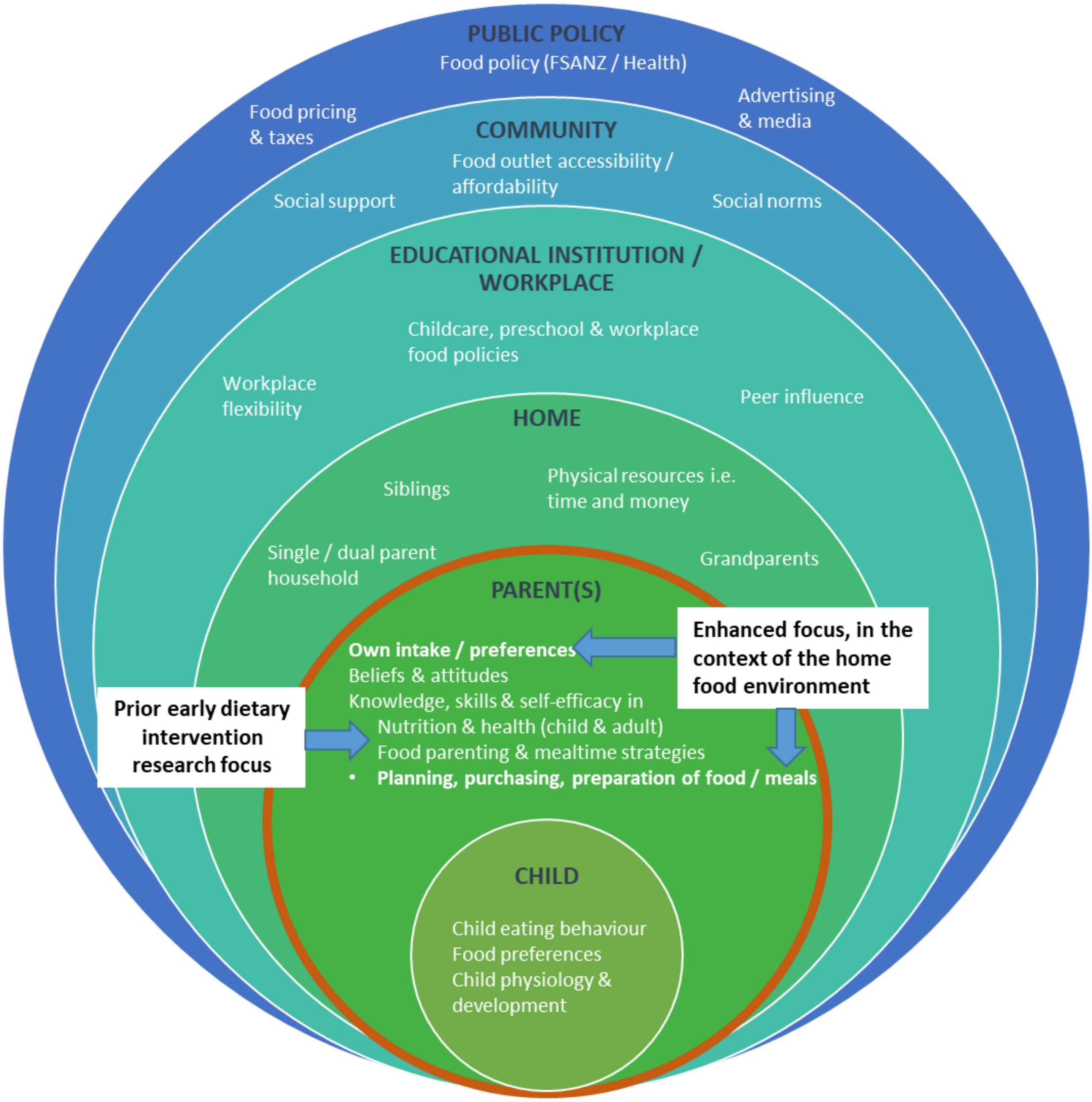


Figure 1-2: A socioecological model describing the key intra- and interpersonal factors influencing child dietary intake (28) - highlighting past research focus, and the enhanced focus of the present work

Although adequate knowledge of the nutritional, behavioural and parenting needs of young children is important, the socioecological model demonstrates that there are other parent factors influencing child dietary intake. Over the course of a lifetime, parents establish their own dietary habits and thus shape the home food environment in which children will grow and develop. The establishment of a healthy home food environment is therefore an important step toward shaping the dietary habits of young children. This section will introduce and explore parental food provision as a key predictor of child dietary intake, and a target for intervention.

1.4.1 Defining parental food provision

In defining parental food provision it is useful to look toward food literacy research. Early food literacy research focused on food preparation and cooking skills as key influences on the provision of healthy food. However more recent research has begun looking beyond skills alone, with Vidgen and Gallegos (98) page 54, defining food literacy as "…the scaffolding that empowers individuals, households, communities or nations to protect diet quality through change and strengthen dietary resilience over time".

From interviews with experts in the field and disadvantaged youths, food literacy was found to be made up of the knowledge, skills and behaviours required for meal planning and management processes, food selection and purchasing, the preparation of food and meals and of course, the consumption (98). Others propose that food literacy also extends to the clean-up and disposal following consumption, including the storage of leftovers for later consumption (99). These processes are thought to be important in enabling individuals to meet their nutritional needs (98). In the context of this thesis, the planning, purchasing and preparation processes associated with providing food to a family or child will be termed 'food provision'.

Food literacy in parents is particularly important as it impacts not just their own intake, but that of their children (100). Parents of young children are generally the food gatekeepers of the household, or those responsible for undertaking the processes associated with food provision. The food provision knowledge, skills and behaviours of parents therefore play a key role in shaping the home food environment. It is unlikely however that parents require proficiency in all aspects of food provision. Literacy in each aspect of food provision enhances resilience against the modern obesogenic environment (98). Furthermore, food literacy is highly contextual, meaning that the knowledge, skills and behaviour required to carry out food provision may be dependent upon the context in which the individual exists (98). Enhancing certain aspects of food literacy in parents may therefore be a way to promote healthier home food environments that broadly impact on the dietary intake of families and children.

1.4.2 Parental food provision literature

Intervention content targeting food provision is relatively common, however it tends not to be the primary focus of early dietary interventions. Of the previously reviewed early dietary interventions, only two were identified that explicitly described intervention components addressing parental food provision. The intervention described by Beinert et al. (81) sought to address the food preparation practices of parents through a 2-day cooking program. Although intervention content addressed the preparation of food for the infant or child, rather than for the whole family. Therefore the effect on broader household food availability may have been limited. Fangupo et al. (84) included interactive stations addressing healthy food shopping and food label interpretation in one of their eight nutrition focused intervention contacts, however this was only a small part of a broader intervention spanning more than 18 months. Neither of these studies had a significant effect on the discretionary food intake of the target children (81, 84).

Other early dietary interventions may have addressed parental food provision, however it was not reported as a core component of the intervention. For example, in their protocol paper, Campbell et al. (101) refers to an intervention component addressing the food environment, which may imply content that addresses food provision. Irrespective, a further review of dietary interventions directly targeting parental food provision is required.

The literature described below was identified non-systematically from electronic databases (e.g. Ovid Medline, PubMed and Google Scholar) and reference lists of relevant literature. As there was no further literature identified in this space targeting children aged less than 3 years, interventions targeting parental food provision in families of preschool and school aged children were also included. Studies were included where a substantial component of the intervention addressed the planning, purchasing and preparation of food and meals. For example, the intervention included more than just a single handout regarding food provision. Although interventions with published dietary outcomes were prioritised, some protocol papers and studies presenting measures of food provision were included to demonstrate the types of literature emerging in this space. Outcome measures describing discretionary choice intake or provision are reported if available, however studies reporting other measures of diet quality such as fruit and vegetable intake were also included.

Food provision interventions targeting parents of preschool-aged children

Four studies were identified that targeted the dietary intake of preschoolers aged between 3 and 4 years through interventions addressing parental food provision (102-105). Of these four studies, one was an RCT (102), one a pilot RCT (105), while two were of quasi-experimental design (103, 104). Each study described a different mode of intervention delivery, including telephone (102), online (105), group skills training (103) and face-to-face in-home education with hands-on activities (104). Facilitators were non-specialist in all three of the studies that were delivered by telephone and face-to-face, although they all involved facilitator training. In the three studies reporting outcomes measures relating to discretionary choices, measures were again biased toward sweet snacks and SSBs.

The Healthy Habits Trial targeted the home food environment of families of 3 to 5-year-old children in order to improve child and parental dietary intake (102). The RCT involved parents of children attending preschools in New South Wales, Australia, and incorporated a telephone-based intervention conducted over a 4-week period. The intervention aimed to introduce new familial norms regarding healthy eating, by targeting parental role-modelling, the availability and accessibility of healthy and discretionary choices, supportive home food routines such as set meal and snack times, and the provision of inexpensive recipes and weekly meal planner templates. They found that the discretionary food score, measured using the reliable and valid Children's Dietary Questionnaire (106), was significantly lower in intervention children compared with controls at two months post-intervention (mean (SD) discretionary food score out of a maximum score of 10.3, with scores above 2 indicating intake exceeding Australian Dietary Guidelines (main analysis): 2.24(0.07) vs 2.57(0.11), $p<0.01$) (71). Although, the effect was no longer significant by 6 months post-intervention (mean (SD) discretionary food score (main analysis) at 6 months: I = 2.29(0.9), C = 2.47(0.1), $p=0.20$) (71). The intervention also had positive effects on the fruit and vegetable intake of both children and parents. Parental fruit and vegetable intake in mean daily serves was greater at almost all follow-up time points to 18 months, by up to 0.71 serves per day (107, 108). Limitations of the study included the use of a survey measure of dietary intake rather than dietary recall, and sample biases toward a well-educated, high socioeconomic (SES) status sample.

The pilot RCT targeted the dietary intake of 30 preschoolers using a parent focused, mobile-optimised website, text messages and social media page (105). The intervention included cooking videos, recipes, food budgeting and meal planning information, with most of the intervention being self-guided or passive in nature. The parental provision of fruit and vegetables was targeted with accessibility of these foods being a particular focus. No discretionary choice outcomes were measured or reported, and there was no intervention effect on the fruit and vegetable intake of children. Although as the study was in pilot stage, it was not powered to detect group differences (105).

The intervention described by Pathirana et al. (103) was unique in its hands-on skills-based approach delivered in a playgroup setting. The intervention included four structured cooking classes with resource packs including recipes. Parents of preschool aged children from low SES backgrounds living in Queensland, Australia were targeted. Discretionary choice intake, including SSBs, flavoured milk, packaged snacks, confectionary and other sweets, was assessed using a valid and reliable tool. Intake of fruit, vegetables and plain milk was also assessed. Outcomes were presented as differences from pre to post-intervention, due to the quasi-experimental design of the study. They found that parent-reported self-efficacy for promoting healthy and limiting unhealthy food significantly improved, and that greater self-efficacy was associated with healthier eating in children. However, there was no significant difference in children's intake of discretionary choices or healthy foods from pre to post-intervention (103).

The final study addressing preschool aged children's intake was a small quasi-experimental pilot study conducted in the US (104). The intervention was delivered by trained Latino peer health educators that also served as role models and social supports. Intervention content included nutrition education regarding cooking, recipe modification and food purchasing. The 10-week intervention delivered to mothers, resulted in significant post-intervention decreases in child intake of added sugars or syrup (mean (SD) teaspoons added to foods/beverages per day: BL = 5.06(3.58), PI = 3.43(2.21), $p<0.001$) and calories from SSBs (mean (SD) kcals/day: BL = 15.5(26), PI = 7.6(12.1), $p=0.04$) (104). The study also found a post-intervention effect on child weight, with a median (interquartile range (IQR)) BMI percentile reduction of 1(0:3)% in those children with a BMI greater than or equal to the 85th percentile. However the study exclusively targeted low-income mothers of Latino background and therefore may not be generalisable to a broader population (104).

Food provision interventions targeting parents of school-aged children

Five studies were identified that targeted parents of school-aged children and reported some form of diet related outcomes (109-113). Two of the studies were based in Australia (111, 113), with the remaining three in the US (109, 110, 112). The studies were mainly RCT's (109-111, 113), and were more diverse in their target population, with one targeting fathers and their children (113) and another including whole families (111). The interventions described were predominantly practical skills-based interventions with two including the provision of produce (109, 112). One study was partly delivered by mobile application (also termed mobile app) (109). Fruit, vegetable and SSB intake were the most common outcome measures, although two studies did not report on children's intake, but rather measures of parent intake and food preparation (109, 110).

An RCT by Fulkerson et al. (111) targeted parents of children aged 8-12 years and compared the efficacy of the Healthy Home Offerings via the Mealtime Environment Plus Program, an experience-based dietary intervention, including meal planning and skill development, to an attention control group. All members of the intervention families were invited to attend the monthly group sessions, which included separate child and parent components. Child dietary outcomes included SSB intake, measured by three child-reported 24-hour recalls. The odds of consuming at least one SSB per day at post-intervention (12 months after baseline) was lower in the intervention group compared with controls (OR = 0.40 (0.17 to 0.95) p=0.04) (111).

The Healthy Dads, Healthy Kids study targeted fathers with overweight or obesity and their 5 to 12-year-old children (113). The 7-week community-based RCT compared the effect of the nutrition education intervention including skills-based components to a group of wait-list controls. There was no intervention effect on child intake of discretionary choices or healthy foods, but there was a positive effect on fathers' intake of discretionary choices and SSB intake. (113).

The Brighter Bites school-based intervention investigated the efficacy of a food co-op model that aimed to increase access to fruit and vegetables while providing low-income families of children aged around 6 years with nutrition education (112). The quasi-experimental study compared the effect of an intervention, including free produce with cooking demonstrations and tastings at school pick-up, and weekly recipe cards and parent handouts, to a standard nutrition education program. At post-intervention, children receiving the intervention consumed less added sugars compared to the comparison group (teaspoons/1000 kcal mean (SD): I = 4.64(2.00), comparison = 5.17(2.43), p=0.014) (112).

Another study investigated the outcomes of a community-based intervention on parents but did not report on child dietary intake. The study evaluated a new program delivered within the existing Expanded Food and Nutrition Education Program, available across many communities in the US, against an existing basic nutrition information program (110). The expanded program addressed topics such as home availability of healthy food, parental modelling and feeding practices, menu planning and home food preparation skills. Parent but not child intake of nutrients and food groups were assessed by 24-hour food record, with both conditions demonstrating post-intervention effects.

Clarke et al. (109) described the efficacy testing of a mobile app 'VeggieBook' that was purpose built to support clients of food pantries. A sample of food pantries in Los Angeles US, were randomised to offer mothers of 9 to 14-year-old children a free mobile phone loaded with the app, along with two different vegetables weekly for four weeks. Control pantries offered participants the same vegetables as intervention pantries, but without the phone and app in order to test the independent effect of the app on preparation of the target vegetables and vegetables more generally. The study found a significant intervention effect on both target vegetable preparation and general vegetable preparation compared with controls, indicating that the app had a positive effect on preparation outside of just the vegetables provided (109). The study did not however provide evidence of a direct effect on children's or families' vegetable consumption (109).

Food provision interventions in early stages of development and testing

Two further studies were identified that described interventions in the early stages of development and testing. Neither have published outcomes as yet, but were still of interest to the present work due to their innovative nature. Brophy-Herb et al. (114) described the protocol for a multi-phase optimisation strategy testing the effects of six intervention components designed to support meals in families of preschoolers (114). The six intervention components for testing include; 1) home delivery of pre-made meals, 2) home delivery of healthy meal ingredients, 3) community kitchens in which to cook healthy meals, 4) healthy eating classes, 5) cooking demonstrations and 6) cookware delivery. Elements of the intervention will address physical resource-related barriers to healthy food preparation, such as inadequate kitchen equipment or access to healthy ingredients. The study will measure and report on fruit and vegetable intake, along with the intake of SSBs, although no discretionary food targets appear to be included (114).

Garvin et al. (115) described the development and feasibility testing of a purpose-designed cooking app. The study investigated the perceptions of low-income parents of young children of their Cooking Matters mobile app. The app incorporated recipes, a meal planning function and shopping lists. The study was largely qualitative, investigating user perceptions of app usefulness and functionality, and the barriers and enablers of app use. Although quantitative survey data was also collected describing parental confidence and attitudes regarding food provision to provide context and support the refinement of future app iterations. They found that the recipe component of the Cooking Matters mobile app was the most popular feature amongst users.

Discussion

The literature addressing parental food provision demonstrates a knowledge gap in interventions targeting parents of young children. Those targeting parents of young children were mostly of low quality and had minimal effect on intake of discretionary choices. Although studies targeting parents of school-aged children were more rigorous in design, they did not all report child dietary outcomes. Those that did only noted small intervention effects on limited measures of discretionary choice intake.

As with the early dietary interventions reviewed previously, there was inconsistency in dietary targets and outcomes which were biased toward healthy food intake, and SSBs. Measuring and reporting on SSB intake in interventions geared towards meal planning and cooking skill development may not accurately reflect dietary changes occurring as a direct result of the intervention, being that SSBs do not generally require planning or preparation. Food provision interventions may be better placed to address intake that is influenced directly by planning and preparation behaviour.

Across all parental food provision studies, there was a greater focus on skills training with more hands-on interventions and alternative modes of delivery than was noted in the previously reviewed early dietary intervention literature. Furthermore, there was greater diversity in the target group, with fathers and whole families being targeted. Although, interventions remained strongly focused on nutrition knowledge and cooking skills and were mostly time intensive in nature, requiring participant attendance to face-to-face sessions. Some of the more recent studies published during the course of this PhD research (105, 109, 114, 115), describe interventions designed to provide families with practical tools and resources to overcome barriers to healthy food provision. These studies demonstrate a burgeoning interest in innovative, parent-centred approaches to addressing child dietary intake.

1.4.3 Summary: opportunities for enhancing early dietary interventions

Past early dietary interventions have focused on parental knowledge of the nutritional, behavioural and parenting needs of young children, leaving an opportunity to explore more family-centred approaches that consider the needs of parents. Parental food provision, including the planning, purchasing and preparation of food and meals might be an ideal target for enhancing the focus of early dietary interventions.

No parental food provision interventions targeting parents of young children were identified outside of those already included in the early dietary intervention review described in section 1.3. Parental food provision interventions targeting preschool and school-aged children were more diverse in design than the early dietary interventions described previously, utilising new technologies and approaches to address barriers to healthy food provision. Studies were mostly low quality, mainly reported on SSBs as a measure of discretionary choice intake, or did not report child dietary outcomes at all. Furthermore, a number of studies are only in the intervention design, development and piloting stages, or were published during the course of this PhD research. This body of literature does not yet provide sufficient evidence as to the efficacy of parental food provision interventions. Although it does provide some important insight into alternative approaches to reducing children's intake of discretionary choices via parental food provision and the home food environment.

1.5 Determinants of parental food provision behaviour

To understand opportunities for future parental food provision interventions, it is important to consider the key determinants of food provision behaviour. Food provision, like any behaviour, requires certain conditions for the behaviour to take place. According to the capability (C), opportunity (O), motivation (M), behaviour (B) (COM-B) system proposed by Michie et al. (116), a person's ability to undertake a behaviour is determined by their capability, opportunity and motivation. Conversely, undertaking a behaviour can influence capability, opportunity and motivation, as indicated by the bi-directional arrows in Figure 1-3.

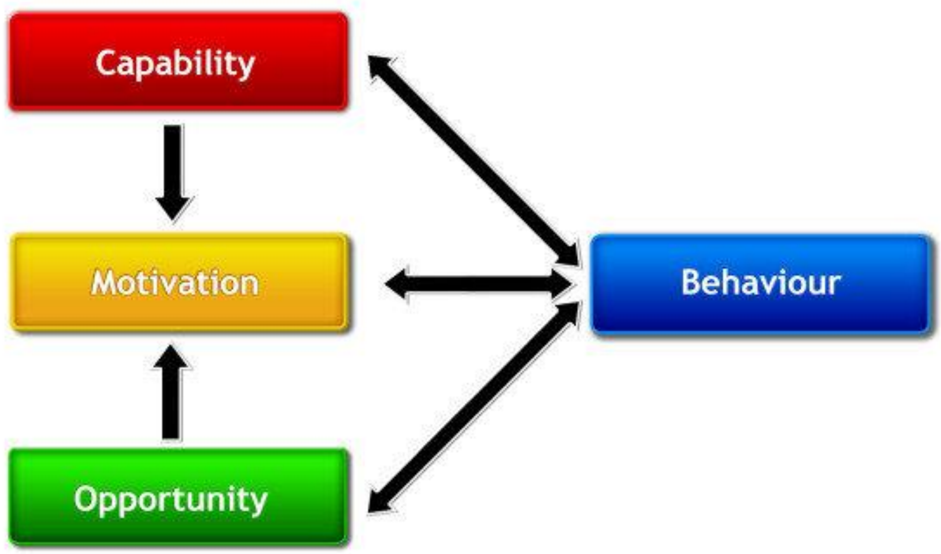


Figure 1-3: The Capability, Opportunity, Motivation – Behaviour (COM-B) system by Michie et al. (116) – image reproduced under the terms of the Creative Commons CC BY license

Capability is defined as the ability to undertake a behaviour and is made up of both psychological and physical capability (116). For example, having cooking and food preparation knowledge, and the physical strength or fine motor ability to handle a knife. Opportunity includes both physical and social factors external to the individual that enable behaviour to take place (116). Physical opportunity relating to food provision therefore includes the money required to purchase kitchen equipment and healthy food, and time in which to undertake food provision-related tasks. Whereas social opportunity includes the broader social norms regarding food preparation. Motivation incorporates both conscious and automatic brain processes that promote behaviour (116). Reflective motivation therefore includes the conscious goals and plans regarding food provision and healthy eating, while automatic motivation includes habitual processes such as selecting the same brand or product at the supermarket time and time again.

Much like food literacy, not every component of the COM-B system is necessary in order to enable behaviour, and the need for capability, opportunity and motivation may be dependent upon context. Knowledge, skills and confidence may enable healthy food provision in the face of external barriers such as inadequate physical resources. For example, knowledge of healthy convenience products may enable time-related barriers to be overcome. Conversely, adequate financial resources may make up for deficiencies in knowledge and skills by allowing the purchase of healthy pre-prepared meals. It is therefore not essential that interventions address all possible enablers of food provision behaviour, but rather target those most important to the target sample and their context.

1.5.1 Motivation: intentions, goals and self-efficacy

Motivation, being made up of constructs such as intentions, goals and confidence or self-efficacy (117), may be required for healthy food provision behaviour to take place. It has therefore been the target of parent-focused dietary interventions of the past. For example, Van Allen et al. (118) found that increases in parental motivation during a paediatric weight management intervention were associated with decreases in child consumption of SSBs and sweets, and in BMI Z-score 6 months post-intervention. Motivation was not however found to be associated with fruit, vegetable or grain intake, suggesting that parental motivation may be important for behaviour change in relation to the provision of discretionary choices in particular (118).

Interventions targeting parental motivation to reduce the provision of discretionary choices to children have shown mixed success. In their review of interventions addressing the parental provision of discretionary choices to 3 to 8-year-old children, Johnson et al. (73) found that parental motivation was the most common target of interventions, followed by aspects of capability (73). The review found that interventions were homogenous in design and only achieved small reductions in children's intake of discretionary choices, suggesting that other aspects of the COM-B system should be addressed.

Goal setting, as a construct of motivation, has long been utilised in dietary interventions to promote positive behaviour change (119). By setting a goal, one envisages a future end-state that they wish to acquire, thus motivating appropriate action (120). Reviews of interventions targeting weight and weight-related behaviour in children have shown that goal setting is used more frequently in effective interventions (121, 122). Similarly, an extensive review of dietary interventions targeting fruit, vegetable and fat intake across all ages found that goal setting was one of the more promising intervention strategies (123). Although goal setting as a strategy in dietary interventions tends to be centred on dietary intake and weight outcomes, rather than how to undertake the behaviours required to reach such goals (for example food purchasing behaviour) (124).

Higher self-efficacy or confidence in one's food and nutrition capabilities have also been associated with healthier food provision practices and dietary intake in cross-sectional research.

An online survey of 1059 Australians who identified themselves as the primary food gatekeeper investigated the relationship between food skills and nutrition knowledge confidence, and the home food environment (125). The survey found that those in the highest cluster of confidence had healthier food purchasing and preparation practices based on cluster analysis of participant responses to six items regarding cooking capabilities and nutrition knowledge (125). An investigation of parental reflective motivation using the health action process approach found that the parental confidence and self-efficacy constructs were strongly associated with children's intake of discretionary choices (126). Although the small amount of variance accounted for by the overall model indicated that aspects of capability and opportunity may be more important than motivation.

In summary, although an important aspect of the COM-B system, motivation alone is unlikely to result in behaviour change without sufficient capability or opportunity. The direction of arrows in the COM-B system (see Figure 1-3) indicates that motivation can in fact be addressed via capability and opportunity (117). Therefore motivation may not be a requirement for behaviour to take place, but rather can be improved by addressing capability and opportunity-related factors.

1.5.2 Capability: knowledge and skills in nutrition and food preparation

Nutrition knowledge is a key capability supporting healthy food choice and therefore dietary intake. However, despite being a common target of dietary interventions, the association between nutrition knowledge and intake is not as strong as might be expected. A systematic review in 2014 investigated nutrition knowledge as a predictor of dietary intake, including evidence from RCT's, quasi-experimental and cross-sectional studies (127). The most reported aspect of dietary intake was fruit and vegetables, with a variety of other dietary measures being represented. Study quality was variable with few using validated tools to measure nutrition knowledge. Only a weak, positive association was found between nutrition knowledge and diet (127).

Nutrition knowledge is closely linked with individual experience and education level (128). A higher education level tends to be associated with better nutrition knowledge and hence a higher quality diet (129). Individual education level cannot be modified through intervention however, so nutrition knowledge is often targeted through educational strategies. Information provision with the aim of increasing nutrition knowledge is the primary strategy for improving diet related outcomes in many dietary interventions (130).

An umbrella review of recent systematic reviews found that the most common dietary intervention components were nutrition education and food labelling information (130). The review included systematic reviews of dietary interventions targeting any age group. Overall, interventions were found to have a modest positive effect on diet quality and food choice, but minimal long-term effect (130). Similarly, a systematic review of interventions delivering nutrition education found that around half of interventions were successful in modifying outcomes relating to nutrition knowledge, behaviour or other markers (131). The findings of these reviews suggest that more than just nutrition knowledge is required to promote healthy dietary intake.

Practical, process related skills are also necessary to promote healthy food provision behaviour (127). Home cooking or cooking 'from scratch' has also been linked with a healthier diet (132-134). The basis for this is that healthy foods tend to be those less adulterated by processing or modification (e.g. raw vegetables, whole cuts of meat). Therefore preparation of such food is required in order to render it safe and acceptable for consumption. Many dietary interventions have been developed and tested with the aim of improving food preparation or cooking skills in order to address diet quality. Three notable reviews provide evidence of the effectiveness of current cooking and food skills interventions (133-136), and thus the relative importance of this aspect of capability.

Two reviews of cooking skills research were conducted by the same team of researchers, with the most recent being an update of the literature since the earlier review (134, 136). The first review covered cooking skills interventions published from 1980 to 2011 (136). Twenty-eight studies were included that described the outcomes of cooking classes, sessions and demonstrations predominantly focused on the food preparation and nutrition knowledge and skills of adults, with only five of the studies specifically targeting parents. Six studies were RCT's and overall study design was deemed to be weak.

Dietary outcomes were assessed in 19 studies, and similar to the previously reviewed literature, there was heterogeneity in the tools used. Outcome measures varied widely and were assessed using mostly questionnaire-based tools that were either not validated, or validity was not reported (136). Sixteen studies reported a positive impact on dietary intake, however 10 of these were non-controlled studies, with most focussing on healthy food and nutrient intake rather than discretionary choices (136).

The updated review identified 34 new studies published between 2011 and 2016, demonstrating an increase in the delivery and/or reporting of cooking skills interventions in recent years (134, 136). The findings of the updated review were largely unchanged from those of the initial review. Interventions remained primarily knowledge and skills-based, and were of low study quality in terms of design and outcome assessment. Dietary outcomes in the form of food group intake most commonly included fruit and vegetable intake, for which results were mostly positive irrespective of study design (134). Four studies reporting discretionary beverage outcomes were largely unsuccessful in modifying intake. Outcomes relating to discretionary food intake were not discussed, however from study summary tables it was clear that discretionary food outcomes were reported in a variety of ways, and with mixed results. There were generally positive outcomes regarding confidence and knowledge related measures (134).

An Australian review of cooking skills interventions reported similar findings (135). The review of 15 cooking skills interventions found that studies were mostly of weak quality, with similar concerns raised regarding study design, the lack of controls and variation in the assessment of dietary outcomes. They found minimal evidence of an effect of cooking skills interventions on intake of discretionary choices. Only eight of 15 studies measured dietary outcomes, and of those, one single component intervention and five multicomponent interventions found intervention effects on diet. Only two of these studies reported a small effect in favour of the intervention on various measures of discretionary choice intake (135).

In summary, the evidence supporting knowledge and skills-based interventions for improving diet-related outcomes is of low quality, with inconsistencies in study design and outcome. Effect sizes are generally small, with positive outcomes mostly associated with healthy food intake such as fruit and vegetables. Knowledge and skills-based interventions may therefore be insufficient to promote positive dietary change (128). Food literacy domains outside of just cooking skills and nutrition knowledge clearly also play an important role in determining dietary intake (136). Barriers to healthy food provision such as family reluctance or resistance to change established behaviours, and limited financial resources may be equally or perhaps even more important than capability-related factors (136).

1.5.3 Opportunity: time and income

Parents ability to undertake tasks relating to food provision is set amongst the opportunity that the home, family and broader social environment affords them (116). The home environment and family structure that surrounds parent and child in Figure 1-2 includes aspects of opportunity. These factors are external to the individual and are largely dependent upon family context and structure, and the broader social and political environment within which the family exists. They are therefore not generally the target of dietary interventions (73), but are rather considered to be barriers or enablers of behaviour.

Time and money are two of the main opportunity-related barriers relevant to healthy dietary intake. They are both well documented as key determinants of dietary intake, and also as key barriers to improving diet-related behaviour. The availability or scarcity of these resources in the home environment is determined by several factors. The number of adults or caregivers, their employment status and the number and age of children, determines the expenses and earning capacity of the household, along with the time available for caregiving and domestic duties. Therefore, time and money are factors that are external to each individual parent and are not easily modified through health interventions. However as key barriers to healthy dietary intake they deserve consideration and may provide a unique opportunity to shift the focus away from individual determinants of behaviour such as capability and motivation (73, 137).

Time

In modern Australian households, more women are in paid employment than ever before, with an almost 6% increase in workforce participation over the last 15 years (138). Seventy percent of Australian mothers in dual-parent households were working in 2019 (139). However men continue to be the primary source of income in most dual-parent households, working on average more hours per week than women (140). In fact fathers of children under the age of 15 years working full-time tend to work slightly more hours than the general male population (140). This means that modern families are juggling more paid work hours than ever before, along with caregiving and domestic duties such as food provision.

Time scarcity is particularly relevant to families with joint responsibilities of work and caregiving. Strazdins et al. (141) investigated time scarcity as a quantified measure based on commitments to common activities such as paid work, domestic work and commuting (141). They found that those most likely to be time poor, after adjusting for all other variables, were employed and had children living in the household (141). They also considered the perception of time scarcity by investigating the self-reported frequency of feeling ‘rushed’. The feeling of being rushed was similarly associated with being employed and having children, but also with being female or a single parent

(141). Qualitative research with working mothers confirms these findings. Jabs et al. (142) found that single mothers, mothers of preschool aged children and those with inflexible jobs expressed more feelings of time scarcity.

Despite these recent increases in workforce participation, women still bear the bulk of responsibility for the planning, purchasing and preparation of food (143). This means less time in which to undertake food provision processes. Time use data from the US shows that in households where the mother is working, she spends 3.6 minutes less time shopping, 17 minutes less time cooking and 10 minutes less time eating daily with her children, compared to households where the mother is not working (144). Furthermore, time scarcity has been cited as a key reason behind the use of convenience foods and lack of home cooking in working parents in qualitative literature (142, 145, 146). Time scarcity may therefore be part of the reason behind the changing food provision habits of modern households.

Female workforce participation has been shown to have a relationship with children's health. At least two Australian studies have shown that full-time maternal working hours are positively associated with child weight status in preschoolers (147, 148). In one study of maternal working hours and weight status in childhood, it was found that preschool aged children of mothers working 35 hours or more per week had a higher risk of overweight and obesity than those whose mothers worked 1 to 24 hours (148). Similarly, another study found that greater maternal working hours were associated with an increased risk of overweight at 4 to 5 years of age (147). The impact of maternal work hours on children's weight status may be via dietary intake.

Several studies have investigated the diet-related mechanisms of the relationship between maternal working hours and child weight status. Research in older samples in Australia, the US and Europe has demonstrated that greater working hours is generally associated with lower dietary quality (147, 149-151). Evidence is sparse in young children, however it is likely that the effect of maternal working hours on weight is via a combination of dietary and other weight-related behaviours such as physical activity.

The focus of past research on maternal working hours as a marker of household time includes a distinct oversight; it fails to consider fathers contribution to time availability or scarcity. Their exclusion from research investigating the impact of maternal working hours on children's diet and health has been justified by the lack of relationship between fathers working hours and child weight status (147, 152). However this argument may no longer hold true as the dynamic of the Australian household changes and parental roles evolve (148). Traditionally fathers have been less involved in the domestic labour of the household, including food provision processes (143). Although disparities in domestic labour persist today, fathers are taking on more responsibility for caregiving duties which may contribute to time availability for food provision tasks (153). Qualitative research with fathers shows that they tend to be involved in support tasks that enable the mother or mother-figure to undertake food provision (154). The time that fathers have available to undertake these support tasks may therefore be important in enabling healthy food provision.

Money

Socioeconomic status has long been understood as a social determinant of the dietary intake of Australian adults and children (155-157). Often represented by income, socioeconomic status is inversely associated with diet quality and key determinants of child dietary intake such as home food availability and accessibility (158-161). Income in particular has been shown to have a strong and consistent association with markers of dietary intake (137). A study of the social determinants of household food expenditure found that income played a more important role in expenditure than education, a marker of knowledge (137).

Changes to income are particularly relevant to modern households with young children. Although the role of the father or father-figure as the primary income earner remains relatively unchanged in Australian households, the mother or mother-figure contributes to family income much more than in the past (143). Financial scarcity may therefore be particularly relevant to families of young children who are experiencing changes in work status. Examples of such changes include periods of unpaid parental leave and the conversion to part-time or casual work hours in order to care for young children.

The mechanism behind the relationship between income and dietary intake is ambiguous. Contrary to popular belief, there is no significant difference between the cost of a healthy versus an unhealthy diet (162). However low-income families spend a substantially greater proportion of their income on food (162). Evidence from research investigating household food expenditure suggests that low-income households spend proportionally more money on both processed (possibly less healthy) and unprocessed foods than high income households, while their expenditure on fruit and vegetables is less than on other unprocessed foods (137). This may be due to the need for shelf stable and acceptable food that is not wasted (145, 158). However, more money does not necessarily mean better food choices and healthier dietary intake.

The interplay between time and money

There is a complex interplay between time and money, such that a higher income may result in less time and vice versa. Those with a higher income tend to work longer hours and therefore experience more time scarcity. More working hours means less time available for food provision processes or for the support tasks that in turn make time available for the primary food provider. This leads to the purchase of takeaway food in order to save time and effort. Venn et al. (137) found that full-time work was associated with lower expenditure on healthy, unprocessed food requiring preparation, and greater expenditure on takeaway foods. Thus time is a moderator of the relationship between income and diet.

Venn and Strazdins (160) also found that while actual and perceived time and income scarcity were independently associated with poorer dietary intake, they acted together to influence eating habits. Income scarcity and the feeling of being rushed, experienced in combination for two years, negatively impacted upon intake of fruit and vegetables in a sample of Australian adults (160). Income and time are therefore important, interrelated determinants of dietary intake.

Coping strategies to overcome opportunity-related barriers

It is not feasible to provide parents with more money or time, however it is possible to support parents to utilise resources in alternative and flexible ways to address opportunity-related barriers to food provision. Coping strategies have been defined as efforts used to manage a difficult or challenging situation, whether the result of those efforts leads to positive outcomes or not (163). Food coping strategies can be used to overcome barriers to enable healthy food provision even during times of disruption and scarcity (164).

Some food coping strategies are associated with healthier dietary outcomes. For example planning meals ahead of time, preparing a shopping list, preparing food in advance and making use of the freezer (165). Although reducing the time burden of food provision during a busy workday evening, these strategies still require knowledge, skills and effort, along with an initial time outlay. These tasks may therefore take time away from other valued activities such as spending time with children or undertaking recreational activities (146). Other food coping strategies used in the modern household include the outsourcing of food provision processes, such as the purchase and delivery of meal kits, healthy pre-made meals and online shopping and grocery delivery (166). These food coping strategies might genuinely reduce the time burden of food provision although they may require a greater financial outlay.

The type of food coping strategies used by parents and families are dependent upon the type of scarcity being experienced. Higher income resulting from increased employment may afford the ability to 'buy' supports to overcome time scarcity. For example purchasing meal kits, time saving kitchen equipment, or engaging a cleaner to free up time for food provision tasks (160). By contrast, a family lacking money but with fewer time commitments may spend more time selecting budget friendly food items and preparing their own food 'from scratch' in order to save on food-related costs. Again, some of these strategies may require knowledge and skills and therefore may not be possible for some individuals to utilise.

The strategies parents use to manage food provision may not always result in positive nutritional outcomes (132). Unhealthy food coping strategies may achieve the goal of minimizing the time burden of food provision, but at the expense of nutrition. Such strategies might include the purchase of fast or takeaway food, or the use of frozen ready-to-heat discretionary foods such as chicken nuggets or frozen potato chips (164). This form of coping has been found to be an unavoidable response to time scarcity, leading to feelings of guilt in working parents (145, 146).

The modern food environment has seen an exponential increase in the availability of discretionary convenience and takeaway or fast foods, such as pizza, burgers and fried chicken. These foods are contributing to suboptimal dietary intake and the subsequent health and economic consequences (164, 167). The ease and speed at which one may purchase such foods, the number and proximity of food outlets along with their high palatability, mean that for many families they are an obvious choice when time is scarce (168). Furthermore, with the rise in digital technology, such as mobile food delivery apps, takeaway and fast food has never been more convenient and accessible. These advancements in the food and technology industry have been an important part of addressing the lack of time modern families are now experiencing, however have had the unfortunate effect of compromising diet quality (2).

In summary, time and money are well cited barriers to healthy food provision that have been largely overlooked as intervention targets. The interplay between time and money means that barriers to food provision may need to be addressed by using time and money in more flexible ways. Supporting families to use healthy food coping strategies that make the most of the resources available to them while minimising nutritional trade-offs will be an important consideration for future dietary interventions.

1.5.4 Summary: determinants of food provision behaviour

Food provision behaviours, encompassing the planning, purchasing and preparation of food and meals, are dependent on various aspects of capability, opportunity and motivation. Traditionally capability and motivation have been the focus of interventions targeting the dietary intake of children and adults. However such interventions have not shown a strong impact on dietary intake, perhaps because of their failure to consider aspects of opportunity.

The availability of time and money in a household is largely external to the individual parent and determined by family context and structure, making them difficult barriers to overcome. Nevertheless, enhancing opportunity could promote resilience against the modern obesogenic food environment. Such a focus has not been well tested to date, despite cross-sectional and qualitative evidence suggesting a need to address opportunity-related barriers. Supporting parents to use food coping strategies that make the most of the time and money available to them, may be an innovative step toward enhancing future parental food provision interventions.

1.6 Summary of evidence gaps: early dietary intake and intervention

Suboptimal dietary intake including the excess consumption of discretionary choices, is a major challenge in Australia. Discretionary choices contribute to energy, saturated fat, added sugars and sodium intake, and displace intake of healthy foods. Excess intakes of discretionary choices start early and persist with age. Intakes mirroring those of adults are established as early as 4 to 8 years, with some evidence suggesting that a rapid deterioration in dietary habits occurs between infancy and toddlerhood. The discretionary choice intake of young children must be addressed in order to curb the health and economic impacts of overweight, obesity and NCDs.

There has been increasing interest in early dietary interventions in recent decades, however few target discretionary choice intake. Existing reviews, along with the review of early dietary interventions targeting children under the age of 3 years described in section 1.3, demonstrated a strong focus on SSBs and sweet and salty snack foods, with mixed intervention effects. Dietary intake data suggests that SSBs and snack foods are universally consumed across all age groups during childhood. However, they are not necessarily the largest contributors to discretionary choice intake amongst the youngest age groups. Cereal based takeaway foods, savoury pastries and dishes containing processed meat are also substantial contributors to energy, saturated fat and sodium intake but appear not to be well targeted by early dietary interventions to date. Furthermore, intake of SSBs and added sugars may already be reducing, suggesting less urgency in addressing intake of these discretionary choices. *A deeper understanding of the discretionary choice intake of young children is required, including both the type and pattern of consumption.*

Parents have been acknowledged as agents of change with respect to young children's dietary intake, and thus are the primary target of early dietary interventions to date. However interventions tend to have a strong focus on improving parent knowledge and skills regarding the nutritional, behavioural and parenting needs of young children, with little attention paid to how parents can achieve a healthy home food environment. Targeting parental food provision behaviour including meal planning, food purchasing and meal preparation may support healthy home food environments. Parental food provision interventions targeting parents of young children are similarly sparse, mainly focused on knowledge and skill development, target mainly SSB intake as a discretionary choice outcome, and have had mixed outcomes. *Enhancing the focus of early dietary interventions by addressing parental food provision behaviour may be a positive step toward more parent-centred interventions. However more than just knowledge and skills may* *need to be addressed in order to have an impact on young children's intake of discretionary choices.*

Capability and motivation are well targeted aspects of the COM-B system in dietary interventions, however their impact on diet has been relatively low. There is a need to address aspects of opportunity in order to enhance the dietary interventions of the future. Time and money are key resources required to support healthy food provision and may be particularly relevant barriers in the modern family context. Yet time and money are rarely targeted in interventions, rather being accepted as fixed barriers to behaviour. *A clearer understanding of the role of time and money as determinants of the discretionary choice intake of young children may enable future interventions to enhance parental opportunity with respect to food provision behaviour.*

1.7 Innovative intervention solutions: mobile apps for improving health behaviour

Increasingly we are looking towards new and innovative technology to address complex problems such as suboptimal dietary intake. Since the introduction of the first iPhone in 2007, and the subsequent launch of Apple's App Store for distributing digital applications in 2008, mobile technology has seen a rapid rise in popularity. Key features of mobile devices include touch screens with high resolution displays, high definition integrated cameras, wireless, cellular and Bluetooth connectivity, global positioning system navigation and location sensing, wearables and other advancements such as machine learning and augmented reality.

Mobile phones and tablets have enabled a raft of new opportunities to provide and support health care. They can be utilised for the collection and monitoring of health-related data, connecting health care professionals with patients, delivering health related information and promoting health behaviour change (169, 170). Mobile applications, also termed 'mobile apps' or simply 'apps', are at the core of much of this technological development. There were almost 2 million apps available in the Apple App Store in late-2019, while the Google Play Store for mobile devices on the Android operating system boasted more than 2.5 million (171).

Health-related apps have become the focus of modern health-care delivery and interventions. In 2018, a survey of Australian healthcare consumers (n=1031) found that 47% used a health-related app on a mobile phone or tablet, compared to 30% in 2016 (172). Despite their increasing popularity, the vast majority of commercial apps available are lacking an evidence-base, primarily because research is finding it difficult to keep up with this fast paced technology (173). Regardless, apps in the health research space are also on the rise. A PubMed search of the term 'mobile app' showed that in the 10 years after the launch of the App Store, publications produced per year increased almost 20-fold from 120 in 2008 to 2229 in 2018.

1.7.1 Mobile apps as a health intervention platform

Mobile apps offer many advantages over traditional modes of intervention delivery. Mobile phones have progressively become cheaper and more accessible. This has led to near universal ownership in Australia, with an estimated 91% of Australians owning a mobile phone, up from 76% in 2013 (174, 175). Therefore, mobile phone-based interventions have the potential to address issues regarding reach that have challenged time-intensive and location limited, face-to-face interventions. Although the initial time and monetary outlay of app development can be substantial, app-based interventions are highly scalable and can be economically viable when delivered to large populations (176).

Mobile phones are also well engrained into day-to-day life making the technology appealing and easy to use. Mobile apps can be used to manage finances, set-up meetings, navigate from place to place, arrange transportation, watch television and even order food. In 2017, it was found that 72% of a sample of Australian mobile phone owners were checking their phones within 30 minutes of waking up (177). Although there is some concern that addiction to mobile phones may have negative consequences, their integration into daily life is now concomitant with the modern lifestyle and seems unlikely to change.

This close integration into daily life provides the unique opportunity to deliver ecological momentary interventions (EMI); interventions delivered during everyday life and activities (178). EMI's can be used to support behaviour both in-time and context, or when and where it occurs. This is an advantage compared to traditional health interventions in the clinic or community setting which require participants to take time out of day-to-day life in order to attend. Interventions embedded into daily life have the potential to minimize intervention burden thus encouraging intervention engagement and adoption.

The ability to integrate apps with other mobile technology such as the global positioning system for location sensing and the camera for augmented reality, means that interventions can go beyond simply the delivery of information (169). Users can set their profile and preferences, while components of apps can be switched on and off, thereby tailoring content and features to the users' specific needs. Furthermore, apps can be designed to react or change with user input, time and context (169). The use of mobile apps in the health intervention space is rapidly expanding as new ways to take advantage of these technologies is discovered.

As with any mode of delivery, there are also disadvantages to using apps in the delivery of health interventions. Research of app-based health interventions is limited by engagement-related challenges, with many interventions failing to achieve engagement adequate to support behaviour change (179). Long-term engagement with app-based interventions is rare, making the longevity of such interventions poor (169). Furthermore, the need for health researchers to form close working relationships with developers and industry (169), the time and financial cost of development and the need for ongoing maintenance of the technology (176), means that app-based interventions may not be practical or feasible in some circumstances.

Mobile technology also poses some risks to the achievement of a healthy lifestyle. For example, mobile food delivery apps have made unhealthy fast food more convenient and accessible. Such mobile food delivery apps provide a connection between app user, local restaurants and delivery drivers. This allows users to place, pay for and track their order all from their mobile phone. This level of convenience makes mobile food delivery an obvious choice when time is scarce. Unfortunately, these apps have increased access to unhealthy food options like never before. On the flipside, apps can also make healthy food more accessible through online grocery shopping and meal kit delivery services. As such, an opportunity exists to explore ways of utilising mobile apps to facilitate healthy food provision in modern households.

1.7.2 App-based dietary interventions: a review of the evidence

Systematic reviews have followed the rise in app-based health research, seeking to understand the efficacy of this new approach to the delivery of health interventions. Early reviews of app-based dietary interventions incorporated mobile health technology in all of its forms, including both text message based interventions, and found relatively few studies reporting dietary outcomes of app-based interventions specifically (180, 181). There are now more reviews emerging that focus specifically on apps as a mode of intervention delivery.

A systematic review and meta-analysis published in 2019 examined the efficacy of app-based interventions for addressing diet and diet-related health outcomes (182). The review included both stand-alone app-based interventions, and multicomponent interventions incorporating strategies such as face-to-face counselling or group education. The overall effect of apps on nutrition behaviours, and the separate effect on energy, and fruit and vegetable intake was investigated, while the moderating effect of the number of behaviour change techniques (BCTs) and other study design factors was tested.

The review identified 41 studies published between 2006 and 2017, 80% of which were published since 2014 (182). Interventions included a mean of seven BCTs per intervention, with all 41 studies including the BCT *Self-monitoring of behaviour*, and 37 including *Feedback on behaviour* (182). Results of the meta-analysis of those studies reporting on a dietary intake-related primary outcome (n=21) showed that overall there was a small, but significant effect in favour of the intervention (Hedges g = 0.19, p=0.004) (182). When fruit and vegetable, and total energy intake were investigated separately however, the effect size for fruit and vegetable intake, but not total energy intake, reached significance (Hedge’s g 0.32, p<0.001). Significant effects were also found on obesity indices and other nutrition-related health markers. Neither the incorporation of non-app based intervention components, nor the behaviour change content (i.e. the number and type of BCTs), had a significant effect on the outcomes (182).

These findings contrast with Schoeppe et al. (183) whose 2016 review found that more of the multicomponent interventions were effective than the stand-alone app-based interventions. Their review included app-based interventions addressing diet and activity behaviours. They included interventions targeting both adults (n=23) and children or adolescents (n=4) (183). Thirteen of the 27 studies targeted dietary intake, seven of which reported improvements in diet-related outcomes. Similar to Villinger et al. (182), it was found that most of the interventions reporting positive effects on health behaviour and outcomes included the BCT *Self-monitoring*.

A scoping review of apps targeting dietary behaviour conducted in 2019 identified 30 studies published between 2013 and 2018. As per the previous reviews, all of the included studies were centred on self-monitoring in the form of dietary logging or tracking functions, whilst 18 also included feedback on behaviour (184). Although the review did not report on intervention outcomes, they noted that the diet-related outcome measures varied widely and focused on healthy food intake.

These reviews support the hypothesis that app-based dietary interventions, even as stand-alone interventions, can modify the dietary intake of adults. Similar to the review of early dietary interventions conducted previously in this chapter, there was substantial variation in the type of dietary outcomes being assessed. This variation meant that effect size could only be calculated for fruit and vegetable intake and not discretionary choices in the meta-analysis. A consistent finding across reviews is the focus of these apps on self-monitoring of dietary behaviour. This highlights that apps thus far have been focused on individual behavioural modification, rather than behaviour in a family context. Furthermore, these reviews have mostly focused on apps directly targeting adults or children/adolescents (i.e. apps for use by older children), rather than parents of younger children.

Apps targeting the dietary intake of young children may be quite different, they are generally targeted indirectly via their parents. It therefore cannot be assumed that the efficacy of app-based interventions in adults extrapolates to children. Similar reviews regarding the efficacy of parent focused app-based interventions on young children's dietary intake are sparse.

In 2020, Zarnowiecki et al. (185) conducted a systematic review of digital interventions targeting parents in order to improve the dietary intake of their children aged between 1 and 12 years. The review identified only one app-based intervention with published outcomes, targeting the fruit, vegetable, candy and SSB intake of preschool aged children (185). The study was deemed to be of 'strong' quality, however found no effect on dietary outcome measures. The review excluded studies targeting children under the age of one year and only covered studies published up to October 2018 (185). As the space is advancing rapidly, an updated review of app-based interventions targeting the dietary intake of young children from birth to 5 years is warranted.

Methods

The following review expanded upon the aforementioned review (185) by including publications addressing children under the age of 1 year, and those published in 2019 and 2020. A search was conducted in PubMed in February 2020, covering publications from 2013 when there was a major emergence of mobile app-based research (182). Search terms included those defining the intervention medium ('mHealth', 'mobile app', 'mobile', 'app' or 'digital'), the target population ('child', 'children', 'parent', 'family', 'mother' or 'father') and the outcomes ('nutrition', 'diet', 'intake', 'healthy eating', 'obesity', 'healthy lifestyle', 'discretionary food' or 'food'). A total of 719 search results were screened.

Studies targeting parents of children up to and including 5 years of age, and reporting child dietary outcomes were included. Interventions targeting older children or designed to be used directly by children were excluded. Protocol papers with no relevant published outcomes and text message-based interventions were also excluded. Due to the limited number of studies in this space, two studies describing a mobile optimised website with text-messaging were included as these were designed to closely mimic a native mobile app. This resulted in a total of four studies addressing children's dietary intake, including the study identified by Zarnowiecki et al. (185) (see Table 1-2 below for a summary of the studies). Although discretionary choice outcomes were only reported for three of the interventions, all were included due to their relevance to the present work. As per the previous review, study quality was assessed using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies (80).

Table 1-2: Summary of app-based dietary interventions targeting the dietary intake of children up to 5 years of age

STUDY	SAMPLE	STUDY DESIGN	INTERVENTION	OUTCOMES	RESULTS
Bakirci-Taylor et al, 2019 (105) Jump2Health US	**Sample:** n=30 mother-child dyads **Recruitment:** Story time at 3 libraries in Lubbock, Texas **Child mean±SD age or age range at BL:** ~3.7y (total sample mean not provided)	**Study design:** RCT **Quality rating:** Weak **Intervention duration:** 10 wks **Data collection:** BL – age 3.7y MI – 5 wks PI – 10 wks	**Intervention condition:** Mobile optimised website, with social media page and text messages, information on increasing child FV consumption, cooking videos/recipes, fussy eating, food budgeting and meal planning **Control condition:** Attention control 12 x text messages on PA **Setting:** Mobile	**Dietary outcomes:** Fruit and vegetable provision (frequency served) **Measurement tool:** 3-day photo-based food records, nutrition qualified staff manually counting presence of total fruit and vegetables **Other outcomes:** Carotenoid levels, anthropometrics, process evaluation	**Frequency of FV served; Total n/wk** *Fruits* MI: I = 117, C = 143, **NS** PI: I = 90, C = 87, **NS** *Vegetables* MI: I = 128, C = 128, **NS** PI: I = 97, C = 92, **NS** **Other Findings:** Positive effect favouring intervention group on carotenoid levels for both children and parents (data not presented)
Delisle Nystrom et al, 2018 (186) MINISTOP Sweden	**Sample:** n=313 parent-child dyads **Recruitment:** Parents identified from population register at Statistics Sweden, invited by mail **Child mean±SD age or age range at BL:** 4.5±0.1y	**Study design:** RCT **Quality rating:** Strong **Intervention duration:** 6 mo **Data collection:** BL – age 4.5y PI – 6mo FU – 12mo	**Intervention condition:** Self-guided mobile app with information on 12 N & PA/sedentary themes, new themes introduced biweekly. Input of child dietary intake and PA, with graphic feedback and automated comments. Optional contact with a dietitian /psychologist via the app **Control condition:** Pamphlet re N & PA in preschoolers consistent with info available from Swedish child health care system **Setting:** App only	**Dietary outcomes:** FV, candy and sweetened beverage intake g or ml/day **Measurement tool:** Photo based food records analysed by trained Nutritionist **Other outcomes:** Anthropometrics, PA, sedentary time	**Intake (g or ml/day); Mean (SD) difference between BL and PI/FU** *Fruit* PI: I = +2.9(78.9), C = -12.1(87.9), **NS** FU: I = +4.3(81.2), C = -10.0(84.5), **NS** *Vegetables* PI: I = -6.7(42.1), C = -3.6(39.7), **NS** FU: I = +59.5(42.8), C = +51.3(39.9), **NS** *Candy* PI: I = -0.7(19.9), C = +3.1(18.5), **NS** FU: I = +1.3(23.3), C = +3.9(18.2), **NS** *Sweetened beverages* PI: I = -12(85), C = +8(83), **p=0.05** FU: I = -4(100), C = +9(128), **NS**
Nezami et al, 2017 (187) N/A	**Sample:** n=51 mother-child dyads **Recruitment:** Mothers with overweight/obesity	**Study design:** RCT **Quality rating:** Moderate **Intervention duration:** 24 wks	**Intervention condition:** 1 x 75 min group session, printed resources, self-monitoring of intake (text message prompts), personalised feedback emails	**Dietary outcomes:** Total fluid ounces of SSBs and 100% fruit juice **Measurement tool:** 1 x 24hr dietary recall	**Intake (fl oz); Model adjusted means (95% CI)** *SSB/juice* MI: I = 1.0(-2.9, 4.9), C = 8.9(4.9, 13.0) Group x time **p<0.01**

US	recruited from the community and online **Child mean±SD age or age range at BL:** 3-5y	**Data collection:** BL – age 3-5y MI – 3mo PI – 6mo	weekly for 12wks then fortnightly for 12wks, lessons on a mobile-optimised website weekly from wks 2-12 and fortnightly from wks 13-24, 3-4 text messages weekly with link to lesson, tips, motivational messages etc **Control condition:** Wait-list **Setting:** Mobile, group	**Other outcomes:** Child and maternal anthropometrics, and maternal intake of caloric beverages	PI: I = 1.2(-2.8, 5.1), C = 9.9(5.8, 14.0) Group x time **p<0.01** **Other Findings:** Positive effect favouring intervention group on maternal intake of caloric beverages and anthropometrics
Russell et al, 2018 (188) Growing healthy Australia	**Sample:** n=645 mother-infant dyads **Recruitment:** Pregnant mothers or parents of infants aged less than 3mo recruited from primary health care provider, by researchers, or online **Child mean±SD age or age range at BL:** 7.4wks	**Study design:** Quasi-experimental, non-randomised control group **Quality rating:** Weak **Intervention duration:** up to 9 mo **Data collection:** BL – age 2wks to 3mo PI – age 9mo	**Intervention condition:** Self-guided mobile app addressing PFP and FV exposure, with 3 x push notifications per week with links to information on the app or website, and a web-based forum **Control condition:** Usual care **Setting:** App only	**Dietary outcomes:** Frequency of offering healthy and unhealthy (discretionary) foods, and whether parents add salt or sugar to infant foods **Measurement tool:** Questionnaire items **Other outcomes:** PFP & beliefs, CEB, parental intentions to offer food	**Provision of food; Mean (SD) frequency** *Healthy food* PI: I = 5.1(1.9), C = 5.2(2.0), **NS** *Unhealthy food* PI: I = 0.3(0.4), C = 0.3(0.5), **NS** **Never add salt or sugar to food; N (%)** PI: I = 174(86.1), C = 235 (84.8), **NS**

anthro = weight, BMI Z-score, waist circumference etc; Bevs = beverages; BF = breastfeeding; BL = baseline; CEB = Child eating behaviour; Disc = discretionary; E = energy; FV = fruit & vegetable; HFE = Home Food Environment; MI = mid-intervention; mo = months; N = nutrition; PA = physical activity; PFP = parental feeding practices; PI = post-intervention; SSB = non-milk sugar sweetened beverages; SCT = social cognitive theory; y = years

Results

Of the four included studies, one targeted parents of infants (188), while three targeted parents of preschool aged children (105, 186, 187). Studies were of mixed quality, with one being rated as strong. Only two studies included stand-alone app-based interventions (186, 188), while the remaining studies were multicomponent, including face-to-face contact, social media groups, online support and handouts.

The two interventions delivered exclusively via a stand-alone app contrasted in terms of study design, quality and outcomes (186, 188). Russell et al. (188) reported on an early infant feeding intervention addressing feeding practices and promoting exposure to fruit and vegetables in infants from birth to 9 months of age. The app delivered three push notifications per week and participants were also included in an online forum. The quasi-experimental study compared the outcomes of infants and mothers using the app to a matched control group utilising usual child health services. Although they did not assess actual dietary intake, they found no group differences in parent reported provision of healthy and discretionary choices, nor in the number that reported adding sugar or salt to their infant's food (188). The questionnaire items used to assess these behaviours were not validated or tested for reliability, and therefore may be subject to bias.

Delisle Nystrom et al. (186) similarly delivered an obesity prevention intervention exclusively via a mobile app to parents of children aged around 4.5 years. The study rated strong for quality, with its RCT design, the invitation of participants from a population-based register, and the use of photo-based food records analysed by trained, blinded Nutritionists to measure outcomes. The intervention spanned six months and addressed both nutrition and physical activity related topics, allowing input and monitoring of child dietary intake with automated tailored feedback. There was also an optional contact with a dietitian or psychologist via the app. They found no group differences in children's intake of fruit, vegetables or candy, but did find a post-intervention reduction in SSBs in the intervention group compared with controls (186).

The two studies utilising mobile optimised websites both targeted preschoolers, and included small sample sizes, one of which was not powered to detect group differences (105, 187). Nezami et al. (187) reported on an intensive, mostly web-based intervention including a mobile optimised website, personalised emails and text messages. The intervention targeted both maternal and child intake of SSBs and fruit juice, and specifically included mothers with overweight or obesity, and children with a high level of SSB and/or juice consumption at baseline. Intervention content was directed toward maternal dietary intake in the hope that their improvement would have a positive effect on their child's dietary intake. The intervention resulted in both mid- and post-intervention reductions in child intake of SSBs and juice compared with controls, while there was also a significant effect in favour of the intervention on maternal dietary intake and anthropometrics. Bakirci-Taylor et al. (105) similarly targeted preschoolers with a mobile optimised website, text messages and a social media page. The intervention included components relevant to food provision, such as cooking videos and meal planning information, however this was in the form of passive content. They targeted the parental provision of fruit and vegetables but found no effect. Although, it is worth noting that the study was in pilot stage and was therefore not powered to detect group differences.

Discussion

Although prior reviews provide evidence that app-based interventions can be effective in promoting dietary change in adults, there is a paucity of evidence regarding app-based dietary interventions targeting parents and children, and reporting dietary outcomes. In preschool aged children between 3 and 5 years of age, there is some evidence to suggest that apps and mobile optimised websites can reduce SSB intake. However these effects were observed in studies that utilised multiple intervention strategies beyond just a mobile app or mobile optimised website, such as personalised emails, text messages and optional contact with a health professional.

The app-based dietary interventions identified were largely focused on the delivery of static content or information, therefore closely mimicking those delivered by more traditional means. They did not make use of the many advantages of mobile technology, such as engaging the user during day-to-day life. Push notifications were the main strategy used to encourage engagement, although they were generally not used in a way that was consistent with EMI.

Only one app-based pilot intervention targeted parental provision practices, by including cooking videos and meal planning information (105). Otherwise, interventions were still more focused on child nutritional needs and behaviour, and parental feeding practices, than on supporting food provision behaviour.

1.7.3 Summary: innovative intervention solutions

Mobile apps offer the opportunity to deliver tailorable interventions in the real-world, minimising the resource intensive nature of traditional interventions. The integration of mobile phones into daily life and the ability to tap into complementary mobile technology provides an opportunity to deliver dietary interventions that go beyond just information provision.

App-based dietary interventions in adults appear to be effective in modifying dietary behaviour, although evidence remains sparse in interventions targeting parents in order to address the dietary intake of young children. The full potential of apps in this space is yet to be seen, with apps needed that move away from static information provision and take advantage of what the technology has to offer.

1.8 Commercially available mobile apps addressing dietary intake

Research is turning toward the commercial app space to fill the gaps in published app-based interventions addressing diet and other health-related behaviours. Commercial apps include those that are available in the public domain and are downloadable for free or at a cost from the Apple App Store or Google Play Store. Researcher developed apps can also be available in the public domain, although tend to only make up a small portion of the apps available in the commercial app stores. Commercial apps may be more advanced than those in the published literature, due to the lag time between app-based intervention development, testing, publication and dissemination in the research space (169). Drawing on advances in commercial technology is an important step in the research pathway, as it can reduce the time and financial cost of app development, and support the development of apps that are more up-to-date with current technology and thus consistent with consumer expectations (169).

1.8.1 Reviews of apps in the commercial space

Reviews assessing commercially available apps in the nutrition space have emerged in the last 5 years. The more common reviews assess apps addressing adult (124, 189-191) and child/adolescent (192, 193) dietary intake directly. Although there have been two reviews targeting the infant feeding practices of parents, the most recently published of the two being an update of the earlier review (194, 195). All reviews involve searches of the commercial app stores. The reviews mostly assess app features and content, app quality including the alignment of content with dietary guidelines, and the presence of BCTs.

One of the earliest reviews, published in 2016, assessed popular commercial apps addressing weight management (189). The review was conducted across both the Google Play Store and Apple App Store and identified 23 apps for inclusion. Included apps had to be rated well by users and commonly downloaded. The majority of apps functioned as behavioural trackers, including diet and physical activity monitoring, although two apps included food-related information. The review found that the quality of information was low (189) based on the information quality domain of the Mobile App Rating Scale (MARS) tool by Stoyanov et al. (196). Apps with interactive features, such as semi-automated data logging, scored better on measures of quality. It was therefore suggested that features reducing the burden associated with use may be important to include in future apps (189). Furthermore, the number of BCTs per app was positively associated with app quality, with an average of 10 per app. Self-monitoring, goal setting and feedback-related BCTs were most commonly used (189).

Also published in 2016, Franco et al. (190) identified and reviewed 13 popular nutrition-related apps from both app stores. Of these apps, nine were diet monitoring apps whilst the remaining four provided dietary plans (190). The focus of the apps was on energy balance for weight loss with some additional educational and nutrient information. Information supporting the achievement of dietary behaviour modification was however limited.

In 2017, Flaherty et al. (124) targeted apps from the Google Play Store that addressed food purchasing behaviour, although the 11 included apps were more focused on weight-related outcomes than food purchasing per se. App content was assessed against the local national dietary guidelines, BCT content mapped and app quality rated using the MARS (124). Four of the 11 apps contained unreliable nutrition information, and engagement quality was the lowest rating MARS domain. Similar to Bardus et al. (189), the BCTs *goal setting* and *self-monitoring* were present in all 11 apps. It was found that apps functioned on the assumption that users already had the knowledge and skills to modify their behaviour, with little nutrition information or content provided. Furthermore, the substantial time and effort involved in using the apps meant that a high level of motivation would be required to support app use in the first place (124).

A more recent review of 44 nutrition related apps from the app stores in China found that only 11 were focused specifically on dietary guidance, with most focusing on health management rather than dietary intake specifically (191). Food and nutrient information were the most common feature of apps while recipe content was the least common. They noted very few features designed to support user adherence to the dietary guidelines (191). Similar to Flaherty et al. (124), engagement quality was the lowest scoring MARS domain.

A review of the Apple App Store in 2013 identified and assessed apps addressing weight related behaviours in children, although the apps reviewed were designed to be used directly by children (192). Twenty-seven apps were included in the review, which found that the vast majority were focused on energy balance and portion control. They also found that apps commonly included the BCTs *goal setting* and *self-monitoring*, and that only three included information in accordance with dietary guidelines. Eight of the apps promoted some form of family involvement, such as providing ‘tips for parents’, while eight included a meal plan with recipes and a shopping list (192).

Schoeppe et al. (193) also focused on apps addressing weight-related behaviours in children, but included apps targeting adolescents. They identified 25 apps, 12 of which addressed dietary intake. Consistent with other reviews, they found that information quality was low. Although they also found that the number of BCTs associated with app features and content was positively associated with app quality. Unlike previous studies, the BCTs identified were focused on providing instructions and encouragement, rather than on *goal setting* and *self-monitoring* (193).

The two reviews identified that targeted parents were focused on infant feeding apps addressing milk feeding behaviour and solid food introduction (194, 195). Cheng et al. (195) was an update of an earlier review by Taki et al. (194), and identified and assessed 47 apps. The apps targeting solid food introduction were focused on providing guidance regarding what, when and how foods should be introduced. Thirty three apps were commercially developed, with the remainder being developed by more reliable organisations such as universities and government departments (195). Regardless, they found that there was relatively poor information depth and coverage, and information was of low quality, as was noted in the earlier review (194). Finally, although overall app quality appeared to have improved since the earlier review, engagement quality was still the lowest rated domain of the MARS (195).

1.8.2 Summary: commercially available mobile apps addressing dietary intake

Commercial apps directly targeting adult and child dietary intake are largely focused on individuals, rather than parents and families. The focus on weight related outcomes, rather than the processes and behaviours leading to dietary intake, was identified as a major flaw of commercially available apps. Commercial apps in this space appear to operate on the assumption that people have adequate capability and opportunity, and only require motivation to achieve behaviour change. Most of the apps reviewed therefore functioned as diet monitoring tools promoting energy balance for weight loss, thus tended to incorporate the BCTs *goal setting* and *self-monitoring*. Although these BCTs have been demonstrated to be effective components of nutrition interventions (197), they may not be enough alone to support behaviour change.

The apps reviewed tended to include very little evidence-based nutrition information in line with national dietary guidelines. This is likely due to their development by commercial organisations rather than government or academic institutions. More collaborative work between commercial app developers and researchers is required in order to develop evidence-based apps supportive of behaviour change (169, 193). Such work could include the pilot testing of popular commercially available apps with users in order to inform the development of higher quality, more effective apps in the future (193).

Reviews of commercially available apps published to date have not yet considered apps that are applicable to parental food provision, except in relation to the introduction of solid food to infants. This may be because of the focus on weight loss rather than diet quality in the commercial app sector (169). Apps addressing diet quality should be a priority for future app development, as diet quality is important beyond simply the role it plays in weight maintenance.

Apps addressing parental food provision in the commercial space may exist, despite not having been identified and reviewed. An enhanced understanding of apps available in the commercial space may assist researchers in identifying what could be achieved and what is still required in order to develop apps that can function effectively from a dietary behaviour change perspective.

1.9 Considerations for the development of app-based dietary interventions

Sections 1.7 and 1.8 introduced mobile apps as a platform for delivering health interventions. The published literature demonstrates that app-based dietary interventions can be effective in modifying the dietary intake of adults, while there is minimal evidence regarding the use of apps as tools to support healthy parental food provision and dietary intake in children. The commercial app space shows similar trends, in that the focus of most diet-related apps is on individual diet monitoring in adults, rather than on improving parental food provision or child dietary intake. This section will bring together the key gaps from the published literature and commercial space, to consider where new evidence is required in order to explore mobile apps for improving parental food provision to young children.

1.9.1 User engagement with app-based dietary interventions

One of the greatest challenges to the success of app-based health interventions is insufficient user engagement to support health behaviour change (179, 198). In 2016, Perski et al. (199) defined engagement with digital behaviour change interventions (including app-based health interventions) as being made up of two constructs; engagement as a subjective experience and engagement as a behaviour. Subjective experience includes the cognitive states of attention, interest and affect, or put more simply, the absorption in and enjoyment of the intervention. While engagement as a behaviour describes the extent of use, including the amount, frequency, duration and depth (199). Some level of user engagement with an intervention is required in order for it to impact upon health behaviour (199).

The context in which an app-based health intervention occurs and the content and delivery of the intervention itself are thought to be key determinants of user engagement (199). Context includes both the target user and the setting or environment within which they are using the intervention. Aspects of the intervention thought to be important include content such as BCTs, social support features and reminders, and delivery features such as personalisation (199). Thus, inadequate engagement may be due to a lack of consideration of the context, and the content and delivery of the intervention during the design and development process.

1.9.2 Incorporating the users voice and context in app-based dietary intervention development

The development of evidence-informed app-based health interventions is cross-disciplinary, involving expertise from the health, behaviour change and computer science fields. However a key stakeholder that also requires consideration is the target user. Combining evidence from the health, behaviour change and computer science disciplines, the commercial app space, and the target user can support the development of evidence-informed app-based interventions that are engaging, usable and therefore effective in modifying health behaviour.

Current approaches to app-based intervention development emphasise the need to involve the users voice (179, 200-202). Early and iterative involvement of the user is encouraged, gaining their perspectives from the concept development stage through to efficacy testing (201, 202). In their recommendations resulting from an international workshop with experts in the field of digital health and behaviour change, Michie et al. (179) advocated the use of a user-centred or person-based approach in the development of digital behaviour change interventions. Both user-centred design and the person-based approach draw on user behaviour, context and needs in order to promote the development of app-based interventions that are engaging, usable and effective (201, 203). Consideration of the target user's context can also enable the development of app-based interventions that are useful in the real-world, as behaviour is occurring.

Both user-centred design and the person-based approach are iterative processes, involving the user from the concept development phase, and seeking input throughout the development and testing cycle (201, 203). The difference in these approaches lies in the discipline underpinning them. User-centred design stems from the computing and technology sector, and was a shift from the market driven approaches to design that were used earlier in the 20th century (203). The approach is focused on the user experience of a product, with usability, functionality and usefulness being key to the design process (203). The person-based approach is similar to user-centred design, but distinct in its health psychology and behaviour change focus (201). The approach involves the investigation of user experience with the behaviour change components of the intervention (201). It encourages the use of mixed methods, including qualitative interviews at all stages of intervention development and evaluation (201). User-centred design and the person-based approach therefore can and should be used in a complementary manner to develop interventions that are both usable and engaging, whilst also promoting positive behaviour change (201).

1.9.3 Evidence and theory informed app-based dietary interventions

Although user perspectives are important, interventions must still be underpinned by both evidence and theory. In Section 1.8, reviews of commercially available apps demonstrated a lack of evidence informed content. While researcher developed apps may have the scientific rigour that commercial apps do not, there remain challenges to their ability to modify health behaviour. Michie et al. (179) suggested that the behaviour change mechanisms of digital behaviour change interventions is often unclear, suggesting a need to strengthen their theoretical underpinning. Coupling credible, evidence-informed nutrition content with appropriate and relevant behaviour change content is critical for the development of effective app-based dietary interventions in the future.

According to Glanz and Bishop (204), page 401, a theory can be defined as “a set of interrelated concepts, definitions, and propositions that explain events or situations by specifying relationships among variables”. Theory can be used to help understand why behaviour occurs or does not occur, and how interventions may function to support or change behaviour (204). For example, the COM-B system can be used to identify barriers and facilitators of behaviour, thus enabling the selection of appropriate intervention functions and content to address these barriers and facilitators. There has been some homogeneity in the behaviour change content used in researcher developed and commercial apps addressing dietary behaviour to date, with content being mostly associated with the COM-B domains of capability and motivation. This suggests that there may be a gap in the types of behaviour change strategies that have been explored in app-based dietary interventions. Using theory such as the COM-B system to understand parental food provision behaviour in the context of the family environment will be important in building on past app-based dietary interventions, and tailoring them to suit the needs of families of young children.

1.9.4 Summary: considerations for the development of app-based dietary interventions

Drawing upon key approaches to digital development in the computing and health behaviour change space is an important step toward developing the digital behaviour change interventions of the future. Incorporating the users voice in the early planning and concept development stages may reduce the overall time and financial cost of intervention development, while promoting the development of apps that are considerate of users behaviour, context and needs. Aspects of user-centred design and the person-based approach can be used to support the development of interventions that are usable and engaging, while evidence and theory informed content and delivery will ensure that app-based interventions are effective in changing health behaviour.

1.10 Summary of evidence gaps: mobile apps as a platform for family focused interventions to support parents

Mobile apps, with their close integration into our daily lives, may be the ideal platform to take dietary interventions beyond face-to-face knowledge and skills development and into the real-world. They are uniquely placed to address day-to-day food provision behaviours such as meal planning, food purchasing and meal preparation, as they are occurring.

App-based dietary interventions have been shown to be generally effective in modifying the dietary intake of adults. However app-based dietary interventions targeting the intake of children via their parents remain sparse. They mostly target preschool and school-aged children, focusing on parental knowledge and skills regarding child dietary needs, and fail to make use of some of the key advantages of mobile technology. A few app-based parental food provision interventions were identified and described earlier in Section 1.4. However they were mostly published during the course of this PhD research, and as they are in various stages of development and testing, little is known as to how such apps could support food provision. *There is an opportunity to explore mobile apps for addressing the parental provision of food to young children to reduce discretionary choice intake.*

Researchers are increasingly turning toward the commercial app sector to identify opportunities for technological advancement in the digital health space. Reviews of the commercial app stores have identified apps directly targeting adult and child/adolescent dietary intake, and the infant feeding practices of parents. The focus of most diet-related apps in the commercial space is individual weight loss through diet monitoring, with little attention paid to the processes and behaviours required to support healthy dietary intake. *Exploring the commercial app sector may be an important first step toward identifying the potential of apps in addressing parental food provision behaviour.*

In exploring apps for addressing parental food provision to young children, challenges to the development of engaging, usable and effective interventions should be considered. Drawing on aspects of user-centred design and the person-based approach could support the development of apps that are considerate of user behaviour, context and needs. *User perspectives of commercial apps could provide new evidence regarding the potential of app-based interventions for modifying parental food provision behaviour in the real-world.*

The lack of evidence informed apps identified in the commercial space, and the bias toward capability and motivation-based behaviour change content in researcher developed apps suggests further opportunities for enhancing the effectiveness of future app-based interventions. *There is a need for apps that are evidence informed and include behaviour change content addressing aspects of opportunity.*

1.11 Thesis aims and structure

1.11.1 Primary aim

The primary aim of this thesis is to develop an evidence-based app concept targeting parental provision of discretionary choices to young children.

1.11.2 Thesis specific aims

In addressing the primary aim, this thesis will:

1. Describe the discretionary choice intake of young children by eating occasion;

2. Examine parental time and income as determinants of young children's discretionary choice intake;

3. Determine the feasibility of apps and app features addressing parental food provision behaviour by:
    a. Conducting a systematic assessment of the quality and behaviour change content of commercially available apps and app features relevant to improving parental provision of food to young children and;
    b. Exploring the utility and acceptability of commercially available apps and app features with parents.

1.11.3 Overview of the thesis structure

Interventions promoting behaviour change at the individual level have been shown to involve the 1 – identification of barriers, 2 – selection of intervention components, 3 – engagement of end-users and 4 – use of theory (200). In addressing the thesis specific aims, Chapters 2, 3 and 4 of this thesis involve each of these key aspects of intervention development. The discussion chapter (Chapter 5) then describes the triangulation of the existing literature, the empirical evidence, and the perspectives of the target user on current technologies in order to address the primary thesis aim. Figure 1-4 demonstrates how the thesis chapters address the thesis aims and key intervention development stages.

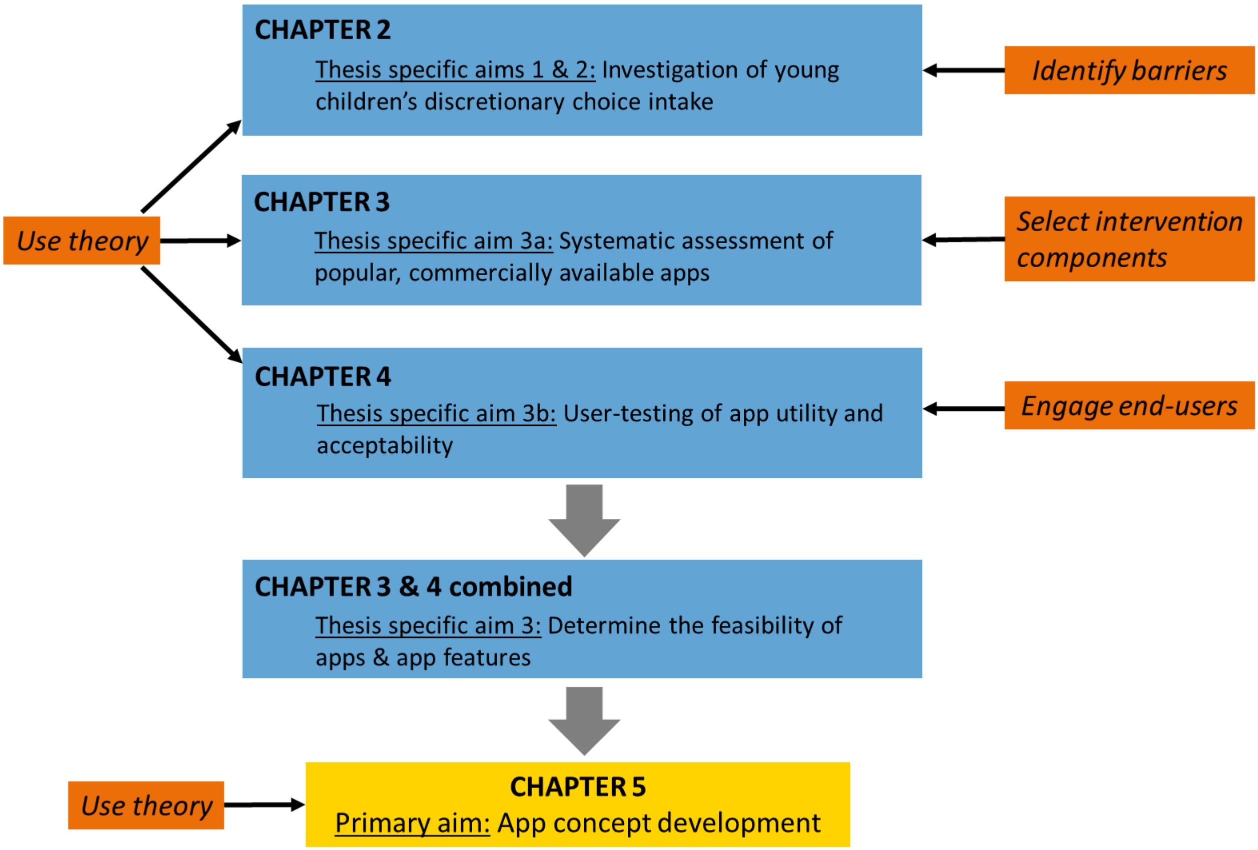


Figure 1-4: The contribution of the thesis chapters to the thesis specific aims, and alignment with the intervention development stages identified by Colquhoun et al. (200)

Identifying barriers

Chapter 2 describes the discretionary choice intake of young children aged 2 years (thesis specific aim 1) through a secondary analysis of dietary intake data. Australian data from an RCT and a cohort study was utilised, with analyses considering the intake of discretionary choices by eating occasion. Further analyses of this dataset included an examination of parental time and income as determinants of young children's intake of discretionary choices, when controlling for child, parent and family factors (thesis specific aim 2). The role of time and income in determining discretionary choice intake at different eating occasions was also explored. This allowed the prioritisation of behavioural support strategies according to key opportunity-related barriers to healthy dietary intake.

Selecting intervention components

In determining the feasibility of apps and app features addressing parental food provision behaviour (thesis specific aim 3), Chapter 3 describes the identification of potential intervention content through a systematic assessment of the quality and behaviour change content of commercially available apps and app features relevant to improving parental provision of food to young children (thesis specific aim 3a). Commercial app stores were systematically searched and apps with the potential to offer behavioural support for the provision of healthy family food identified. App scope and characteristics were described, and app quality assessed. A behavioural analysis of apps was conducted to understand the behaviour change content of food provision apps.

Engaging the end-user

Chapter 4 explores the utility and acceptability of commercially available apps and app features with parents (thesis specific aim 3b) in order to determine their feasibility in addressing parental food provision behaviour (thesis specific aim 3). Apps and app features were selected from the aforementioned systematic assessment for testing, with the mixed methods design of the study drawing on aspects of user-centred design and the person-based approach. Rich qualitative interview data were supported by quantitative data, providing evidence of the utility, quality, usability, functionality and engagement of existing commercially available apps. User's needs were considered in the allocation of apps, and testing was conducted in a real-life context to encourage user engagement and therefore gain knowledge of value to future intervention development. This research provided further evidence to support the selection of intervention components, feeding into app concept development.

Using theory

Behaviour change theory underpinned each of the three studies making up this thesis, and the proposed app concept. The COM-B system was used to guide the identification of barriers in Chapter 2, with a particular focus on opportunity-related barriers of time and money (116). In Chapter 3, a behavioural analysis of apps was conducted, mapping content and features against the behaviour change technique taxonomy version 1 (BCTTv1) (205). User-testing of apps described in Chapter 4 involved app allocation on the basis of parental need guided by a COM-B self-evaluation questionnaire (116). Finally, the app concept described in Chapter 5 was guided by behaviour change theory, with app features and content proposed according to their delivery of BCTs relevant to key COM-B barriers of healthy parental food provision behaviour.

CHAPTER 2: THE DISCRETIONARY CHOICE INTAKE OF YOUNG AUSTRALIAN CHILDREN

2.1 Descriptive title

Discretionary choice intake in young Australian children: an investigation of the what, when and why of intake

2.2 Overview

Chapter 1 described the excess discretionary choice intake of Australian children and highlighted the need for early intervention to halt the deterioration of diet quality over the early years. A deeper understanding of the discretionary choice intake of young children will support the enhancement of past interventions. Gaps in our knowledge include the types of discretionary choices consumed by young children and the pattern of consumption across eating occasions. This chapter therefore addresses thesis specific aim 1; to describe the discretionary choice intake of young children by eating occasion. A secondary analysis of dietary intake data of young Australian children aged 2 years is presented. This in-depth exploration of young children's discretionary choice intake will provide an understanding of both what is consumed and when, acknowledging that consumption of such foods does not occur in isolation, but rather in the context of daily eating patterns. This knowledge will contribute to the development of more effective interventions that are tailored to the specific dietary habits of young children.

Chapter 1 also identified a gap in dietary interventions addressing opportunity-related determinants of parental food provision behaviour, with most interventions to date being focused on knowledge, skills and self-efficacy. The role of time and money as determinants of young children's intake of discretionary choices, and thus parental provision behaviour, is yet to be explored. This chapter therefore also addresses thesis specific aim 2; to examine parental time and income as determinants of young children's discretionary choice intake. An understanding of the role of opportunity-related determinants of intake such as time and money will support a shift in focus from capability and motivation toward factors external to the individual. An exploration of the differential role of time and money across eating occasions will support the tailoring of intervention strategies according to actual patterns of consumption.

2.3 Introduction

Australian children's consumption of discretionary choices is excessive from as early as the second year of life (16, 19). Addressing this early excessive intake of discretionary choices may prevent the development of unhealthy food preferences that track into adulthood. Interventions targeting the discretionary choice intake of young children have had limited effectiveness and vary widely in their dietary targets (73). Discretionary choice intake occurs as a part of whole diets and eating occasions, and in the context of the person and their environment. Therefore, a deeper understanding of the type, pattern and determinants, or the what, when and why of discretionary choices consumed by young children, may promote the development of more effective, fit-for-purpose interventions.

The review described in Chapter 1 (section 1.3) found that interventions targeting the discretionary choice intake of 0 to 3-year-old children have focused on either broad measures of intake or specific foods and beverages. Broad measures included total energy intake from discretionary choices, proportion of daily energy from discretionary food, and lipid or sugar dense foods. Specific food and beverage measures varied widely but with a bias toward SSBs and snacks. Ten of 12 studies measured SSB intake (81-84, 87-94), four sweet and salty snack foods (82, 84, 90, 93, 94), and three fried potato (83, 84, 93, 94). As cereal based takeaway foods, savoury pastries and dishes containing processed meats are all top contributors to energy, saturated fat and sodium amongst children of all ages (25), there is some disconnect between the targets and outcome measures of early dietary interventions, and actual intake. An improved understanding of the types of discretionary choices being consumed by young Australian children, and their contribution to energy and nutrient intake is required. This will support the selection of intervention targets and outcome measures that are most relevant to young children.

Research describing children's dietary intake has largely considered total consumption of food and beverages, irrespective of when it is consumed. However, research in children and adults suggests that dietary intake differs by eating occasion (206, 207). In Australia, the typical eating pattern consists of three main meals, namely breakfast, lunch and dinner, and in young children close to three snacks per day (206). While meat and alternatives, grains, vegetables, cereal-based takeaway foods (e.g. pizza, burgers and spring rolls), savoury pastries and processed meats are common at the evening meal, dairy, fruit, sweet biscuits, cakes and salty snacks tend to predominate snack occasions (25, 206, 207). This evidence to date regarding dietary intake by eating occasion has come from pooled samples of both adults and children (207) or has focused on only one type of eating occasion, such as snacks (206). Therefore a thorough investigation of young children's discretionary choice intake by eating occasion is required.

In addressing parental food provision behaviour, it is crucial to understand the key determinants of young children's intake. As introduced in Chapter 1 (Section 1.2), children's intake is influenced by a variety of factors at the child, parent, household and broader community levels (159). Figure 2-1 below presents the key child, parent and household level factors discussed in Chapter 1, and proposes their relationship with children's intake of discretionary choices, and with one another. Although some of these relationships are well supported by research in young children, such as the role of child eating behaviours and parent feeding practices, less is known about the role of family or household level factors as determinants of young children's discretionary choice intake.

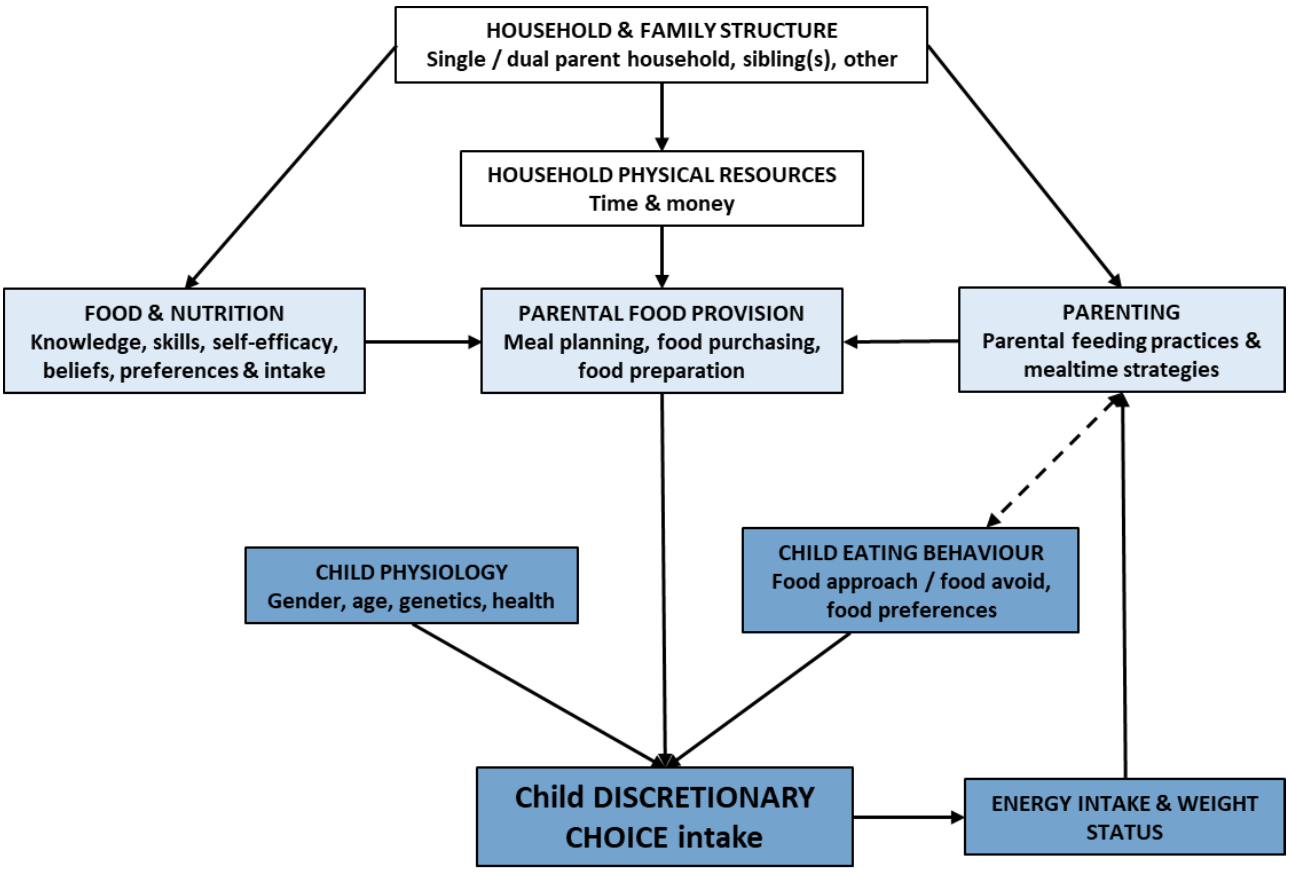


Figure 2-1: Conceptual model of determinants of young children's discretionary choice intake, with child factors in dark blue, parent factors in light blue, and external family/household factors in white.

It was established in Chapter 1 that time and money are important aspects of the opportunity domain of the COM-B system as it relates to food provision behaviour. Adequate money to purchase ingredients and cooking equipment, and time in which to prepare meals may support healthy food provision, whilst scarcity of these resources has been associated with poorer dietary outcomes (160). Interventions targeting young children's discretionary choice intake have tended to focus on parental capability and motivation relating to modifiable individual factors, such as child eating behaviour, parental feeding practices, nutrition knowledge and cooking skills. This leaves a gap in our understanding of the role of opportunity-related determinants of young children's discretionary choice intake which tend to exist at the household level.

Research in school-aged children provides evidence of the important role of household level determinants of intake, particularly in relation to discretionary choices. Cross-sectional research with 9 to 13-year-old Australian children found that attitudes, self-efficacy and a supportive home food environment were important determinants of both fruit and vegetable intake and discretionary choice intake (156, 157), while parent feeding practices and home food availability were important determinants of discretionary choice intake only (157). Notably, markers of socioeconomic position, such as parental education, income and employment, moderated many of the relationships between determinants and discretionary choice intake. The amount of time mothers spent in employment seemed to be particularly important (157). These findings suggest that time and money may be particularly important determinants of the discretionary choice intake of school-aged children, although their role as determinants of young children's intake is yet to be investigated.

The resources required for parents to provide healthy food may not be consistent across eating occasions. For example, the evening meal which traditionally incorporates unprocessed ingredients such as meat, vegetables and grains (207), may take more time to plan, purchase and prepare than food consumed at other eating occasions. Whereas snacks, which commonly feature ready-to-eat foods such as biscuits and salty snacks, dairy products and fruit, typically require less preparation (206, 207). Qualitative evidence supports the hypothesis that main meals are more time intensive to provide, with low-income employed parents citing time scarcity as a key barrier to evening meal provision (142, 145). The purchase of fast food after a day at work has been described as a response to time scarcity (142). Therefore the differential role of time and money on young children's discretionary choice intake at different eating occasions should also be explored. Such evidence would support the development of more tailored intervention strategies.

2.4 Aims and objectives

The aim of this study was to investigate the discretionary choice intake of young children by eating occasion, and the role of time and money as determinants of discretionary choice intake by:

1. Describing the usual energy and nutrient intake of young children both across the day and by eating occasion;
2. Describing young children's intake of the five food groups and discretionary choices across the day and by eating occasion, both as a proportion of overall intake, and at the food and food group level;
3. Investigating the relationship between time, money and discretionary choice intake in young children, when controlling for child, parental and family factors, and;
4. Determining if associations between time, money and discretionary choice intake is different by eating occasion

2.5 Methods

2.5.1 Study design, setting and sample

This study was a secondary analysis of data collected as part of the NOURISH and South Australian Infants Dietary Intake (SAIDI) studies. NOURISH, a multi-centre RCT, recruited first-time mothers of healthy infants (i.e. born >35 weeks gestation, weighing ≥2500g at birth, and without medical conditions that could impact upon their dietary intake) across Adelaide and Brisbane in 2008 and 2009 (87, 208). Mother-infant dyads were included if the mother was aged at least 18 years and had proficient written and verbal English. Participants were randomised to receive an infant and toddler feeding intervention promoting positive feeding practices and the development of healthy food preferences, or usual care. The intervention was delivered in two modules taking place at 4 to 6 months and 12 to 15 months (Australasian Clinical Trials Registration ACTRN 1260800056392) (209).

The longitudinal SAIDI study was conducted simultaneously, but in Adelaide and regional South Australia only. Recruitment and inclusion and exclusion criteria were identical, except that both primi and multiparous mothers were recruited. SAIDI participants did not receive an intervention, thus mirroring the NOURISH control arm. Recruitment and data collection procedures for both studies have been described in detail previously (75, 87, 208-210). Ethics approval was sought and received from eleven Human Research Ethics Committees in South Australia and Queensland, covering Flinders University and Queensland University of Technology, along with each recruitment hospital.

Mothers were approached in hospital, after the birth of their child, and introduced to the study. Mothers who were interested in taking part were provided with study information and asked to complete a brief questionnaire including contact information. Subsequently, they were contacted for full enrolment into the study at child age 4 to 6 months, when baseline data was collected.

2.5.2 Data collection

Data were collected at birth and baseline via parent completed questionnaire. Questionnaire items covered infant feeding and parenting practices, maternal and family demographics, and infant and maternal anthropometrics. At 2 years of age, a similar questionnaire was repeated, along with one 24-hour recall and two 24-hour food records for the collection of dietary intake data. Participants with at least two full days of intake reported (i.e. one recall and two food records, or one recall and one record, or two records) were included in the present study. Both NOURISH intervention and control participants were included, as no differences in dietary intake have been previously reported between the conditions at 2 year follow-up (87).

The 24-hour recall utilised a standardised three-pass protocol, and was conducted by trained Dietitians via telephone (211). Participants were not aware of the day on which to expect the telephone call, with both weekdays and weekend days being included across the sample. Images of standard measurements and drink bottles, along with a set of measuring spoons was provided to support participants in recalling quantities consumed. Food recall data included the time of food consumption, a description of the food (including brand and variety if known) and the quantity consumed. For mixed foods, participants were asked to recall the recipe, total yield, and quantity consumed. On completion of the 24-hour recall, participants were assigned 2 days on which to complete the food records, again with weekdays and weekend days represented across the sample. For recording purposes, participants were provided with a food record booklet, along with a booklet to provide to other carers (such as grandparents and childcare) for recording food intake in the parent's absence. Food records and carers booklets were returned via reply paid envelope, and data were checked on receipt for completeness. Where possible, missing data were followed up by telephone.

2.5.3 Dietary intake data preparation

Food intake data were entered into FoodWorks Professional Version 9 (Xyris Software Pty Ltd, Australia) which used energy and nutrient data from the 2007 AUSNUT database (212). Data were then exported into SPSS Version 22 (IBM, US), and merged with the 8-digit food codes from the AUSNUT 2007 database in order to group and analyse food intake. Data were cleaned according to a standard protocol (87).

Eating occasion definition

Food recalls and records included time of food or beverage consumption only. Therefore defined time of day ranges were used to categorise food and beverage intake into eating occasions (206, 213). The categorisation of meals and snacks according to only the largest eating occasion within a defined time of day range (214) was considered, however was deemed inappropriate for the present sample. This was due to the tendency for young children to consume small, frequent meals, the implications of which being an overrepresentation of snack eating occasions. Therefore all food and beverages consumed during defined time of day ranges represented main meals and snacks.

The time of day ranges were constructed by plotting the energy and protein content of eating occasions across the day for the whole sample to observe when peaks in energy and protein intake occurred (see Appendix 2 for plots including and excluding milk intake). Late night and the early hours of the morning were included in the time of day ranges to capture overnight milk feeds which were still common amongst this age group. This resulted in the following time of day ranges being used to define eating occasions:

- Before breakfast snack: Midnight – 5:59 am
- Breakfast: 6:00 – 8:59 am
- Morning snack: 9:00 – 11:29 am
- Lunch: 11:30 – 2:29 pm
- Afternoon snack: 2:30 – 4:59 pm
- Evening meal: 5:00 – 7:59 pm
- Evening snack: 8:00 – 11:59 pm

A small number of participants had foods or meals with no time of consumption recorded (18 of 544 participants (3.3%), a mean (SD) of 654 (484) kj per participant). These foods and meals were excluded from analyses. Where whole days or meals were lacking time of consumption information (n=19, 3.5%), proxy data were used (e.g. by checking the hard copy for order of consumption and descriptions of meals and snacks such as breakfast, morning tea).

Separate eating occasions within a meal or snack period were defined using a 15-minute time interval approach (214) in order to determine the number of eating occasions per meal, snack or day. Leech et al. (214) reported in their work in adults that a neutral definition, such as the consumption of at least 210 kJ (50 kcal) and separated in time from the surrounding eating occasions by 15 minutes, predicted intake most accurately. However, in the present work, no minimum energy content criterion was applied due to the young age of the sample and their tendency to consume small, frequent meals. Therefore a separate eating occasion was defined as the consumption of any food or beverage (excluding water) starting more than 15 minutes before or after the start of any other eating occasion. If an eating occasion occurred within 15 minutes of another eating occasion, the start time of the first eating occasion was considered as the start time of both (e.g. an eating occasion at 2pm, and at 2:12pm, were considered as one eating occasion, starting at 2pm).

Classifying and grouping foods

Foods and beverages from the five food groups (also termed 'healthy' foods and beverages) and discretionary choices were identified using the Australian Bureau of Statistics (ABS) discretionary food (215). According to the ADGs, the five food groups include; grain foods, vegetables and legumes/beans, fruit, milk, yoghurt, cheese and/or alternatives and lean meat and poultry, fish and alternatives (14). Whereas discretionary choices are defined as those that are not essential for meeting nutrient requirements, and are generally energy dense, higher in saturated fat, added sugars, sodium and/or alcohol, and low in fibre (14). Although not the primary focus of the present work, intake of foods and beverages from the five food groups was presented in addition to discretionary choice intake to provide an overall context to young children's intake.

As NOURISH and SAIDI data were coded according to the AUSNUT 2007 food codes, there were minor discrepancies with the ABS discretionary food flag which was based on the AUSNUT 2011-13 codes. Where codes did not match, AUSNUT food and food group names were used to identify discretionary choices. One modification to the discretionary food flag was made in relation to chicken nuggets. The ABS discretionary food flag was allocated to fast-food restaurant nuggets, but not nuggets prepared from frozen, which had an almost identical nutrient profile. Therefore all nuggets were flagged as discretionary for the purpose of this analysis.

The AUSNUT 8-digit food codes were used to identify and group foods at the major group and sub-major group level. The 8-digit food code corresponds to individual food items (e.g. 16201011 – 'Strawberry, raw'), with the first 2 and 3 digits corresponding to the major group (e.g. 16 = 'Fruit products and dishes') and sub-major group (e.g. 162 = 'Berry fruit') respectively.

Usual intake

The Multiple Source Method (MSM) online tool was used for calculating usual intake of energy and nutrients (216). The MSM calculates intake at the individual level using two or more days of dietary intake data (217). The tool was used to calculate usual intake of energy (kilojoules), total fat (grams), saturated fat (grams) and sodium (milligrams) both across the day, and at the main meals and snacks (combined). Added sugars were not included as AUSNUT 2007 did not include added sugars data. Usual intake at snacks was determined by combining intake across the four daily snack occasions (defined earlier), as there were numerous inconsistent consumers and non-consumers at snack times (i.e. those only consuming once in the 3-day period, or not at all). Having limited data regarding frequency of intake would have resulted in more assumptions being made about habitual consumption, so it was deemed to be more appropriate to analyse usual intake of snacks combined. Similarly, usual intake could not be determined for major and sub-major food groups due to infrequent consumption and a lack of frequency data.

2.5.4 Demographic data preparation

Demographic data utilised in the present study included both infant and child data, maternal and paternal data, and family and household data. The primary carer and parent involved in data collection was almost exclusively the mother. In one case, maternal data was provided at all data collection points except at 2 years when the father took over as primary carer. In this instance working hours data for this father was included with maternal data as he was the primary and sole carer at child age two years. Where the term 'mother' or 'maternal' is used in the present work, it includes this one anomaly as described.

Data collected at infant birth included child gender, maternal age and parental educational attainment. Maternal Body Mass Index (BMI, kg/m^2) was calculated from weight and height data collected at child age 4-6 months. All other data were collected at child age 2 years, including child age, weight and height, CEBQ items, maternal and paternal working hours, marital status, household income, number of children in the household and Food Parenting and Structure Questionnaire (FPSQ) items (described below) (51, 53, 218).

Child BMI Z-score was calculated using child weight and height measured according to a standardised protocol and the World Health Organization Anthro version 3.0.1 and macros program (Department of Nutrition for Health and Development, World Health Organization) (219, 220). A correction of 0.7cm was added to child height for those aged greater than 2 years to account for the use of recumbent length in the reference sample (220).

Thirty-five CEBQ items were used to calculate scores for four subscales of food approach (*food responsiveness, emotional over-eating, enjoyment of food* and *desire to drink*) and four of food avoid (*satiety responsiveness, slowness in eating, emotional under-eating* and *food fussiness*) eating behaviours (51). These subscales were derived from existing literature, interviews with parents and successive testing with separate samples of parents and children aged 2 to 9 years of age, and with internal validity and test-retest reliability established (51). It was subsequently validated in the 2-year-old NOURISH sample, with the original 8 factor model providing a good fit with the data and sub-scales showing good internal consistency (Cronbach's alpha values of 0.73 – 0.91) (221). The two subscales *satiety responsiveness* and *slowness in eating* were combined into a single mean score, due to past research suggesting that these subscales are highly correlated (51, 53, 221). Mean scores were calculated for the remaining seven CEBQ subscales (six of the original subscales and one made up of *satiety responsiveness* and *slowness in eating*), with scores for each item between one, indicating low, and five, indicating high levels of each eating behaviour.

Maternal and paternal education data were collected by multiple-choice questions, with categories collapsed to create a dichotomous variable – *university educated* (made up of a single category *university educated*) versus *not university educated* (made up of *school education up to Year 12, Technical and Further Education (TAFE)/Trade qualification or certificate/diploma*). For household income, a multiple-choice question with six categories regarding annual gross household income in AUD was used (*$0-20000, $20001-35000, $35001-50000, $50001-70000, $70001-100000, more than $100000*). The first three and last three categories were combined to create a dichotomous variable that allowed comparison of low-income to mid/high-income households (*less than $50000,* and *$50000 or more*) (222). A series of questions regarding other children in the household (to take into account all other children sharing the household at least half of the time, including siblings, half-siblings and stepchildren) were used to create a dichotomous variable to represent *single-child* versus *multiple-child households*. Marital status response categories were also collapsed to create a dichotomous variable, *partnered* (including both *married* and *de facto*) versus not partnered (*single*, *separated*, *divorced* and *widowed*).

As past research has found non-linear relationships between maternal work hours and children's weight and weight-related outcomes (144, 148), the average number of maternal and paternal working hours per week was grouped into categories for analysis. Maternal working hours were grouped into four categories, including: *not working, working 1 to <21 hours, 21 to <35 hours,* and *35 hours or more* per week. Paternal working hours were grouped differently to account for differences in the spread of working hours amongst fathers: *not working, working 1 to <35 hours, 35 to 40 hours* and *greater than 40 hours* per week. Categories were used to create dummy coded variables, with the reference category being the group with the greatest number of responses (*not working* for maternal working hours and *working 35 to 40 hours* for paternal working hours).

Items and sub-scales from the FPSQ were included to represent parental feeding practices. The FPSQ was developed using NOURISH data to be used to assess parental feeding practices in young children less than 3 years of age (53). The nine factor model showed good overall fit, and predictive validity was demonstrated against CEBQ subscales (53). Internal reliability was demonstrated with Cronbach's alpha values between 0.61 and 0.87 (53). Four of the seven sub-scales were included in the present research, namely *reward for behaviour, reward for eating, covert restriction, and overt restriction,* along with the single item *same food as the rest of the family* (218).

Missing data

Nine (1.7% of 544) participants had missing data on five or more variables and were therefore excluded from the regression analyses. A further nine (1.7% of 544) participants were missing data regarding paternal education, all of whom were single mothers at the time of infant birth. As these data were not missing at random they could not be imputed, so these participants were also excluded. Of the remaining participants (n=526), six (1.1%) had missing data for two variables and 62 (11.8%) had missing data for one variable only, mostly for the variables *paternal work hours*, *household income* and *maternal BMI.* These data were imputed with maximum likelihood estimation, on the basis of being missing at random or missing completely at random, although sensitivity analyses with all participants with available income data were also conducted. Descriptives were run on the original sample of n=544 (with missing data) and on the sample of n=526 with imputed data, which were found to be similar. The proportion of imputed data was 4% or less for each variable which was well below the threshold of 25% as suggested by Lodder (223). Of the sample with complete or imputed data, all participants had dietary intake data for the dependent variables except for one child who was a non-consumer of snacks and was therefore excluded from the regression model with discretionary intake at snacks as the dependent variable.

2.5.5 Data analysis

All analyses were conducted in SPSS version 25 (IBM, US). Descriptives for sociodemographic data included medians and IQR for continuous variables to account for extreme outliers whilst allowing for consistency of descriptives across multiple measures. Counts and percentages were used to present categorical data. The sociodemographic characteristics of the NOURISH and SAIDI samples were compared using independent samples t-tests and Chi square analyses.

Descriptive analysis of dietary intake data

Normality of data were examined using histograms, skewness and kurtosis. Outliers were defined as cases 1.5 times above the upper or below the lower quartile, and were checked against raw data records. As skewness and kurtosis for approximately one third of the energy and nutrient data indicated non-normal distribution, medians with IQR were presented. Mean intake of energy in kilojoules from healthy foods/beverages and discretionary choices at each meal and across all snacks over the 2 or 3 days recorded was calculated per child, with the median and IQR being calculated across the whole sample. Similarly, the median and IQR for the number of eating occasions per meal and across snacks was also calculated. The contribution of each meal and all snacks to total daily intake of energy and key nutrients was calculated, while the contribution of healthy foods and beverages, and discretionary choices to overall intake and to each meal was calculated, with the median and IQR of the sample presented. Sensitivity analyses were conducted by group allocation (i.e. NOURISH intervention versus control/SAIDI) for dietary intake data.

The most commonly consumed healthy foods/beverages and discretionary choices were presented according to sub-major group. In the case of fruit and vegetables, the major group was used as the sub-major grouping would under-represent the popularity of these foods, and provide a level of detail unnecessary for the present research (for example groups at the sub-major level for fruit include berry fruits, pome fruits, citrus fruit, stone fruit). The top five foods and top three beverages according to the number of consumers (i.e. participant consumed the food or beverage at least once across the 2 or 3 days of dietary data provided) was determined, with the mean and SD energy contribution of these foods and beverages at each main meal and across snacks calculated.

Regression analyses

Hierarchical regression models were conducted to investigate the role of time and money as determinants of young children's intake of discretionary choices. Use of hierarchical regression analyses allowed for an understanding of the contribution of each level of the conceptual model to the model (Figure 2-1). A total of 24 sociodemographic factors representing components of the conceptual model were included in the analyses. After dummy coding of work hours variables and the inclusion of intervention condition (NOURISH intervention versus control group) the total number of variables included in each regression model was 29. With a sample size of 526, this resulted in 18 cases per variable, meeting most sample per variable recommendations which tend to lie between 5 and 20 participants (224).

Three separate hierarchical regression analyses were conducted, with the dependent variable describing the proportion of total energy intake from discretionary choices 1) across the day (i.e. main meals and snacks combined), 2) at main meals only, and 3) at snacks only. In each model variables were entered in six steps, with the variables representing time and money entered first, followed by family, parental and child factors, as follows:

1. Time and money – maternal work hours (3 dummy coded variables; not working vs 1 to <21 hours, not working vs 21 to <35 hours and not working vs 35+ hours), paternal work hours (3 dummy coded variables; working 35 to 40 hours vs not working, working 35 to 40 hours vs 1 to <35 hours, and working 35 to 40 hours vs more than 40 hours) and household income
2. Household structure – relationship status, highest level of paternal education and number of children in the household
3. Maternal factors – highest level of maternal education, maternal age at infant birth, maternal BMI
4. Parental feeding practices – reward for behaviour, reward for eating, covert restriction,

overt restriction, same food as rest of family and group allocation

5. Child physiological factors – child gender, child BMI Z-score and child age
6. Child eating behaviour factors – food responsiveness, enjoyment of food, satiety responsiveness/slowness in eating, food fussiness, emotional overeating, emotional undereating and desire to drink

For each regression model, there was independence of residuals, with Durbin-Watson statistics of around 2. Linearity of the relationship between the dependent variables and all independent variables was confirmed with scatterplots, and plots of studentised residuals against unstandardized predicted value. Visual inspection of the studentised residuals against unstandardized predicted value plots also confirmed homoscedasticity. There was no multicollinearity, assessed by correlations, tolerance values and variance inflation factor values. Outliers were checked, but Cook's distances were well below 1, and leverage values above 0.2, indicating no influential data points. Statistical significance was measured at the $p \leq 0.05$ level.

2.6 Results

Figure 2-2 describes study participants based on data availability, and Table 2-1 presents demographic information for the maximum available sample at child age 2 years. Seven hundred and nineteen participants provided some data at the 2-year collection point, 654 of whom provided survey data. Most mothers had a partner (95%, n=618/654) and a household income over $50000 AUD per year (82%, n=518/631), just over half were university educated (58%, n=417/716), and had only one child (56%, n=356/634), and less than half (43%, n=275/639) were not working. Fathers were mostly working full-time (82%, n=525/640), while just under half were university educated (43%, n=298/640). Participants retained at the 2-year data collection point were found to be older, with slightly older children at baseline, and were more likely to hold university qualifications, compared with the sample at baseline (data published elsewhere) (225).

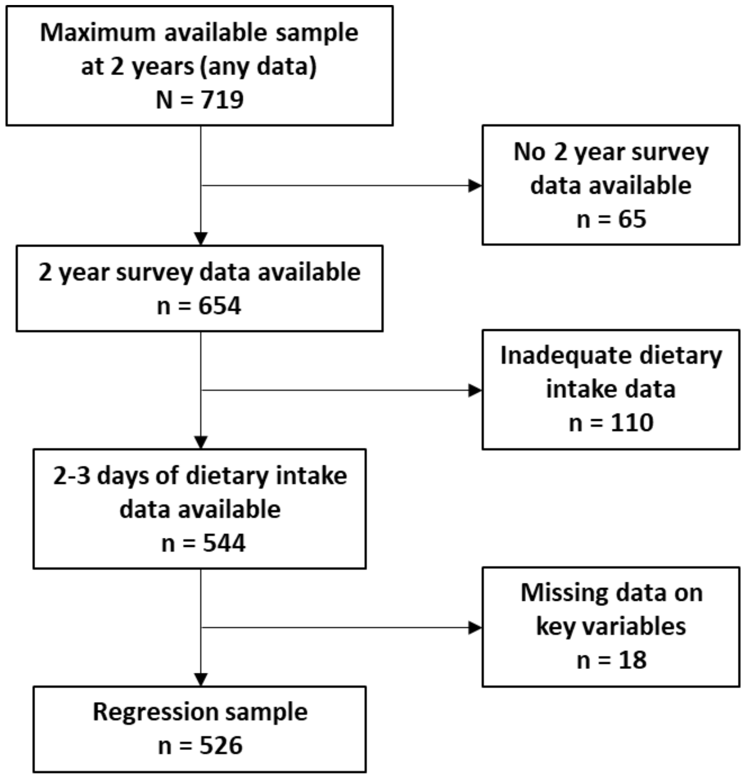


Figure 2-2: Study participants based on survey and dietary intake data availability

Five hundred and forty-four children had 2 (n=10) or 3 (n=534) days of dietary intake data, collected at median child age of 2 years. Compared with the maximum available sample, the regression sample of 526 included mothers that were slightly older (median(IQR) 32(28:35) years versus 31(28:35) years), more likely to be partnered (n=513/526, 98% versus n=618/654, 94%), university educated (325/526, 62% versus 417/716, 58%), and of a higher income (449/526, 85% versus 518/631, 82%). There were no significant differences between the NOURISH intervention and control groups for any key sociodemographic characteristics (i.e. child age, BMI Z-score, child gender, maternal age, BMI, education, marital status, household income, number of other children in household and maternal working hours; analyses using all available data for those with 2 or 3 days of dietary data n=544, data not presented). However, SAIDI children, compared with NOURISH children (both intervention and control) were younger (1.97(0.05) versus 2.00(0.05) years, $p<0.001$), with older mothers (32.7(4.8) versus 31.2(4.7) years, $p=0.001$). Additionally, SAIDI mothers worked more ($p=0.007$), had a lower education level ($p<0.001$), a lower household income ($p<0.001$) and more children ($p<0.001$).

Table 2-1: Child, parental & household characteristics of the maximum sample at child age 2 years (N=719) and regression sample (n=526)

Characteristic	Categories	Maximum avail sample[a] n		Regression sample[b] (n=526)
			n (%) or median (IQR)	
Child variables				
Child gender	Male	716	338 (47)	240 (46)
	Female		378 (53)	286 (54)
Child age (years)		713	2.00 (1.97, 2.03)	1.99 (1.96, 2.03)
Child BMI Z-score		704	0.76 (0.06, 1.47)	0.79 (0.12, 1.51)
Parental & family variables				
Maternal age (years)[c]		716	31.0 (28.0, 35.0)	32.0 (28.0, 35.0)
Maternal BMI (kg/m^2)[d]		701	24.8 (22.2, 28.6)	24.6 (22.1, 28.2)
Marital status	Single	654	36 (6)	13 (2)
	Partnered		618 (94)	513 (98)
Maternal education[c]	University	716	417 (58)	325 (62)
	No university		299 (42)	201 (38)
Paternal education[c]	University	700	298 (43)	232 (44)
	No university		402 (57)	294 (56)
Maternal working hours[e]	Not working	639	275 (43)	217 (41)
	1 to <21 hours		166 (26)	146 (28)
	21 to <35 hours		135 (21)	115 (22)
	35+ hours		63 (10)	48 (9)
Paternal working hours	Not working	640	26 (4)	20 (4)
	1 to <35 hours		53 (8)	54 (10)
	35 to 40 hours		360 (56)	301 (57)
	>40 hours		165 (26)	138 (26)
	N/A		36 (6)	13 (2)
Household income	Less than 50k	631	113 (18)	77 (15)
	50k or more		518 (82)	449 (85)
Number of children	One	634	356 (56)	289 (55)
	More than one		278 (44)	237 (45)
Study allocation	NOURISH Intervention	719	253 (35)	172 (33)
	NOURISH Control		279 (39)	187 (36)
	SAIDI		187 (26)	167 (32)
Food parenting and structure questionnaire subscales				
Reward for behaviour[f]		653	1.5 (1.3, 2.3)	1.5 (1.3, 2.3)
Reward for eating[f]		654	1.5 (1.0, 2.3)	1.5 (1.0, 2.0)
Covert restriction[f]		652	3.3 (2.5, 3.8)	3.3 (2.5, 3.8)
Overt restriction[f]		653	3.5 (2.8, 4.0)	3.5 (2.8, 4.0)
Same food[f]		652	5.0 (3.0, 5.0)	5.0 (3.0, 5.0)
Child eating behaviour questionnaire subscales				
Food responsiveness[g]		653	2.2 (1.8, 2.6)	2.2 (1.8, 2.6)
Enjoyment of food[g]		653	4.0 (3.5, 4.3)	4.0 (3.5, 4.3)
Satiety responsiveness / slowness in eating[g]		653	3.0 (2.7, 3.3)	3.0 (2.7, 3.3)
Food fussiness[g]		653	2.5 (2.0, 2.8)	2.5 (2.0, 2.8)
Emotional overeating[g]		652	1.5 (1.0, 2.0)	1.5 (1.0, 2.0)
Emotional undereating[g]		653	3.0 (2.3, 3.5)	3.0 (2.3, 3.5)
Desire to drink[g]		653	2.7 (2.3, 3.3)	2.7 (2.3, 3.3)
Proportion of daily energy intake from discretionary choices				
Total including main meals & snacks			N/A	19.6 (13.2, 27.8)
Main meals only			N/A	11.7 (6.7, 17.8)
Snacks only			N/A	6.5 (2.9, 10.8)[h]

a Sample size varies between n=631 and n=719 due to missing data, with n=719 providing some data at 2-year data collection, of which n=654 provided survey data
b Regression sample includes imputed missing data
c Data collected at recruitment / child birth
d Data collected at Time 1 / child age 4-6 months

e Includes n=1 father, who became the primary caregiver shortly before T3 measurements (all other maternal data are from the mother at earlier time points)
f Food Parenting and Structure Questionnaire subscales/items - score between 1 and 5, with higher scores indicating more of the parenting practice
g Child Eating Behaviour Questionnaire subscales - score between 1 and 5, with higher scores indicating more of the eating behaviour
h Sample size for percent energy intake from discretionary choices at snacks was 525, as one non-consumer of snacks was excluded from analyses
EI = energy intake, IQR = interquartile range, BMI = body mass index N/A = dietary data not available

2.6.1 Usual intake

Table 2-2 presents usual intake data for energy, fat, saturated fat and sodium across the day and at meals and snacks, the proportion of daily energy/nutrients from meals and snacks, and the proportion of energy from healthy and discretionary foods and beverages. Snack occasions combined, followed by the evening meal, contributed the greatest proportion of total daily energy intake (median of 1365kJ and 1329kJ respectively), but were also made up of the most eating occasions (median of almost three and two separate eating occasions respectively). The number of eating occasions per day varied between one and 16 with a median (6:8) of seven per day, four of which were consumed as main meals (i.e. during time of day ranges defined as breakfast, lunch and dinner) and three as snacks. The evening meal was the largest contributor to total daily intake of fat and saturated fat (medians of around 12g and 6g respectively), making up around 30% of intake in both cases. Lunch contributed the greatest proportion of total daily sodium intake (median of 386mg, 31% of total daily intake), followed by the evening meal (median of 369mg, 30% of total daily intake).

Healthy foods and beverages made up around 80% of total energy intake, whilst discretionary choices contributed 20%. The three main meals combined (i.e. breakfast, lunch and the evening meal) contributed a larger overall proportion of energy intake from discretionary choices than all snacks combined (median of 554kJ, 62% of total daily energy intake from discretionary foods, compared with 314kJ, 36%). The majority of discretionary energy intake at main meals was consumed at lunch and the evening meal, as breakfast consisted primarily of healthy foods and beverages (96% of breakfast energy intake). The majority of energy intake consumed at snacks was consumed between breakfast and lunch (i.e. morning snack), and lunch and the evening meal (i.e. afternoon snack) (87% based on raw data, not presented). Furthermore, these two snack times accounted for almost all of the discretionary energy consumed at snack times (i.e. all snacks combined accounted for 36% of discretionary intake compared with 35% from morning and afternoon snacks combined).

Sensitivity analyses conducted by group allocation (NOURISH intervention and control, and SAIDI) for usual daily intake of energy, fat, saturated fat and sodium demonstrated no significant differences across the three groups (data not presented). Similarly, no differences were found between NOURISH intervention and control groups for the proportion of healthy and discretionary energy intake across the day or at meals and snacks. There were differences between the total NOURISH sample and the SAIDI sample for healthy and discretionary energy intake, however this was likely due to sociodemographic differences in the samples, which are explored and accounted for in subsequent analyses.

Table 2-2: Usual intake of nutrients and intake of the healthy foods/beverages and discretionary choices across the day, and by eating occasion (n=544)

	Total daily intake	**Main meals - combined**	Breakfast	Lunch	Evening meal	**Snacks - combined**
				Median (IQR)		
Usual intake (median (IQR))						
Energy (kJ)	4750 (4307, 5304)	3382 (2979, 3814)	963 (737, 1208)	1096 (922, 1266)	1329 (1110, 1571)	1365 (1110, 1632)
Fat (g)	41.9 (36.7, 48.2)	30.5 (26.8, 35.2)	7.1 (5.2, 9.9)	10.5 (8.6, 12.5)	12.4 (10.5, 14.9)	11.1 (8.1, 14.5)
Saturated fat (g)	20.3 (16.8, 23.9)	14.4 (12.1, 17.3)	3.5 (2.4, 5.0)	4.7 (3.6, 6.0)	6.0 (4.5, 7.3)	5.5 (4.0, 7.5)
Sodium (mg)	1267 (1076, 1484)	980 (832, 1125)	192 (142, 253)	386 (307, 478)	369 (282, 473)	281 (211, 371)
Healthy food/bevs energy (kJ)	3794 (3184, 4399)	2767 (2222, 3353)	892 (666, 1116)	834 (615, 1071)	1078 (772, 1405)	967 (664, 1370)
Discretionary energy (kJ)	949 (591, 1371)	554 (309, 869)	33 (0, 115)	218 (72, 419)	199 (61, 423)	314 (148, 526)
Percent total daily intake (median (IQR))						
Energy	100	72 (66, 77)	21 (16, 25)	23 (20, 26)	28 (24, 32)	29 (23, 34)
Fat	100	74 (67, 81)	17 (13, 23)	25 (21, 30)	31 (26, 35)	27 (20, 33)
Saturated fat	100	73 (65, 81)	18 (13, 24)	24 (19, 30)	30 (25, 36)	28 (21, 35)
Sodium	100	79 (70, 85)	16 (11, 21)	31 (26, 37)	30 (25, 35)	23 (17, 29)
Healthy food/bevs energy	81 (73, 87)	75 (65, 82)	25 (19, 31)	22 (17, 27)	28 (22, 36)	26 (18, 35)
Discretionary energy	20 (13, 28)	62 (46, 78)	5 (0, 15)	26 (12, 41)	22 (9, 36)	36 (22, 52)

2.6.2 Commonly consumed foods

Table 2-3 presents the five most commonly consumed healthy and discretionary foods and three most commonly consumed healthy and discretionary beverages by eating occasion. *Regular breads and bread rolls*, and *fruit and fruit products/dishes* featured in the top five healthy foods for each main meal and at snacks, with the exception of bread at the evening meal. *Dairy milk*, *fruit and vegetable juices* and *infant formula and human breastmilk* were consistently the most commonly consumed non-water healthy beverages, with *dairy milk* being consumed by at least 50% of the sample at each eating occasion.

The three largest contributors to energy intake in a single consumption were *cakes, muffins, scones and cake-type desserts* consumed at snacks, and *sausages, frankfurts and saveloys* (discretionary foods) and *pasta and pasta products* (healthy foods) consumed at the evening meal. *Processed meats* featured in the top five discretionary foods consumed at both lunch and the evening meal, while *fried vegetable products and dishes* (primarily being made up of fried potato in the form of potato chips and French fries, wedges and gems) also featured in the top five at the evening meal. Although *sausages, frankfurts and saveloys* came in behind *cakes, muffins, scones and cake-type desserts* in terms of the percent consuming and the mean energy contribution per consumption, when combined with other categories of processed meats such as chicken nuggets and hamburger patties, the group as a whole was consumed by almost half of the sample (n=254), and provided a mean of 590kJ per consumption (data not presented).

Cordials (sugar or artificially sweetened beverage bases diluted with water), *other beverage flavourings and prepared beverages* and *fruit and vegetable drinks* (i.e. sugar-sweetened juice) featured consistently in the top three discretionary beverages, except at the evening meal where *soft-drinks and flavoured mineral waters* (also called soda - carbonated sugar-sweetened or artificially-sweetened beverages) replaced *fruit and vegetable drinks*. The proportion of participants consuming each type of beverage varied between 2 to 5%.

Table 2-3: Top 5 foods and top 3 beverages consumed by food group and eating occasion, and mean energy contribution per consumption

Meal (n consumers[a])	Category	Food code	Food/food group description	n (%) of consumers[a]	Mean (SD) energy (kj) per consumption
Breakfast (n = 539)	Healthy food[b]	125	Breakfast cereal, ready to eat	362 (67)	341 (176)
		122	Regular breads, and bread rolls (plain/unfilled/untopped varieties)	292 (54)	278 (155)
		16	Fruit and fruit products/dishes	263 (49)	169 (109)
		143	Margarine and table spreads	153 (28)	115 (107)
		121	Flours and other cereal grains and starches (i.e. oats/porridge)	92 (17)	458 (274)
	Healthy beverages[b]	191	Dairy milk (cow, sheep and goat)[c]	485 (90)	345 (178)
		113	Fruit and vegetable juices	90 (17)	127 (95)
		321	Infant formula and human breastmilk	54 (10)	353 (164)
	Discretionary food	311	Yeast, and yeast vegetable or meat extracts (i.e. Vegemite)	155 (29)	31 (22)
		271	Sugar, honey and syrups	138 (26)	94 (86)
		141	Butters	87 (16)	134 (77)
		272	Jam and lemon spreads, chocolate spreads, sauces	68 (13)	99 (101)
		125	Breakfast cereals, ready to eat, high sugar (e.g. Nutrigrain, Milo)	48 (9)	252 (158)
	Discretionary beverages	114	Cordials[d]	13 (2)	96 (110)
		118	Other beverage flavourings and prepared beverages (i.e. Milo)	9 (2)	53 (56)
		113	Fruit and vegetable drinks	8 (2)	174 (136)
Lunch (n = 544)	Healthy food[b]	122	Regular breads, and bread rolls (plain/unfilled/untopped varieties)	408 (75)	383 (186)
		16	Fruit and fruit products/dishes	334 (61)	167 (123)
		194	Cheese	327 (60)	296 (199)
		24	Vegetable products and dishes	278 (51)	129 (181)
		143	Margarine and table spreads	171 (31)	114 (96)
	Healthy beverages[b]	191	Dairy milk (cow, sheep and goat)[c]	258 (47)	410 (227)
		113	Fruit and vegetable juices	77 (14)	161 (116)
		321	Infant formula and human breastmilk	42 (8)	373 (186)
	Discretionary food	186	Processed meats (i.e. ham, bacon, salami)	186 (34)	231 (204)
		311	Yeast, and yeast vegetable or meat extracts (i.e. Vegemite)	145 (27)	35 (28)
		231	Gravies and savoury sauces	101 (19)	75 (91)
		141	Butters	95 (18)	166 (120)
		131	Sweet biscuits	83 (15)	335 (189)
	Discretionary beverages	113	Fruit and vegetable drinks	23 (4)	229 (141)
		114	Cordials[d]	20 (4)	211 (282)
		118	Other beverage flavourings and prepared beverages	8 (2)	78 (90)

Evening meal (n = 544)	Healthy food[b]	24	Vegetable products and dishes	483 (89)	146 (234)
		16	Fruit and fruit products/dishes	288 (53)	167 (137)
		194	Cheese	222 (41)	273 (213)
		124	Pasta and pasta products (without sauce)	200 (37)	461 (352)
		181	Beef, sheep and pork, unprocessed	193 (36)	414 (395)
	Healthy beverages[b]	191	Dairy milk (cow, sheep and goat)[c]	365 (67)	428 (215)
		113	Fruit and vegetable juices	92 (17)	141 (123)
		321	Infant formula and human breastmilk	57 (11)	385 (203)
	Discretionary food	231	Gravies and savoury sauces	198 (36)	81 (113)
		185	Sausages, frankfurts and saveloys	111 (20)	594 (333)
		24	Fried vegetable products and dishes (i.e. fried potato)	109 (20)	487 (379)
		195	Frozen milk products (i.e. icecream, frozen yoghurt)	84 (15)	292 (219)
		186	Processed meat (i.e. ham, bacon, salami)	67 (12)	173 (155)
	Discretionary beverages	114	Cordials[d]	21 (4)	158 (140)
		118	Other beverage flavourings and prepared beverages	11 (2)	65 (64)
		115	Soft-drinks[e], and flavoured mineral waters	9 (2)	84 (95)
Snacks (n = 544)	Healthy food[b]	16	Fruit and fruit products/dishes	516 (95)	183 (109)
		122	Regular breads, and bread rolls (plain/unfilled/untopped varieties)	234 (43)	312 (167)
		194	Cheese	226 (42)	289 (217)
		132	Savoury biscuits	223 (41)	173 (116)
		192	Yoghurt	157 (29)	451 (304)
	Healthy beverages[b]	191	Dairy milk (cow, sheep and goat)[c]	364 (67)	393 (206)
		113	Fruit and vegetable juices	123 (23)	143 (117)
		321	Infant formula and human breastmilk	72 (13)	350 (181)
	Discretionary food	131	Sweet biscuits	248 (46)	309 (159)
		132	Savoury biscuits	123 (23)	254 (160)
		133	Cakes, muffins, scones, and cake-type desserts	119 (22)	608 (371)
		311	Yeast, and yeast vegetable or meat extracts (i.e. Vegemite)	112 (21)	33 (24)
		282	Fruit, nut and seed-bars (i.e. muesli bars, dried fruit/sugar bars)	99 (18)	329 (212)
	Discretionary beverages	114	Cordials[d]	29 (5)	187 (266)
		118	Other beverage flavourings and prepared beverages	23 (4)	67 (65)
		113	Fruit and vegetable drinks	21 (4)	261 (151)

a Consumers = children who consumed the meal or a food from the food group on at least one recall/record day
b Healthy food/beverages = foods and beverages included in the five food groups (according to the Australian Dietary Guidelines)
c This includes milk consumed with cereal products
c Sugar sweetened or artificially sweetened beverage base diluted with water
d Carbonated sugar sweetened or artificially sweetened beverages

2.6.3 Time, money and discretionary choice intake

The three regression models investigating the relationship between time, money and discretionary choice intake are presented in Tables 2-4, 2-5 and 2-6. Tables present the hierarchical regression results at steps 1 – time and money, 4 – family and parent factors and 6 – child factors only. The models accounted for 11.7% of the variance in total discretionary choice intake (R^2=0.117, $F(29, 496)$=3.40, p<0.001, Table 2-4), 11.4% in discretionary choice intake at main meals (R^2=0.114, $F(29, 496)$=3.33, p<0.001, Table 2-5) and 5.2% at snacks (R^2=0.052, $F(29, 495)$=2.00, p=0.002, Table 2-6). The majority of variance was accounted for by the time and money (Step 1) and primary carer parenting (Step 4) steps of the regressions. Child factors did not add substantially to the models (R^2 change (Δ) at Steps 5 (child physiology) and 6 (child eating behaviour): total discretionary choice intake $R^2\Delta$=0.010, p=0.13 and $R^2\Delta$=0.016, p=0.21; discretionary choice intake at main meals $R^2\Delta$=0.011, p=0.10 and $R^2\Delta$=0.016, p=0.22; and discretionary choice intake at snacks $R^2\Delta$=0.005, p=0.45 and $R^2\Delta$=0.016, p=0.25). However, in the case of discretionary intake at main meals, household structure (Step 2) contributed significantly to the model, owing largely to the effect of paternal education ($R^2\Delta$=0.037, p<0.001). Sensitivity analyses excluding the cases (n=17) with imputed household income data had similar results (see Appendix 3) with all associations in the same direction, but a slight increase in p values due to the reduced sample size.

Time and money (Step 1 of the hierarchical regression) accounted for a significant amount of variance in all three models, mostly owing to the household income variable (representing money). Household income showed a consistent, inverse relationship with discretionary choice intake across all three models after accounting for all other covariates (β= -0.15, p=0.002; β= -0.12, p=0.02; and β= -0.13, p=0.01 for total discretionary energy intake at main meals and snacks combined, at main meals only and at snacks only respectively). This means that children of families with a gross household income below $50000 AUD per annum consumed significantly more energy from discretionary choices (irrespective of eating occasion) than those with household incomes of $50000 AUD or more.

In models 1 and 2 investigating total daily discretionary choice intake at main meals and snacks combined, and at main meals only (Tables 2-4 and 2-5), maternal work hours contributed significantly to the models after controlling for child physiological and behavioural factors. Children with mothers working from 21 up to but not including 35 hours per week consumed significantly more energy from discretionary choices across the day (β=0.11, p=0.03) and at main meals (β=0.10, p=0.04), than children with mothers who were not working (reference group). Whereas having a father working greater than 40 hours was associated with a lower intake of discretionary choices at main meals (β= -0.11, p=0.01), even after adjustment for fathers education and household income, both of which were independently inversely associated with discretionary intake at main meals (β= -0.12, p=0.01 and β= -0.12, p=0.02 respectively). Although maternal work hours were not associated with intake of discretionary choices at snacks, children with fathers not working consumed less discretionary choices at snacks than their peers with fathers working a standard full-time week of 35 to 40 hours (β= -0.09, p=0.047). The association between snack discretionary intake with paternal education was the opposite to that found for main meals, where children with fathers that had a university education consumed more energy from discretionary choices at snacks than children with fathers without a university education (β=0.12, p=0.01).

Of the remaining covariates, covert restriction was found to be an important determinant across all three models (β= -0.16, p<0.001; β= -0.14, p=0.001 and β= -0.14, p=0.003 respectively). This indicates that children whose mothers reported using more covert restriction practices (such as avoiding bringing discretionary choices into the home) had a lower intake of discretionary choices both across the day, and at main meals and snacks.

Table 2-4: Regression analyses of time and money, family, parent and child factors, and proportion of total energy intake from discretionary choices (main meals and snacks combined) in 2-year-old Australian children (n=526)

		Step 1 (time and money)				Step 4 (+ family & parent factors)				Step 6 (+ child factors)			
Step		B (95% CI)	SE B	β	p	B (95% CI)	SE B	β	p	B (95% CI)	SE B	β	p
	Constant	*30.14 (24.92, 35.36)*	*2.66*		*<.001*	*28.86 (17.48, 40.24)*	*5.79*		*<.001*	*26.12 (-11.45, 63.69)*	*19.12*		*.17*
1	Maternal working hrs (ref: Not working)												
	1 to <21 hrs	0.33 (-1.92, 2.58)	1.15	0.01	.77	0.68 (-1.55, 2.90)	1.13	0.03	.55	0.86 (-1.37, 3.09)	1.14	0.04	.45
	21 to <35 hrs	2.21 (-0.24, 4.65)	1.24	0.09	.08	2.34 (-0.18, 4.85)	1.28	0.09	.07	2.81 (0.27, 5.35)	1.29	0.11	.03*
	35+ hrs	-0.43 (-3.84, 2.98)	1.74	-0.01	.80	-1.10 (-4.53, 2.33)	1.75	-0.03	.53	-0.74 (-4.17, 2.69)	1.74	-0.02	.67
	Paternal working hrs (ref: 35 to 40 hrs)												
	Not working	-3.50 (-8.43, 1.44)	2.51	-0.06	.16	-1.51 (-6.37, 3.36)	2.48	-0.03	.54	-1.74 (-6.63, 3.16)	2.49	-0.03	.49
	1 to <35 hrs	-0.54 (-3.72, 2.63)	1.61	-0.02	.74	-0.23 (-3.35, 2.89)	1.59	-0.01	.88	-0.56 (-3.70, 2.57)	1.60	-0.02	.73
	>40 hrs	-1.27 (-3.43, 0.90)	1.10	-0.05	.25	-1.79 (-3.89, 0.31)	1.07	-0.07	.09	-1.96 (-4.06, 0.14)	1.07	-0.08	.07
	Household income (ref: <50k)	-5.06 (-7.78, -2.33)	1.39	-0.17	<.001*	-4.35 (-7.23, -1.47)	1.47	-0.14	.003*	-4.60 (-7.48, -1.72)	1.47	-0.15	.002*
2	Partnered (ref: single)					1.67 (-4.43, 7.77)	3.10	0.02	.59	3.15 (-3.01, 9.31)	3.14	0.05	.32
	Paternal education (ref: no uni)[a]					-0.90 (-2.88, 1.08)	1.01	-0.04	.37	-0.82 (-2.80, 1.16)	1.01	-0.04	.42
	No of children (ref: one child)					0.96 (-1.06, 2.98)	1.03	0.04	.35	1.11 (-0.92, 3.14)	1.03	0.05	.28
3	Maternal education (ref: no uni)[a]					-1.10 (-3.15, 0.96)	1.05	-0.05	.30	-1.41 (-3.48, 0.65)	1.05	-0.06	.18
	Maternal age[a]					-0.06 (-0.26, 0.14)	0.10	-0.03	.53	-0.07 (-0.28, 0.13)	0.10	-0.03	.47
	Maternal BMI[b]					0.06 (-0.11, 0.24)	0.09	0.03	.47	0.06 (-0.12, 0.24)	0.09	0.03	.53
4	Reward for behaviour					1.70 (0.09, 3.32)	0.82	0.11	.04*	1.63 (-0.04, 3.29)	0.85	0.10	.06
	Reward for eating					1.77 (0.29, 3.26)	0.76	0.12	.02*	1.77 (0.26, 3.28)	0.77	0.12	.02*
	Covert restriction					-2.13 (-3.19, -1.06)	0.54	-0.17	<.001*	-2.00 (-3.07, -0.94)	0.54	-0.16	<.001*
	Overt restriction					-0.34 (-1.39, 0.72)	0.54	-0.03	.53	-0.49 (-1.59, 0.61)	0.56	-0.04	.38
	Same food					0.15 (-0.63, 0.93)	0.40	0.02	.71	0.06 (-0.80, 0.92)	0.44	0.01	.89
	Group allocation (ref: NOURISH control/SAIDI)					-1.01 (-3.03, 1.00)	1.03	-0.04	.32	-1.30 (-3.33, 0.73)	1.04	-0.06	.21
5	Child gender (ref: male)									1.10 (-0.71, 2.91)	0.92	0.05	.23
	Child age									-1.76 (-18.04, 14.53)	8.29	-0.01	.83
	Child BMI Z-score									-0.72 (-1.64, 0.21)	0.47	-0.07	.13
6	Food responsiveness									-0.38 (-2.27, 1.50)	0.96	-0.02	.69
	Enjoyment of food									0.09 (-2.14, 2.33)	1.14	0.01	.93
	Satiety & slowness									2.47 (0.29, 4.64)	1.11	0.12	.03*
	Food fussiness									-0.24 (-2.06, 1.58)	0.93	-0.02	.80
	Emotional overeating									1.75 (-0.46, 3.96)	1.13	0.08	.12
	Emotional undereating									-1.11 (-2.26, 0.04)	0.58	-0.09	.06
	Desire to drink									-0.16 (-1.30, 0.98)	0.58	-0.01	.78
	Adjusted R^2	**0.025 (p=.005*)**				**0.108 (p<.001*)**				**0.117 (p<.001*)**			
	R^2 change					**0.076 (p<.001*)**				**0.016 (p=.205)**			

a At recruitment/child birth; b At Time 1/child age 4-6 months; ref = reference category

Table 2-5: Regression analyses of time and money, family, parent and child factors, and proportion of total energy intake from discretionary choices (main meals only) in 2-year-old Australia children (n=526)

		Step 1 (time and money)				Step 4 (+ family & parent factors)				Step 6 (+ child factors)			
Step		**B (95% CI)**	**SE B**	**β**	**p**	**B (95% CI)**	**SE B**	**β**	**p**	**B (95% CI)**	**SE B**	**β**	**p**
Constant		*18.82 (14.84, 22.79)*	*2.02*		*<.001*	*18.59 (9.93, 27.24)*	*4.41*		*<.001*	*12.82 (-15.75, 41.39)*	*14.54*		*.38*
1	Maternal working hrs (reference group = Not working)												
	1 to <21 hrs	-0.22 (-1.94, 1.49)	0.87	-0.01	.80	0.01 (-1.68, 1.70)	0.86	0.00	.99	0.19 (-1.51, 1.89)	0.86	0.01	.83
	21 to <35 hrs	1.43 (-0.43, 3.29)	0.95	0.07	.13	1.58 (-0.33, 3.49)	0.97	0.08	.11	2.04 (0.10, 3.97)	0.98	0.10	.04*
	35+ hrs	0.12 (-2.48, 2.72)	1.32	0.004	.93	-0.41 (-3.02, 2.20)	1.33	-0.02	.76	-0.16 (-2.77, 2.44)	1.33	-0.01	.90
	Paternal working hrs (reference group = 35 to 40 hrs)												
	Not working	-0.65 (-4.41, 3.11)	1.91	-0.02	.74	1.02 (-2.68, 4.72)	1.88	0.02	.59	0.69 (-3.03, 4.42)	1.90	0.02	.71
	1 to <35 hrs	-1.01 (-3.43, 1.40)	1.23	-0.04	.41	-0.87 (-3.24, 1.50)	1.21	-0.03	.47	-1.12 (-3.51, 1.26)	1.21	-0.04	.36
	>40 hrs	-1.43 (-3.08, 0.22)	0.84	-0.08	.09	-1.96 (-3.56, -0.37)	0.81	-0.11	.02*	-2.11 (-3.71, -0.51)	0.81	-0.11	.01*
	Household income (ref: <50k)	-3.15 (-5.23, -1.08)	1.06	-0.14	.003*	-2.49 (-4.68, -0.30)	1.12	-0.11	.03*	-2.69 (-4.88, -0.50)	1.12	-0.12	.02*
2	Partnered (ref: single)					2.23 (-2.41, 6.87)	2.36	0.04	.35	3.33 (-1.35, 8.02)	2.39	0.06	.16
	Paternal education (ref: no uni)[a]					-1.98 (-3.49, -0.48)	0.77	-0.12	.01*	-1.93 (-3.44, -0.43)	0.77	-0.12	.01*
	No of children (ref: one child)					1.09 (-0.45, 2.63)	0.78	0.07	.16	1.22 (-0.32, 2.77)	0.79	0.07	.12
3	Maternal education (ref: no uni)[a]					-0.88 (-2.44, 0.68)	0.80	-0.05	.27	-1.10 (-2.67, 0.47)	0.80	-0.07	.17
	Maternal age[a]					-0.05 (-0.20, 0.10)	0.08	-0.03	.53	-0.06 (-0.21, 0.10)	0.08	-0.03	.46
	Maternal BMI[b]					0.05 (-0.08, 0.19)	0.07	0.03	.42	0.06 (-0.07, 0.20)	0.07	0.04	.37
4	Reward for behaviour					0.82 (-0.41, 2.05)	0.62	0.07	.19	0.82 (-0.44, 2.09)	0.65	0.07	.20
	Reward for eating					1.25 (0.12, 2.38)	0.58	0.11	.03*	1.35 (0.20, 2.50)	0.58	0.12	.02*
	Covert restriction					-1.44 (-2.25, -0.63)	0.41	-0.15	.001*	-1.33 (-2.14, -0.52)	0.41	-0.14	.001*
	Overt restriction					-0.30 (-1.10, 0.50)	0.41	-0.03	.46	-0.31 (-1.14, 0.53)	0.43	-0.03	.47
	Same food					-0.22 (-0.82, 0.37)	0.30	-0.03	.46	-0.41 (-1.07, 0.24)	0.33	-0.06	.22
	Group allocation (ref: NOURISH control/SAIDI)					-0.80 (-2.33, 0.74)	0.78	-0.05	.31	-1.03 (-2.58, 0.52)	0.79	-0.06	.19
5	Child gender (ref: male)									0.40 (-0.98, 1.77)	0.70	0.02	.57
	Child age									1.57 (-10.82, 13.96)	6.30	0.01	.80
	Child BMI Z-score									-0.70 (-1.40, 0.003)	0.36	-0.09	.051
6	Food responsiveness									-0.14 (-1.58, 1.30)	0.73	-0.01	.85
	Enjoyment of food									0.18 (-1.51, 1.88)	0.86	0.01	.83
	Satiety & slowness									1.82 (0.16, 3.47)	0.84	0.12	.03*
	Food fussiness									-0.70 (-2.09, 0.68)	0.70	-0.06	.32
	Emotional overeating									0.99 (-0.70, 2.67)	0.86	0.06	.25
	Emotional undereating									-1.01 (-1.88, -0.14)	0.44	-0.11	.02*
	Desire to drink									-0.17 (-1.03, 0.70)	0.44	-0.02	.71
	Adjusted R^2	**0.018 (p=.020*)**				**0.104 (p<.001*)**				**0.114 (p<.001*)**			
	R^2 change					**0.058 (p<.001*)**				**0.016 (p=.216)**			

a At recruitment/child birth; b At Time 1/child age 4-6 months; ref = reference category

Table 2-6: Regression analyses of time and money, family, parent and child factors, and proportion of total energy intake from discretionary choices (snacks only) in 2-year-old Australian children (n=525)

		Step 1 (time and money)				Step 4 (+ family & parent factors)				Step 6 (+ child factors)			
Step		**B (95% CI)**	**SE B**	**β**	**p**	**B (95% CI)**	**SE B**	**β**	**p**	**B (95% CI)**	**SE B**	**β**	**p**
Constant		*11.63 (8.73, 14.52)*	*1.47*		*<.001**	*11.93 (5.44, 18.42)*	*3.30*		*<.001**	*10.94 (-9.59, 33.41)*		*1.09*	*.28*
1	Maternal working hrs (reference group = Not working)												
	1 to <21 hrs	0.66 (-0.59, 1.91)	0.64	0.05	.30	0.83 (-0.44, 2.10)	0.65	0.06	.20	0.83 (-0.45, 2.11)	0.65	0.06	.20
	21 to <35 hrs	0.58 (-0.78, 1.93)	0.69	0.04	.40	0.59 (-0.85, 2.02)	0.73	0.04	.42	0.67 (-0.79, 2.12)	0.74	0.05	.37
	35+ hrs	-0.57 (-2.47, 1.32)	0.96	-0.03	.55	-0.70 (-2.65, 1.26)	1.00	-0.03	.48	-0.53 (-2.49, 1.44)	1.00	-0.03	.60
	Paternal working hrs (reference group = 35 to 40 hrs)												
	Not working	-3.44 (-6.18, -0.70)	1.39	-0.11	.01*	-2.84 (-5.61, -0.07)	1.41	-0.09	.045*	-2.84 (-5.64, -0.04)	1.43	-0.09	.047*
	1 to <35 hrs	-0.15 (-1.91, 1.61)	0.90	-0.01	.86	0.09 (-1.69, 1.86)	0.91	0.004	.92	-0.01 (-1.81, 1.78)	0.91	-0.001	.99
	>40 hrs	-0.33 (-1.53, 0.87)	0.61	-0.03	.59	-0.31 (-1.51, 0.88)	0.61	-0.02	.61	-0.26 (-1.46, 0.94)	0.61	-0.02	.67
	Household income (ref: <50k)	-2.18 (-3.69, -0.67)	0.77	-0.13	.01*	-2.14 (-3.78, -0.50)	0.84	-0.13	.01*	-2.16 (-3.81, -0.51)	0.84	-0.13	.01*
2	Partnered (ref: single)					-0.21 (-3.69, 3.27)	1.77	-0.01	.91	-0.002 (-3.53, 3.52)	1.79	0.00	.99
	Paternal education (ref: no uni)[a]					1.37 (0.24, 2.49)	0.57	0.11	.02*	1.44 (0.31, 2.58)	0.58	0.12	.01*
	No of children (ref: one child)					0.08 (-1.07, 1.23)	0.59	0.01	.89	0.08 (-1.08, 1.25)	0.59	0.01	.89
3	Maternal education (ref: no uni)[a]					-0.30 (-1.47, 0.87)	0.60	-0.02	.62	-0.41 (-1.59, 0.77)	0.60	-0.03	.49
	Maternal age[a]					-0.03 (-0.14, 0.09)	0.06	-0.02	.62	-0.04 (-0.15, 0.08)	0.06	-0.03	.53
	Maternal BMI[b]					0.02 (-0.08, 0.12)	0.05	0.02	.68	0.02 (-0.09, 0.12)	0.05	0.02	.75
4	Reward for behaviour					0.85 (-0.07, 1.76)	0.47	0.10	.07	0.73 (-0.22, 1.68)	0.49	0.08	.13
	Reward for eating					0.43 (-0.41, 1.28)	0.43	0.05	.32	0.28 (-0.59, 1.14)	0.44	0.04	.53
	Covert restriction					-0.94 (-1.55, -0.33)	0.31	-0.14	.002*	-0.94 (-1.55, -0.33)	0.31	-0.14	.003*
	Overt restriction					-0.17 (-0.77, 0.44)	0.31	-0.03	.59	-0.34 (-0.97, 0.29)	0.32	-0.05	.29
	Same food					0.28 (-0.17, 0.73)	0.23	0.06	.22	0.44 (-0.06, 0.93)	0.25	0.09	.08
	Group allocation (ref: NOURISH control/SAIDI)					-0.72 (-1.87, 0.43)	0.59	-0.06	.22	-0.81 (-1.98, 0.35)	0.59	-0.06	.17
5	Child gender (ref: male)									0.68 (-0.36, 1.72)	0.53	0.06	.20
	Child age									-3.21 (-12.52, 6.11)	4.74	-0.03	.50
	Child BMI Z-score									-0.18 (-0.71, 0.35)	0.27	-0.03	.50
6	Food responsiveness									-0.20 (-1.27, 0.89)	0.55	-0.02	.72
	Enjoyment of food									0.30 (-0.98, 1.58)	0.65	0.03	.64
	Satiety & slowness									0.67 (-0.58, 1.92)	0.63	0.06	.29
	Food fussiness									0.81 (-0.23, 1.85)	0.53	0.09	.13
	Emotional overeating									0.68 (-0.59, 1.95)	0.65	0.06	.29
	Emotional undereating									0.16 (-0.50, 0.81)	0.34	0.02	.64
	Desire to drink									-0.03 (-0.68, 0.63)	0.33	-0.004	.94
	Adjusted R^2	**0.016 (p=.031*)**				**0.049 (p=.001*)**				**0.052 (p=.002*)**			
	R^2 change					**0.044 (p=.001*)**				**0.016 (p=.253)**			

a At recruitment/child birth; b At Time 1/child age 4-6 months; ref = reference category

2.7 Discussion

2.7.1 Summary

This study explored the discretionary choice intake of young Australian children by eating occasion and investigated time and money as determinants of intake. Main meals were found to be major contributors to energy intake from discretionary choices, and fat, saturated fat and sodium intake, mostly due to the consumption of processed meats. Whereas the most commonly consumed discretionary choice and the largest contributor to young children's discretionary energy intake, namely sweet biscuits and cakes respectively, were consumed at snacks. The regression models investigating household, parent and child determinants of discretionary choice intake explained more variance in intake at main meals compared with snacks, although the overall variance accounted for in each of the models was low. Time and money, represented by maternal and paternal working hours, and household income, were found to be determinants of young children's discretionary choice intake, with associations differing according to eating occasion.

2.7.2 The discretionary choice intake of young children by eating occasion

Main meals

The eating pattern of the present sample was found to be similar to that of older children and adults. National data representing both adults and children shows that eating patterns in Australia typically consist of three main meals providing the majority of energy and nutrients, with non-starchy vegetables, grains and meat, poultry and fish featuring as the main healthy foods consumed (207, 213). Similarly, secondary analyses of a national children's survey show that in 2 to 4-year-olds, 67% of total daily energy intake is consumed at main meals (213). The present sample of young Australian children similarly consumed almost three quarters of their daily energy intake at main meals, with the majority of daily energy from healthy foods and beverages being consumed at these eating occasions.

Main meals, predominantly lunch and the evening meal, were responsible for over half of young children's daily intake of discretionary energy and a substantial proportion of sodium and saturated fat intake respectively. This reflects the popular discretionary food choices consumed at these eating occasions, including processed meats and fried potatoes. Recent research investigating the discretionary choice intake of a population-based sample of Australian children aged 2 to 18 years found that processed dinner meats (including chicken nuggets and sausages) were the fourth highest contributor to energy intake and also a significant contributor to saturated fat and sodium intake (25). Although contributing a substantial proportion of daily energy, sodium and saturated fat intake, these discretionary choices are often consumed in combination with other foods which are not considered discretionary, such as vegetables and pasta.

Evidence from prior analyses of NOURISH and SAIDI data suggests that the consumption of processed meat appears to start early. Analyses of meat and alternatives consumption showed that although processed meats were not consumed by infants at 9 months of age, 24% of participants were consuming beef, lamb and veal based processed meats by 11 to 17 months of age, while 23% were consuming pork-based processed meats (75). By 2 years, these figures had reached almost 30 and 40% respectively, with median portion sizes consumed being greater than any of the pure meat counterparts (75). This rate of consumption appears to persist into adulthood, with around 38% of adults consuming processed meat at the last national health survey (226). Targeting processed meat consumption at main meals in young children may prevent the development of a preference for these foods that tracks into adulthood.

Snacks

Snack occasions combined contributed more overall energy than any of the individual main meals, but this is because snacks generally consisted of almost three separate eating occasions while each of the main meals only consisted of one to two. This is reflective of recent increases in snacking occasions in Australian children identified in the 1995 to the 2007 and 2011-12 National Nutrition Surveys (206). In 1995 children aged 2 to 3 years of age had a mean of 2.2 snack occasions per day, with this increasing to 2.7 and 2.6 in subsequent surveys (206). Snacks contributed around a third of young children's discretionary energy intake, with sweet biscuits being the snack food of choice behind fruit. Whilst consumed by a smaller proportion of the sample, cakes and muffins contributed a larger amount of energy per consumption than sweet biscuits. The popularity of sweet biscuits, and high energy contribution of cakes and muffins is consistent with 2011-12 population based data across most age groups from 2 to 18 years (25, 206). Analyses using nationally representative data show that sweet biscuits were one of the most commonly consumed foods across children of all ages (25). Furthermore, after SSBs, cakes, muffins and slices were the largest contributors to added sugars intake (25). Although added sugars data were not available in the present work, it is likely that this finding would have been mirrored. Thus sweet biscuit and cake consumption at snacks also make important targets for future early dietary interventions.

SSBs were generally only consumed by a small proportion of the sample at each eating occasion. Although the combined total daily intake of SSBs per child is likely still substantial. In other secondary analyses of the NOURISH and SAIDI 2 year data, it was shown that SSBs were consumed by at least 9% of the sample on the day of the 24 hour recall (76). This figure is much lower than the 30% of 2 to 3-year-olds and 41% of 4 to 8-year-olds shown to be consuming SSBs in the latest national health survey (25). This demonstrates that SSB intake may become more problematic with age. Furthermore, as pointed out in Chapter 1, there has been a reduction in SSB intake over recent decades which has been particularly pronounced in younger children. This suggests that SSB intake need not be as high a priority for intervention as other discretionary choices.

Discretionary choices as an intervention target

Overall, discretionary choices contributed around 20% of this samples daily energy intake, lower than the 30% observed in 2 to 3-year-olds in the latest national health survey data, but nevertheless concerning (17). Prior early dietary interventions targeting discretionary choice intake have had a strong focus on SSBs, sweet and salty snacks and fried potato (74, 81-83, 88, 89, 91, 92, 94). This corresponds with a reduction in intakes of SSBs and added sugars over the last two decades (27). This reduction will likely be bolstered by the push for Australian policy to follow the increasing introduction of SSB taxes internationally as an effective population-based measure to promote a reduction in intake (227). Although further reductions in intake of SSBs and sugary snacks would be positive, early intervention efforts may be better placed targeting intakes of discretionary choices that have not yet seen such reductions.

Young children's intake of discretionary choices at main meals should not be overlooked as an opportunity for intervention. Processed meat consumed at lunch and the evening meal made a substantial contribution to children's intake of energy from discretionary choices and have tended not to be the target of early dietary interventions in young children to date. Although not the only discretionary choice requiring attention at main meals, processed meats present a good case study supporting the benefits of a shift in focus toward discretionary choice intake at main meals.

Processed meats have been shown to be directly associated with long-term health impacts in adults. In 2011, Larsson and Orsini (228) found that processed meat consumption was associated with an increased risk of mortality by all causes. While Wang et al. (229) demonstrated that an increase in intake of one serving of 50g of processed meat was associated with a 15% greater risk of all cause and cardiovascular mortality, and an 8% greater risk of cancer-related mortality. There is little place for processed meat in the diets of young children, who are advised to avoid such discretionary choices in order to maintain a healthy weight and reduce the risk of chronic disease (14).

The potential for reductions in energy, saturated fat and sodium intake, coupled with possible spill-over effects on healthy food intake such as vegetables and legumes, make main meals a particularly important target of future interventions. Sui et al. (207) demonstrated that the consumption of processed meat at lunch or dinner is associated with a lower intake of non-starchy vegetables at the same meal, while healthier cuts of meat were generally accompanied by non-starchy vegetables. Strategies to reduce discretionary choice intake at main meals may therefore have the added benefit of promoting increases in healthy food intake such as vegetables; the food group farthest from meeting recommendations in Australian children (16).

The implications of reductions in discretionary choice intake are important to consider. Both moderation and substitution of discretionary choices has been shown to be effective for reducing energy, added sugars and sodium intake in simulation modelling of national dietary intake data (230). Moderation involves a reduction in the portion size or frequency of consumption, while substitution involves replacing discretionary choices with healthy foods (230). Substitution with healthy foods was shown to have the least impact on micronutrient, protein and fibre intake (230). Although substituting processed meat with lean meat is likely to be positive from an energy and macronutrient perspective (230), it does not necessarily align with the recent national and international push toward lower overall meat intake and an increased intake of plant-based foods (231-233). Similar to processed meat, a high intake of red meat has been associated with an increased risk of all-cause mortality (228, 229). It may also be prohibitive from a cost perspective. Lean meat is more expensive and less well accepted by young children than processed meats, and may be a driver of the use of processed meat in families with a lower income who are conscious of the financial impact of wasted food (145). Advice to moderate or substitute children's intake of discretionary choices should therefore be considerate of both cost and acceptance to young children, while also remaining in line with current evidence and dietary guidelines.

2.7.3 The role of time and money in the discretionary choice intake of young children

This study found that time and money, and parental factors such as feeding practices and paternal educational status, explained a significant amount of the variance in young children's intake of energy from discretionary choices. Furthermore, the models explained more variation in main meal intake than snack intake, with almost double the variance accounted for by the main meal model. This suggests that time, money and parental factors are more important determinants of child intake of discretionary choices at main meals compared with snacks.

Despite the number of key household, parental and child factors accounted for in the models, the amount of variance explained was relatively small. Regardless, the variance explained is of a similar magnitude to another study investigating the influence of the home environment on child intake, although the study was different in its focus on the discretionary snack and beverage intake of school aged children (234). Couch et al. (234) found that their model incorporating a series of social cultural, physical environment, and child and parent characteristics, explained 9 and 16% of the variance in sweet and savoury snacks, and SSBs respectively in children aged between 6 and 11 years. This suggests that although child, parent and household factors are important, there are likely other determinants at play that have not been captured in the present work.

The low variance explained in this study may be due to the lack of predictor variables representing broader household and environmental influences of intake. As discussed in Chapter 1, individual, household and environmental factors influence the dietary intake of young children. The present model included variables representing factors at the individual and household level, but lacked variables representing the home food environment. Research in preschool-aged Australian children found that accessibility of discretionary choices and parental strategies for managing child feeding behaviour were significant mediators of the effect of an intervention on child discretionary choice intake, with the mediation model accounting for almost 40% of the variance in child intake (71). Furthermore, local food environments including supermarkets, food outlets and childcare centres, and food-related policy such as those influencing food pricing and marketing may also play a role in child intake of discretionary choices (58). Predictor variables representing the home food environment such as food availability and parent intake, and the broader food environment outside of the home including frequency and type of childcare utilised would have been useful. Finally, possible underreporting of discretionary choice intake due to social desirability bias is a risk with parent-reported dietary intake methods. This may have resulted in lower overall energy intake from discretionary choices, thus reducing the amount of variance explained by the models.

Time

Both maternal and paternal working hours, conceptualised in this study as time, were associated with young children's intake of energy from discretionary choices. It was found that children of mothers working from 21 up to 35 hours per week consumed on average 2.8% more energy from discretionary choices daily, which equates to approximately 136kJ based on the average energy intake of the sample. This relationship appears to only occur with regards to discretionary choice intake at main meals and not snacks.

Studies investigating the association between maternal working hours and children's dietary intake have been in older children, with findings varying to the present work. Studies have mainly found that greater maternal working hours are associated with lower dietary quality. In an Australian study, part-time maternal employment had a protective effect on child weight status at 4 to 5 years and 6 to 7 years of age (147). This effect was mainly due to less television viewing, and the indirect effect this had on snacking behaviour, measured by the frequency of consumption of a range of sweet and savoury snacks (147). Similarly, in US school-aged children a 20-hour increase in maternal working hours was associated with an increased likelihood of consuming fast food at least once per week and consuming SSBs at least once per day (150). Another US-based study found that adolescents of mothers working full-time consumed fewer family meals and less fruit and vegetables compared to those of part-time and unemployed mothers (149). In a study of multiple European countries, full-time maternal employment was found to be negatively associated with children's diet quality, although the effect was relatively small (151). The inclusion of parent and child covariates, such as paternal working hours, may account for the difference in findings in the present work.

The inclusion of paternal working hours in this study was unique, with prior research in this space not generally accounting for paternal working hours (147, 148, 152). Children with fathers working greater than 40 hours per week consumed less energy in the form of discretionary choices at main meals, while children of fathers who were not working consumed significantly less energy in the form of discretionary snacks. Reasons cited for the exclusion of paternal working hours in past research includes the more influential role of the mother as primary caregiver and food provider, and that fathers working hours have not generally been shown to be associated with child weight (147, 152). Although it is true that the mother is more frequently the primary caregiver and the food provider in Australian households (125), the present findings are a reminder that the father or father figure may also be a key influencer of child discretionary choice intake. Whether their role in influencing children's discretionary choice intake is direct through their contribution to food provision tasks, or indirect through the provision of support to the primary food provider, is unclear and warrants further investigation. Amongst an increasing body of research considering the role of fathers in shaping children's food intake and preferences, and therefore health (95, 96, 113, 235), this study speaks to the need to consider fathers and the parental partnership as a whole in future early dietary interventions.

There is no simple explanation for the non-linear findings of this study in relation to maternal and paternal working hours. Past research has similarly found non-linear relationships with weight and weight-related behaviours (147, 148, 152). The inclusion of household income in the present model means that the relationship cannot be explained by the effect of work hours on income. A possible explanation is that no or low maternal work hours allows more time for food-related processes, whilst full-time work hours may necessitate a level of organisation and flexibility regarding food-related processes that offers some protection. For example, by making use of childcare meal provision or seeking support from family members. Furthermore, the enrichment that full-time employment may add to maternal capability for example, may outweigh negative effects on time (148). It is important to recognise that these relationships may not be due to the effect of work hours on time at all, and may not be casual. More research is needed to understand if these relationships are due to the availability or scarcity of time, or are occurring through some other mechanism, such as maternal self-efficacy.

Money

Consistent with prior research in Australian children, income was inversely associated with discretionary choice intake in young children in all three models (19, 236). All other factors being held constant, an income of less than $50000 AUD per annum was associated with a 4.6% higher intake of energy from discretionary choices than an income of $50000 AUD or more. Using the mean energy intake of the sample, this difference equates to approximately 222kJ daily. Although this amount may seem small, it is the equivalent of just over one third of a serve of discretionary choices. Viewing it from a healthy food perspective, this amount of energy could be displacing 1.5 serves of mixed vegetables in children of families with a low income. Considering the current low intake of vegetables in children (17), and the concern that discretionary choices may be displacing healthy food intake (15), this amount is not insubstantial.

The mechanisms of the relationship between income and discretionary choice intake are also unclear, being that there is no substantial difference between the cost of healthy and unhealthy diets (162). Although to families with a low disposable income, the purchase of unhealthy but palatable food may be a cost-effective form of pleasure (237). The acceptability of discretionary choices to young children may also be critical in the decision to utilise such foods. Low-income households may be driven to serve acceptable foods that are not rejected and wasted (145). Furthermore, a lower disposable income may be a barrier to the purchase of other behavioural supports for the preparation of healthy food, such as healthy pre-prepared meals, or cooking equipment to reduce the burden of the food preparation process. Regardless of the mechanism, money is an important determinant of children's discretionary choice intake across eating occasions and should therefore be considered when planning interventions or policy strategies to address this intake.

The differential role of time and money by eating occasion

Although money showed a consistent association with discretionary choice intake across eating occasions, the role of time, represented by parental working hours, varied by eating occasion. Both maternal and paternal work hours were associated with children's intake of discretionary choices at main meals, whilst only paternal work hours appeared to be important at snacks. Main meals require more planning than snacks, and generally involve staple ingredients that require preparation prior to consumption. Main meal provision may therefore be more vulnerable to time scarcity than snack provision.

Processed meats such as sausages, burger patties, chicken nuggets, fish fingers and frozen potato chips are examples of convenience foods that require little to no preparation and were commonly consumed by young children at main meals. This may explain their popularity as a food coping strategy, where trade-offs in food provisioning are made in order to cope with time-related constraints (99). Horning et al. (238) in their work investigating parents' reasons for purchasing packaged, processed meals, found that those who worked more hours per week were more likely to report time scarcity as a reason for purchasing convenience foods. Similarly Pescud and Pettigrew (145) found that in low-income households, convenience foods were served with the aim of saving time. Therefore the use of unhealthy convenience and fast foods at main meals may be partly driven by time scarcity.

The lower amount of variance accounted for by the snack model suggests that time, money and other parent and child factors play a less important role in children's intake of discretionary choices at snack occasions. A discrete choice experiment with parents of children aged 3 to 7 years found that neither time nor cost were significant factors influencing parental snack choice when weighed up against factors such as child acceptance or resistance, co-parent support and home food availability (239). It is generally an expectation that snacks are quick and easy to prepare and serve, suggesting that time in particular may play a less important role in children's intake of snacks. Qualitative research shows that low-income mothers of preschool aged children see snacks as requiring little preparation, but also as playing a less important nutritional role than main meals (237). Rather parents see snacks for their hedonic value, and their value as a tool to manage their children's behaviour (237). Consistent with the present work, this demonstrates that the drivers of parental food provision at main meals and snacks may be different, thus requiring different intervention approaches in order to improve their nutritional quality.

Covariates

The parental feeding practices step of the regression model resulted in the largest increase in variance of all models owing to the parental feeding practice *covert restriction*. Child factors such as physiology and eating behaviour were less important in this age group. Covert restriction is the act of restricting a child's food environment in such a way that they are unaware of it; for example avoiding purchasing and bringing certain foods and beverages into the house (218). This contrasts with overt restriction which includes more direct control and restriction of child intake (157, 218). Similar work in children of a range of ages confirms the importance of this parental feeding practice in limiting discretionary choice intake (55, 157). This practice could be viewed as a marker of home food availability with those using covert practices modifying the home food environment positively. This highlights the importance of targeting aspects of parental food provision such as food purchasing in order to restrict the availability of discretionary choices at the household level.

Two child eating behaviours were associated with discretionary choice intake at main meals but not at snacks. Specifically, *satiety responsiveness and slowness in eating* was positively associated and *emotional undereating* negatively associated with discretionary choice intake at main meals. The former finding makes sense in the context of young, and potentially fussy eaters, and is supported by prior research. Children who are responsive to satiety cues and perceived to be slow in eating may be assumed to be fussy or have inadequate intake. This may elicit unhealthy parental feeding practices in response in order to encourage consumption. Common behaviours parents may use to manage such child eating behaviour might include persuasive feeding practices such as offering familiar or favourite foods, or rewarding the consumption of healthy foods with discretionary choices. Jansen et al. (53) found that the parenting practices *reward for eating* and *persuasive feeding* were positively associated with *satiety responsiveness and slowness in eating* in NOURISH children. Similarly, a cross-sectional study based in Australia and New Zealand found that in children aged 1 to 10 years, *persuasive feeding* and *reward for eating* was positively associated with higher *satiety responsiveness*, *slowness in eating* and *emotional undereating* (240). Regardless, the contribution of these factors to the overall model was not significant, therefore they may not be as important as household and parental factors in predicting young children's intake of energy from discretionary choices.

2.7.4 Strengths and limitations

This study was unique in its account of young children's discretionary choice intake according to eating occasions, and in its investigation of time and money as determinants of discretionary choice intake in a sample of young Australian children. The use of 24-hour food recalls and records, and the calculation of usual intake, were strengths of this work. The incorporation of both maternal and paternal factors was important in recognising the influence of both parents on food provision, whilst the inclusion of a broad range of covariates ensured that key parent and child factors were adjusted for.

This research was however limited by the use of work hours as a proxy for time, as it does not take into account time commitments outside of work or when work hours take place (e.g. night shifts). Furthermore, work hours do not consider an individual's perception of time and income scarcity, both of which have been identified as equally important factors (160, 241). Analyses involving more robust and diverse measures of time scarcity are needed.

Although dietary recalls and records are an accurate measure of self-reported intake when compared to doubly labelled water (242), they are prone to misreporting bias. In adults, self-report dietary recalls and records tend to result in underreporting of energy intake, while in young children, intake reported via parent proxy is generally overreported (243). Parent-reported multiple pass 24-hour dietary recalls have been shown to overestimate the energy intake of toddlers aged 12 to 24 months by 29%, when compared with 3-day weighed food records (244). However overreporting was primarily in healthy food groups, such as milk, grains, fruits and vegetables, while intake of sweets did not differ between methods (244). Regardless, results of parent reported dietary recalls and records should be interpreted with caution as social desirability bias may lead to underreporting of discretionary choices (245).

The time constraints of the program of research also impacted upon the type and extent of statistical analyses that could be conducted. Analyses that allow the investigation of pathways and interactions between maternal and paternal work hours, and work hours and income, may have supported a deeper understanding of the interplay between time and money. Furthermore, it would have been beneficial to repeat the regression analyses using other markers of intake such as the proportion of energy from the five food groups.

Use of an existing dataset was also a limitation, with missing data on a number of key variables and a lack of variables comprehensively representing child, parent and household determinants of child intake (such as home food availability and parental intake and modelling). Furthermore, as with similar community-based obesity prevention studies (82), NOURISH participants were older, of a higher education and more likely to be partnered than the broader population (87). The sample retained over the course of the study was similarly biased (82, 87), as was shown in the present work. The inclusion of SAIDI participants improved the diversity of the sample, due to recruitment in regional areas and the inclusion of multiparous parents, however the overall sample may not be representative of the broader Australian population. Sociodemographic covariates were included in the regression models in order to adjust for these differences.

Implications for practice and future research

This study confirmed time and money as important opportunity-related determinants of young children's discretionary choice intake that require consideration in future intervention design. There may also be merit in tailoring intervention strategies according to eating occasion, as the type of discretionary foods and beverages consumed and the determinants of intake were found to differ by eating occasion. Discretionary choices consumed at main meals are yet to receive attention in early dietary interventions and are more strongly determined by household and parent factors than intake at snack occasions. A shift in focus toward discretionary choice intake at main meals attends to a key research gap, and is consistent with the recent policy focus on the practical application of the dietary guidelines by eating occasion, such as that seen in the 'ChooseMyPlate' campaign in the United States (246). Intake of snack-based discretionary choices may benefit from strategies that focus on broader environmental influences, such as product reformulation (230).

This research has also highlighted the important role of the father or father-figure in influencing children's intake of discretionary choices. Paternal work hours and education were associated with children's discretionary choice intake at both main meals and snacks. The contribution of fathers to opportunity-related determinants of children's discretionary choice intake will be an important consideration for future research.

2.8 Conclusion

This deep-dive investigation into the what, when and why of young children's discretionary choice intake has provided new evidence that can be used to enhance future early dietary interventions. The exploration of intake through a novel eating occasions lens, has provided a thorough picture of young children's discretionary choice intake across the day. Together with the investigation of under-represented opportunity-related determinants of discretionary choice intake, this research will support the development of intervention strategies that are tailored to specific needs of families of young children.

Commonly consumed discretionary choices at main meals and snacks were identified, with both eating occasions found to contribute substantially to young children's overall diet quality. Although main meal consumption of discretionary choices was highlighted as a novel opportunity for intervention. Time and money were confirmed as key determinants of young children's discretionary choice intake, and along with parental factors, were shown to play a different and more important role in intake at main meals compared with snacks. This suggests that interventions addressing household and parent level factors may be better placed focusing on intake at main meals. Although interventions at a number of socioecological levels will be required in order to maximise behaviour change with respect to discretionary choice intake.

CHAPTER 3: A REVIEW OF COMMERCIALLY AVAILABLE FOOD PROVISION APPS

3.1 Descriptive title

Mobile apps to support healthy parental food provision: a systematic assessment of popular, commercially available apps

3.2 Overview

In Chapter 1 it was established that an enhanced focus on parental food provision is required in order to address the excess discretionary choice intake of young children. Mobile apps were identified as a platform to deliver support for day-to-day food provision behaviours as they occur. Reviews of app-based dietary intervention studies and nutrition-related apps in the commercial space have identified apps directly targeting the intake of children and adults. However there is little known about the role of apps in addressing parental food provision behaviour.

Chapter 2 confirmed that time and money are important determinants of young children's intake of discretionary choices. These opportunity-related determinants of young children's intake warrant consideration as targets for future interventions. Apps in the research and commercial space have so far been focused on individual capability and motivation through goal setting and diet monitoring. This leaves a gap in app-based tools for addressing time and money as barriers to healthy food provision behaviour.

This chapter describes a study addressing <u>thesis specific aim 3</u>; to determine the feasibility of apps and app features addressing parental food provision behaviour. Specifically, this chapter reports on a systematic assessment of the quality and behaviour change content of popular, commercially available apps and app features relevant to improving parental provision of food to young children (<u>thesis specific aim 3a</u>). By exploring the commercial sector this study allowed the identification of apps and app features with behaviour change potential that are yet to be developed or considered in the research space.

This work was published in the *Journal of Medical Internet Research mHealth and uHealth*, a leading journal in the health informatics space, with an impact factor 4.301. Although not yet ranked in SCImago, it is a sister journal to the *Journal of Medical Internet Research* which is a quartile one journal in the Medicine, Health Informatics category. The publication has been cited five times, and has an Altmetric score of 24, this being in the top 25% of all outputs scored by Altmetric (as at 04/06/2020). The PhD candidate led the research, conducting all searches, extracting the data, and assessing the apps for quality and behaviour change content. A second reviewer conducted double screening and assessed a subset of the included sample of apps for quality and BCT content. The PhD candidate also interpreted the findings of the review, and prepared and edited the full draft manuscript prior to seeking input from the supervisory team.

This chapter is based on the original submission to the *Journal of Medical Internet Research mHealth and uHealth,* prior to publication. Modifications have been made to the introduction and concluding statement to add context and the manuscript formatted for consistency with this thesis. See Appendix 4 for the signed co-authorship approval form and Appendix 5 for the final published version of the manuscript:

Mauch CE, Wycherley TP, Laws RA, Johnson BJ, Bell LK, Golley RK, Mobile Apps to Support Healthy Family Food Provision: Systematic Assessment of Popular, Commercially Available Apps, JMIR mHealth uHealth 2018;6(12):e11867, DOI:10.2196/11867

3.3 Introduction

Excessive consumption of energy-dense, nutrient-poor foods is a key cause of poor diet quality (17, 25, 247, 248) and is contributing to the high prevalence of overweight and obesity globally (14, 249, 250). In Australia, these foods are contributing 30 to 40% of the total daily energy intake of children and adolescents (17). Similar figures have been reported in the United States and Canada, with children and adolescents consuming at least one third of their daily energy intake in the form of energy-dense, nutrient-poor foods (248, 251). The increasing reliance on these generally highly processed foods may be in part due to the conflicting demands that the modern lifestyle places on the resources available for parental food provision (148).

Food provision, encompassing the planning, purchasing and preparation of food, requires significant time and both mental (e.g. food preparation knowledge, planning skills) and physical (e.g. food preparation facilities) resource (164, 252, 253). The use of food coping strategies (such as meal planning, shopping list writing, use of convenience ingredients or pre-prepared meals, and seeking support) can enable families to overcome resource-related barriers to food provision (including time or income scarcity). Some strategies, such as the purchase of fast or convenience food, occur at the detriment of diet quality (142, 145, 160, 165, 254). Whereas other strategies, such as meal planning and shopping list use, have been associated with healthier food preparation (165). Dietary interventions supporting the use of healthy food coping strategies are warranted, and in fact desired by parents (255). However interventions supporting parents to improve their children's dietary intake are primarily focused on education rather than skill development, and are of moderate effectiveness (73). Addressing opportunity-related food provision barriers and supporting the adoption of healthy food coping behaviours may enhance the effectiveness of interventions to improve child and family diet quality (252, 253, 256).

Health interventions delivered by mobile apps have the potential to address opportunity-related barriers to healthy food provision by offering practical behavioural support, remotely, interactively and in context (173). The unique placement of mobile phones within our daily lives, along with technological advancements such as GPS, machine learning and data tracking, means that apps are positioned to deliver ecological momentary interventions (173, 178). Although the initial time and monetary outlay for app development can be substantial, they are highly scalable, and with mobile phone ownership nearing saturation, they have the potential to reach a diverse population (169, 257). Furthermore, interventions can be personalised based on user input, which may improve user-engagement and intervention fidelity (169, 178). The current popularity of health and nutrition-related apps in both the general public and in research, along with the opportunities that the technology provides, makes it an important platform to explore for future family dietary interventions (169, 258).

Reviews of nutrition-related mobile health interventions have examined their effectiveness in relation to behavioural and weight-related outcomes (180, 182, 183, 259, 260). A meta-analysis of 12 diet and physical activity focused app studies, found that delivery of an intervention via mobile app significantly reduced weight compared to controls (-1.04 kg, 95% CI -1.80 to -0.27 kg) (259). Similarly, a systematic review found moderate evidence that diet and physical activity apps lead to improvements in health-related behaviours and outcomes (19 of 27 apps) (183). More recently, a systematic review and meta-analysis of app-based interventions found a small but significant effect in favour of the intervention amongst the 21 studies reporting on a dietary intake related outcome (182). However, these reviews have generally focused on apps for weight loss and/or diet monitoring, with limited relevance to parental food provision (180, 182, 183, 259, 260).

A recent scoping review identified studies describing apps relevant to families, although the focus was primarily on apps supporting parental feeding practices (i.e. responding to vegetable refusal, food portions), and monitoring of family members snack intake (261). The same review identified a small subset (n=9 of 47, 19%) of mainly app development studies describing food access and food purchasing apps (261). These apps were found to utilise environmental support features such as recipe suggestions and augmented reality tagging of products in the supermarket aisle (261). Therefore while there is evidence of the development of apps providing behavioural support for aspects of food provision, there is a paucity of published research exploring the use of apps for families that consider a range of food provision processes. In order to understand the potential role of apps in addressing a range of food provision processes, it is crucial to look to existing, commercially available apps to support innovation in future research studies (169).

Reviews of apps in the commercial space have assessed app features and quality, and identified the BCT content of nutrition, physical activity and weight management apps targeting adults (124, 189, 190) and children (192, 193). These reviews found that there remains a need to enhance app quality and utilise behaviour change theory in app development as important precursors to app effectiveness (124, 189, 193). The focus of these apps on diet and weight-related outcomes (such as calorie-counting and weight monitoring), rather than the behaviours leading to healthy dietary intake and weight, may limit their behaviour change potential (124). Similar to reviews of published app studies, commercial apps pertaining to food provision in a family context are yet to be explored. To ensure that current technological and behaviour change potential in this area is fully understood, and to understand gaps in the commercial space, a review of existing, commercial apps addressing parental food provision is required.

3.4 Aims and objectives

Thus, the purpose of this review was to identify and assess popular, commercially available mobile apps that have the potential to offer behavioural support for the provision of healthy family food. Specifically, the objectives of this systematic assessment were to describe app scope and characteristics, assess app quality, and conduct a behavioural analysis of app content and features.

3.5 Methods

3.5.1 Search strategy

Systematic searches were conducted in the Google Play Store and Apple App Store between August and November of 2017. The search strategy was modelled on prior systematic assessments in similar fields of research (189, 190, 193, 194). Google Play searches were conducted on a personal computer in a Google Chrome web browser without Google account login. App Store searches were performed using the app on an iPad, as the store does not include a search function when used on a personal computer (190). Search terms relating to the food provision process were selected, and pilot searches in both stores resulted in the following primary terms being used to identify apps for inclusion:

- WHO: child, children, toddler, kid, kids, preschooler, family, families, parent
- WHAT: nutrition, food, meal, menu, recipe, recipes, diet
- HOW: plan, planning, planner, shopping, supermarket, grocery, budget, cook, cooking prep, preparation

Terms were combined into groups reflecting the various stages of the food provision process, including; meal planning, food budgeting, nutrition, food, and cooking knowledge, food purchasing and meal preparation. Two to three word combinations were then generated for each group (e.g. meal planner, child meal plan) and the first combination from a group was entered with the first 50 results being checked by title and description against the inclusion/exclusion criteria. This was repeated for subsequent search terms from that group until a term returned no new apps that met the inclusion criteria. The search was then deemed saturated for that group, and the next group of search terms applied.

3.5.2 App selection

Apps were included if they were applicable to parents with children, written in the English language and had a user rating of at least four stars in the Google Play Store (to ensure that only popular, functional apps were reviewed) (189). This limit was unable to be applied in the Apple App Store as most apps had insufficient reviews to be given a star rating. All free, paid and freemium apps were included, except where the app was subscription only with no freemium version. The following app types were excluded: weight loss, diet monitoring and calorie counter apps, generic apps with only one food-related component (i.e. personal organisers with a shopping list), infant food/feeding apps, apps focused on child feeding practices, E-books or magazines, and recipe apps focused solely on unhealthy food (i.e. cakes) or one key ingredient/cuisine. Apps were also excluded if their use was contingent upon involvement in a research study or a face-to-face component, or if they were subscription apps with no free version. The initial screen using this criteria was conducted using the app name, description and screenshots of the app found within the stores. Approximately 10% of the screened apps (selected randomly, using the random number function within Microsoft Excel 2016) were checked by a second reviewer for correct inclusion/exclusion. Agreement was 94% (256 of 273), with discrepancies discussed and consensus reached (194).

Due to large numbers of similar and generic apps (e.g. basic shopping list apps), a second and third screen was undertaken with additional exclusion criteria. At the second screen, apps with only one food related component (i.e. recipes only), less than 20 reviews in the Google Play store (193), and duplicates between stores were excluded. Apps were then grouped according to their primary purpose as described in the Google Play Store or App Store, and a third screen applied to ensure that the final sample provided good representation of the features available in such apps. Using the app description in the Google Play Store and App Store apps were included at the third screen if they had at least one unique feature not yet described in another app from that group of apps, or features that were combined in a unique way.

3.5.3 Data extraction and assessment

Once all eligible apps were identified, an Apple iPad Mini Version 4 (Model A1550) and Lenovo Tab3 7 Essential (Model TB3-710F) were used to download apps for assessment. Where apps were ‘freemium’ (i.e. available for free but with some features only accessible with payment), the paid version was purchased, except where subscription was required. These apps were downloaded and assessed in the free version. Apps were used for a minimum of 10 minutes before data extraction or assessment began (196). Reviewers used individual apps for a period of time (generally on a number of occasions) that was sufficient to familiarize themselves with the apps features and functionality. The time spent using apps varied because of the significant heterogeneity of the included apps. Data extraction was checked and apps were assessed independently by a second reviewer in a random sample of 20% (n=11).

App characteristics

App information including app and developer name, operating system availability, version, affiliations, cost structure, user rating and number of downloads (where available), and app scope (i.e. target audience and behaviour), was extracted into a purpose designed Microsoft Excel 2016 spreadsheet. The primary direction of data into or out of the app was determined and described as input, output or both. App content such as information, videos, images and recipes, were defined as ‘output’, whereas features requiring user input, such as entering items into shopping lists or meal planners, were defined as ‘input’.

App quality

App quality was assessed using the Mobile App Rating Scale (MARS), an objective and reliable measure of the quality of health-related apps (196). The domains assessed by the MARS tool include engagement, functionality, aesthetics and information (196). An optional domain regarding subjective app quality was not included in the present study. Apps were rated between one and five for each of the criteria, with four mean domain scores and an overall mean score across all four domains being indicative of app quality (a score of five indicating the best performing apps). Both reviewers viewed an online training video prior to app assessment (262). Inter-rater reliability of the overall MARS score was tested on the sample of double assessed apps using the two-way random effects intraclass correlation coefficient (ICC) (263). The resulting ICC value of 0.74 indicated good inter-rater reliability (264).

App content and features

Data regarding app content and features were sorted into two distinct categories; ‘Behavioural support content and features’ and ‘Technical features’. ‘Behavioural support content and features’ were those that may enable the performance of a behaviour relating to the provision of healthy family food. ‘Technical features’ did not offer behavioural support but were important to the overall functioning of the app. App content was then assessed for the presence of BCTs against the BCT Taxonomy Version 1 (BCTTv1) (205). Both reviewers underwent online training prior to coding (265). The agreement between reviewers regarding the presence of BCTs was tested in the 11 double assessed apps using Kappa and prevalence adjusted and bias adjusted Kappa (PABAK) and was near perfect (Kappa mean 0.82 (range 0.66-1), PABAK 0.97 (range 0.94-1)) (266).

3.5.4 Data analysis

Means (SD) for each MARS subscale and the overall MARS score were calculated using Microsoft Excel 2016 for each app. A summary score was calculated for each app type (i.e. recipe/recipe managers, meal planners, shopping lists, family organisers and food choice apps) along withan overall mean score for all apps. The mean (SD) number of BCTs per app and app type were calculated and the total number of apps from each app type incorporating the BCT was presented graphically. The presence of behavioural content and features, and technical features was tallied for each app type and for all apps.

3.6 Results

3.6.1 App selection

A total of 2881 apps were screened across the Google Play Store and Apple App Store. The final number included for assessment was 51 (see Figure 3-1).

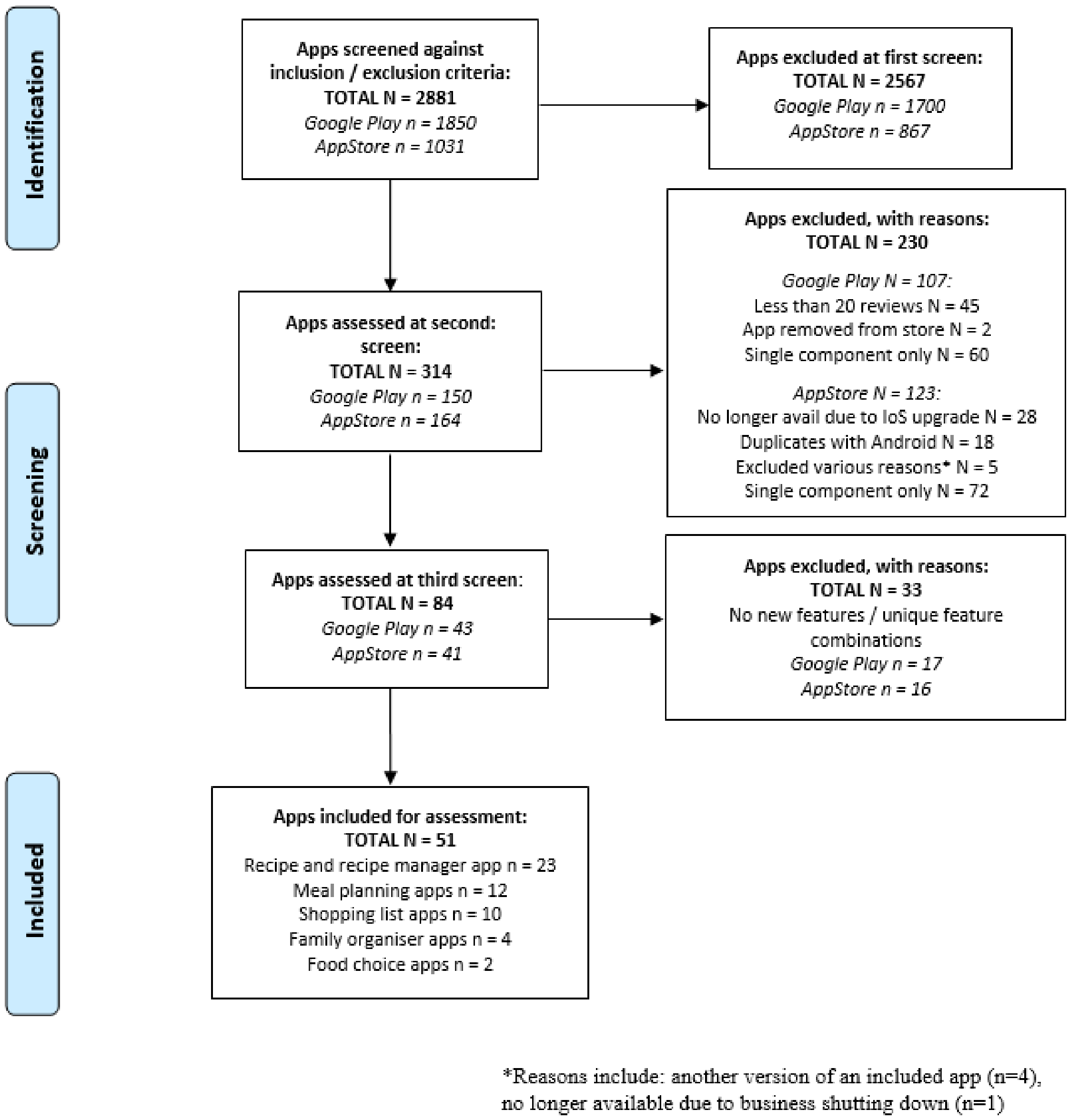


Figure 3-1: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram for popular, commercially available apps addressing parental food provision

3.6.2 App characteristics

Selected apps fell into five categories of app type: Recipe & recipe manager apps which provided recipes and/or digital storage of recipes; meal planning apps which allowed the planning and recording of meals in advance; shopping list apps which allowed recording of grocery items for purchase; family organiser apps which included meal planners and shopping lists synced between family members; and food choice apps which provided nutrition and/or produce information to support food purchasing.

Recipe and recipe manager apps were the most common app type in the sample (n=23/51, 45%), followed by meal planning apps (n=12/51, 24%). Almost all apps were developed by commercial enterprises, with the exception of one app developed by a government body, and another by a non-government research institute in collaboration with a private health insurer. Approximately one third (n=16/51, 31%) of apps were free to download and use (see Appendix 6 for individual app details including MARS scores). The primary behavioural targets of the apps included food purchasing (n=46/51, 90%), meal preparation (n=39/51, 76%), meal planning (n=24/51, 47%) and food choice (n=5/51, 10%). Half (n=26/51, 51%) of the apps operated primarily on input from the app user with shopping lists and family organisers being most reliant on user data input. Only one quarter of apps incorporated both significant user data input along with app information output (n=13/51, 25%).

3.6.3 App quality

The mean MARS score for app quality was highest for food choice apps and family organiser apps (3.5 ± 0.6 out of 5 for each), followed by recipe and recipe manager apps (3.4 ± 0.5). Shopping list apps had the lowest total MARS scores, with half of the apps scoring below 2.5 (for MARS scores by app type, see Table 3-1, and by individual app, see Appendix 6 for individual app details including MARS scores). Engagement was the lowest scoring domain for each app type with shopping lists and meal planners performing the worst. Most app types scored well for functionality (mean across all app types 3.6 ± 0.7).

Table 3-1: Mean (SD) Mobile App Rating Scale (MARS) subscale scores and total scores by app type

App	n	Subscale score				Total MARS
		Engagement	Functionality	Aesthetics	Information	
Recipe & recipe manager apps	23	2.7(0.6)	3.8(0.6)	3.6(0.8)	3.4(0.4)	3.4 (0.5)
Meal planning apps	12	2.5(0.8)	3.8(0.7)	3.2(1.0)	3.2(0.6)	3.1(0.7)
Shopping list apps	10	2.1(0.4)	3.0(0.9)	2.9(0.9)	2.9(0.5)	2.7(0.6)
Family organiser apps	4	3.2(0.7)	3.7(0.6)	3.7(0.9)	3.6(0.5)	3.5(0.6)
Food choice apps	2	2.7(1.3)	4.4(0.2)	2.8(0.2)	4.0(0.7)	3.5(0.6)
ALL APPS	51	2.6(0.7)	3.6(0.7)	3.3(0.9)	3.3(0.6)	3.2(0.6)

3.6.4 App content and features

Behavioural support content and features

App content and features relating to the provision of healthy family food are presented by app type (see Table 3-2, and Appendix 7 for details by individual app). Several common app features supported the use of key healthy food coping strategies, for example meal planners, shopping lists and social supports. Meal planners were the primary feature of all 12 meal planning apps, and featured in around half of the overall sample (n=26 of 51, 51%). Shopping lists featured almost universally (n=44 of 51, 86%) and where incorporated into other app types (as opposed to a stand-alone shopping list app) they generally offered automated list generation. Similarly, almost all (n=48 of 51, 94%) apps included the ability to share app content by email and/or social media.

Recipes and recipe managers (the primary feature of recipe and recipe manager apps, n=23) were present in more than half of the overall sample (recipes n=33 of 51, 65%, and recipe managers n=28 of 51, 55%). Food preparation skills instructions were uncommon (n=7 of 51, 14%) and included either text, image and/or video based instructions. Reminders and/or prompts were included in almost a third of apps (n=27 of 51, 27%) A small number of apps included general and produce-related nutrition information (n=8 of 51, 16%) while only three apps (6%) included the ability to purchase food for delivery.

Table 3-2: App behavioural support content and features presented by app type and across all apps

Behavioural support feature/content	Recipe & recipe manager apps (n=23)	Meal planning apps (n=12)	Shopping list apps (n=10)	Family organiser apps (n=4)	Food choice apps (n=2)	ALL APPS (n=51)
	n(%)					
Meal planners & meal plans	10(44)	12(100)	2(20)	2(50)	0(0)	26(51)
Shopping list	20(87)	9(75)	10(100)	4(100)	1(50)	44(86)
Social community/connectivity[a]	10(44)	4(33)	0(0)	0(0)	0(0)	14(27)
Other social supports[b]	23(100)	11(92)	9(90)	4(100)	1(50)	48(94)
Recipes	19(83)	6(50)	4(40)	3(75)	1(50)	33(65)
Recipe managers	13(57)	6(50)	7(70)	2(50)	0(0)	28(55)
Pantry/fridge manager	1(4)	1(8)	5(50)	0(0)	0(0)	7(14)
Food preparation skills instructions	6(26)	1(8)	0(0)	0(0)	0(0)	7(14)
Reminders & prompts[c]	4(17)	4(33)	5(50)	1(25)	0(0)	14(27)
Encouragement & incentives[d]	8(35)	1(8)	4(40)	2(50)	0(0)	15(29)
Produce purchasing information	0(0)	0(0)	0(0)	0(0)	1(50)	1(2)
Produce storage information	1(4)	0(0)	0(0)	0(0)	1(50)	2(4)
Produce nutrition information	1(4)	1(8)	1(10)	0(0)	2(100)	5(10)
Recipe nutrition information	6(26)	3(25)	1(10)	0(0)	0(0)	10(20)
Other nutrition information	2(9)	1(8)	0(0)	0(0)	0(0)	3(6)
Food purchase & delivery	1(4)	1(8)	1(10)	0(0)	0(0)	3(6)

a Social community/connectivity = Community (with following), upload recipes/images, rate, review, like, comment
b Other social supports = Sharing to social media, sending via email, shared calendar, private messaging
c Reminders & prompts = Recipe suggestions on entering the supermarket, supermarket proximity alert, reminders (to cook, plan meals, shop)
d Encouragement & incentives = Positive messages, points, rewards, competitions, sales/discounts, other notifications (e.g. new content, offers)

Nineteen of the 93 BCTs in the taxonomy were identified as being present across the 51 apps, with a mean (SD) of 3.9 ± 1.9 per app ranging from one to 10 (see Figure 3-2 and Appendix 8 for details by individual app). Family organiser apps followed by meal planning apps, were identified as having the greatest number of BCTs (5.5 ± 3.1 and 4.8 ± 1.9 respectively). Recipe and recipe manager apps included an average of four BCTs per app (3.9 ± 1.5), while food choice apps and shopping list apps were identified as including the least number of BCTs (2.5 ± 0.7 and 2.3 ± 0.8 respectively). The only BCT that was identified as being present across all apps was *12.5 Adding objects to the environment*. This was due to features such as shopping lists and meal planners that were thought to add objects to the environment that may subsequently enable a behaviour relating to healthy food provision. Recipe and recipe managers commonly included the BCT *4.1 Instruction on how to perform the behaviour* (n=19, 83%), owing to the inclusion of recipes with step-by-step instructions. Eleven (92%) and 10 (83%) of 12 meal planning apps included BCTs *1.1 Goal setting (behaviour)* and *1.4 Action planning*, owing primarily to the ability to plan meals in advance.

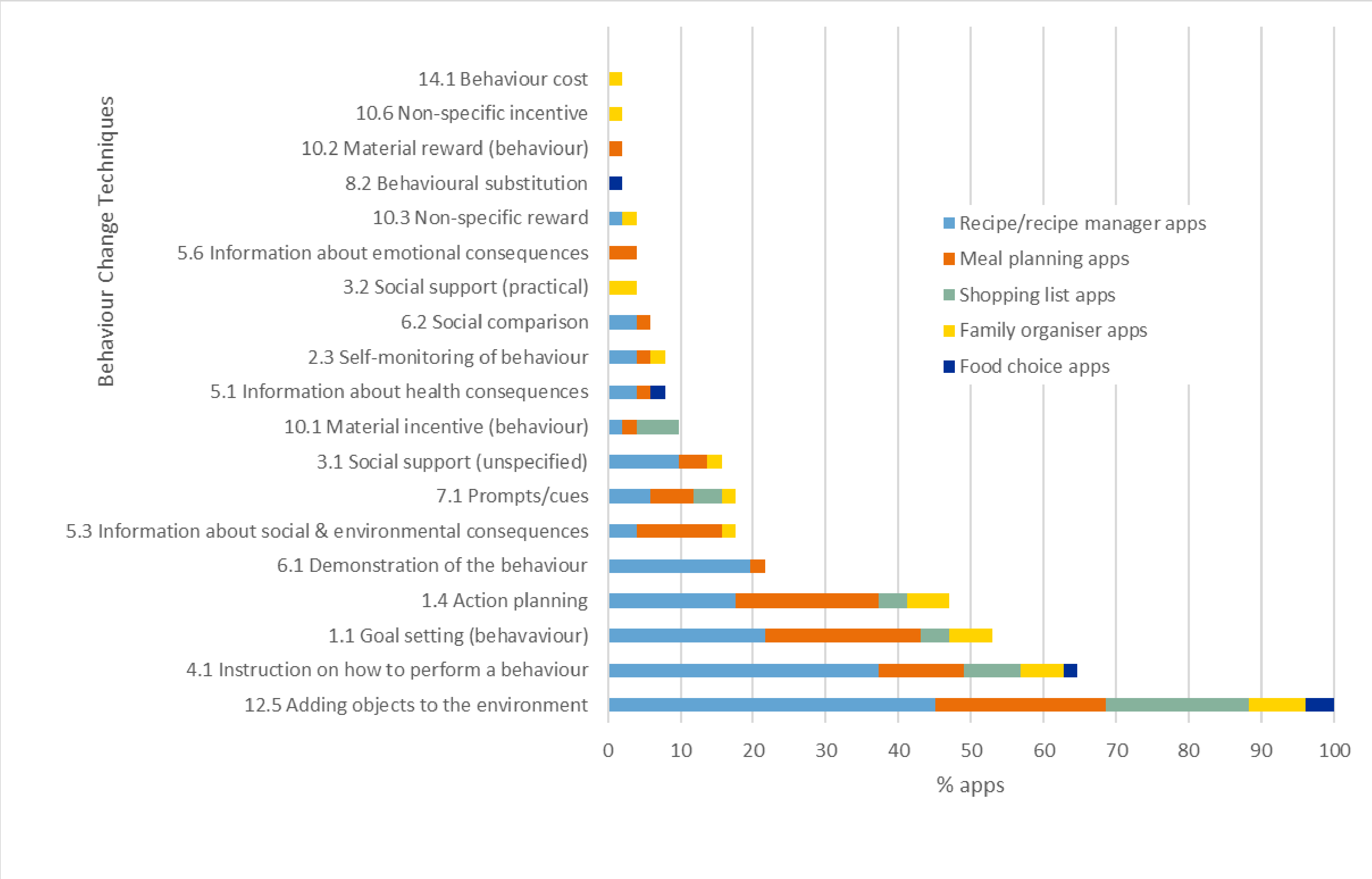


Figure 3-2: Proportion of apps identified with behaviour change technique present, by mobile app type

Technical features

Technical features were grouped separately as they were unlikely to directly support behaviour, but remained important to the overall functioning and engagement of the mobile apps (see Table 3-3 and Appendix 7 for details by individual app). Two thirds of apps (n=35 of 51, 69%) allowed some level of personalization, such as a customised recipe display based on food preferences, dietary requirements, or number of serves required. More than half of all apps (n=29 of 51, 57%), predominantly recipe and recipe manager apps, included practical features such as cooking timers, unit converters (i.e. cups to milliliters), voice input of data, hands free commands, and automatic screen lock to prevent the device from sleeping while the app is in use. A little over half of the apps allowed syncing between devices and cloud back-up (n=30 of 51, 59% and n=29 of 51, 57% respectively).

Table 3-3: Technical features presented by app type and across all apps

Technical feature	Recipe/recipe manager apps (n=23)	Meal planning apps (n=12)	Shopping list apps (n=10)	Family organiser apps (n=4)	Food choice apps (n=2)	ALL APPS (n=51)
	n(%)					
Personalization	20(87)	9(75)	4(40)	1(25)	1(50)	35(69)
Practical features[b]	17(74)	4(33)	7(70)	1(25)	0(0)	29(57)
Syncing between devices	12(52)	6(26)	8(80)	4(100)	0(0)	30(59)
Cloud back-up	14(61)	5(42)	7(70)	3(75)	0(0)	29(57)
User/family profile[c]	7(30)	3(25)	0(0)	3(75)	0(0)	13(25)
Miscellaneous & optional purchases[d]	4(17)	2(17)	5(50)	2(50)	0(0)	13(25)
Search & display options[e]	19(83)	5(22)	8(80)	4(100)	1(50)	37(73)
Other input options[f]	6(26)	6(26)	10(100)	3(75)	1(50)	26(51)
Requires login	12(52)	6(26)	7(70)	3(75)	0(0)	28(55)
Web access required	21(91)	10(83)	5(50)	4(100)	2(100)	42(82)

a Personalization = Food preferences, dietary requirements, favourites lists, scale recipes to serves required, add notes or rating to recipes (private)
b Practical features = Prevents device from sleeping, voice command, audio reading, hands free, smart watch compatible, cooking timers, unit conversions
c User/family profile = Individual profile or profile of individual family members/family as a whole
d Miscellaneous & optional purchases = To-do lists, optional purchases (e.g. hard copy cookbook, cooking equipment)
e Search & display options = Search functions e.g. by ingredient, recipe name, category (e.g. vegetarian), novel search functions e.g. by shaking device, by photo
f Other input options = common items lists, history/recurring items, barcode scanners, add images, coupons, loyalty cards

3.7 Discussion

3.7.1 Summary

This review identified and assessed commercially available mobile apps addressing parental food provision. Most apps provided behavioural support for the use of healthy food coping strategies, although supports were biased towards planning behaviours which may appeal to some, but not all users. App features and content mapped to relatively few BCTs, with the higher quality family organiser apps, meal planning apps and recipe and recipe manager apps incorporating the greatest number of techniques respectively. Recipe and recipe manager apps, meal planning apps and family organisers with integrated meal planning and shopping lists, were found to be highly functional with regards to their performance and ease of use, and incorporated a range of behavioural support features that could be used to address barriers to healthy food provision such as time scarcity and mental load.

3.7.2 App characteristics and quality

The majority of apps targeted meal planning and shopping list use, both considered healthy food coping strategies (165). Although these food coping strategies are associated with healthier food preparation practices, they are best suited to those more inclined to plan (142). Few apps effectively addressed food coping strategies such as preparing meals with few ingredients on hand, utilizing healthy convenience foods (i.e. frozen or canned products, meal kits) or seeking support. Furthermore, observed features often required extensive data input (e.g. recipe managers, family organisers) which may be a barrier to app engagement or use (267).

Although most apps were generally functional in terms of their performance, ease of use, navigation and gestural design, their low ratings for the engagement domain of the quality assessment was a concern, given this is a key predictor of long-term use (169). A recent review of eleven weight loss apps addressing food purchasing behaviour reported similar findings (124). Whereas others have identified concerns regarding information quality, and highlighted the need for evidence-based content (193). However, as the information within the apps assessed in the present review was mostly limited to recipes or food skills, the information quality rating is less relevant. The evidence base of such apps should be in their delivery of behavioural supports, to ensure that they have a positive influence on the food provision process.

3.7.3 Behavioural analysis

Mobile app behavioural supports such as shopping lists, meal planners and recipe managers have the advantage of delivering BCTs in the real-world, when behaviours are likely to occur, thus improving the chance of positively shaping behaviour (173, 178). However, the number of BCTs identified in the present sample of apps was lower compared to similar reviews of weight loss and general nutrition apps (189, 193), reflecting the development of these apps for commercial purposes rather than for behaviour change or health promotion. This indicates significant scope for increasing the behaviour change potential of future apps in this space.

There were a number of app types and features that should be considered in the development of future evidence-based, behaviour-change theory driven apps targeting food provision in families. Meal planning apps and features, supporting the formation of intentions to prepare a healthy meal, were identified as including the second largest mean number of BCTs. Most notably they incorporated *1.1 Goal Setting (behaviour)* and *1.4 Action Planning*. The two meal planning apps with the highest MARS scores and largest number of BCTs allowed the user to outsource some aspects of the planning and purchasing process. One included automated meal plans and shopping lists produced using an internal bank of recipes, while the other offered meal kit ordering and delivery. These apps could be suitable for those not naturally inclined to plan and willing to relinquish some decision-making regarding meals. However, inadequate personalization, complex recipes and the high cost associated with ingredients and box kits may be barriers to the widespread use of such apps.

Shopping lists as a stand-alone app type generally failed to offer more than the conventional paper and pen method, so it was unsurprising that they performed poorly on all domains of the MARS, and mapped against very few BCTs. Where shopping lists were incorporated into other app types and allowed automatic list generation through recipes, they have the potential to reduce the time burden associated with shopping list writing. Linking to online grocery ordering would add a further efficiency, however this feature was uncommon, only being incorporated into two of 51 apps.

Another feature with the potential to increase efficiencies relating to food purchasing is the ability to sync grocery lists between family members (i.e. a shared shopping list). This feature could be utilised to share the mental and physical load of planning and purchasing food. Family organisers generally offered the ability to share such tasks amongst family members, but most were expensive (e.g. up to $69.99 AUD per year subscription), requiring an ongoing subscription in order to access such features. Furthermore, they required significant data input and are likely suited to those with established planning skills.

Few apps incorporated timely reminders and prompts, which is a missed opportunity to take advantage of mobile apps ability to offer ecological momentary intervention (178). If used appropriately (i.e. not overwhelmingly) and timed to coincide with the performance of food–related behaviours, reminders and prompts in the form of push-notifications could act to reduce the mental load of the food provision process. Supermarket proximity alerts and reminders of the planned evening meal, were effective, albeit uncommon, examples of such push-notifications, delivering the BCT *7.1 Prompts & cues.*

Most of the apps assessed provided limited information, generally in the form of recipes and food skills, which is consistent with the move toward more data input style apps. This content was associated with *4.1 Instruction on how to perform a behaviour*, and where video or image content was included, *6.1 Demonstration of the behaviour*. However, most apps providing recipes or food skills were not focused on healthy food preparation or use of healthy food coping strategies (i.e. utilising frozen/canned foods, cooking from few ingredients), and few directly targeted families. Nutrition information delivered in the context of food purchasing, such as in one reviewed app that suggested healthier alternatives to scanned products, may be more likely to support behaviour change than generic nutrition information. However, it is possible that the way information is presented and the functionality of the app delivering it determines its efficacy in changing behaviour. For example, the convenience of the information (i.e. barcode scanners for searching), and the pairing of recipes with relevant food skills videos, hands free commands, single directions displayed per page and text to speech functions.

3.7.4 Review strengths and limitations

Although the search strategy of the present review was systematic and based on similar reviews of commercial apps for nutrition and weight management (189, 190, 193), it was limited by the lack of standardised methods for searching commercial mobile app stores. Along with the limited and variable information provided in app descriptions, these factors made it difficult to ensure all eligible apps were captured, particularly high quality apps. There were also limitations relating to the use and interpretation of the MARS score. The information quality domain was limited to assessing the accuracy of the app description and the credibility of the app developer in the absence of assessable information, and should therefore be interpreted with caution. Moreover, although family organiser apps and food choice apps scored the highest MARS ratings, they were based on only four and two apps respectively. Finally, the coding of BCTs was limited to features and content that could be accessed or viewed within the assessment period. Therefore some push notifications may have been overlooked, while lengthy blogs within apps were excluded from detailed analysis.

Despite its limitations, this review assessed a large number of apps and provides unique information about their behaviour change potential by not only describing and assessing app scope, characteristics and quality, but also through a behavioural analysis of app content and features. Reviewer training, along with the use of a second reviewer in a 20% sample improves the objectivity and accuracy of the data extracted and assessed in this review. Furthermore, although the target group of the present work is families, the findings have applications to food planning, purchasing and preparation behaviours in a range of contexts and target groups.

Implications for practice and future research

The findings of this review suggest that recipe and recipe manager apps, family organiser apps and meal planning apps in particular should be explored as viable options for nutrition promotion interventions. Future apps should combine a range of behavioural support features such as meal planners, shopping lists, simple recipes, reminders and prompts and food ordering to reduce the burden of the food provision process and maximize behaviour change potential. Consideration of food coping strategies other than meal planning, or the incorporation of skills training, prompts and encouragement to plan meals, would make these apps applicable to people less inclined to plan. While particular attention should be paid to personalization features, they should also provide a level of automation that reduces the need for excessive data input. Finally, researchers and developers should be mindful of the needs of modern families and consider the engagement qualities of such apps to ensure their effectiveness and longevity.

3.8 Conclusion

This review, assessing commercially available apps for parental food provision, demonstrates the potential of apps in delivering behavioural support for healthy food coping strategies. The use of apps to functionally or behaviourally support food provision processes is a far cry from the way apps have been used in the past, where monitoring and feedback, and the delivery of static content predominate (182). The behaviour change potential of apps supporting automated meal planning and shopping list generation, and the opportunity to address food provision in a whole of family context was identified. Although the bias toward planning behaviours, with few addressing alternative time-saving food coping strategies, along with their comparatively low behaviour change content may limit their usefulness and effectiveness in time-scarce modern families.

CHAPTER 4: USER-TESTING OF PARENTAL FOOD PROVISION APPS

4.1 Descriptive title

Commercially available apps to support healthy parental food provision: User-testing of app utility, acceptability and engagement

4.2 Overview

Chapter 3 identified the quality and behaviour change content of apps and app features in the commercial space that could be used to support healthy parental food provision. In taking apps and app features from the commercial sector and applying them in a behaviour change intervention, more evidence is needed regarding their utility and acceptability. Chapter 1 highlighted the value in incorporating the target users voice in the early stages of app-based intervention development. User-testing can support the development of more engaging and usable interventions that are effective in modifying health behaviour.

This chapter therefore describes the second study contributing to <u>thesis specific aim 3</u>; to determine the feasibility of apps and app features addressing parental food provision behaviour. The study involves user-testing of commercially available apps and app features, exploring app utility and acceptability (<u>thesis specific aim 3b</u>). Apps and app features identified during the systematic assessment of commercial apps described in Chapter 3. Working parents were the primary target of the study, due to evidence generated in Chapter 2 regarding time and money as determinants of young children's discretionary choice intake. The purpose of this study was to provide an understanding of the role of these apps and app features in addressing key enablers and barriers of healthy parental food provision, further supporting the selection of content and features for an app concept.

The study was funded by a Flinders Foundation seed grant valued at $21500. The PhD candidate conceived the study idea and prepared the grant application for submission, acting as associate investigator. The primary supervisor (Professor Rebecca Golley) and co-investigators on the grant (Professor Anthony Maeder, Dr Rachel Laws and Dr Ivanka Prichard) provided expert input into the grant regarding research methods and data analysis.

This chapter has been submitted as a manuscript to the *Journal of Medical Internet Research* which is a quartile one journal in the Medicine, Health Informatics category, with an impact factor of 5.03 in 2019. The manuscript is currently under review, see Appendix 4 for the signed co-authorship approval form and Appendix 9 for the submitted manuscript.

Mauch CE, Laws RA, Prichard I, Maeder A, Wycherley TP, Golley RK, Commercially available apps to support healthy family meals: User-testing of app utility, acceptability and engagement. JMIR (under review), 2020, DOI:10.2196/preprints.22990

4.3 Introduction

Modern parents juggling caregiving and paid employment experience a range of capability, motivation, and opportunity-related barriers to the provision of healthy food to their families. Parent focused dietary interventions to date have tended to target capability (e.g. knowledge and skills) and motivation (e.g. confidence in supporting child health) (73). However in Chapter 2 it was established that opportunity-related determinants such as time and money are also important, particularly with respect to main meal quality. Future dietary interventions should consider a range of enablers relevant to the planning, purchasing and preparation of food to promote resilience against the broader unhealthy food environment.

Early parenthood may present opportunities to promote behaviour change at times when barriers to food provision are changing (268). The return to work of the primary carer after a period of parental leave, and changes in employment status can result in the scarcity of time and/or money (268). Food coping strategies such as meal planning, preparing food in advance and ordering shopping online may enable healthy food provision when resources are scarce (146, 165). However some food coping strategies are not supportive of good nutrition, such as the purchase of unhealthy fast or take-away foods (164). Equipping parents with behavioural supports that enable healthy food during times of scarcity may promote the development of healthy and positive food preferences in their children that track into later life.

The systematic assessment in Chapter 3 highlighted a proliferation of meal and shopping planning, recipe and recipe manager, and family organiser apps and features, signalling the emergence of the technological capability to support families, in real-time, to use healthy food coping strategies (269). Although this research allowed the identification of apps and app features that could be utilised in the development of future app-based dietary interventions, the acceptability and utility of such apps and app features with the target user is unknown (269). The next step in realising the potential of these apps and app features in a family context is to incorporate the target users voice. This will support the development of an app concept that is considerate of the target users behaviour, context and needs (179), and is therefore engaging, usable and effective in modifying health behaviour (201, 203).

Only one prior study has been identified that applied a user-testing approach to a range of commercially available mobile apps (270). The Australian study conducted in 2014 tested the feasibility and appeal of seven apps addressing barriers and enablers of healthy eating such as food budgeting, meal planning and cooking skills (270). Apps were tested with socioeconomically disadvantaged women, with each participant testing all seven apps. Recipe apps were found to be useful due to their libraries of recipes, whilst a shopping list app and app containing information regarding seasonal produce were reported to result in healthier eating habits (270). This study provided early evidence of the potential of apps addressing food provision in promoting positive behaviour change. However the age of the study limits the relevance of findings in the present day, while the use of non-validated questionnaire items of limited scope makes it difficult to draw clear conclusions regarding the feasibility of apps in this space.

4.4 Aims and objectives

The aim of this study was to determine the feasibility of apps and app features addressing parental food provision behaviour, by testing current, commercially available apps in the real-world. The study drew on principles of the person-based approach and user-centred design (201, 203) by incorporating mixed methods to investigate:

1. The utility of apps and app features in relation to the planning, purchasing and preparation of food
2. The acceptability of apps and app features, in terms of quality, usability, functionality and engagement

4.5 Methods

4.5.1 Study design

This mixed methods study was conducted between February to June 2019. Participants completed a baseline survey, with a sub-sample undertaking a four-week app testing period followed by another survey and semi-structured interview (see Figure 4-1).

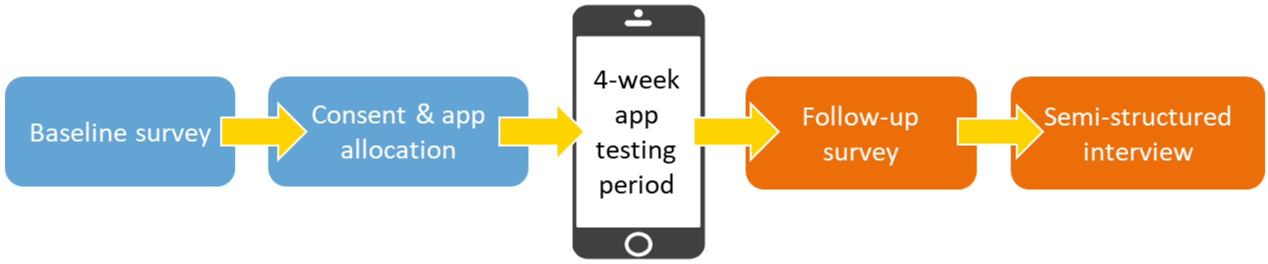


Figure 4-1: Flow of study stages

Five apps were selected for testing from the sample of 51 reviewed in the systematic assessment described in Chapter 3 (269). Apps were selected to represent key content and features of interest identified in the review. They rated well for quality (according to MARS score) compared to similar apps, were available for free or in a freemium format that did not significantly limit functionality or access to key features for testing, and were available on both Apple and Android operating systems. Apps selected for testing included a:

- **barcode scanning app** containing nutrition information supporting food selection;
- **family organiser app** with a shared shopping list, calendar and personalised tasks and reminders;
- **meal planning app** with automated, personalised meal plans and shopping lists;
- **recipe app** containing text, photo and video recipe and food preparation content;
- **recipe manager app** for storing personal recipes and preparing meal plans/shopping lists

Table 4-1 provides a summary of key app content and features of interest, MARS scores and behaviour change content (see Appendix 10 for more detailed tabulated summaries of the selected apps based on data from the systematic assessment described in Chapter 3). App names have been intentionally suppressed.

Table 4-1: MARS quality score, BCTs and key content and features of the apps selected for testing

App	MARS score (overall)	Key content & features of interest	No of BCTs	BCTs linked with app content & features
Barcode scanning app	3.9	Product specific nutrition information – generated via barcode scanner	2	8.2 Behavioural substitution 12.5 Adding objects to the environment
Family organiser app	4.2	Shopping list – synced between users Family calendar – personalised tasks and reminders	10	1.1 Goal setting (behaviour) 1.4 Action planning 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.3 Information about social & environmental consequences 7.1 Prompts/cues 10.3 Non-specific reward 10.6 Non-specific incentive 12.5 Adding objects to the environment 14.1 Behaviour cost
Meal planning app	4.2	Recipes – personalised content based on preferences Meal planning – automated or manual Shopping list – automatically generated from recipe content	7	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 5.3 Information about social & environmental consequences 5.6 Information about emotional consequences 12.5 Adding objects to the environment
Recipe app	4.2	Recipes – text, photo and video Food preparation skills – text, photo and video	4	4.1 Instruction on how to perform the behaviour 6.1 Demonstration of the behaviour 6.2 Social comparison 12.5 Adding objects to the environment
Recipe manager app	3.7	Recipe storage – automatic population from online or manual entry Meal planning – manual Shopping list – automatically generated from recipe content	4	1.1 Goal setting (behaviour) 1.4 Action planning 4.1 Instruction on how to perform the behaviour 12.5 Adding objects to the environment

4.5.2 Study sample and recruitment

Eligibility criteria included being a single or partnered parent in paid employment (or self-employed), with themselves or their partner having returned to work from a period of parental leave in the last 6 months. Other eligibility criteria included being based in Australia and the main food gatekeeper of the household. Parents who did not own at least one Apple or Android mobile device with internet access or whose partner was not in paid employment were excluded.

Recruitment was via a purpose-built Facebook page and advertising campaign, and physical flyers posted around a university campus and in childcare centres. These recruitment channels have been utilised successfully in prior research (270-272). Paid Facebook advertising campaigns initially targeted low socioeconomic status metropolitan postal areas within Adelaide, Victoria, Sydney and Melbourne, in order to recruit a diverse and representative sample. Twenty-two postal areas in the northern, southern and western suburbs of Adelaide, and one each in Melbourne, Sydney and Brisbane that were classified as decile 1 (the lowest socioeconomic decile), and had a large usual resident population were identified and selected using ABS data (273). The initial campaign ran for 2 weeks, after which a second 2-week campaign was conducted, this time without postcode restrictions in order to meet recruitment targets. Other Facebook pages and groups that had followers likely to fall in the target group (e.g. Playgroup South Australia, the Multiple Birth Association, a child feeding page and a South Australian Paediatric medical clinic) were also contacted and asked to share the study page or recruitment posts. Privately owned South Australian childcare centres (n=28) were contacted via email to seek permission to display fliers regarding recruitment. Thirteen centres provided consent and were subsequently emailed and/or mailed flyers to display in their centres. Finally, recruitment flyers were posted on public noticeboards around the Flinders University campus at Bedford Park.

Online baseline survey completion constituted consent for the survey only. Participants provided contact details at the end of the survey to indicate interest in the app testing stage of the study. Interested participants were then emailed a letter of introduction, a participant information sheet and a consent form. Consent was by return email, with between one and three email reminders sent to non-responders until recruitment and app allocation goals were met.

A target sample size of 50 was set for the app testing stage of the study, in order to have a minimum of 10 participants test each app (with each participant testing two apps). This was comparable to similar feasibility and pilot app testing studies (270, 274). Ethics approval was obtained from the Flinders University Social and Behavioural Research Ethics Committee (project no. 8211) through a low risk application (see Appendix 11 for ethics approval notice).

4.5.3 App allocation and testing

App allocation was guided by the COM-B system for enablers and barriers of behaviour (117). A set of 11 baseline questions modelled on the COM-B self-evaluation questionnaire (117) exploring the perceived enablers of healthy food provision, were mapped to the apps for testing. Participants were each assigned two of the five mobile apps for testing, based on their responses to these questions (see section 4.5.5 for details of the items and how they were mapped to app content and features). The allocation of apps according to COM-B self-evaluation questionnaire items meant that participants received apps that were more likely to suit their individual needs, therefore encouraging greater engagement and more useful feedback. While the allocation of two apps (rather than just one) was to allow participants to experience a broad range of content and features and encourage them to envisage how complementary features could be combined. Participants were not aware of the included apps or how they were mapped to these questions when completing the baseline survey.

Consenting participants were contacted via telephone or email (n=9) for app allocation and set-up, with at least three attempts made to contact participants. Participants were emailed a checklist of tasks to complete in each app to encourage a minimum level of interaction (270). They were encouraged to use the apps as much as they wished during the following 4 weeks, but were requested to use each app for a minimum of 10 minutes on at least one occasion to ensure that they were familiar enough with the apps to provide feedback.

4.5.4 Follow-up

At the completion of the 4-week app testing period, participants were emailed a link to the follow-up survey, with between one and three reminder emails sent to non-responders. Following receipt of the follow-up survey, participants were contacted by telephone to conduct a semi-structured interview (until data saturation was reached). Participants involved in app testing were provided with a meal-kit or grocery voucher (for those residing outside of the delivery area of the selected meal-kit supplier) to the value of $85 AUD in compensation for their time.

4.5.5 Data collection

Baseline survey

The baseline survey included questions regarding demographic characteristics, parent diet quality, food provision behaviours, including current use of food coping strategies and self-identified enablers of healthy food and meal provision (see Appendix 12 for the full baseline survey). Twelve demographic items were adapted from NOURISH surveys (209) and from the Cornell Working Parents Nutrition Survey (The Cornell Food Research Group) (132). Items included parent age, gender, highest level of education, relationship status, family income, usual occupation, work hours, partner's work hours (if applicable), work flexibility, number and age of children and childcare use. Diet quality measures were adapted from the validated Short Food Survey (275), and included questions relating to fruit and vegetable intake (two items), frequency of consumption of wholegrain and wholemeal breads (one item), type of milk (one item) and spreads used (one item), and frequency and quantity of discretionary foods and beverages consumed (10 items). For discretionary items, a question regarding the frequency of consumption (i.e. daily, weekly, monthly) of the discretionary choice was followed by a question regarding the number of times it was usually consumed (e.g. twice, three times). Parental self-efficacy in food provision, and current use of food coping strategies were measured using a 16-item tool modelled on questions developed by Morin et al. (165). Although the original items were pilot tested and developed by content experts, they were not validated or reliability tested (165). Minor changes were made to the wording of the items to define the food coping strategies more clearly, while the scales were modified to make them more quantifiable and easier to interpret. Additional items were added as indicated below, to reflect modern food coping strategies such as online shopping and build upon the prior tool.

Three items were included that assessed parental self-efficacy in planning, purchasing and preparation skills, using a five-point likert scale indicating agreement with each statement (from 1 = strongly disagree to 5 = strongly agree). Four items addressed the use of away from home or convenience related food coping strategies, assessed using a six-point likert scale indicating the frequency of use (1 = never; 2 = rarely; 3 = once per month; 4 = 2-3 times per month; 5 = once per week; 6 = more than once per week):

- Eat in a family restaurant or pub
- Eat in a fast-food restaurant

- Use delivery or quick takeaway services
- Buy convenience foods (such as frozen or pre-prepared meals)

The remaining nine items addressed the use of planning and organisation, and cooking and food preparation related food coping strategies. Items were assessed using a six-point likert scale indicating frequency of use of the food coping strategy (1 = never; 2 = rarely; 3 = sometimes; 4 = about half the time; 5 = most of the time; 6 = always). Planning and organisation related items included:

- Plan meals in advance
- Make/use a shopping list
- Use online shopping *(new item)*
- Use a meal kit delivery service *(new item)*
- Share responsibility with other family members for planning, shopping and cooking meals *(new item)*

Cooking and food preparation related items included:

- Prepare meals with only a few ingredients
- Prepare meals in advance
- Double recipes, so that I have leftovers
- Use canned or frozen products in my cooking *(new item)*

COM-B self-evaluation items addressing key enablers of food provision behaviour were mapped to app content and features for testing (see Table 4-2 below). Due to removal of one app from the study in the planning stages (a meal kit app), there was one capability enabler that was not mapped to any particular app (namely 'Have better strategies to manage the mental load of planning, purchasing and preparing healthy meals') and was therefore used for reporting purposes only. It was determined that the excluded app could not be used as a stand-alone tool for supporting meal planning, purchasing and preparation, and was therefore inappropriate to include in the study. The items were not an exhaustive list, as apps and app features identified in the systematic assessment did not address all possible barriers and enablers (for example money). Therefore an open-ended question was included to provide participants with the opportunity to describe other barriers and enablers outside of those specified. Responses to this open-ended question were descriptive only and not used for app allocation purposes.

Table 4-2: COM-B self-evaluation items with corresponding apps and app content/features

What do you think it would take for you to provide healthier meals for your family?	*I would need to:*	App	Relevant content/feature
Capability	Have better food preparation and/or cooking skills	Recipe app	Recipe and food preparation skills content
	Learn how to choose healthy food at the supermarket	Barcode scanning app	Product specific nutrition information
	Learn how to plan healthy meals	Meal planning app	Automated & manual meal planning based on preferences
	Have better strategies to manage the mental load of planning, purchasing and preparing healthy meals	Not mapped	N/A[a]
Opportunity	Have more time to plan, buy and prepare healthy meals	Meal planning app	Automated meal planning and shopping list generation
	Have more healthy recipes and meal ideas	Recipe app	Recipe content
	Have guidance in choosing healthy food/meals	Barcode scanning app	Product specific nutrition information
	Have a better way of planning and recording meals and groceries for the coming week	Recipe manager app	Recipe storage, meal planning, shopping list
	Have more support or help from my partner/family	Family organiser app	Shared calendar & shopping lists
	Have more reminders to plan, shop or cook	Family organiser app	Task & calendar event reminders
Motivation	Have clear goals or plans toward preparing healthy meals	Recipe manager app	Manual meal planning

a Used for reporting purposes only due to removal of an app in planning stages of study.

COM-B items were rated on a seven-point likert scale from strongly disagree (1) to strongly agree (7). Responses were converted to a numeric score between one and seven, with higher scores indicating greater agreement with the statement. The scores were tallied for each app and the two apps receiving the highest score (and therefore deemed most likely to meet the participants needs) were allocated to the participant for testing. The participants current and prior use of apps for the planning, purchasing and preparation of food was taken into account to ensure the apps they were testing were new to them. Where a particular app was not allocated to at least 10 participants, some participants were allocated these apps despite a lower COM-B score, to ensure that adequate data was collected for each app.

Follow-up survey

The follow-up survey included items regarding the device type used, self-reported frequency and duration of use, and app usability and quality (see Appendix 13). Frequency of app use was measured for each of the four weeks of the testing period using a four-point response scale (i.e.

didn't use the app, once, 2-4 times or *5 or more times*), while average duration of app use (per use) was measured using a three-point response scale (i.e. *less than one minute, 1-5 minutes* or *more than 5 minutes*).

The System Usability Scale (SUS) was used to assess usability of the apps (276). The SUS is a brief scale made up of 10 statements regarding the complexity or ease of use of a piece of technology, which has demonstrated reliability (277) and validity (278) in comparing two or more systems. Participants indicated their agreement on a five-point response scale from strongly disagree (1) to strongly agree (5), allowing for the calculation of a usability score between zero and 100 (276). The version of the SUS created by Bangor et al. (277) with modified wording for ease of understanding, was used in the present study.

User-perceived app quality was measured via the user version of the Mobile App Rating Scale (uMARS), which was found to have excellent internal consistency and test-retest reliability in a sample of youths (279). The 16-items making up the engagement, functionality, aesthetics and subjective quality subscales were included in the present study (279). The information quality sub-scale was excluded from the survey, as four of five apps did not provide information apart from recipes. Instead, a modified version of the item from this subscale addressing the credibility of the app was included (i.e. 'Does the app seem to come from a credible source?') as credibility has been shown to be important to app engagement in past research (272).

Semi-structured interview

Reporting of qualitative methods and findings are in accordance with the COREQ (Consolidated criteria for reporting qualitative research) checklist (280). Semi-structured interviews were conducted by a female research assistant with prior experience conducting semi-structured interviews. A research assistant conducted the interviews in order to reduce the potential for interviewer bias, being that the PhD candidate had previously used and assessed the apps. The research assistant had no prior contact with participants, and participants were only aware of her first name prior to the interview. The research assistant's PhD focus was family meals, but not digital technology, and she was not a parent herself. Only three of the interviews were conducted by the PhD candidate, including a pilot interview and the two final interviews which were conducted whilst the research assistant was unavailable.

Interview questions addressed the following domains, and were repeated for each of the two apps allocated where appropriate (see Appendix 14 for the full interview guide):

- App feature and content acceptability – which app was preferred, and general like or dislike of the apps, and their features and content
- App engagement – how and in what situations were the apps used
- Family member engagement – did other family members use or engage with the app
- App usefulness – did the app address self-identified needs
- App improvements – did the app need improving, and if so how
- General app ideas and suggestions – having experienced the apps, what would they like to see in an app supporting the planning, purchasing and preparation of meals

Questions were developed with guidance from the supervisory team and co-investigators on the grant. Questions were initially tested with the research assistant, after she had been introduced to the apps and used them for at least 10 minutes (having had no prior experience with the apps). Similarly, the research assistant practiced interviewing the PhD candidate prior to commencing formal interviews. Feedback from the research assistant was incorporated before piloting with one participant, which resulted in only minor modifications. As interviews were conducted, the PhD candidate listened to the audio and made notes, discussing progress with the research assistant. Once the PhD candidate was satisfied with the interview schedule and progress of the interviews, they were discussed at least on a weekly basis. Once data saturation for an app or app combination was reached, determined by no new information emerging, participants testing those apps were only asked to complete the follow-up survey. Participants representing as diverse a sample as possible were prioritised for interview (i.e. single parents, parents of a lower income).

Interviews generally took between 30 and 60 minutes, depending upon how actively the participants used the apps (i.e. if they only used an app once, some questions were excluded due to a lack of relevance). Interviews were audio-recorded with the participants' permission, using a speaker phone and audio-recorder. Interviews were transcribed verbatim by an independent transcription company, with each transcriber signing a confidentiality agreement. Participants were informed of their right to view and correct the transcriptions through the participant information sheet, however no participants requested their transcripts.

4.5.6 Data analysis

Quantitative data

Quantitative data were analysed using SPSS Version 22 (IBM, US), with data being checked and cleaned prior to analyses. Parental work hours were converted from a continuous variable into groups, while some categorical variables were collapsed into fewer groups to simplify the presentation and interpretation of demographic data. Education was collapsed from four categories to two (i.e. *year 12 or less*, *certificate (e.g. TAFE or similar)* and *advanced diploma or diploma* into *no university*, and *Bachelor degree or above* into *University*); income from seven categories into three (i.e. *$0 - $20 000, $20 001 - $35 000,* and *$35 001 - $50 000, $50 001 - $70 000 per year* into *$70 000 or less per year*, and *$70 001 - $100 000* and *more than $100 000 per year*, into *more than $70 000 per year*, and *prefer not to say*); relationship status from three categories into two (i.e. *married/defacto* into *partnered,* and *single/never married* and *separated/divorced/widowed* into *single*); work flexibility from four categories into two (i.e. *yes, I am able to work flexible hours* and *yes, with approval in special situations* into *some flexibility*, and *no, not likely* and *no, definitely not* into *mostly inflexible*); shift work status from five categories into two (i.e. *morning shifts, afternoon shifts, night shifts* and *other* into *some or all shift work*, and *day*); and childcare from twelve categories into four (i.e. *day care/childcare centre, family day care, preschool/kindergarten, occasional care, gym, leisure or community care, after school care,* and *nanny* into *formal*; *grandparent, other relative, child's parent living elsewhere, other* into *informal*, and where at least one formal and one informal form of childcare was selected, *combination*, and *none*).

Vegetable and fruit intake from the Short Food Survey were also collapsed into three categories each to simplify reporting (i.e. for vegetables *less than one serve,* and *one serve* into *one or less serves*; *two, three* and *four serves* into *two to four serves*, and *five* and *six or more serves* into *five or more serves*; and for fruit *less than one serve,* and *one serve* into *one or less serves*; *two, three, four, five,* and *six or more serves* into *two or more serves*, and *don't eat fruit).* Discretionary choice items from the Short Food Survey were converted to total serves of discretionary choices consumed daily using age and gender specific adjustment factors (281). Baseline data including sample demographics, diet quality, and use of food coping strategies and COM-B enablers were presented descriptively (e.g. n (%), mean (SD), and median (IQR)). Median (IQR) values were used to present COM-B self-evaluation item scores, as some items were positively skewed.

Follow-up data regarding self-reported frequency and duration of app use and uMARS ratings were calculated by app and presented descriptively as n, % for app use, and mean, SD for uMARS score. SUS scores were calculated as per Brooke (276). The likert scale was converted to scores between zero (strongly disagree) and four (strongly agree), with scores for five of the 10 items being reversed, so that a score of zero indicated a low level of usability, and a score of four indicating a high level of usability. The summed score across all 10 items was then multiplied by 2.5 to generate a score out of 100. The median (IQR) score of the sample was presented, due to a positive skew in the data. As per Bangor et al. (277), a median score below 50 were considered as indicative of poor levels of usability, while 50 to 70 were marginal, above 70 were passable, and above 90 were superior. Scores for uMARS items were summed and averaged for each subscale, and across all items for the overall uMARS score.

Qualitative data

The PhD candidate listened to the recordings, checked transcriptions and made notes on the interviews before coding transcriptions using NVivo software (QSR International). Interview data was coded exclusively by the PhD candidate, with feedback provided by members of the supervisory team and co-investigators on the grant. Data was coded using a theoretical thematic approach informed by Braun and Clarke (282). Coding took a largely inductive approach, with interview data initially sorted into groups based on the study objectives, interview questions and app characteristics. The PhD candidate then read over the initial groups, organising data into major and minor themes and generating an initial conceptual model (282). A meeting was then undertaken with the supervisory team and co-investigators where the initial conceptual model was discussed. A revision of major and minor themes was then undertaken and the final conceptual model with links back to quantitative data ascertained. Interview results were presented, where appropriate, according to app, while relevant demographic characteristics, food coping strategies and COM-B enablers were used to better understand the context of the qualitative data. When presenting interview results, names have been changed to preserve anonymity, while the gender of participants has not been identified in order to protect the anonymity of the only male involved in the app testing phase of the study. When describing the demographics of participants in relation to their quotes, working hours, the age of the children in their household (relative to the majority of participants) and/or indicators of socioeconomic status (e.g. education, income, marital status) were used.

4.6 Results

4.6.1 Sample characteristics

A sample of 133 parents completed the baseline survey (Figure 4-2). Participants were mostly partnered (n=122/133, 92%) females (n=130/133, 98%), aged 34 ± 4 years. Two thirds (n=90/133, 68%) of participant households were made up of one parent working full-time (most often the other parent, n=110/122, 90% of dual-parent households), and one parent working part-time. In almost 80% of households (n=106/133) the youngest child was less than 2 years of age, and 62% (n=80/130) of households included more than one child. Only 7% (n=9) of participants were meeting the Australian guidelines for daily vegetable intake, while most (n=107/133, 80%) were meeting the guidelines for daily fruit intake. Participants reported a mean (SD) consumption of 3.0 (2.1) discretionary choice serves per day, not including alcohol (Table 4-3).

Of the 133 who completed the baseline survey, 67 (50%) were allocated apps (Figure 4-2). Sixty-two surveys were completed at follow-up (93% of those participants allocated apps), with 36 participants undertaking a semi-structured interview. The sample completing the follow-up survey was similar to the baseline sample, except that more participants completing the follow-up survey had a university degree (n=51/62, 82% vs n=83/133, 62%) and a household income greater than $70000 AUD per annum (n=47/62, 76% vs n=92/133, 69%) (data not presented). The difference in level of education was also apparent between the sample of 36 participants with interviews compared to the baseline sample, while the sample of 36 were also more likely to be unpartnered (n=5/36, 14% vs n=11/133, 8%), and with an income of $70000 AUD per annum or less (n=9/36, 25% vs n=25/133, 19%) (Table 4-3). Differences were also noted in self-reported competency in planning meals (n=25/36, 70% agreed/strongly agreed vs n=83/133, 62%) and competency in cooking (n=7/36, 19% disagreed vs n=17/133, 13%), while there were only marginal differences in the distribution of frequency of use of food coping strategies (data not reported).

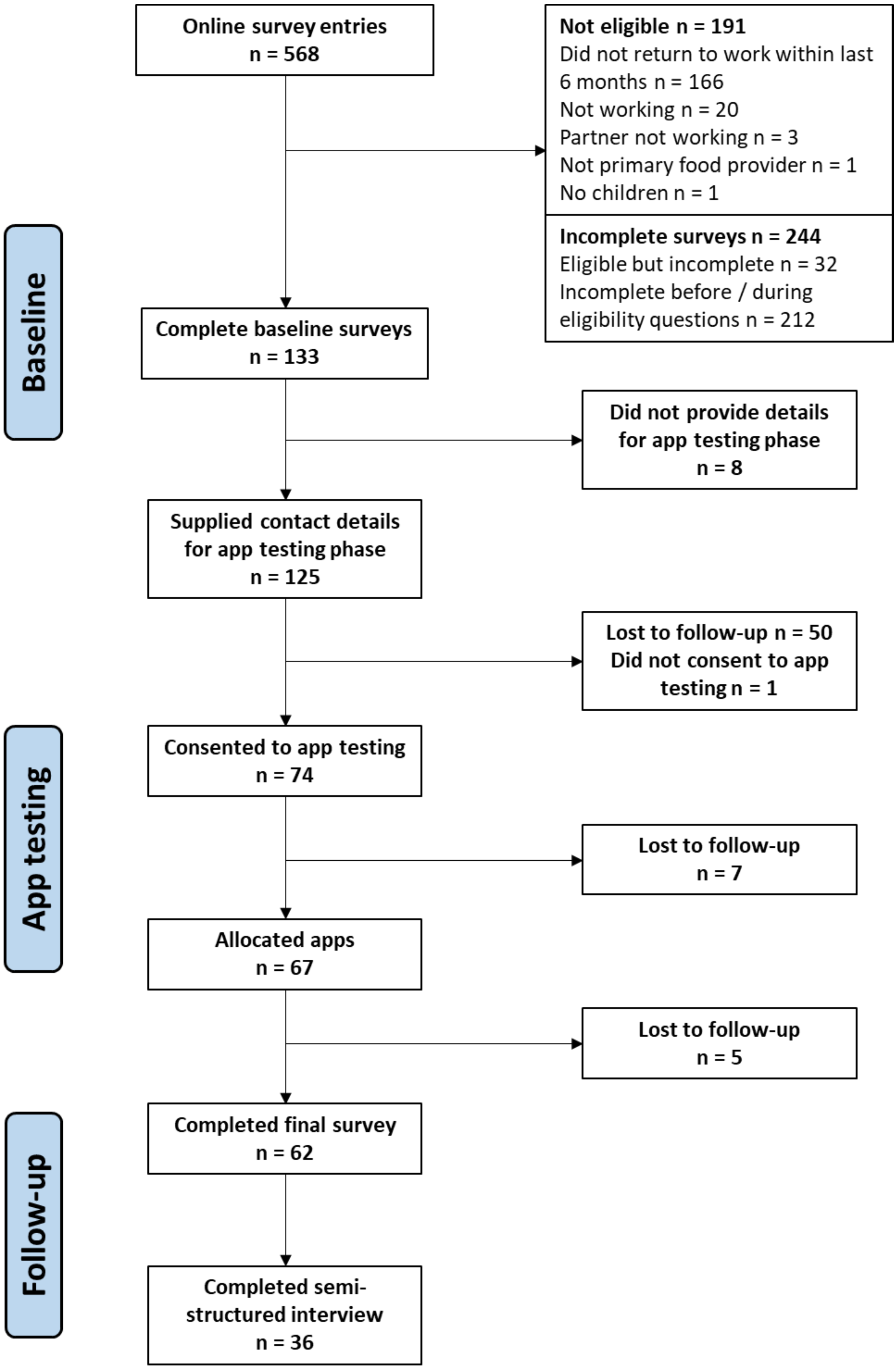


Figure 4-2: Flow of participants through the study stages

Table 4-3: Demographic characteristics of the full survey sample at baseline, and the sample completing semi-structured interviews

Characteristic	Categories	Sample with baseline survey data		Sample completing interviews	
		N	n (%) or M(SD)	n	n (%) or M(SD)
Participant characteristics					
Age (years)		131	33.8 (4.3)	36	33.6(4.3)
Gender	Female	133	130 (98)	36	35 (97)
	Male		3 (2)		1 (3)
Highest level of education	University	133	83 (62)	36	28 (78)
	No university		50 (38)		8 (22)
Using apps or websites currently	Yes	133	32 (24)	36	9 (25)
	No		101 (76)		27 (75)
Family characteristics					
Relationship status	Partnered	133	122 (92)	36	31 (86)
	Single		11 (8)		5 (14)
No. of children	One child	130[a]	50 (39)	35[a]	13 (37)
	More than one child		80 (62)		22 (63)
Age of youngest child	Less than 2 years	133	106 (78)	36	29 (81)
	2-4 years		21 (16)		5 (14)
	5-12 years		6 (5)		2 (6)
Type of childcare used weekly	None	133	8 (6)	36	4 (11)
	Formal care		69 (52)		16 (44)
	Informal care		15 (11)		2 (6)
	Combination		41 (31)		14 (39)
Household income (gross per annum)	70k AUD or less	133	25 (19)	36	9 (25)
	More than 70k AUD		92 (69)		24 (67)
	Prefer not to say		16 (12)		3 (8)
Work status					
Working hours	1 to <21 hours	133	45 (34)	36	14 (39)
	21 to <35 hours		58 (44)		14 (39)
	35+ hours		30 (23)		8 (22)
Co-parent working hours	1 to <35 hours	133	3 (2)	36	0 (0)
	21 to <35 hours		9 (7)		2 (6)
	35 to 40 hours		63 (47)		22 (61)
	>40 hours		47 (35)		7 (19)
	N/A (participant is single)		11 (8)		5 (14)
Family work schedule	Both part-time	133	9 (7)	36	1 (3)
	Part-time & full-time		90 (68)		26 (72)
	Both full-time		23 (17)		4 (11)
	Single working parent		11 (8)		5 (14)
Shift work	Day	133	113 (85)	36	31 (86)
	Some or all shift work		20 (15)		5 (14)
Weekdays or weekend days	Weekdays	133	108 (81)	36	28 (78)
	Weekends or combination		25 (19)		8 (22)
Flexibility of work schedule	Some flexibility	133	82 (62)	36	20 (56)
	Mostly inflexible		51 (38)		16 (44)
Dietary intake					
Vegetable intake (serves per day)	1 or less	133	26 (20)	36	8 (22)
	2-4		98 (74)		26 (72)
	5 or more		9 (7)		2 (6)
Fruit intake (serves per day)	Don't eat fruit	133	4 (3)	36	1 (3)
	1 or less		69 (52)		17 (47)
	2 or more		60 (45)		18 (50)
Frequency of use of wholemeal/grain bread	Always	133	52 (39)	36	14 (39)
	Usually		35 (26)		9 (25)
	Sometimes		35 (26)		10 (28)
	Never		9 (7)		3 (8)

	Don't eat bread		2 (2)		0 (0)
Type of milk usually used	Whole/full cream (4% fat)	132[a]	75 (57)	36	20 (56)
	Reduced fat (1-2%)		18 (14)		6 (17)
	Skim (<1% fat)		12 (9)		5 (14)
	Regular soy		10 (8)		2 (6)
	Don't use cows or soy milk		5 (4)		1 (3)
	Other		12 (9)		2 (6)
Type of spread usually used	Butter	133	65 (49)	36	19 (53)
	Table margarine		14 (11)		7 (19)
	Unsaturated margarine		47 (35)		7 (19)
	Don't use spread		7 (5)		3 (8)
Discretionary intake (serves)[b]		118[a]	3.0 (2.1)	33[a]	3.0 (2.2)

a Numbers vary from 133/36 due to missing data
b Excluding alcohol

4.6.2 Self-reported competency in food provision and use of food coping strategies

More than half of the sample reported feeling competent in their ability to plan, choose and cook food and meals for their family (Figure 4-3). Most participants reported feeling competent (responding agree/strongly agree) in cooking (n=98/133, 74%), with fewer feeling competent in planning meals (n=83/133, 62%).

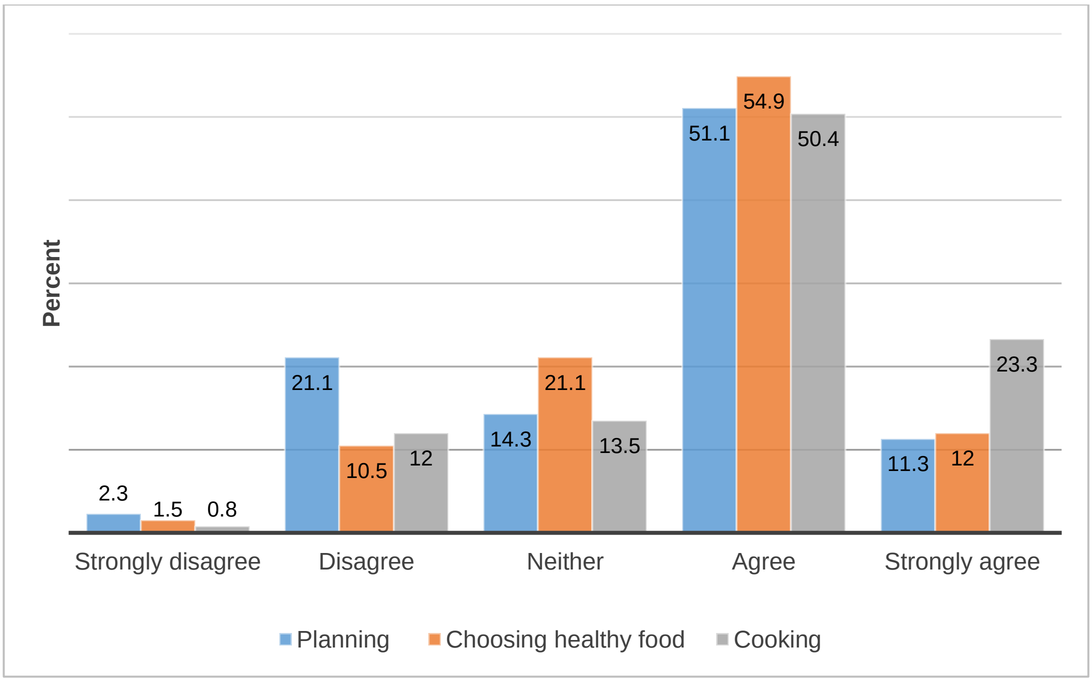


Figure 4-3: Self-reported competency in food provision behaviours (N=133)

Almost 70% (n=92/133) of the sample reported eating in a family restaurant or pub at least once per month, and 60% (n=78/133) used take-away/delivery services at least once per month (Figure 4-4).

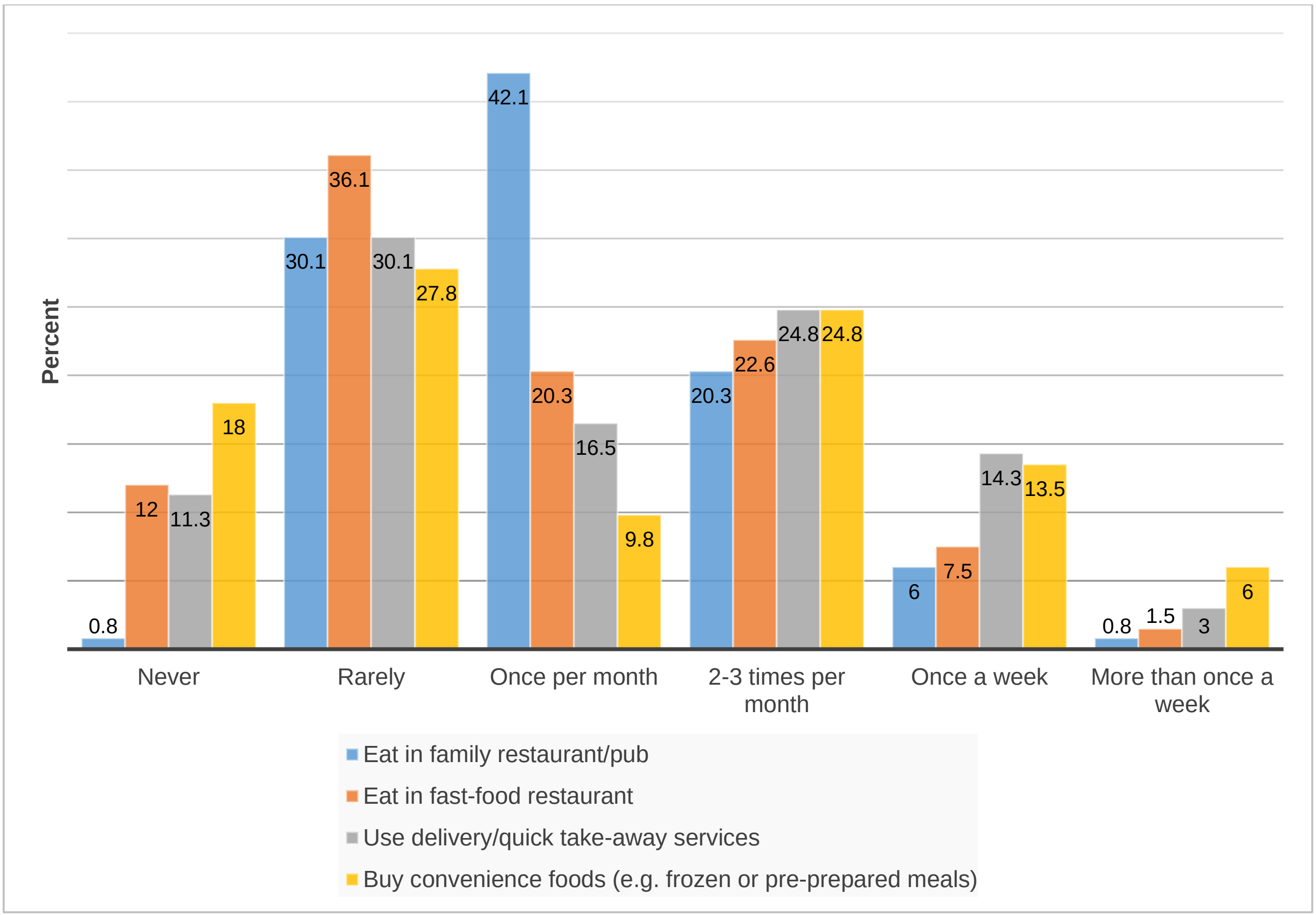


Figure 4-4: Away from home or convenience related food coping strategies (N=133)

Two thirds or more of the sample used cooking and food preparation related food coping strategies at least sometimes (e.g. use of canned or frozen products in cooking 86%, n=114/133; preparing meals with few ingredients 85%, n=113/133; doubling recipes 84%, n=112/133; and preparing meals in advance 72%, n=96/133) (Figure 4-5). Planning or process related food coping strategies were used comparatively less, with 83% (n=111/133) never or rarely using meal kit delivery and 44% (n=59/133) never or rarely ordering groceries online (Figure 4-6). Similarly, about half of the sample (51%, n=68/133) never or rarely shared food provision responsibilities with others. Only one quarter (24%, n=32/133) of the sample reported using apps or websites to support food provision at the time of the study.

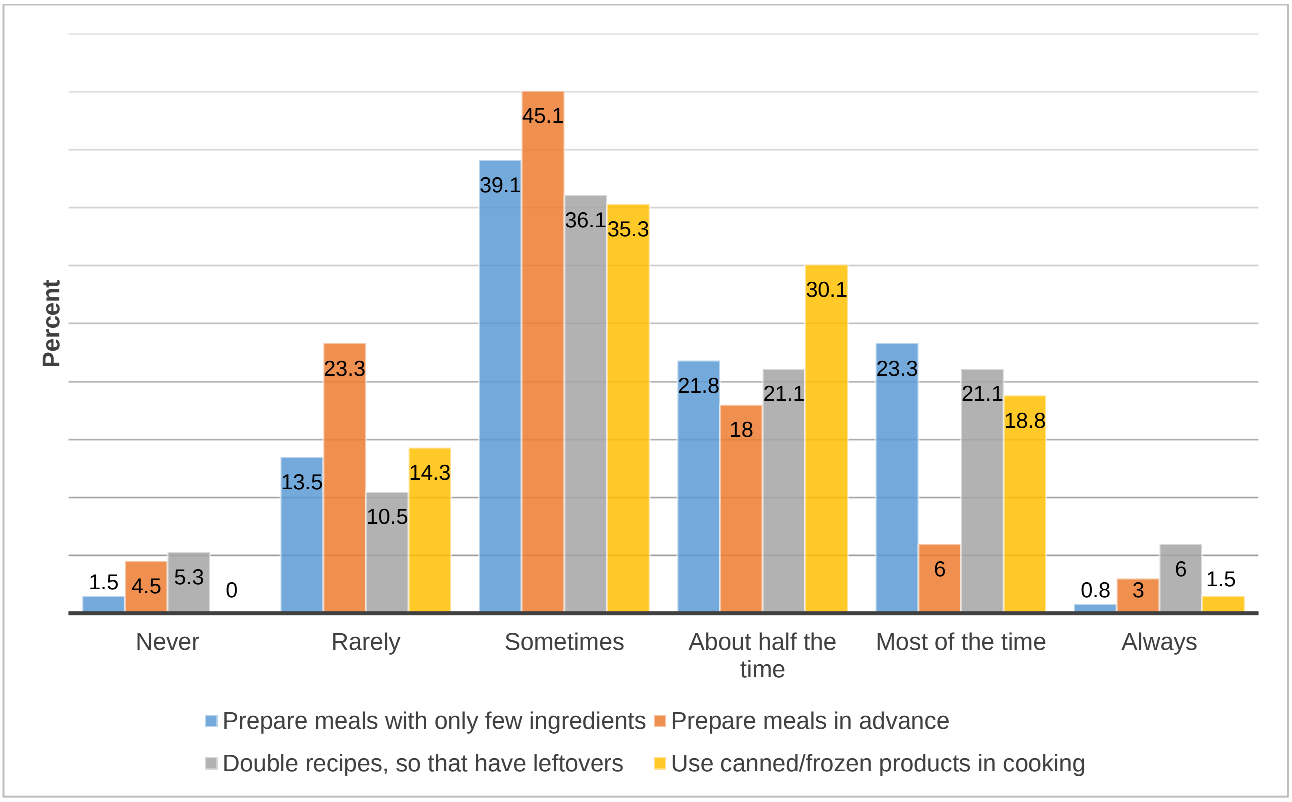


Figure 4-5: Cooking and food preparation related food coping strategies (N=133)

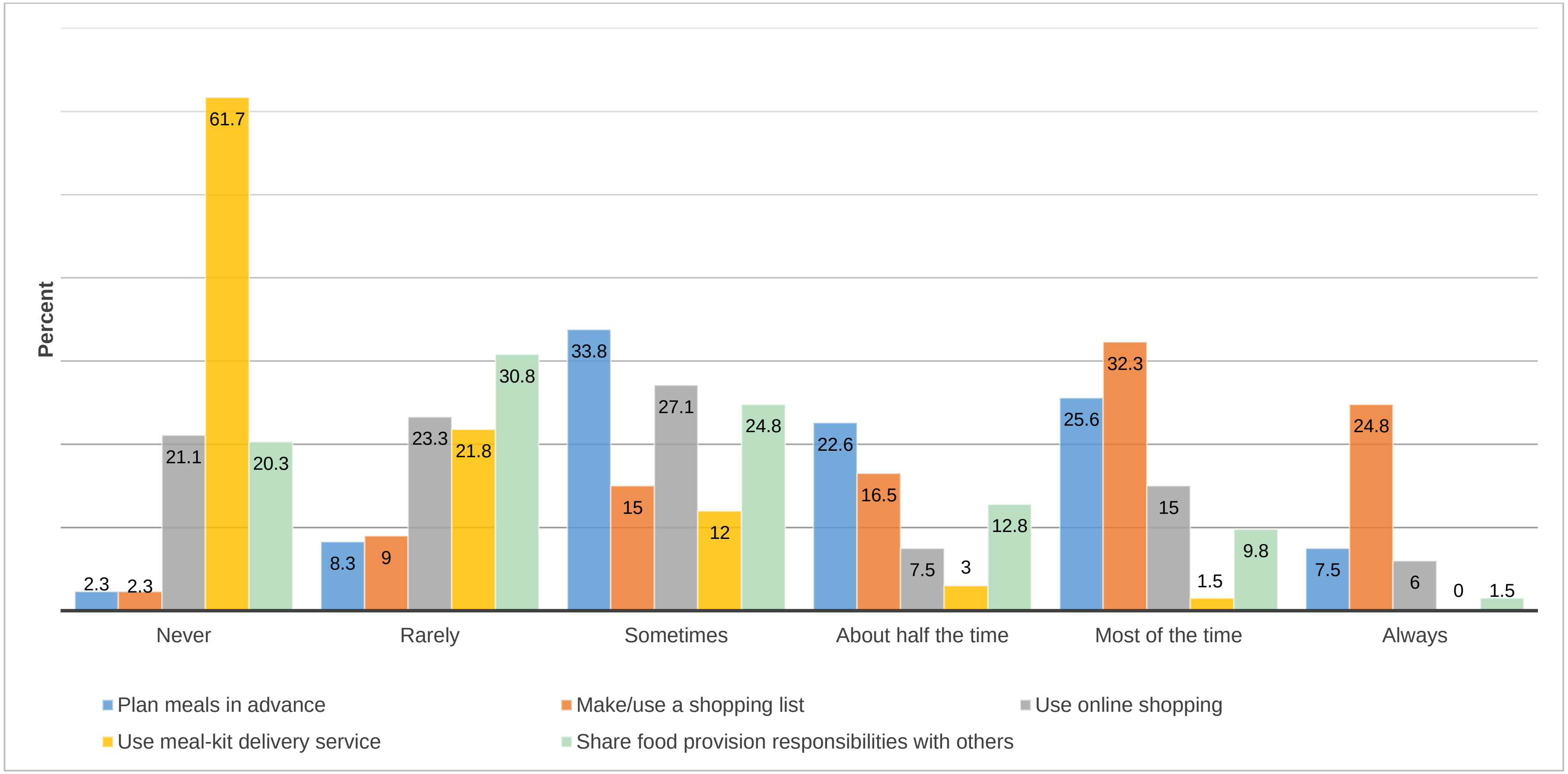


Figure 4-6: Planning and process related food coping strategies (N=133)

4.6.3 COM-B self-evaluation

Table 4-4 presents the results of the COM-B self-evaluation items used to allocate apps to participants. More than three quarters of participants agreed that they would need to have more healthy recipes and meal ideas (n=109/133, 82% agreed/strongly agreed, median(IQR) 6(6:7)), have more time to plan, buy and prepare healthy meals (n=107/133, 80% agreed/strongly agree, median(IQR) 6(6:7)) and have better strategies to manage the mental load of planning, purchasing and preparing healthy meals (n=103/133, 77% agreed/strongly agreed, median(IQR) 6(6:7)). Almost two thirds also felt that they would need a better way of planning and recording meals and groceries for the coming week (n=87/133, 65% agreed/strongly agreed, median(IQR) 6(5:6)). Learning how to choose healthy food at the supermarket and having better food preparation and/or cooking skills were not priorities for this sample with only 23 and 33% of the sample indicating agreement with these items respectively. When asked what else they felt they needed to enable healthy meal provision, 10 participants reiterated the importance of more time, with a further 10 feeling that they needed financial or budget related support, and five reported needing support with toddler eating behaviour.

Table 4-4: COM-B self-evaluation item mean (SD) scores and proportion of sample responding agree or strongly agreed (N=133)

What do you think it would take for you to provide healthier meals for your family?	*I would need to:*	Median (IQR) item score[a]	n (%) agreed[b]
Capability	Have better food preparation and/or cooking skills	5 (3:6)	44 (33)
	Learn how to choose healthy food at the supermarket	5 (2:5)	30 (23)
	Learn how to plan healthy meals	6 (5:6)	72 (54)
	Have better strategies to manage the mental load of planning, purchasing and preparing healthy meals[c]	6 (6:7)	103 (77)
Opportunity	Have more time to plan, buy and prepare healthy meals	6 (6:7)	107 (80)
	Have more healthy recipes and meal ideas	6 (6:7)	109 (82)
	Have guidance in choosing healthy food/meals	5 (4:6)	38 (29)
	Have a better way of planning and recording meals and groceries for the coming week	6 (5:6)	87 (65)
	Have more support or help from my partner/family	5 (4:6)	43 (32)
	Have more reminders to plan, shop or cook	5 (4:6)	43 (32)
Motivation	Have clear goals or plans toward preparing healthy meals	6 (5:6)	76 (57)

a 1 = strongly disagree to 7 = strongly agree
b 'Agreed' includes either a score of 6 = agree or 7 = strongly agree
c Item excluded from app allocation process due to the decision to remove an app from the study which mapped to this item

4.6.4 Follow-up data

The following section draws on both the quantitative data collected in the follow-up survey (n=62 participants) and the qualitative data from the interviews (n=36) (see Figure 4-2). Amongst the 36 participants completing interviews, there were nine different combinations of apps allocated. The most common sets of apps allocated were the recipe manager app with the family organiser (n=7) or meal planning app (n=6), and the barcode scanning app with the recipe app (n=6). In six cases, participants were allocated an app that received a lower COM-B score in the self-evaluation than another. In the case of the barcode scanning app (n=4) and family organiser app (n=1) this was to ensure adequate numbers of participants tested these apps. In one case, the recipe manager app was substituted with the recipe app as the participant had reportedly used the recipe manager in the past.

Figure 4-7 shows the conceptual model of major and minor themes emerging from the semi-structured interviews, and how these themes may relate to ongoing use or disengagement with the apps. The quantitative data has been positioned within this model to demonstrate relationships with app acceptability, usefulness, and engagement.

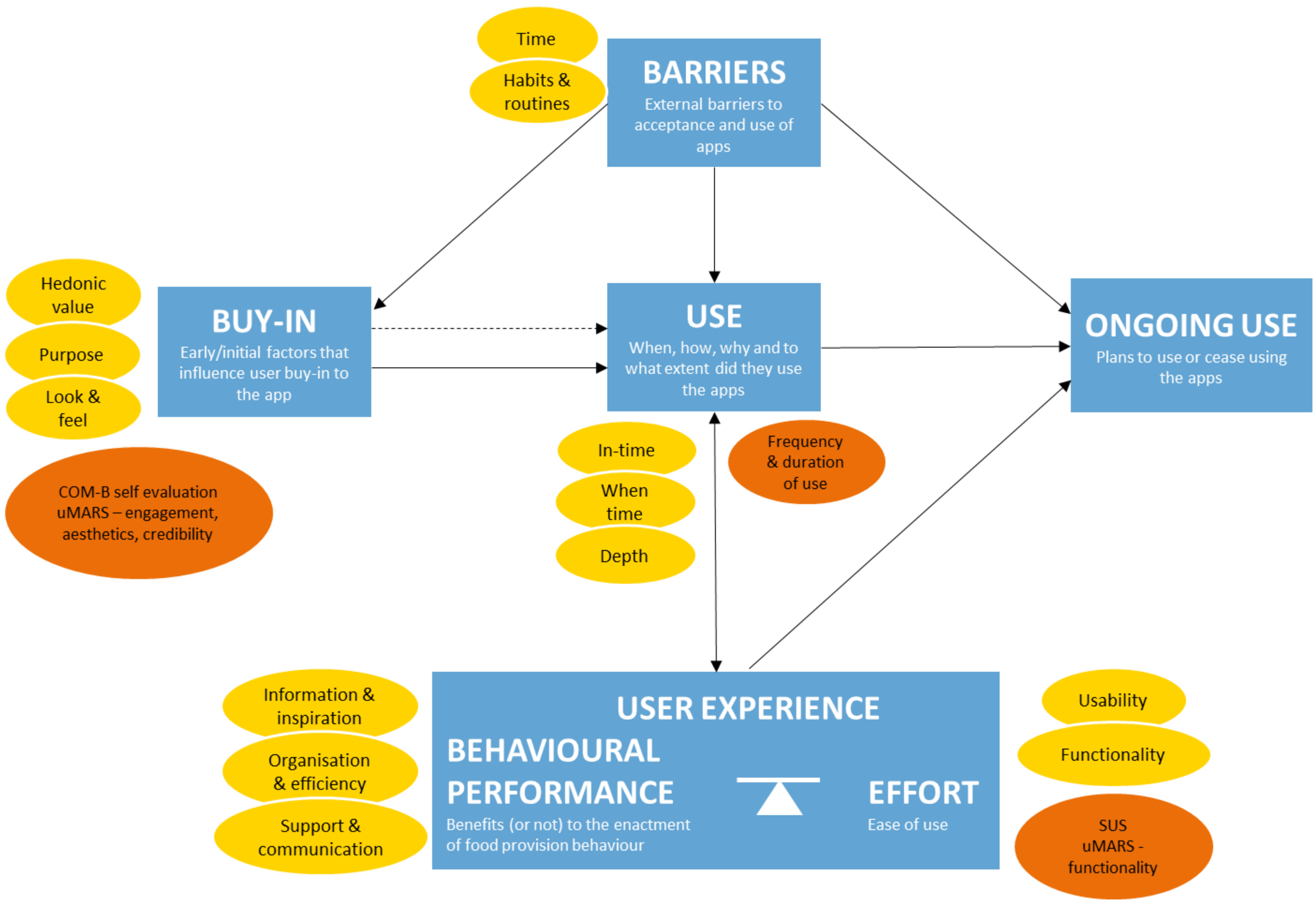


Figure 4-7: Conceptual diagram of major (blue) and minor themes (yellow) with quantitative data (orange), and how these may relate to ongoing use or disengagement with the app(s)

4.6.5 Buy-in

Early impressions of the apps were key to user buy-in and subsequent use. Participant buy-in to an app was driven by their self-identified COM-B needs and the 'fit' of the app with those needs. However, visual and hedonic values of the apps were also important and could contribute to drawing them in or turning them off from the start. These attributes shaped participants' initial impressions of the apps, with negative impressions tending to be difficult to overcome.

Purpose

The purpose of the app(s) appeared to be an important early factor affecting the acceptance and 'buy-in' to the app(s). Participants discussed the alignment of this purpose with their self-identified COM-B needs, or the needs of their family, at that moment in time and under their specific circumstances. Buy-in to apps also varied depending on participants self-reported level of competency in planning, choosing and cooking food. The following participants were both allocated the meal planning app and had opposing acceptance of the app based on need. The former indicated low levels of competency in planning, choosing and cooking food and a need for increased capability in planning, while the latter identified herself as competent in all processes and therefore did not feel that it 'fit' her needs as well:

> *"(…) for probably what I was looking for which was meal planning, [meal planning app] was more appropriate."* **Mia, working 1 to <21 hrs/wk**

> *"I think it's just the, my way of cooking and planning, it just wasn't as good as a fit as, like, the [recipe manager] was."* **Charlotte, no university education, working 1 to <21 hrs/wk**

The clarity of the purpose of the app was also important to early buy-in, with participants indicating that if the purpose of the app was unclear or vague, it was a turn-off. But trying to do too much or serve too many purposes was equally problematic, with some participants finding the app(s) overwhelming.

> *"…I think, it had a big overarching purpose but lots of, like, little purposes in there that just, kind of meant that you had to wade through more stuff to figure out what you wanted to use it for."* **Jo, working 21 to <35 hrs/wk**

Furthermore, even where an app was deemed relevant, some participants still wanted it to have a purpose above and beyond that which they could already achieve with more traditional methods such as Google searches. This participant explained that unless apps in this space became essential, they would simply cause more burden:

"So, unless there was a way in which we found that it worked to be an essential thing, it was just another app on the phone, another thing to do." **Mary, working 21 to <35 hrs/wk**

Look and feel

The visual appeal of the apps was key to the early impression an app made on participants and was discussed to some extent by all participants. It could either draw them in, particularly where the app included visually appealing recipes, or promptly turn them off, where the visuals appeared 'boring' or 'basic'. While some participants described the importance of a 'professional' look and feel to the credibility and trustworthiness of an app.

"I guess 'cause it didn't have recipes in it, it didn't have the, um – the immediate effect of the – the images that the other one did when I compared the two" **Elena, older children, 1 to <21 hrs/wk**

"…you'd like trust and you feel comfort in knowing that, you know, it just feels like a team of people has worked behind it (…) Like there'd been more research and more time put into preparing it." **Tiffany, single parent, no university education, working 21 to <35 hrs/wk**

The aesthetics quality subscale score of the uMARS aligned well with interview data, with the more visual apps (i.e. the recipe app – mean(SD) 4.3(0.5), meal planning app – 4.1(0.6) and barcode scanning app – 4.0(0.7)) scoring higher on the subscale than the apps requiring more input and containing less content (i.e. the recipe manager – 3.4(0.6) and the family organiser – 3.4(0.6)). The pattern was similar with the credibility subscale, with the same three apps ranking the highest for perceived credibility (Table 4-5).

Table 4-5: Mean (SD) uMARS subscale scores, total score and subjective quality score by app (n=62)

App	n[a]	Subscale score[a]				Total uMARS score[a]	Subjective quality score[a]
		Engagement	Functionality	Aesthetics	Credibility		
Meal planning app	35	3.5 (0.5)	4.2 (0.5)	4.1 (0.6)	4.0 (0.8)	3.9 (0.5)	3.0 (0.9)
Recipe manager app	32	3.0 (0.7)	3.7 (0.9)	3.4 (0.6)	3.8 (0.8)	3.5 (0.6)	2.7 (1.1)
Recipe app	29	3.7 (0.6)	4.2 (0.6)	4.3 (0.5)	4.1 (0.7)	4.1 (0.4)	3.1 (0.9)
Barcode scanning app	12	3.6 (0.7)	4.2 (0.6)	4.0 (0.7)	4.3 (0.8)	4.0 (0.6)	3.4 (1.0)
Family organiser app	12	3.4 (0.8)	3.8 (0.7)	3.8 (0.7)	3.6 (0.5)	3.6 (0.6)	2.7 (1.1)

a n=4 participants completed the uMARS for only one app, due to a lack of use of the second app
b Scores range from 1 (low quality) and 5 (high quality) of subscales and for total score/subjective quality score

Hedonic value

The hedonic value of apps, or the pleasure associated with their use, played a role in app buy-in. Novelty was important for some participants, who referred to the apps as being ‘clever’ or different to what they were used to. Some participants commented that they had not even considered that there might be apps available to support food provision:

> *“…I hadn’t even, um, really thought about the fact that there were apps out there to support with meal prep and healthy eating and all of that, outside of things like, um Lite n’ Easy and Weight Watchers. So it (…) broadened my, um, understanding of what was out there…”*
> **Harper, working 21 to <35 hrs/wk**

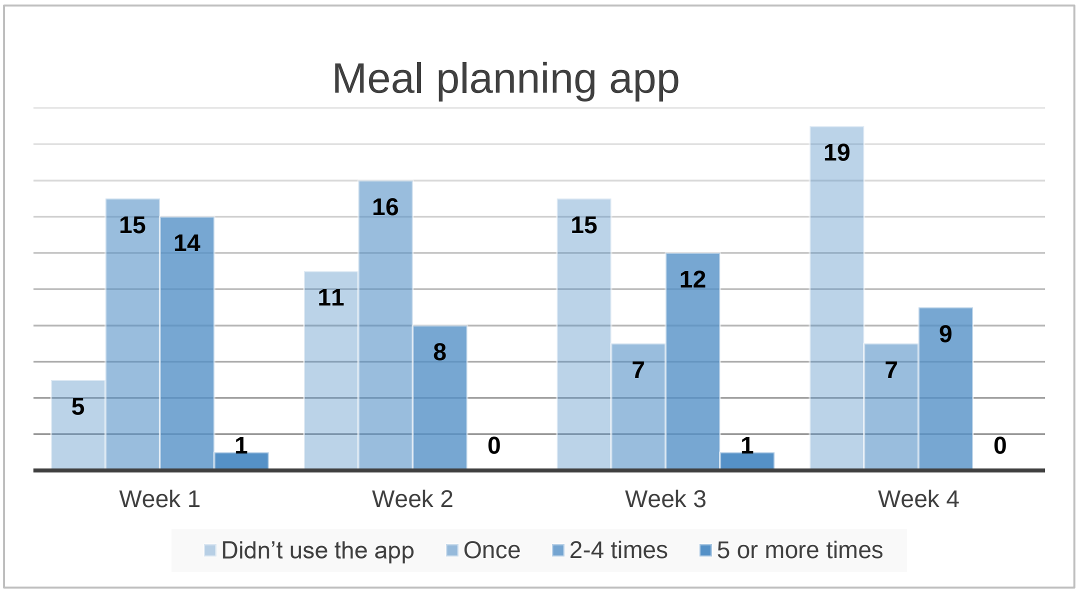
The fun (or lack of fun) involved in their early interactions with the apps was referred to by some participants (n=9) as playing an important role in app buy-in. Participants mainly referred to fun, excitement and enjoyment, or a lack of those properties, particularly when discussing those apps with little content.

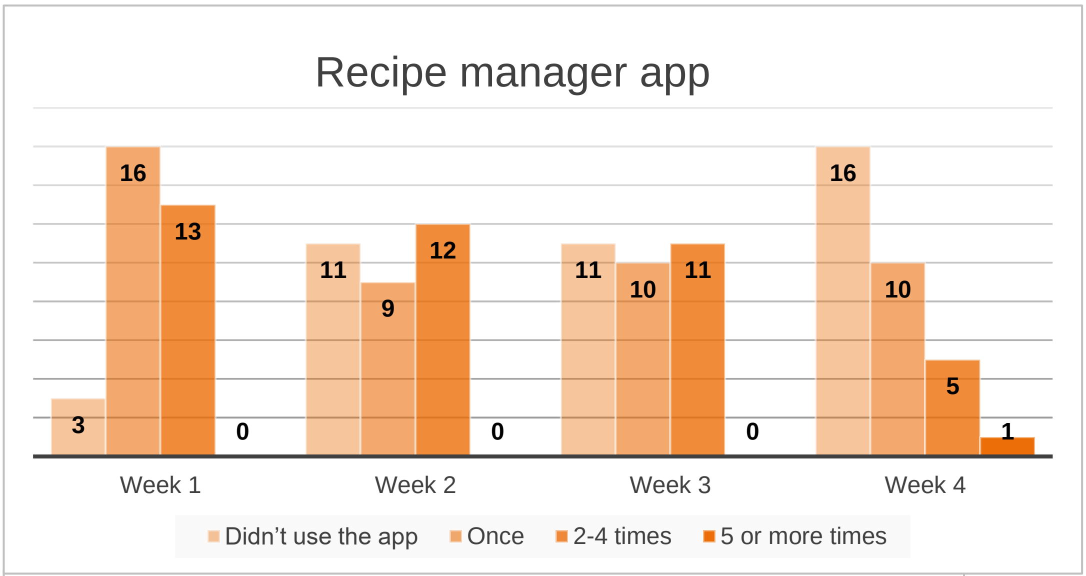
> *“…I didn’t want to use the app. (…) I wasn’t excited by it.”* **Sophie, working 21 to <35 hrs/wk**

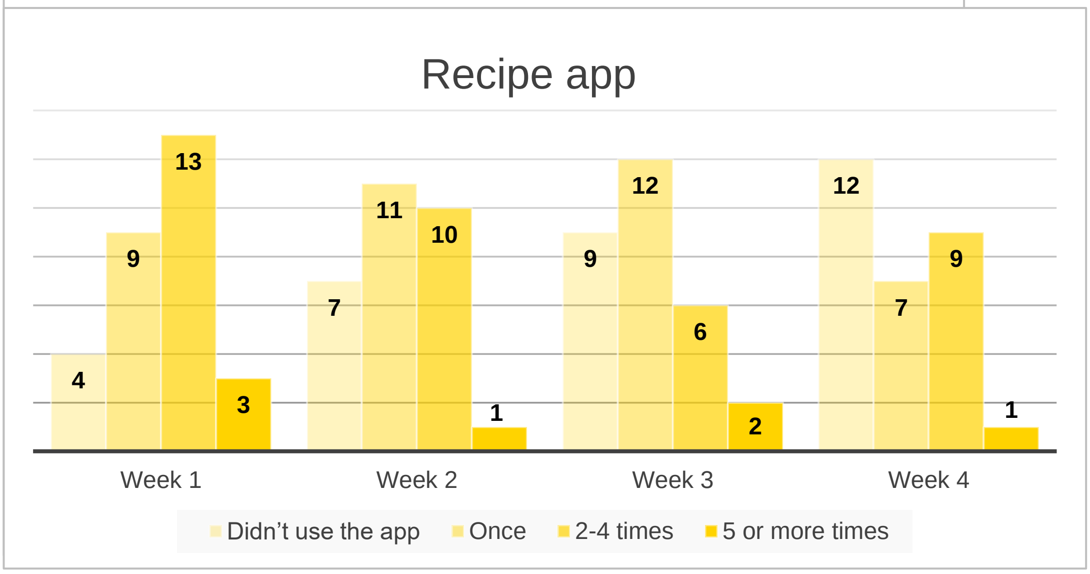
Two of the five engagement subscale items of the uMARS relate to the hedonic value of apps, namely the entertainment and interest qualities. Overall, the engagement subscale was the lowest scoring quality of the apps (see Table 4-5 above), with the high input, low content apps scoring the lowest on this domain.

4.6.6 Use

The self-reported frequency of app use provided some indication of app acceptance (or lack of) (see Figure 4-8 and Appendix 15). More participants used the apps at least once in the first week than in subsequent weeks. The barcode scanning app was used most frequently over the testing period, with at least seven of the 12 participants allocated the app using it at least two to four times per week. Use of this app was relatively brief, with nine of the 12 users reporting spending 1 to 5 minutes at a time on the app (Table 4-6). There was a rapid drop-off in use of the family organiser after the first week, consistent with findings of the interview data that demonstrated poor acceptance of this app. The meal planning app also demonstrated a decline in use over time, however this app was reportedly used for more than 5 minutes on each occasion by more than 22 of the 35 users.


Meal planning app
15
14
1
5
16
11
8
0
15
12
7
1
19
9
7
0
Week 1
Week 2
Week 3
Week 4
Didn't use the app
Once
2-4 times
5 or more times


Recipe manager app
16
13
3
0
12
11
9
0
11
10
11
0
16
10
5
1
Week 1
Week 2
Week 3
Week 4
Didn't use the app
Once
2-4 times
5 or more times


Recipe app
13
9
4
3
11
10
7
1
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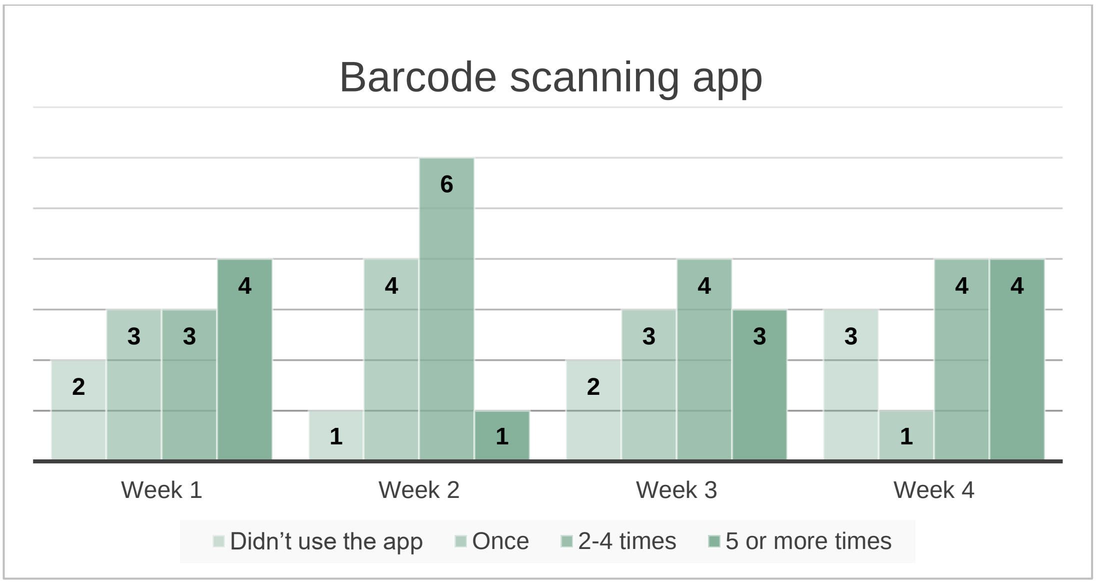
Week 1
Week 2
Week 3
Week 4
Didn't use the app
Once
2-4 times
5 or more times



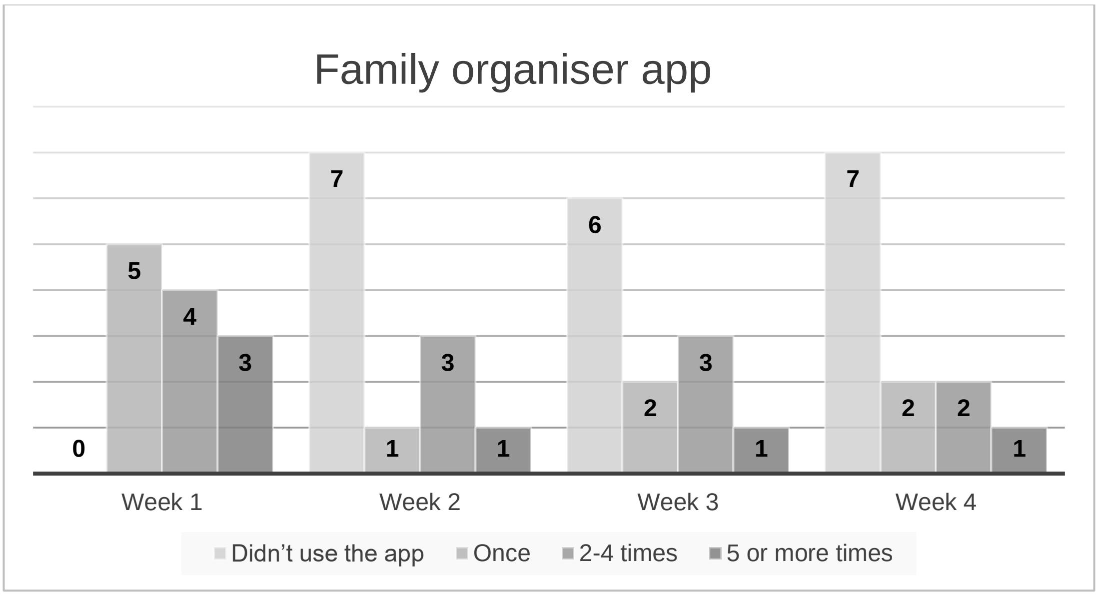


Figure 4-8: Frequency of app use, by app and by week across the 4-week testing period

Table 4-6: Self-reported duration of use of apps on each interaction during the 4-week testing period, by app and across the total sample (n=62)

App	N	Less than 1 minute	1 to 5 minutes	More than 5 minutes
		n (%)	n (%)	n (%)
Meal planning app	35	2 (6)	11 (31)	22 (63)
Recipe manager app	32	1 (3)	16 (50)	15 (47)
Recipe app	29	0 (0)	14 (48)	15 (52)
Barcode scanner app	12	0 (0)	9 (75)	3 (25)
Family organiser app	12	1 (8)	5 (42)	6 (50)

Participants description of the timing and context in which they used the apps led to two key sub-themes, in-time and when-time. In-time use of apps occurred when food provision behaviour was taking place such as whilst planning meals, shopping or cooking. This type of use was purposeful or planned and undertaken to achieve a specific task. By contrast, when time use tended to be exploratory and took place in spare moments when it was convenient to do so.

Another sub-theme of app use that emerged was the depth to which participants used the apps. During discussions of app features, some participants described not exploring the apps deeply enough to have knowledge of their content, features and functionality.

In-time

Use of apps during food provision processes was common, including using the meal planning feature whilst planning meals for the week ahead, using the barcode scanner whilst shopping and using recipes and/or food preparation instructions whilst cooking. The common link was purposeful use to achieve a task.

> *"Right, what are we going to eat this week, what do you feel like?" So we would discuss it together, um, and then decide on the meals (…) then I would go grocery shopping, that's right, and then I would like use it in the supermarket once and tick everything off and then I would put it away until I needed to cook every night."* **Blair, working 21 to <35 hrs/wk**

However, a number of participants spoke of the challenge of using apps in-time, particularly in reference to using apps in supermarkets. Participants reported being embarrassed about using the scanner in a supermarket for fear of judgement, forgetting to use the shopping list once they got there, or finding it impractical to have a phone out whilst shopping with young children in tow.

> *"I tend to try and keep my phone away when I shop. (…) Um, probably because I am trying to balance having a one-year-old and doing the food shopping."* **Debbie, working 1 to <21 hrs/wk**

When-time

When-time use on the other hand was primarily for the purpose of exploration or browsing, mostly associated with recipe content. This type of use took place in spare moments, when time was available to them, for example, when their children were in bed. This type of use appeared to be for information seeking, as opposed to functional tasks. It was sometimes conducted on the spur of the moment, for example, if nothing had been planned for dinner an app could be used to inspire or provide ideas in order to answer the question of 'what's for dinner'.

"…when the kids were sort of asleep and I had time I'd just sort of, you know, played around with the app, um, yeah, just looked up some recipes and that type of thing so – 'cause I just had some time to actually do it." **Dianne, working 1 to <21 hrs/wk**

Depth

The depth of use of apps was also a key sub-theme, with some participants appearing not to have explored the apps deeply enough to have knowledge of the key features. This may have impacted upon participant perception of app utility, particularly where their lack of depth in exploration and use of the app may have limited their understanding of what the apps could actually do. Some participants even described desirable features that were unaware already existing in the apps.

"I don't think I was even aware of it. (…) So, um, not so much with the meal planning. As I said, I – I didn't really use – I don't think I even found that function." **Bianca, working 21 to <35 hrs/wk**

4.6.7 Barriers

Participants described external barriers that impacted upon their acceptance and use of the apps, and on their ability to incorporate the apps as new behavioural strategies to support food provision. Time and habits emerged as key sub-themes.

Time

Time scarcity was reported to be a barrier to app use and the adoption of apps as new behavioural supports. They reported not having enough time or simply being too busy to use or adopt the apps. Some participants gave an indication that perhaps it was not necessarily a true lack of time, so much as having other more important priorities than using an app or changing their behaviour to incorporate the app into their usual food provision behaviour.

"I think, real or just perceived, I think, that's a, um, a time issue, I feel, like, (…) there's other things I should be doing…" **Cora, working 21 to <35 hrs/wk**

Interestingly, only participants working part-time and not full-time brought up time as a barrier (n=8 working 1 to <21 hours per week and n=6 working 21 to <35 hours per week), and all but one had partners working regular full time hours (i.e. 35 to 40 hours per week). However, those discussing time as a barrier generally had more than one child (n=11 of 14).

Habits and routines

Existing habits were a key barrier to participants willingness and ability to incorporate or use the apps as a part of their behavioural strategies to manage food provision. If participants already had established habits that worked well, they found it difficult to see the relevance of the app to them.

Habits reported to act as barriers to use of apps included buying food according to a budget or what is on special or in-season, already being a planner, preferring paper lists, having other 'go-to' apps and websites, or using other food coping strategies. These habits tended to, in the participants mind, render the app(s) redundant, and result in limited buy-in and use of the app. Ultimately, habits were described as difficult to break or change, and generally the use of these apps required the formation new habits, as pointed out by this participant.

> *"I'm inconsistent and I'm not good at forming habits. So I think this is one of those things where it's the – the app can be as brilliant as it is but if I'm not going to actually actively go out of my way to build that habit, (…) it's only as good as I'm going to make it."* **Sophie, working 21 to <35 hrs/wk**

Sticking with what they know the kids will eat, or recipes that are tried and tested and they know by memory tended to be the key fall back, particularly when there were major disruptions to their routine, such as a change of job.

> *"…I actually ended up changing jobs, like, right in the middle of, um, trialling the app. (…) I tried to settle back to just doing what was easy…"* **Harper, working 21 to <35 hrs/wk**

4.6.8 User experience

Participant experience with the apps was organised under two major themes – the behavioural performance of the apps and the effort associated with app use. Behavioural performance encompassed the contribution, both positive or otherwise, apps made to the performance of food provision behaviours. Whilst effort referred to the ease of use and functionality of the apps. These aspects of the apps were weighed up against one another in determining app acceptability.

Behavioural performance

<u>*Information and inspiration*</u>

Three of the five apps tested provided information that could be used to support parental food provision. Most participants found the recipe content of the recipe app and meal planning app useful in providing inspiration, breaking the monotony, and in encouraging variety in meals. This inspiration seeking may have been a way of increasing motivation for food provision, a task that was described by some as a 'means to an end'. Some felt that this inspiration led to positive dietary change, whether directly through following the recipes, or indirectly by prompting them to consider healthier food provision.

"…usually if I was, you know, tired or whatever, I might just turn to a freezer meal that can put in the oven or whatever, whereas this kind of made me think, like making it from scratch and like, still find easy ways to get, you know, vegetables into my kids" **Kathryn, working 1 to <21 hrs/wk**

Two participants explicitly stated that the cooking and food preparation skills videos directly influenced their cooking by teaching them new skills. One of these participants (partnered mother, no university education, income of $70000 AUD or less per annum) identified herself as having low levels of cooking competence. She found that the inclusion of step by step instructions and videos enabled the development of new food preparation skills, which in turn were perceived to have impacted on her diet in a positive way. However, most other participants felt competent in their cooking skills according to the quantitative data and did not find the cooking skills videos particularly useful.

"…I used to throw it all in at once. I've now learnt that you don't throw it all in at once. You actually cook some things and take them out of the pan and put other things in and cook it first (…) I wasn't very healthy beforehand. It's actually made me eat veggies and that's helped me with energy and stuff." **Holly, lower income, no university education, working 21 to <35 hrs/wk**

Conversely to the above views, many participants felt that the recipes provided by the meal planning app and recipe app were not well suited to their needs. Participants generally felt that the apps could be improved by including recipes that were suitable for families with young children, in particular quick and easy meals that were healthy, and suited the needs of young and often fussy, children. Many participants also suggested that more explicit nutrition information focusing on guidelines relevant to Australia was required in these apps to enable them to select healthy food and therefore make positive dietary changes.

"…if it was Australian and it was aligned to the Australian (…) food guidelines, that are prepared, you know, fruit and veg and helping me, um, tick off how many serves I'm getting in each meal, something like that would be a nice bonus." **Blair, working 21 to <35 hrs/wk**

The barcode scanning app that addressed food choice was found on the most part to be helpful from a food selection perspective, but this app was tested by a relatively small sample that indicated a need for such support. One key concern was the practicality of the information, with some frustration expressed surrounding swaps that were not easy or logical, uncertainty over how to interpret or use the information provided, and the cost and availability of products. Participants suggested that this particular type of app could be enhanced by including some practical product information also, such as the location, availability and cost of products.

"It's fantastic. Like, I'm just actually looking at a box of cereal I've got in my kitchen now, and that's four – four and a half stars, health star rating, whereas the stuff I had before, like, was maybe two, one and a half." **Alex, no university education, working 21 to <35 hrs/wk**

<u>*Organisation and efficiency*</u>

The organisation and efficiency aspects of the meal planning app and the recipe manager app were generally found to be positive. Many participants discussed planning ahead, being prepared and feeling organised. Participants found the ability to automatically generate a shopping list from planned or selected meals particularly useful, as it made the process of meal planning and shopping list preparation simpler and more efficient. The benefits of organisation and efficiency were discussed, including saving time and money, reducing mental load, enabling the preparation and/or consumption of healthier food, and reducing over-shopping and food waste. The most commonly stated benefit being saving time, particularly in association with the use of meal planning features and the automatic generation of shopping lists.

"…just being more prepared and having options there instead of having to go out and buy things on the spur of the moment and ending up with six other things also." **Emma, older children, lower income, no university education, working 1 to <21 hrs/wk**

The meal planning app and recipe manager app appeared to have a positive effect on the mental or emotional load of some participants. The organisational aspects of these apps were key to a reduction in last minute decision making and shopping, leading to lower stress and an easy answer to the question 'what's for dinner'. In a few cases participants noticed cost savings and a reduction in food waste associated with only purchasing what was needed. Others found that having a plan increased accountability meaning that they were less likely to rely on unhealthy food coping strategies such as purchasing take-away food.

"Like, it took away the decisions, decisions I had to make, I think, I had already made them, and then, I didn't need to stress about it, basically." **Blair, working 21 to <35 hrs/wk**

"…having the plan there it, sort of, I mean, it almost makes you more accountable for doing it, because if you've then bought the ingredients for those, um, meals then you know it's there (…) then it really cuts out the excuses of, oh, I'm tired, we're running late, let's get a pizza." **Cora, working 21 to <35 hrs/wk**

For those participants that already considered themselves planners, the app did not change their behaviour. However many referred to the apps being an alternative tool to utilise when undertaking these established behaviours. For others, the apps enabled new behaviours. For this participant, the app enabled her to undertake meal planning and through this process she began to understand the benefits of such behaviour:

"It met my needs very well, because I didn't really do planning before at all, and now I do, so I mean it taught me, um, I think it taught me in that I actually did it and then I understood how much less stressful that is, to plan meals. (…) So it was kind of through experience, that I understood that it was a worthwhile process…" **Blair, working 21 to <35 hrs/wk**

A suggested improvement to the efficiency of the apps with automated shopping list generation was to somehow link or integrate the shopping list with supermarket online shopping, to 'close the loop' and thus complete the process from planning to purchasing within the app. Nine participants independently suggested this same additional feature.

"Here's the recipe, and you know adjust your- adjust your shopping list if needed, you know go through the, your supermarket of choice, get it delivered when you want, done." **Fae, working 21 to <35 hrs/wk**

Reminders in the form of push notifications were also seen as a useful prompt to undertake planning behaviours, and to remind family members to undertake support tasks. Although, as only two apps included such reminders, it was a feature that a number of participants wanted to see in the other apps, particularly in the form of reminders to plan meals for the week, to prepare a shopping list, to go shopping for ingredients, and of the meal planned for each night.

<u>Support and communication</u>

Support and communication features were minimal in this set of apps, so this theme was not particularly strong from the perspective of benefits gained. Furthermore, the main app that included support and communication features was the family organiser app, which was not found to be as relevant to this sample of participants as expected. Regardless, some participants commented on the capacity of apps to involve others in 'support' tasks, or even just to start a conversation about these tasks. The family organiser, which was centred around communication between family members, was perceived by some as being an acceptable way of communicating the need for support with household tasks. Although some participants perceived food provision tasks as being 'their role' or 'job', stating that they were unwilling to share or give that role up.

"If I set a task, my husband would get a notification. Or I can send him the message saying, hey, did you remember to put the washing out? Um, and because it's coming from a cutesy little app it was less like nagging. It was kind of like a task, you know, that you would do within a game." **Mary, working 21 to <35 hrs/wk**

Around half of the sample could see the potential of these apps in enabling communication and the outsourcing of tasks to others, suggesting that more syncing and sharing features would be highly valued. Participants were particularly interested in seeing a shared interface for meal planners in order to provide a central place for storing information such as the meal plan, recipes and shopping list. These participants wanted syncing capabilities so that other family members could contribute to food provision-related tasks, and as a means of communicating.

> *"…it would definitely be accessible across multiple devices. Um, so, you know, that, like, that everyone who's old enough and interested, in the family could contribute. (…) he wouldn't be constantly asking me every day, "What's for tea tonight?""* **Brianna, working 35+ hrs/wk**

Effort

<u>*Usability*</u>

The usability of the apps was a key aspect related to their acceptance and therefore use, reflected in both the quantitative and qualitative data. Ease and simplicity of use was referred to regularly in relation to the meal planning app, barcode scanning app and recipe app and seemed to be highly valued. The System Usability Scale scores aligned well with this finding, with the same three apps scoring above 70 (median (IQR) SUS score: meal planning app 78 (68:88), barcode scanning app 79 (56:90) and recipe app 80 (58:89)) indicating an acceptable level of usability. Conversely, the family organiser app scored a median (IQR) of 48 (34:73) indicating that its usability was marginal or of concern. Although generally receiving mixed reviews during the interviews regarding usability, the recipe manager app was also deemed to be acceptable with a median (IQR) SUS score of 75 (54:86)).

Reasons provided for finding the meal planning app, barcode scanning app and recipe app particularly easy to use was that they were more intuitive, self-explanatory, and required very little input from the user. Participants also spoke about the accessibility and convenience of the technology, being that their mobile phone is generally always on them. It was felt that the apps allowed them to access information and undertake tasks whenever and wherever it suited them. Other usability related reasons provided for liking or accepting technology for supporting food provision included the streamlining of processes and the ability to store information in one place.

> *"It's quick for meals and then the grocery, and then it comes up with a list and then you can cook it so that's what I like about it."* ***Fae, working 21 to <35 hrs/wk***

Conversely, the family organiser was generally reported to be more complex and therefore clunky or difficult to use. Key reasons for this included the navigational complexity of the app and the inclusion of an excessive number of features. Many participants were unhappy with the level of effort involved in those apps that required a substantial user input. Although for one participant who found the family organiser relevant and its behavioural performance valuable, the usability was perceived as acceptable, contrary to the feedback of other participants. A few participants suggested that the more complex apps might be simplified by allowing components or features to be switched on or off according to need. In the case of the recipe manager, it was suggested that the app could include a bank of recipes, to balance the input and effort requirement of this app type.

> *"I thought if I did want to make it all a digital version it would take me lots of time just putting it all on there so I just use my book. (…) too much work for not enough gain…"* **Phoebe, working 1 to <21 hrs/wk**

> *"I would try and pare it back, um, filter it down and allow certain sections to be on or off or start on a basic mode, something like that, to get the hang of it, and then when you wanted to, um, add modules or turn stuff on, that kind of thing..."* **Blair, working 21 to <35 hrs/wk**

<u>*Functionality*</u>

The functionality sub-theme of the major theme 'effort' refers to the functioning, both positively and negatively, of certain features of the apps. Shopping lists of some form were included in all five apps and on the most part their functionality was acceptable. Although a number of participants remarked that it was just as easy to write it out on paper and perhaps more practical when walking down the aisles of a supermarket. Participants reported liking the automatic generation of shopping lists from recipes in the meal planner and recipe manager, whilst still allowing modification according to need. A key functionality concern was the consolidation of ingredients from recipes, with some apps performing this task better than others.

> *"It was good 'cause you could tick off what you already had and (…) if you did the weekly planning you could accumulate all of your shopping together..."* **Emma, older children, lower income, no university education, working 1 to <21 hrs/wk**

Participants indicated that they particularly liked the personalisation aspects of the apps for tailoring the app to their needs, from modifying portion sizes to filtering recipes according to dietary preferences and dietary requirements, such as food allergies and intolerances. The recipe importing functionality of the recipe manager was one such feature, however some participants had challenges with certain web content not being compatible. Some participants testing both the meal planning app and recipe manager app suggested that merging the two by including recipe importing in the meal planning app would allow further personalisation of content. Other suggestions for improving the personalisation features of the apps included incorporating the ability to search or filter recipes according to multiple ingredients, allowing searches based on ingredients they already have at home.

The functionality of recipe content was reported to be better than recipe content on websites with less vertical scrolling. However some complained about the impact of development in the Northern Hemisphere on terminology, measurements and the seasonality of recipe content. Furthermore, the limitations that the freemium apps imposed, such as a limit on the number of recipes that could be saved or on the number of recipes available to view also caused some frustration. There were also concerns regarding navigation between key app features, with an example being the meal planner, where once a meal plan was set-up, it was not possible to return to the recipe content unless the meal plan was reset.

Although the barcode scanning app was generally reported to function well, a major limitation reported by participants was the inability to utilise it whilst shopping online. For those that relied on online shopping, it limited their use of the app in the way it was intended (i.e. whilst shopping) and suggested that allowing text entry of items would be helpful.

4.6.9 Ongoing use

This theme related to intended ongoing use, with most participants reporting that they would aim to use at least one of the apps periodically into the future, as required or when they had time. Those that found the apps particularly useful were a lot more certain about what their future use of the apps might look like, while some articulated specific plans around further utilising the apps in different or extended ways. With regards to the family organiser, many people referred to seeing the potential in the future, when the kids were older and able to be involved. This seems to be consistent with the experience of the one participant with children old enough to use the app (i.e. school aged).

4.7 Discussion

4.7.1 Summary

This study aimed to assess the feasibility of existing commercially available apps in supporting parents to plan, purchase and prepare healthy food. Apps and app features tested were found to enable in-time planning behaviour, promoting organisation and efficiency in the food provision processes of working parents. The purpose of the apps and how well they aligned with self-identified needs was important to initial buy-in and use of the apps. The effort involved in using the apps was a key influence on acceptability and was weighed up against the behavioural performance or perceived behavioural benefits of the apps. The balance between these two factors appeared to be key to the usefulness of these apps as tools to support food provision. The lack of family friendly recipe and nutrition content was a limitation to the utility of the apps in this sample of parents. Time scarcity, a self-identified barrier to healthy food provision, acted as a barrier to engagement with these app-based tools. Ongoing use of these apps is likely dependent upon a combination of the extent of app buy-in, context of use, user experience and the influence of external barriers.

4.7.2 App utility

This study sample identified a need for ways to reduce the time and mental burden of food provision. These needs aligned with the apps and app features found to be most useful and acceptable, with planning features promoting organisation and efficiency and reportedly leading to a reduction in the time and mental burden of food provision. Meal planning and shopping list preparation as food coping strategies were used at least sometimes by most of the participants at baseline. Such planning and organisation strategies for managing food provision have been shown to be used by working mothers experiencing time scarcity in qualitative research (142). While these same strategies have also been found to be associated with a higher intake of vegetables and fruit in Australian women (283).

Food coping strategies centred around planning and organisation may not be suited to all personality types and family situations. Jabs et al. (142) in their qualitative study investigating low-income, working mothers time management strategies relating to food provision, found that mothers fell into one of three ‘timestyles’; active, reactive and spontaneous. Mothers with an active timestyle had the tendency to structure their time, using planning and organisation strategies. Whereas those with reactive or spontaneous timestyles tended not to plan, rather reacting to circumstances as they occurred (142). While less predictable work schedules and family structure may also make the use of planning and organisation strategies somewhat more difficult (254). Indeed, research investigating low-income parents perceptions of a recently developed meal planning app found that the majority of parents did not plan meals in advance, rather reacting to their day-to-day life as required (115). So the use of planning and organisation strategies, although ideal from a health perspective, may be challenging for some. Consideration of strategies outside of planning, and the incorporation of automated and streamlined planning features such as generation of shopping lists from meal plans and recipes might make these apps more widely acceptable and appealing even to those not inclined to plan.

In contrast to the more interactive planning-related features, the passive recipe content of the meal planning and recipe apps appeared to satisfy participants' need for ideas with regards to healthy meals. Inspiration was the main sub-theme arising from discussions regarding the behavioural performance of apps with recipe content. This finding is consistent with research investigating parental preferences for a food provision-related program targeting the dietary intake of young children (284). In their discrete choice experiment, Virudachalam et al. (284) found that the higher income, older and partnered participants of their research were more interested in creative cooking without recipes, rather than healthy cooking per se. This may explain the finding with regards to inspiration, considering the similarly biased sample in the present study. Although the lack of family friendly recipes may have limited parents' ability to use the recipes for anything other than inspiration.

Inspiration alone is unlikely to produce positive behaviour change in terms of food provision, with participants aptly suggesting the need for more explicit nutrition content in the apps. The present samples suggestion of incorporating serve based nutrition information relevant to young children is consistent with the findings of Burrows et al. (285) work investigating parental preferences for an eHealth family healthy lifestyle program. They found that the most popular program content was practical nutrition information such as healthy portion sizes and recipes (285). These findings suggest that although these apps may be capable of supporting the behavioural performance of food provision processes, their lack of family friendly content was a limitation to their utility in families.

4.7.3 App acceptability

This study was unique in its goal of allocating and testing apps on the basis of participant need. The alignment between the apps purpose and this need appeared to be important in determining app acceptability and use. Past research has shown that when technology is new or unfamiliar users tend to rely on external facilitating conditions, such as need, context and circumstances, to determine their acceptance and use of the technology (286). Furthermore, addressing the needs of the target group has been described as one of the top ranked concerns of experts and users alike in recent usability research relating to health and wellness apps (287). Evidence suggests that this may be particularly important in women (286), with their acceptance of technology being dependent upon its ability to meet their needs at the time of introduction. This reinforces the importance of user-centred research such as the current study in early app-based intervention development. Such insights may promote the development of more tailored apps and app features, thereby encouraging user buy-in and engagement (179).

Engagement

The timing and context of use of planning-related app features may explain their usefulness in addressing time-related barriers to food provision behaviour. Engagement with planning-related app features tended to occur in-time, when food provision tasks were being undertaken. So rather than needing to put time aside to use these planning-related features, their use was integrated into daily life and activities. EMI's, or interventions occurring in-time, stemmed from the need to support individual behaviour in everyday life outside of the research or clinic setting (178). Evidence for EMI's in the app-based dietary intervention space thus far is limited (288, 289), with the vast majority of evidence being for in-time diet monitoring, assessment and feedback (i.e. ecological momentary assessment) (290-292). The integration of apps into daily life and habits is thought to be an important aspect of the usability of health apps (287), and may be key to their ability to modify or support food provision behaviour. Furthermore, this integration into daily life may overcome some of the engagement-related challenges experienced by app-based interventions of the past.

Relatively few participants used the apps consistently and to the full extent intended in allocating them. Key reasons for this lack of buy-in and use of the apps included the barriers of time and existing habits. As discussed in Chapter 1 and 2, time scarcity is a commonly cited barrier to healthy food provision behaviours (160, 164). It is therefore unsurprising that time could also act as a barrier to the uptake of new digital solutions to food provision, especially when the use of such technology requires the formation of new habits (286). A conundrum exists then, as parents identified a need for time related support, however find that time-scarcity prevents them from making use of such supports. Garvin et al. (115) similarly found that time was cited as a barrier to meal planning and shopping list preparation in their study investigating parental perceptions of a meal planning app. Aligning app use with everyday food provision tasks, automation of key features and integration with services such as online shopping may help to alleviate the time burden of app use, thus promoting engagement.

Prior habits and routines with regards to food provision also acted as key barriers to app acceptance and engagement. This theme aligns with the habit construct of the consumer version of the Unified Theory of Acceptance and Use of Technology (UTAUT2) (286). The UTAUT2 model has been theorised as being key to consumers behavioural intention to use, and subsequently their acceptance and use of technology (286). In the UTAUT2 model, habit is conceptualised as prior behaviour and the development of habitual behaviour with regards to the technology being tested (286). Habit is thought to impact upon the relationship between the intention to use technology and actual use (286).

Forming a habit, particularly with new and unfamiliar technology, is challenging. Habits require repetition and practice to be formed, and can be difficult to break, particularly in a stable environment (293). Another app testing study with parents has also described established food provision habits as barriers to the development of new habits with technology (115). Therefore rather than expecting parents to overcome prior habits relating to food provision or to form new habits with these apps, it may be more effective to consider other ways of positioning the role of these apps in their lives. Apps may not need to be utilised as primary food coping strategies but could be positioned as tools to support the maintenance of healthy habits during times of stress or disruption. This may reduce the need for new habit formation, whilst also addressing parental concerns regarding the time-burden of the technology.

Quality

Consistent with prior work (124), the engagement subscale of the uMARS was the lowest scoring quality subscale for this sample of apps, particularly in those with minimal existing content. This is concerning, as user engagement is a major challenge to the efficacy and longevity of app-based health interventions (116). Part of the reason for the low engagement sub-scale score may be the purpose of this group of apps. The use of the apps in-time and context to achieve everyday tasks such as meal planning, shopping and food preparation is driven by need. These tasks are generally not always associated with pleasure, nor were the apps supporting these tasks. Participants rarely expressed enjoyment or pleasure in using the apps, although some found the novelty of the apps enjoyable. Novelty is thought to play an early role in the hedonic value of technology (286). Although once a user is familiar with a piece of technology, the pleasure resulting from its novelty is generally reduced (286), speaking to the need for other qualities that promote ongoing engagement. As the enjoyment or pleasure associated with use of technology has been shown to be important to the usability, acceptance and use of apps (286, 287), enhancing the pleasure associated with the use of this group of apps should be a key consideration in the future.

Usability and functionality

The need to minimise the time and mental burden of these apps was also reflected in participants assessment of the usability of the apps. Usability has been described as the effectiveness, efficiency and satisfaction with which users utilise technology to achieve their goals (287). It is thought to be key to retaining users and is therefore seen to be paramount to the efficacy of apps (287). In their work investigating the alignment between experts and users views on usability, Liew et al. (287) found that satisfaction (i.e. likability, and the comfort and pleasure associated with app use) ranked the highest. However aspects of efficiency were also considered important (287). Participants in the present study appeared to weigh up the behavioural performance of the apps against the effort required to make use of them when determining app acceptability.

The themes emerging from participants' experience with the apps aligned with the constructs 'performance expectancy' and 'effort expectancy' of the UTAUT2 model (286). 'Performance expectancy' refers to the behavioural benefits of the technology to the user and 'effort expectancy' with the effort required to use it (286). Individual characteristics such as gender are thought to moderate the effect of these constructs on intention to use technology (286). For example, there is evidence that the level of effort or the process involved in using technology is more important to women than men (286). This may be part of the reason why participants in the present study, who were almost exclusively female, appeared to value ease of use so highly and weighed the behavioural performance of the apps against this when determining their acceptance of the technology.

Considering the added pressures these families are experiencing with regards to time and mental load, it is important to balance the effort required to use an app with the behavioural performance that it enables. This explains parents' preference for features with automation, such as meal plans generated from a recipe bank, their suggestion for integration with services such as online shopping and their desire for syncing to promote support from other family members. While the lower level of acceptance of the family organiser and the recipe manager apps was likely reflective of the level of effort and input required to use them. The case for integration and automation to minimise the time and effort involved in using apps to support food provision tasks is therefore strong.

4.7.4 Context and need

This study included primarily working mothers of young children who identified as the primary food gatekeeper. It was evident that the balance between work and the food provision role was challenging, even despite most participants' self-reported competency in planning, shopping and cooking skills. Use of food coping strategies largely reflected these competencies, with more consistent use of cooking and food preparation related strategies, and meal planning/shopping list use over the outsourcing of tasks through online shopping, meal kit delivery and support from other family members. This is consistent with the findings of Morin et al. (165), who found that working parents with high self-reported competency in food provision were more likely to plan and cook meals in advance, and prepare meals with few ingredients. Whereas lower competency was associated with less healthy food coping strategies such as eating in fast-food restaurants (165). The present sample was relatively well educated and of a higher income than the broader Australian population (e.g. 62-78% with a University qualification in the present sample(s), versus 35-38% in the broader Australian population of women of a similar age) (294). Their behaviour with regards to meal management may therefore be specific to their circumstances. For example, their preference for eating at family restaurants or pubs over fast-food restaurants may reflect the higher disposable income of the sample.

There was some evidence that needs were different for people of different sociodemographic backgrounds, although this was not tested statistically. This sample identified a need for information in the form of healthy recipes and meal ideas, and for ways to reduce the time and mental burden of providing food. While support regarding food choice, and food preparation and cooking skills was not a high a priority. This could be a reflection of the higher income and education level of the sample, which has been previously associated with greater knowledge, skills and confidence when it comes to food and nutrition (125, 295). The discrete choice experiment mentioned earlier also found that the older, higher income, partnered parents in their sample had a preference for meal planning and time-saving strategies (284). Whereas younger, lower income, single parents were more interested in support regarding healthy cooking and nutrition (284). The greater need for functional supports to reduce the time and mental burden of food provision may be more synonymous with the time-poor, but financially more secure, dual-parent working family. Future research in households where different resources are scarce, such as money, knowledge and skills, may need to consider apps and app features that were less represented in the present work.

4.7.5 Strengths and limitations

Strengths of this study included the allocation and testing of apps on the basis of need, and the mixed methods approach incorporating rich qualitative data triangulated with quantitative findings, both drawing on aspects of user-centred design and the person-based approach. Making use of existing commercial technology to learn lessons and draw inspiration supports early app development without substantial time and funding investment. This is important in a field of research that can be time sensitive and costly. Although this study did not assess dietary behaviour change resulting from the use of these mobile apps, it does provide early evidence to support future app development and testing. This background research with the target user is considered essential to the early planning stages of app-based interventions, prior to prototype development and more rigorous efficacy testing (201). Engaging the target user supports the development of interventions that are engaging and usable, and therefore more likely to be effective in changing health-related behaviour.

This study did involve some limitations, particularly with regards to the generalisability of the results. The sample was mostly of high socioeconomic status and working typical office hours rather than shift or weekend work, which may have led to a homogeneity in the results. However, there was representation of single parents, and parents of lower socioeconomic status, and effort was taken to incorporate their voices as best as possible in the results. Irrespective of sociodemographics, the dietary intake of the study sample reflects the eating habits of the broader Australian population. Participants reported consuming too few vegetables and fruit, and excessive discretionary choices. The 6-7% of the present sample meeting the guidelines of five or more serves of vegetables per day is comparable to the 6-10% of Australian females aged between 25 and 44 meeting the guidelines in the latest national survey (17). Similarly for fruit, the 45-50% consuming two or more serves per day is comparable with the 45-46% of the broader population meeting these guidelines (17). In terms of discretionary choice intake, AHS data show that females aged between 31 and 50 years of age consumed a mean of 4.1 serves per day, inclusive of alcohol (296). Although the present sample consumed a mean of 3 serves per day, this is still in excess of the recommended 2 serves per day maximum (14), and did not include alcohol consumption. This suggests that the present sample would similarly benefit from food provision related support, much the same as the broader Australian population.

The allocation of apps to need, although innovative and thought to be a strength of the work, also had its limitations. The apps allocated were not always deemed relevant or suitable to participants. This seemed to be particularly the case with the family organiser. Most parents testing this app felt that it was not relevant to families with young children who were not yet capable of being involved in support tasks, even though it was hoped that the app would encourage communication between parents and/or carers. Therefore much of the feedback regarding this app should be taken with caution, considering that most felt the app was not relevant to their family's stage or context.

Implications for practice and future research

The alignment of the apps purpose with parent needs was found to be key to app acceptability, reinforcing the importance of early app development with the user to enable tailoring of apps to the needs of the target group. However, there was some evidence that needs differed by participant competency in food provision tasks and by sociodemographic factors. Although this may speak to the need for different interventions in different subsets, it also may strengthen the case for better tailoring within a single app (179). Although the resources required for the development of such an app are likely to be high, the benefits from an engagement and effectiveness perspective may outweigh this cost.

The strength of these apps addressing food provision may lie in their ability to be integrated into everyday life, promoting healthy food provision in-time and context. Meal planning apps with integration and automation may be the nexus between national nutrition guidelines and healthy dietary intake in families, addressing key barriers to healthy food provision tasks. The incorporation of features enabling alternative food coping strategies such as online shopping and other parent/carer support may be what drives the shift toward digital solutions to food provision. However, the use of any new technology such as this will always require user effort, and it is clear that the balance between effort and outcome should be at the core of app development in the future. Otherwise there is a risk of causing unnecessary time and mental burden, rather than addressing it.

4.8 Conclusion

This study has provided insights into the role of mobile apps in supporting parents to achieve healthy food provision in a family context. Meal planning apps and features promoting organisation present feasible solutions to supporting healthy food provision. They may reduce the time and mental burden of these processes if designed with these opportunity-related determinants of food provision in mind The behaviour change potential of such apps may lie in their ability to be integrated into day-to-day life, addressing food provision behaviour both in-time and context. However in their current state they fail to meet the specific needs of parents with regards to family friendly recipe and nutrition content, and are biased toward those that are more inclined to plan in the first place. Consideration of features and content that promote planning behaviours in those less inclined to plan, and the needs of parents of different socioeconomic backgrounds will be important for future app development.

CHAPTER 5: DISCUSSION, APP CONCEPT AND CONCLUSION

5.1 Overview

The overarching aim of this thesis was to develop an evidence-based app concept aiming to reduce parental provision of discretionary choices to young children. To address this aim, three studies were conducted exploring young children's discretionary choice intake and digital intervention approaches for supporting parental food provision. Chapter 2 reported a secondary analysis of Australian children's dietary intake data. The study enabled a deeper understanding of young children's intake of discretionary choices, and explored time and money as determinants of this intake. Chapter 3 and 4 explored the feasibility of mobile apps for addressing the parental provision of discretionary choices to young children. Chapter 3 involved the identification of potential intervention components through a systematic assessment of popular, commercially available food provision apps. Chapter 4 then engaged working parents in utility and acceptability testing of apps and app features identified and selected from Chapter 3. This work was overlaid with behaviour change theory, with the COM-B system guiding barrier identification and app allocation for testing, and intervention components mapped against the BCTTv1 to understand their behaviour change potential.

This discussion chapter involves the triangulation of the empirical evidence, user perspectives of commercial technology and behaviour change theory to inform an evidence-based app concept addressing parental provision of discretionary choices to young children. The key findings of each of the three main studies making up the program of research are summarised in the context of the evidence gaps identified in the thesis introduction. The findings are then discussed as they relate to the overarching thesis aim, and an app concept described. Finally, future directions of the broader fields of research are proposed.

5.2 Summary of main findings

5.2.1 A deeper understanding of discretionary choice intake in young children: the what, when and why

In Chapter 1, it was highlighted that children are consuming excess discretionary choices (17). It was shown that discretionary choice intake starts early in life and mirrors that of adults by school age (16, 18, 19). Discretionary choices are associated with poor health (1, 3-5) and can displace intake of healthy foods. Minimising children's exposure to discretionary choices in early life when eating behaviour and food preferences are being established may prevent the development of a preference for these foods and beverages and thus reduce intake in later life.

Early dietary interventions targeting the nutritional, behavioural and parenting needs of young children have had limited effect on children’s intake of discretionary choices (73, 74, 77). Addressing parental food provision, including the planning, purchasing and preparation of meals, was identified as a way to enhance past interventions by focusing on parents and their needs. Capability and motivation-related factors such as knowledge, skills and self-efficacy are well-targeted enablers of healthy dietary intake and food provision. This gap in our understanding of the role of opportunity-related determinants of intake such as time and money was therefore the focus of Chapter 2.

It was determined that a deeper understanding of the discretionary choice intake of young children, including the type, pattern and determinants of intake, was required to develop more effective interventions that are tailored to the needs of young children and their parents. Chapter 2 therefore addressed thesis specific aim 1 by describing the discretionary choice intake of young children by eating occasion. Thesis specific aim 2 was also addressed by examining parental time and money as determinants of young children’s discretionary choice intake. This deep-dive into the what, when and why of young Australian children’s discretionary choice intake took a novel eating occasion approach. It also investigated under-represented opportunity-related determinants of intake, specifically time and money.

Previous interventions have targeted SSBs and snack foods, however main meal intake of discretionary choices was identified as a novel target for early dietary interventions. Main meal eating occasions were found to contribute a larger proportion of overall discretionary energy intake than snack occasions, and contributed a substantial proportion of fat, saturated fat and sodium intake. Original contributions to knowledge included the finding that household, parent and child factors explained more variation in the intake of discretionary choices at main meals than at snacks. Main meal intake of discretionary choices may therefore be more amenable to modification through interventions targeting household and individual level factors than intake at snacks.

Time and money, represented by parental work hours and household income, contributed significantly to the models. This suggested that these factors are important determinants of young children's discretionary choice intake and thus parental food provision. Original contributions to knowledge included the consistent and strong association between money and discretionary choice intake across the day, and the differential role of time across eating occasions. Both maternal and paternal work hours were found to be determinants of discretionary choice intake at main meals, while only paternal work hours were important at snacks. These findings suggest that there may be value in targeting time as a barrier to healthy parental food provision, and that both mothers and fathers time is important.

5.2.2 The feasibility of apps and app features addressing parental food provision

In Chapter 1, mobile apps were identified as a unique opportunity to address parental food provision behaviour in-time. App-based interventions have been moderately effective in eliciting dietary change in adults (182), however their focus on individual weight loss and diet monitoring has limited relevance and application in a family context. Similar issues exist in the commercial app space, along with a lack of evidence-base. The few apps identified that specifically addressed dietary intake in children focused on the delivery of static content, thus failing to capitalise on the many advantages offered by the technology (105, 186-188, 297). Chapters 3 and 4 combined therefore addressed thesis specific aim 3, to determine the feasibility of apps and app features addressing parental food provision behaviour.

In Chapter 3 thesis specific aim 3a was addressed by conducting a systematic assessment of the quality and behaviour change content of commercially available apps and app features relevant to improving parental provision of food to young children. App scope and characteristics were described, quality assessed and app content and features mapped against the BCTTv1 (205). The work described in Chapter 3 explored apps and app features that had not yet been considered in a research setting or in a context relevant to healthy parental food provision. Searches in commercial app stores were designed to identify apps and app features addressing the planning, purchasing and preparation of food and meals.

Five broad categories of apps were identified in the review as being relevant to parental food provision, including 1 – recipe and recipe manager apps; 2 – meal planning apps; 3 – shopping list apps; 4 – family organiser apps and 5 – food choice apps. Recipe and recipe manager apps, meal planning apps and family organiser apps were found to offer behavioural support for the use of healthy food coping strategies. Meal planning features and automated shopping list generation showed the potential to address barriers to healthy food provision such as time scarcity and mental load. However none of the apps specifically addressed money as a barrier to food provision. Further shortfalls of the technology included their lack of BCTs, evidence-based nutrition content suitable for families of young children, and alternative food coping strategies.

Chapter 3 made an original contribution to knowledge in its identification of apps and app features for addressing nutrition in a whole family context, unlike the individual weight loss and diet monitoring focus of prior app-based dietary interventions. The review was used to select apps and app features for user-testing on the basis of their behaviour change content and quality. Incorporating the users voice was the next step in investigating the feasibility of mobile apps in supporting healthy parental food provision. This led to Chapter 4 which addressed thesis specific aim 3b; to explore the utility and acceptability of commercially available apps and app features with parents.

Five apps were selected for testing from the 51 apps reviewed in Chapter 3, including a meal planning app, a recipe manager app, a recipe app, a family organiser app and a barcode scanning app. Working parents were the target group for user-testing, with their behaviour, context and needs being at the forefront of the research. The work drew on aspects of user-centred design and the person-based approach, including the observation of real-world use of the apps and the use of a mixed methods design. Such approaches are thought to result in more engaging, usable and effective apps (179, 201).

Apps and app features enabling planning were found to be feasible solutions for supporting healthy parental food provision. They were well accepted and promoted organisation and efficiency, addressing key barriers to healthy food provision such as time and mental load. Original contributions to knowledge included the potential of these apps and app features for addressing behaviour in-time when food provision behaviour is occurring. This contributed to their behaviour change potential and set them apart from nutrition-related apps in the research space thus far. However, for these apps and app features to be truly useful in supporting healthy food provision, the effort involved in their use, and their lack of family friendly recipes and evidence-based nutrition content would need to be addressed.

Consistent with app-based research to date, engagement remained a key barrier to the utility of these app-based tools for supporting parental food provision behaviour. Time was identified as one of the main barriers to healthy food provision in need of addressing yet was also a barrier to app buy-in and engagement. Habits were also thought to be a key barrier to app use, with the challenge associated with breaking existing habits and the formation of new habits being cited. Automation and integration showed promise in addressing these barriers by reducing the burden associated with app use.

5.3 Discussion

This thesis has generated evidence to inform an app concept for addressing parental food provision to young children, with the aim of reducing their intake of discretionary choices. The program of research has allowed an exploration of the problem of young children's discretionary choice intake, key opportunity-related determinants of intake and the feasibility of commercial apps and app features for reducing intake. This section will describe how the evidence generated, the existing literature, and behaviour change theory has driven the selection of intervention components to support healthy parental food provision. The selected components are brought together into an app concept with specific content and features associated with behaviour change described.

The development of engaging, usable and effective app-based health interventions remains a challenge (179). Efforts to overcome the barriers to realising the full potential of digital health has driven the methods of research selected for this thesis. A summary paper of findings from an international workshop of experts regarding the development and evaluation of effective digital behaviour change interventions described the key challenges for the area as including; a lack of clarity regarding the mechanisms through which interventions have their effect; and insufficient engagement with interventions to produce behaviour change (179). Therefore in taking forward the evidence generated in this thesis to develop an app concept, the following section will cover the problem and its key determinants; the proposed app concept and the behaviour change theory underpinning the features and content selected and; strategies for maximising engagement with the app.

5.3.1 The problem and its determinants

Discretionary choice intake at main meals

Young children's intake of discretionary choices has been highlighted consistently throughout this thesis as a major problem in need of addressing, with a focus on parental food provision as the behavioural target. Chapter 2 demonstrated that discretionary choice intake at both main meals and snacks requires addressing, with processed meat, fried potatoes, cakes and biscuits being particularly relevant to this age group. As past research has focused on snacks and SSBs, discretionary choices consumed at main meals provide a gap in need of addressing in early dietary interventions.

Young children's intake of discretionary choices at main meals was shown to be more vulnerable to household, parent and child level determinants of intake than intake at snacks. Coupled with the potential for positive spill-over effects onto healthy food intake such as vegetables, main meals appear to be a good target for an app concept addressing parental food provision. Therefore the following discussion will consider an app concept addressing parental food provision at main meals. This does not mean to say that the app concept described in this thesis is not relevant to intake of discretionary choices at snack times. However if the app concept was to target discretionary choice intake at snack times directly, its core content and features should first be similarly validated and tailored to consider the determinants of intake specific to this eating occasion.

Barriers to healthy parental food provision: money, time and mental load

This thesis prioritised an investigation of opportunity-related determinants of young children's dietary intake. Chapter 2 therefore focused on time and money as determinants of young children's dietary intake, however also controlled for other determinants, including aspects of capability. Chapter 4 then built on this initial investigation by considering parents self-identified needs for supporting healthy food provision behaviour. This investigation focused on those determinants that could be addressed by identified app content and features. Although not an exhaustive investigation, it did provide further evidence regarding aspects of the COM-B system in need of addressing. Key determinants of healthy food provision behaviour will now be discussed with a focus on those areas least well covered by interventions thus far, and on those which the commercial apps assessed and tested may be best placed to address.

Chapter 2 demonstrated a strong and consistent inverse relationship between household income and young children's discretionary choice intake, irrespective of eating occasion. Although there is a strong evidence base supporting this socioeconomic patterning of dietary intake, it is mostly in older age groups (155-158, 160, 161) and the mechanisms of the relationship remain unclear. Commercial apps addressing food provision did not incorporate features that could be used to directly address this issue, and hence there is no user-testing data to draw upon regarding how best to approach this barrier from a digital perspective. Regardless, the role of money as a determinant of young children's dietary intake should not be ignored. Rather apps and app content must be developed with this socioeconomic determinant of health in mind so as not to create greater disparities in health.

The need for healthy recipes and meal ideas to support the provision of healthy food was rated as the most important COM-B enabler. Diets in line with dietary guidelines have been shown to be cheaper than current, unhealthy diets. Lee et al. (162) tested the difference between current, unhealthy diets and healthy diets in line with the Australian dietary guidelines, across households with different composition and income. It was found that healthy diets cost between 88% and 99% of the cost of current, unhealthy diets in households with children (162). The promotion of diets in line with the dietary guidelines is therefore unlikely to place any further financial burden on low-income households. Therefore, recipe and meal ideas in line with current dietary guidelines would be supportive of both cost-saving and improved health in families with children. However consideration would need to be made as to the suitability of recipes to families of young children so as to maximise child acceptance and reduce food waste, which may also be a key cost-related barrier to the provision of healthy food.

Time is also considered to be a social determinant of health, and is closely related to the financial position of a household through employment status (137, 141, 160). In Chapter 2, time was found to be an important determinant of young children's discretionary choice intake, with both mothers and father's contribution to time being shown to play a role. Chapter 2 took an economic perspective of time, viewing it as a resource required for the production of food (164). Evidence from studies investigating maternal work hours and children's dietary intake supports the theory that time as a resource can facilitate or act as a barrier to healthy family food provision (147, 150, 151). However the non-linear relationship between work hours and young children's dietary intake suggests that more time does not necessarily lead to healthier outcomes. Perhaps the reason for this is because it is not simply measurable time, but also the perception of time scarcity that is important.

The perception of time scarcity is perhaps an equally important determinant of diet-related behaviour as time itself (141, 160). Chapter 4 investigated a limited number of self-perceived COM-B enablers of healthy food provision in parents (primarily mothers) who had recently returned to work after a period of parental leave. Time for food provision tasks was ranked as the second most important COM-B enabler of food provision. Further emphasising the importance of time, in the semi-structured interviews parents also described time as a barrier to healthy food provision behaviour and to the acceptance and use of app-based food provision tools. As described in Chapter 1, qualitative evidence from mostly mothers highlights the role of perceived time scarcity in reduced home food preparation and a greater reliance on unhealthy food coping strategies (142, 145, 146). Actual time aside, the perception of time scarcity is clearly an important barrier to healthy food provision.

Food provision tasks are thought to be some of the most time consuming of household tasks, and their burden is constant as they must be performed on a regular basis (143, 298). In contemporary society women continue to shoulder this burden whilst also juggling the demands of work and caregiving (99, 143, 298). Furthermore, the transition to parenthood may be a key stage in the development of inequality in the division of household labour (299). A report of the 2018 Household, Income and Labour Dynamics in Australia survey found that partnered women with dependent children spent almost double the amount of time on housework compared with men (300). Although there has been a slight and gradual shift toward more male contribution to domestic household labour, this inequality continues today and is leaving modern mothers in a state of time-scarcity and stress (141-143).

Having strategies to address the mental load of food provision was considered a similarly important enabler in the COM-B self-evaluation questionnaire. Much like the time burden, women bear the majority of the mental burden of domestic labour irrespective of their employment status (301, 302). Although the mental processes underpinning food provision often occur concurrently with the physical demands, they are thought to be a distinct set of processes (302). Until recently the mental processes associated with the everyday management of a household, including those required for food provision, were not well acknowledged in sociological literature. They were simply accepted as being synonymous with the physical demands of domestic labour (302). Popular media has played a key role in drawing attention to these processes, and in giving them a name: the ‘mental load’ (303, 304). French feminist cartoonist ‘Emma’ depicted and described the mental load in her comic strip ‘You should’ve asked’ (304). See Figure 5-1 for one of the cartoons in her ‘You should’ve asked’ series depicting the mental load being experienced by modern women juggling employment, domestic duties and caregiving (304).

Figure 5-1: 'You should have asked' cartoon number 13 by Emma (304) from the book 'The Mental Load' Seven Stories Edition – cartoon reproduced with permission

Research defining mental load describes four key components; anticipation, identification, decision-making and monitoring (302). Each of these mental processes can be applied to the context of healthy food provision. Anticipation of the family's schedule for the week and thus identification of meals suitable to time constraints might take place in the early meal planning stage. Decision-making regarding which meals to select then follows, with additional considerations as to the food already available in the house and thus needing to be used. Finally the outcomes of the decision must be monitored to ensure that the food purchased is utilised as planned and before expiry dates are reached. Therefore much of the mental load of food provision occurs during the planning stages and tends to go unseen by other members of the family (302).

The desire to minimise mental load may lead to food provision practices that are less supportive of healthy dietary intake. Higher work stress has been associated with less healthy family food environments including less frequent family meals and more frequent fast food consumption (149). Unhealthy food coping strategies such as the purchase of fast food may be used to reduce the mental burden of food provision amongst competing mental demands (146). Furthermore, lower executive functioning may mean that some mothers have a lower propensity to manage the mental load of healthy food provision (305). A reduction in the mental load associated with food provision may therefore support healthier parental food provision practices and thus dietary intake in children.

Summary

In summary, money, time and mental load are key determinants of healthy food provision in need of addressing in contemporary society. These resources are under significant pressure as families juggle the competing demands of modern life and are consequently contributing to low diet quality in children. They also represent key social inequities of health, and gender inequities in domestic household labour that are impacting upon parental capacity to maintain a healthy household food environment. Although there are many other barriers and facilitators of healthy food provision, these aspects of parental opportunity and capability have been less well addressed in past research and thus deserve attention. Furthermore, they are interrelated so should be considered together when developing future interventions. Future technologically driven solutions should aim to address the physical, mental and financial burden of healthy food provision, thus offering a viable alternative to the less healthy food coping strategies so often relied upon by modern families.

5.3.2 An app concept with behaviour change theory driven features and content

Grounding future apps in behaviour change theory will ensure that they are effective in modifying health behaviours (179, 200, 201). Although it was out of scope for the present study to follow the full Behaviour Change Wheel (BCW) process for intervention design (117), aspects of the process have been drawn upon throughout the program of research. The COM-B system for understanding behaviour underpinned the investigation of determinants of young children's discretionary choice intake, and parents self-identified needs with respect to healthy food provision, while the behaviour change content of apps and app features was identified using the BCTTv1 (116). The BCW enables the linking of COM-B determinants with appropriate behaviour change content through the 'intervention function' step of the process (117). Thus, this section will discuss the selection of app features and content according to their delivery of BCTs relevant to the key COM-B determinants of healthy food provision behaviour as identified in section 5.3.1.

The COM-B system posits that having adequate capability, motivation and opportunity facilitates behaviour, however a lack of these same factors can act as a barrier to behaviour (116). For example, having nutrition knowledge and cooking skills may enable the preparation of meals for one's family. However when time and money are scarce, or mental resource is low, knowledge, skills and motivation may not be enough to enable healthy food provision, leading to behaviour that is less supportive of good diet quality. Interventions should therefore address aspects of capability, opportunity and/or motivation to promote positive health behaviour. This PhD research has identified aspects of opportunity and capability, namely time, money and mental load, as being key determinants of food provision in need of behavioural support (117).

Michie et al. (117) describes the intervention functions required to address each domain of the COM-B system. Intervention functions are defined as the broad categories or components of interventions that are considered to be capable of changing behaviour (117). BCTs are then linked to these intervention functions to allow the selection of the 'active ingredients' of interventions (117). There are three key intervention functions common to addressing aspects of opportunity and capability such as time, money and mental load (117), including:

- Enablement – increasing the means or reducing barriers to a behaviour, for example by providing behavioural support for planning and organisation;
- Environmental restructuring – changing the physical or social context, for example by reducing the time demand of the behaviour;
- Training – imparting skills, for example by providing training regarding time management and organisation

Table 5-1 below demonstrates how key app features and content that were identified, tested and selected for inclusion in the app concept deliver BCTs relevant to these intervention functions. Figure 5-2 then provides a conceptual diagram depicting the app concept, including its key content, features and BCT's. The following section will discuss the selection of key app features and content according to their behaviour change mechanism, and make recommendations for their inclusion in the overarching app concept.

Table 5-1: The selection of key app features and content according to intervention function and behaviour change technique

Intervention function	Behaviour change technique	Selected app feature/content
Enablement	1.1 Goal setting (behaviour)	Selection of healthy main meals ahead of time
	1.4 Action planning	Allocation of main meals to days & times
	3.2 Social support (practical)	Synced/shared app for use between parents/caregivers
Environmental restructuring	7.1 Prompts and cues	Push notification reminders to undertake key food provision tasks
	12.1 Restructuring the physical environment	Link to online shopping
	12.5 Adding objects to the environment	Automated meal planning & shopping list generation
Training	2.3 Self-monitoring of behaviour	Recording preparation of planned meals
	4.1 Instruction on how to perform a behaviour	Tailored healthy recipe content with serving-based nutrition information & nutritionally balanced meal planning advice
	8.1 Behavioural practice/rehearsal	Planning process with support (i.e. optional manual planning with guidance)

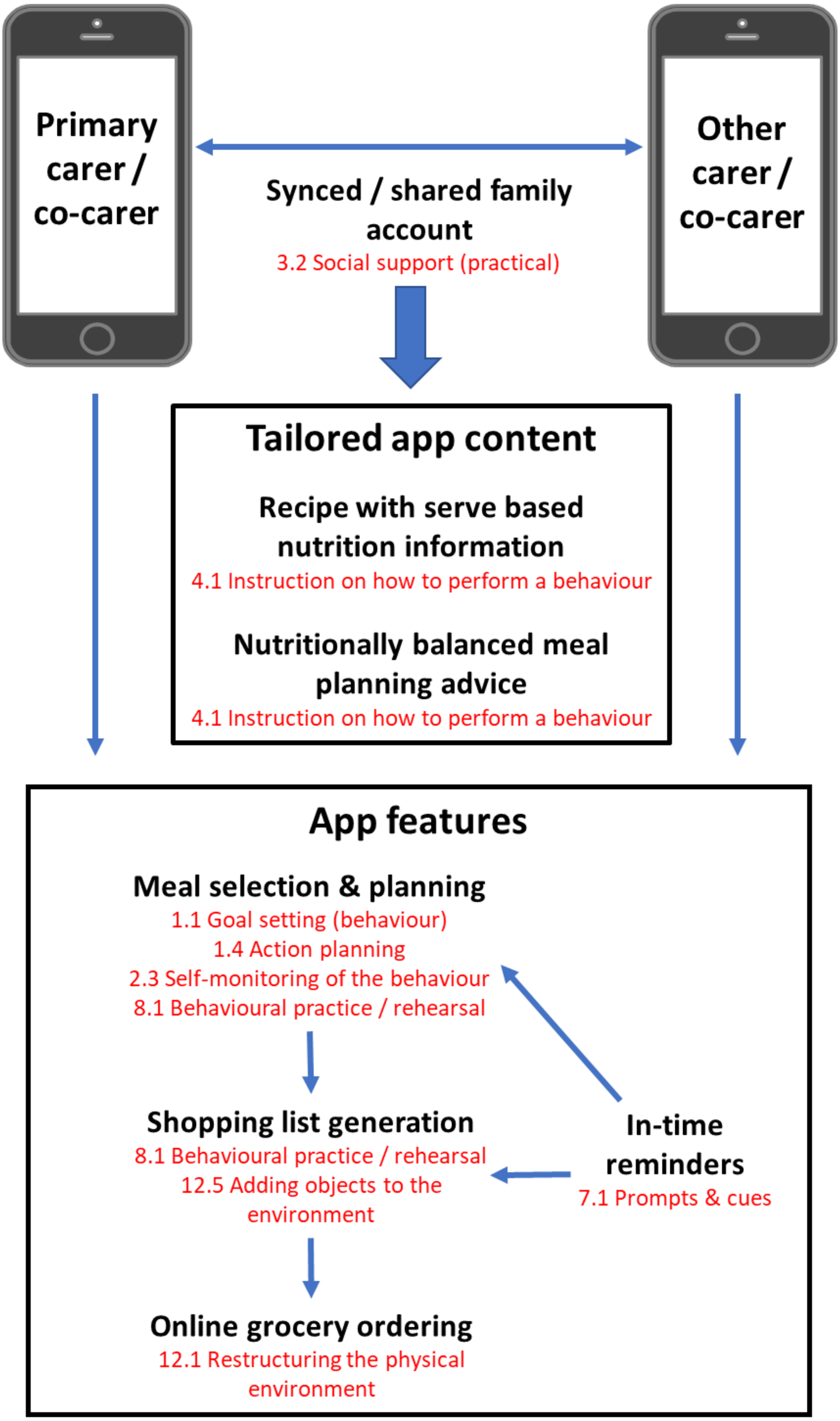


Figure 5-2: Key features of the app concept, with associated behaviour change techniques (in red)

5.3.3 Enablement: providing the tools

Meal planning features for promoting organisation and efficiency

Planning and organisational strategies are commonly used by parents to enable food provision when time is scarce (142). Meal planning and shopping list use enable home food preparation, thus reducing the need to rely on unhealthy food coping strategies such as the purchase of fast foods (306). When planning does not occur, families may be inclined to be more reactive to their situation in order to maintain food provision, even if it comes at the expense of nutrition (99, 115, 142). Planning strategies have therefore been linked with healthier dietary intake and a lower incidence of obesity in adults (283, 306). However the planning that underpins food provision is considered by working women to be the most challenging aspect of food provision (142, 143) and therefore may be bolstered with digital behavioural support.

Meal planning capability was supported by half of the apps reviewed in Chapter 3, was the core feature of meal planning apps and was associated with the greatest number of BCTs. Meal planning apps and some recipe manager apps were focused on the organisational side of food provision, allowing the user to select recipes or foods, allocating them to a day and time. The higher quality meal planning apps, such as that included in the user-testing study, allowed the generation of meal plans from an existing bank of recipes. Parents reported that the meal planning features supported organisation and efficiency, thus saving time and reducing the mental load of food provision.

App features supporting the planning of meals in advance and the allocation of meals to specific days and times, were linked with goal setting and action planning BCTs which are associated with the intervention function 'enablement'. Goal setting allows one to envisage a future end-state that they wish to acquire (120), and is a core component of traditional and digital nutrition interventions alike (119, 121-123). Action planning extends goal setting behaviour by prompting detailed planning as to how the goal will be carried out, specifying details such as timing and context (205). The reason planning is thought to be so effective from a behaviour change perspective is that it provides the link between intention and behaviour (307). Providing behavioural support for healthy meal planning may therefore ensure that parents have healthy plans and intentions for meals, thus reducing the likelihood of using unhealthy food coping strategies.

Support and communication features for sharing the load

The unique placement of apps as tools for engaging both parents in a dual-parent household in food provision, marks a new opportunity in the delivery of family-centred interventions. This contrasts with early dietary interventions that tend to be targeted toward the mother as the primary caregiver (82-88, 91, 94). A systematic review of fathers' involvement in obesity treatment and prevention programs demonstrated that fathers are rarely involved in or targeted by interventions (235). Chapter 2 highlighted the role of paternal working hours and education level as determinants of young children's discretionary choice intake. Combined with evidence regarding the association between fathers and children's dietary intake (95), this suggests a need to include fathers in early dietary interventions, with mobile apps providing a tool to enable this.

Social support features may enable healthy food provision by making the management processes associated with food provision more visible, thus enabling the time and mental burden to be shared. A synced or shared app containing family recipes, meal plans and shopping lists could facilitate sharing and simplify the communication of tasks by alleviating questions such as 'what's for dinner?' or 'do we need anything at the shops?'. In fact, failure to include social support features in food provision apps could even create barriers to the sharing of food provision tasks. For example having a meal planning app exclusively on one parents' password protected mobile phone might prevent another parent or caregiver from actively supporting food provision. Although participants in the app testing study did not prioritise social support in the COM-B self-evaluation questionnaire, they did highlight the value in incorporating features enabling support and communication.

Enabling fathers or other caregivers to take on more responsibility for food provision behaviour may promote more equal sharing between parents of the time and mental burden (143). Not only might this make healthy food provision more achievable amongst competing demands, but it also might go some of the way toward reducing gender disparities in domestic labour. Although women undertake the majority of food provision tasks, Australian qualitative research demonstrated that fathers often play a support or assistance role in family mealtimes (154). This may be due to a lower skill level in the kitchen, although fathers were shown to be quite aware of this limitation and of the need to support family mealtimes in other ways (154). The same may be the case with respect to mental load, where women have been shown to act as the household 'manager' and tend to take on more of the processes with a high cognitive burden (302). Whereas men tend to support the final decision-making stage (302). Mobile technology is well placed to enable support and communication between parents regarding food provision, thus addressing the barriers of time and mental load being bourne mostly by mothers.

Recommendations for the app concept – enablement

The overall app concept is focused on the provision of behavioural support to healthy meal planning. A meal planning focus would be best suited to addressing main meals as the target for behavioural support. The process of selecting meals in advance and allocating them to days and times would be associated with the BCTs *1.1 Goal setting (behaviour)* and *1.4 Action planning* (see the 'App features' box in Figure 5-2).

The app could be accessible to multiple family members via a shared account or through the syncing of user profiles, enabling social support (BCT *3.2 Social support practical*). A synced or shared family-centred app could act as a tool to involve other parents or caregivers in food provision tasks, allowing the mental load of meal planning to be shared and enabling communication regarding food provision tasks (such as groceries needing purchasing).

5.3.4 Environmental restructuring: reducing the burden

Automation & integration to reduce the time and mental burden

It is unreasonable to expect modern, working mothers to undertake food provision processes in the same time-consuming manner as in the past. Doing so ignores the barriers of time and mental load that are common to working mothers today and may even contribute further to existing gender disparities (143). Reduced time spent on home food preparation and food provision tasks such as shopping, has occurred in parallel with increasing female workforce participation and declining dietary quality (144, 150). Female workforce participation has also had many wide-ranging positive impacts on contemporary society however and thus cannot be held to blame for the unintended consequences it has had on food provision behaviour. Rather, modern solutions to supporting food provision should promote efficiency and ease whilst also enabling good nutrition, therefore being sympathetic to the barriers being experienced by modern working mothers (150).

Automated and integrated features may support reductions in the time and mental burden of food provision, whilst ensuring that apps themselves do not inadvertently place a greater time and mental burden on the primary food provider. According to the environmental restructuring intervention function, reductions in the demand of food provision on time and mental load would make healthier food provision behaviour easier to achieve (117). This is the premise upon which many food coping strategies are built (165). For example doubling recipes to provide leftovers for use on a night when time is scarce (165, 254), or the use of meal kits which require less planning and mental resource (308). The review of commercial apps in Chapter 3 identified key automated app features with potential to similarly achieve reductions in time and mental resource, namely the generation of meal plans based on family needs and preferences, and shopping lists from these meal plans. User-testing then demonstrated the acceptability of these planning-related features, while the integration of apps with online shopping was suggested by users as a further time-saving food coping strategy.

Automated and integrated features may also be key to making planning focused apps more acceptable to a wider user group. Not all people have the tendency to plan (142), nor is planning ahead even possible for some families when work commitments are inconsistent and unpredictable (99). A recent paper describing the early development and testing of a meal planning app in the US found that low-income parents of young children were less interested in the planning feature of their app (115). Parents mostly reported that they were not 'planners', and felt that it was a waste of time and effort planning when they were not able to stick to the plan (115). Minimising the time and effort associated with meal planning may go some of the way to promoting this behaviour when it is difficult or less preferred.

The relinquishing of responsibility and decision-making that is inherent with the automation of food provision processes may require a shift in attitudes and expectations around home food preparation. Meal kits are an example of a modern food coping strategy that has disrupted social norms whilst reducing the time and mental burden of food provision (166). Hertz and Halkier (166) suggested that meal kits may be an acceptable solution to reducing the burden of meal planning and food purchasing whilst still adhering to the social expectations of home food preparation. Furthermore, there is emerging evidence supporting their use as a strategy to improve dietary intake (308). Similarly the planning and purchasing processes inherent in getting food on the table may be the easiest aspects to automate in a food provision app, whilst also being the most socially acceptable tasks to outsource in societies where home food preparation is still highly valued (309).

Although still only a relatively small market in Australia, the online grocery market is on the rise with an almost 40% increase in sales in the 12-months to October 2018 (310). As more purchasing behaviour shifts online, food provision apps could support online shopping as a key time-saving food coping strategy, perhaps even making them a viable alternative to less healthy digital food coping strategies such as app-based food delivery services (e.g. Uber Eats). Although 45% of parents in the user-testing study never or rarely used online shopping as a food coping strategy, working parents of young children are known to be key adopters of online shopping for the purpose of saving time (311). Changing the social norms surrounding food shopping will likely be an important part of the wider uptake of digital tools incorporating online shopping (312).

Although there remains some debate on the matter, online shopping has typically been associated with healthier choices (313). A recent review found that online shopping compared to shopping in a bricks and mortar store may improve access to fresh produce and reduce impulse purchases of less healthy foods and beverages (313). This may be due to the difference in the visual presentation of products, with a reduction in the 'vividness' of less healthy products in the online environment (314). A healthy meal planning app that simplifies and automates meal planning, and integrates with online shopping would thus bypass some of the triggers to impulse buying that are associated with more traditional food purchasing strategies (for example product placement) (315).

Recommendations for the app concept – environmental restructuring

App features could include automated meal planning and shopping list generation from recipes, with these tools being associated with the BCT *12.5 Adding objects to the environment*. The app could then be integrated with online grocery shopping, allowing shopping lists to be linked directly to an online grocery shopping platform for the purchase of ingredients (see the 'App features' box in Figure 5-2). This feature would be associated with the BCT *12.1 Restructuring the physical environment* by facilitating the simple and efficient purchase of ingredients according to a healthy meal plan.

5.3.5 Training: learning through practice

Evidence-based recipe and nutrition content to enhance skills in healthy meal planning

Food-based dietary guidelines were established in Australia in the 1990's to guide the dietary intake of the population across the life course (316). The ADG's provide general guidance as to optimal dietary intake for health, while the Australian Guide to Healthy Eating (AGHE) provides specific recommendations regarding both the type and quantity of food that should be consumed every day (316). Although more practical than the ADG's, the AGHE does not incorporate advice to support the conversion of raw or unprocessed single foods and beverages into the foods and meals that make up a healthy daily eating pattern. This leaves individuals to interpret and apply the dietary guidelines in the real-world.

The interpretation and application of the dietary guidelines into day-to-day life is complex and requires food literacy (98), along with adequate resources such as time (143). There has been some shift toward more practical, eating occasion-based guidelines internationally, such as in the Choose My Plate campaign in the US (246). However, there remains a need to support the public in translating the dietary guidelines into practical behaviour that better reflects our daily eating patterns and thus supports optimal intake. A mobile app incorporating evidence-based nutrition content and supporting food provision behaviour may be the tool required to enable the application of dietary guidelines in the real-world.

Apps targeting children's dietary intake have so far been largely focused on the delivery of static nutrition information in order to increase knowledge (105, 186, 188, 297). Whereas commercial apps included in the present work mostly included recipe content rather than nutrition information. Parents in the user-testing study identified the need for healthy recipe ideas as being the most important enabler of healthy food provision. However, they found that the complexity of recipes, the cost associated with ingredients, and the lack of consideration of the developmental needs of young children made the recipe content of the apps largely unsuitable for families. Furthermore, although Chapter 2 demonstrated the importance of time and money as opportunity-related determinants of young children's intake of discretionary choices, recipe content was not tailored to address these. Underpinning future food provision apps with recipe content that is supportive of intake in line with the dietary guidelines, suitable for families of young children, whilst also being sensitive to the barriers of time, money and mental load will be crucial in taking these apps from commercial products to public health interventions for improving dietary intake.

Evidence-based content need not be delivered as general information, but instead could serve a more practical purpose. To the sample of parents included in the user-testing study, desirable nutrition information included serve based information relevant to the dietary guidelines, rather than information to assist them in healthy food selection at the supermarket, such as that provided in the barcode scanning app. This is consistent with prior research investigating parent preferences for nutrition intervention content, finding that parents prioritise portion related information and recipes (285). Practical content such as healthy recipes and serve based nutrition information, could not only support healthy meal planning and food preparation, but also promote skill development.

Training is an intervention function that can serve to improve food provision behaviour through skill development. The bi-directional arrows in the COM-B system demonstrate that undertaking a behaviour can in turn enhance capability, opportunity or motivation (117). Essentially, one can learn or become motivated through doing. As this participant in the user-testing study so aptly stated:

> *"…it taught me in that I actually did it and then I understood how much less stressful that is, to plan meals. (…) So it was kind of through experience, that I understood that it was a worthwhile process…"* **Blair, working 21 to <35 hrs/wk**

Skill development is a common strategy in interventions addressing food provision behaviour (134). Although there is often a bias toward cooking in skills based dietary interventions, meal planning and shopping can also be addressed (134). These types of interventions tend to take people outside of their usual setting, conducting skills training in a class or group setting (134). An advantage of mobile apps as a delivery platform is in their ability to enhance skills in the real-world during activities of daily life. Incorporating evidence-based content to support skill development regarding meal planning in line with dietary guidelines may not only impact dietary intake in the short-term, but may also have an effect beyond user disengagement with the app.

Recommendations for the app concept – training

Evidence-based app content in the form of healthy recipes and serving-based nutrition information could enable behaviour consistent with the Australian Dietary Guidelines. Nutritionally balanced meal planning support would ensure a clearly defined link between recipe content and family nutrition, whilst promoting skill development. This could promote the selection of meals on the basis of variety across the week. Recipe content and nutritionally balanced meal planning support would be associated with the BCT *4.1 Instruction on how to perform the behaviour* and *8.1 Behavioural practice/rehearsal.* Monitoring and recording the completion of prepared meals would be associated with the BCT *2.3 Self-monitoring of behaviour* (see 'Tailored app content' box of Figure 5-2).

Recipe content would need to be relevant to families of young children, with foods appropriate to the developmental stage of infancy and toddlerhood. Early tailoring of the recipe content during app set-up would ensure that recipes are suited to individual family needs, preferences and size. Recipe content would also be a place to encourage the use of healthy food coping strategies such as healthy convenience foods and the doubling of recipes. Recipes would also need to be simple and quick to prepare with minimal and inexpensive kitchen equipment, so as not to contribute to social inequities of health.

5.3.6 Engagement: integration into daily life

Engagement with a behaviour change intervention is considered necessary for effectiveness (199, 317). However participant engagement remains a major challenge for traditional face-to-face (318) and digital interventions alike (179). In the digital behaviour change space, engagement has been defined as more than just the frequency or amount of use, but rather as a combination of the extent of use and the subjective experience (199). Inadequate participant engagement can limit the ability of digital interventions to change behaviour (179). Therefore, in developing app-based health interventions it is crucial to consider how to promote adequate user engagement to promote positive behaviour change.

The mobile app review described in Chapter 3 found that the engagement quality domain of the MARS was typically rated the lowest, with this domain measuring the fun, interest, customisability, and interactivity of apps (279). This was supported by the user-testing study, with participants consistently rating engagement quality the lowest of all the uMARS domains. During the interviews, participants also reported low levels of enjoyment or pleasure in using the apps. Consistent with digital engagement literature, app novelty, and the enjoyment or pleasure associated with app use were shown to be important aspects of app buy-in (199, 286). A lack of these aspects may mean that outside of the research setting, apps supporting food provision processes may not be attractive to users. Enhancing the hedonic value of food provision apps by including features and content associated with novelty, interest and pleasure such as gamification (319) would build upon the current commercial offerings and promote user engagement (286).

Longer-term use of apps may however be dependent upon more than just the pleasure associated with its use. The integration of food provision apps with day-to-day life may be key to prompting consistent, purposeful and perhaps longer-term engagement. User-testing demonstrated that planning-related features were generally engaged with in-time when food provision behaviour was being undertaken. This is quite different to the function of most current diet monitoring apps, which are reliant on user motivation or desire rather than behavioural need (124). Apps providing practical in-time behavioural support for day-to-day food provision behaviour may promote more purposeful engagement, thus embedding nutrition support into regular food provision processes.

Ecological momentary interventions show promise in providing support and care in the real-world, outside of the clinic setting (178). They have been shown to be effective in achieving smoking cessation, weight loss and in reducing anxiety (178). As EMI's require less human contact, they require less resources and can be more acceptable to people that are reluctant to engage with the health-care system (288). Although they have been used for addressing other health related behaviours, they are not yet commonplace in dietary intervention (288). Furthermore, EMI's in this space focus on dietary intake behaviour, rather than food provision behaviour. The present work has therefore identified a new opportunity to deliver EMI's that address the day-to-day behaviours necessary to enable healthy dietary intake.

In-time use might be further encouraged through the inclusion of tailorable in-time notifications coinciding with key food provision behaviours. Push notifications have been shown to be reasonably well accepted and useful in prompting users to undertake tasks (320). Nevertheless users tend to become less responsive to push notifications over time (320), so it is important to ensure that they are used sparingly and strategically so that they encourage engagement and are not switched off or ignored (321). Push notifications were not a common feature of the apps that were assessed and tested, however participants indicated a desire for notifications in the form of reminders to plan, purchase ingredients and prepare meals.

Tailoring of app content and features can ensure that apps meet users' needs and context, and has been shown to be a key driver of engagement (317). The app testing study demonstrated that the relevance of apps to users' needs was an important determinant of app acceptance and engagement. As needs differed even across the relatively homogenous sample of parents involved in the user-testing study, tailoring of app content and features may be necessary in ensuring broader app acceptability and thus engagement (179). Tailoring can increase the cost of app development however, and can make overall app set-up overwhelming (179). Therefore careful consideration of how to achieve adequate, and not excessive, tailoring to promote engagement is crucial.

Long-term app use may not be necessary to achieve behaviour change with respect to parental food provision. Rather than expecting parents to form new food provision habits with an app-based tool, it may sufficient to position such an app as a coping strategy for use during times of disruption, or as a temporary training tool to enhance knowledge and skills for the future. Furthermore, use in such a manner may address parental concerns regarding the time-burden of app-based tools for supporting food provision practices.

Recommendations for the app concept – engagement strategies

The app could be positioned as a tool to support food provision behaviour in the real-world, as it occurs. In-time reminders could be incorporated to prompt the enactment of key food provision behaviour from planning to purchasing and finally the preparation of meals. This would be associated with the BCT *7.1 Prompts and cues* (see 'App features' box of Figure 5-2).

Visually appealing recipe content and gamification may promote early engagement and buy-in with the food provision app by ensuring interest and pleasure. Longer-term engagement however would likely be driven by need, and tailoring of app content and features to need would assist in ensuring the app is suited to individual needs. App tailoring including the ability to switch whole features on or off (for example automated meal planning), the curation of recipe contents and personalisation of notification frequency and timing, would assist in ensuring the app is relevant to individual user's needs.

5.3.7 Summary

App-based solutions to overcoming opportunity and capability-related barriers to healthy food provision may promote a reduction in young children's intake of discretionary choices at main meals. A food provision app such as that proposed could offer parents with in-time behavioural support and skill development for healthy food provision, and reduce the burden of food provision on time, money and mental resources. The proposed app concept includes features promoting simplified and even automated food provision behaviours. It could act as a tool to engage another parent or caregiver, marking an opportunity to involve fathers and potentially address gender disparities in food provision. Evidence-based recipe and nutrition content would build upon the current commercial offering and complement practical behavioural support features by encouraging and enabling the application of dietary guidelines in the real-world. Content and features with hedonic value would promote initial uptake and engagement, however the true value of such an app may be in its ability to address food provision behaviour in the real-world, both when and where it is occurring. This in-time engagement may promote longer-term app use and thus address engagement related issues plaguing digital behaviour change intervention development to date.

5.4 Strengths, limitations and ethical considerations

Throughout the chapters of this thesis, the strengths and limitations of the individual studies have been discussed. This following section will therefore consider the strengths and limitations applicable to the thesis as a whole. Ethical issues relating to the work conducted will also be considered.

5.4.1 Strengths

This thesis has contributed new knowledge to the space of digital behaviour change solutions in the nutrition space, through its triangulation of the empirical evidence, user perspectives and behaviour change theory. The unique combination of methodologies, from the quantitative dietary intake data analyses, to the review and user-testing of commercially available apps, allowed the identification of new opportunities for the advancement of early dietary interventions and app-based dietary interventions. Where the present work stands apart from the app-based dietary interventions of the past is in its shift away from the education-based model of intervention, rather looking toward apps as tools for delivering behavioural support in the real-world. The rich and diverse body of work undertaken has allowed creative conceptualisation of the role that future apps could play in supporting healthy parental food provision and young children's dietary intake.

The assessment and testing of commercial technology to support the conceptualisation of an app-concept has also been a key strength of this work. The pace of technological change and thus the need for efficiency in app development has been identified as a key challenge to digital behaviour change intervention development (179). Commercial technology is often at a more advanced stage than the technology being used in the nutrition and behaviour change research space, due to the slow pace of the traditional research translation cycle (179, 322). Drawing on the commercial sector during the early stages of intervention planning and design can ensure that researcher developed technology is up to speed with commercial technological advances.

Understanding the commercial market is also an advantage for health researchers working with developers and industry. Although health researchers are better equipped to understand how to promote positive health behaviour, they do not have the technological knowledge and skills of app developers or researchers in the digital field (169). This research using commercial technology could be useful to health researchers working with digital developers and digital behaviour change experts in planning and designing future interventions. Furthermore, the application of existing commercial apps in the health intervention space may also be a lever for researcher and industry partnerships. The knowledge generated through the course of this PhD research could be used to value add to the commercial technology sector, offering commercial developers alternative angles by which to develop, market and distribute their technology.

The consideration of the unique needs of families of young children throughout this program of research has allowed a thorough understanding of their behaviour, context and needs. This has allowed the realisation of the potential of technology to support healthy food provision behaviour in the family context. The behavioural nutrition focus of the work, placing importance on addressing the barriers that modern parents face to food provision was a key strength. Barriers to healthy food provision were viewed from a different angle, with opportunity-related constraints considered as potential targets for behavioural support. The quantitative analyses of individual and household level drivers of children's discretionary choice intake, to the user insights of commercial apps allocated according to need, provided evidence for which app-based dietary interventions could work in which context. This is a major step toward the development of technology that is both effective in modifying dietary behaviour, and acceptable and useful to the target group.

5.4.2 Limitations

Despite the unique and diverse methodologies utilised throughout this thesis, the work undertaken does not demonstrate the efficacy of apps in promoting positive dietary behaviour change in parents and their children. It would be ideal to be able to test the apps and app features considered in the present work in a more rigorous RCT design. However, as the apps were not designed to support health behaviour change it would have been inappropriate to progress to efficacy testing without first understanding their role in supporting positive dietary behaviour change and enhancing their evidence base. Furthermore, budget and time constraints prevented the development of an app prototype. This leaves much to be learned regarding the true behaviour change potential of these apps and app features, which will need to be investigated in future research.

The rapid pace of technological advancement also presents challenges to this work and indeed all work in the space of digital behaviour change intervention development (179). As technology continues to advance, the findings of work such as this may quickly become out-dated. Nevertheless, the generation of broader background evidence supporting an app concept from current commercial technologies and behaviour change theory should make this evidence useful to the wider research community and to industry for some time yet. Although there is a need to communicate and disseminate this work whilst it remains relevant and useful to the present state of digital behaviour change research.

It would have been ideal to use an intervention development framework to guide the development of the app concept. Frameworks such as the BCW (117) or the IDEAS (Integrate, Design, Assess and Share) framework (202) are designed to support the development of more effective behaviour change interventions. However these frameworks are very involved and incorporate processes that were beyond the scope of this thesis. Instead, the work has drawn upon select components of such frameworks where possible, and has addressed some of the aspects considered as most important to digital behaviour change intervention development including the consideration of the context, needs and behaviour of the target user, the incorporation of behaviour change theory and the consideration of engagement as a barrier to intervention effectiveness (179, 200, 201).

The secondary analysis sample and the sample involved in user-testing were consistently biased toward a higher income and higher level of education. This limitation is relatively commonplace in nutrition and health research. Indeed a number of key studies in the area of early dietary intervention have experienced a similar bias, even despite genuine attempts to recruit representative samples (82, 323, 324). This tendency for sample bias was considered during the design of each study wherever possible and was acknowledged in the discussion of each study throughout the thesis.

In the secondary analysis, the inclusion of SAIDI participants improved the diversity of the sample. The SAIDI study recruited a greater proportion of mothers with a lower education level and household income, possibly due to its lower participant burden compared with the NOURISH study. Furthermore, the regression model incorporated key indicators of SES. In the user-testing study, targeted social media advertising in areas of lower SES was conducted, albeit with limited success. Interviews were therefore prioritised to ensure as diverse a representation of parents as possible. This method assisted in the inclusion of the voices of single and low-income parents in particular. Although another sampling strategy such as maximum variation sampling might have helped to recruit a more heterogenous sample (325), the time and resources needed to use such a strategy were beyond the scope of the present work. Regardless of the sample bias, comparison with a national, representative sample of similar age and gender showed that the user-testing study sample had similar dietary shortfalls to the broader population, suggesting a similar need for nutrition-related support and guidance.

Despite these efforts there was some homogeneity amongst user perspectives of apps. The barriers to healthy food provision behaviour and therefore needs in terms of behavioural support, may be different in parents of lower education and lower income who were not as well represented in this research. The evidence generated and the resulting app concept are likely still applicable to a range of parents, however it must be acknowledged that the app concept may not be suited to the needs of all populations and contexts. Furthermore, this speaks to the need for tailoring to be built into future technology to enable wider application. It would also be of benefit to conduct further targeted research with groups experiencing different barriers to food provision, such as those of a low income or those lacking food preparation skills.

5.4.3 Ethical considerations

There were a number of considerations made in the design and conduct of this work to ensure that it adhered with the National Statement on Ethical Conduct in Human Research (326). The app testing study was designed as a 'low risk' study, in which the only risks to participants was possible discomfort and inconvenience. Informed consent was assured by having a two-stage consent process, allowing participants the maximum opportunity to consider their involvement in the research. The collection of parent data via telephone and online minimised risks to children (i.e. as no child data was collected and no contact with children required). Furthermore, the inconvenience in terms of the time involved in the research was addressed by providing participants with meal kits or grocery vouchers to recognise both the time spent on the study.

It is important to acknowledge that there was some risk associated with the use of commercial apps in the app testing study. Data security and privacy is increasingly of concern in the digital health space, with personal information being collected and shared with third-parties in some instances (327). Upon downloading each app, participants were required to accept the privacy policy set out by the developer, which may have included the collection and storage of such user information. The risk in the present work was minimal however, with very little personal data requiring input into the apps (only two apps required an email address in order to create an account). This is however an important consideration to make in future research with commercially developed apps.

5.5 Future directions

This thesis has contributed new knowledge to the areas of children's dietary intake, parental food provision, and digital health. The findings suggest directions for future research in each of these fields. Evidence from the secondary analysis of young children's discretionary choice intake suggested that there may be different determinants of intake across eating occasions. Extending this work to investigate the determinants of healthy food intake across eating occasions would allow a more complete understanding of the role of these determinants and thus better tailoring of interventions. Such research should consider determinants beyond just the individual and household level, and differences in these relationships by age group.

The work described in Chapter 2 suggested the need for further investigation into parental use of time and the division of labour. It was clear that both maternal and paternal working hours were associated with the discretionary choice intake of young children. However, the underlying mechanisms of these relationships remain unclear. The investigation of use of time of both parents, taking into account activities outside of work, would allow a greater understanding of the role that time plays in parental food provision. Extending this work further by measuring the perception of time scarcity and the division of food provision tasks in dual-parent working households may help to unpack the non-linear relationships found between working hours and discretionary choice intake.

The findings of the app testing study present a new opportunity in the app-based dietary intervention space – the opportunity to engage and involve both parents or caregivers in a health intervention simultaneously. Mothers have tended to be the primary target of early dietary interventions, which likely only contributes to the gender disparity regarding carer responsibilities and household labour. Digital solutions such as those investigated in the present work may present an opportunity to make progress toward a more equal division of carer responsibilities and household labour, by engaging not just mothers but fathers and other carergivers also. Future research could consider how whole of family digital interventions might be utilised in a range of early dietary interventions such as in those promoting breastfeeding and supporting complementary feeding.

Future research should also consider the advancing digital food environment. The need for convenience with regards to food provision seems unlikely to wane (99, 328). Therefore, instead of pushing against the tide of convenience, adaptation may be required, where nutrition researchers are involved in the development of digital tools that support both convenience and health simultaneously. Developing partnerships with industry to co-design such solutions is important as there is already technology emerging in this space, and there is also the potential for greater financial support and direct links with the target user when working with industry. An example of such digital solutions is the Woolworths collaboration with Jamie Oliver 'Making Healthier Easier', incorporating recipes and nutrition information, and direct ordering of groceries from recipe content (329). The internet of things may provide further opportunities to embed behavioural support tools for healthy food provision into daily life, by tapping into products such as smart fridges. Future research should consider how nutrition support could be incorporated into these increasingly ubiquitous technologies.

5.6 Conclusion

This thesis aimed to develop an evidence-based app concept targeting parental provision of discretionary choices to young children. The rich evidence generated, capitalising on commercial mobile technology and considering the target users' behaviour, needs and context could contribute to the development of behavioural change theory grounded apps for promoting healthy parental food provision in the future. This PhD confirmed that opportunity-related determinants such as time and money do indeed play a role in the discretionary choice intake of young children. Combined with the capability-related barrier of mental load, time and money present new opportunities for behavioural support in food provision interventions.

Apps were demonstrated to be feasible solutions to healthy food provision, with an app concept proposed that could offer parents with in-time behavioural support and skill development for healthy meal planning in line with dietary guidelines, whilst reducing the burden of food provision behaviour on time, money and mental resources. Such an app could also be used as a tool to enable support and communication between parents and caregivers, and to restructure the physical environment by automating aspects of food provision behaviour and integrating with external supports such as online shopping. The development of app-based solutions to healthy food provision that have a place in day-to-day life may be the answer to the engagement-related challenges of digital behaviour change research to date.

To make progress toward healthy food provision in the contemporary family context, the traditional model of food provision must be reimagined. It is no longer feasible to expect modern parents to spend their precious resources on time-intensive, costly and mentally demanding food provision tasks. Indeed, the time and mental resources spent on such tasks is reducing in response to the increasing demands of modern life. This thesis has demonstrated that the future of healthy food provision could lie in the digitalisation of key behaviours, creating a paradigm shift from the traditional, time-intensive food provision model of the past to one of healthy, time-saving convenience. In considering apps as tools to enable simplified or even automated healthy meal planning, shopping list preparation and food purchasing, rather than as a passive platform for the delivery of education, this work has identified new options for dietary interventions to be integrated into daily family life. Such digital tools may provide the practical support families need to apply the dietary guidelines in a family context, thus posing a viable healthy alternative to less healthy food coping strategies.

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APPENDIX 1: EARLY DIETARY INTERVENTIONS, DETAILED TABLE

Table 1: Early intervention studies addressing discretionary choice intake in children aged up to 3 years

STUDY	SAMPLE	STUDY DESIGN	INTERVENTION	OUTCOMES	RESULTS	OTHER FINDINGS
Beinert et al, 2017 N/A Norway	**Sample:** N=110 parent-infant pairs **Recruitment:** Health care centres **Child mean±SD age or age range at BL:** 4-6mo	**Study design:** RCT **Quality rating:** Weak **Intervention duration:** 2 consecutive days **Data collection:** BL – age 6mo FU – age 15mo & age 24mo	**Intervention condition:** 2-day cooking classes x 4 hrs each, delivered by a home economics teacher and masters student (public health), addressing N, solids introduction & food preparation (by meal) **Control condition:** Usual care – well child services **Setting:** Group	**Discretionary outcomes:** Sweet bevs (including juice) (times/day) **Measure:** FFQ **Other outcomes:** FV, water, commercially made porridge & homemade porridge intake, food scepticism (neophobia)	**Intake (times/day); Mean (SD)** *Sweet bevs* 15mo FU: I = 0.59(0.7), C = 0.56(0.66), **NS** 24mo FU: I = 1.05(0.87), C = 0.89(0.64), **NS**	
Campbell et al, 2013 INFANT Australia	**Sample:** N=542 mother-infant pairs **Recruitment:** First-time parent groups **Child mean±SD age or age range at BL:** 3.9±1.6mo	**Study design:** Cluster RCT **Quality rating:** Moderate **Intervention duration:** Infant age 4 to 19mo **Data collection:** BL – age 4mo MI – age 9mo PI – age 20mo	**Intervention condition:** 6 x 2hr Dietitian delivered education, every 3mo. Six key messages addressing N, FV, family meals, PA, PFP, parental modelling **Control condition:** Usual care – well child services **Setting:** Group	**Discretionary outcomes:** Intake (g/day) disc sweet & savoury snacks, & bevs **Measure:** 2-3 x 24hr recalls **Other outcomes:** Anthro, FV intake, PA, sedentary time, PFP, parent knowledge	**Intake (g/day); Mean (SD)** *Sweet snacks* MI: I = 1.5(3.7), C = 2.1(5.8), **p=0.04 Cohen's D = 0.12** PI: I = 11.0(14.1), C = 14.7(15.7), **p=0.01 Cohen's D = 0.25** *Savoury snacks* MI: I = 0.7(2.3), C = 0.7(2.2), **NS** PI: I = 4.8(7.9), C = 5.8(10.4), **NS** *Disc bevs* MI: I = 2.1(13.2), C = 6.6(26.8), **p=0.008 Cohen's D = 0.21** PI: I = 23.7(58.8), C = 25.4(67.5), **NS**	
Doring et al, 2016 PRIMROSE Sweden	**Sample:** N=1355 families (mothers & infants), 1369 infants **Recruitment:**	**Study design:** Cluster RCT **Quality rating:** Moderate **Intervention duration:** 39	**Intervention condition:** 9 x clinic nurse delivered motivational interviewing sessions. Messages addressing N & PA for infant/child &	**Discretionary outcomes:** French fries (times/mo), sugared drinks (incl sweetened milk) (times/wk) & disc calories (incl savory snacks, SSBs,	**Consumption (times/mo); Mean (SE)** *French fries* PI: I = 1.5(0.07), C = 1.8(0.07), **p<0.001 Cohen's D = 0.19** **Consumption (times/wk); Mean (SE)** *Sugared drinks*	Group differences in favour of I relating to child V intake & maternal intake of French fries, disc calories

	Child health care centres **Child mean±SD age or age range at BL:** 6.7±1.1mo	months, starting at approx. 9mo of age **Data collection:** BL – age 7mo PI – age 4y	parent (if necessary), with SCT underpinning **Control condition:** Usual care – well child services **Setting:** Individual, telephone & group	chocolate, pastries, cake, icecream) (times/wk) **Measure:** FFQ **Other outcomes:** Anthro, PA, FV & fish intake, & maternal anthro, PA, FV, fish, disc food/bev intake	PI: I = 2.2(0.18), C = 2.7(0.15), **p=0.04** **Cohen's D = 0.13** *Disc calories* PI: I = 5.3(0.17), C = 5.9(0.12), **p=0.01** **Cohen's D = 0.19**	
Fangupo et al, 2015 Prevention of Overweight in Infancy (POI) New Zealand	**Sample:** N=666 mother-infant pairs **Recruitment:** Queen Mary Maternity Unit, Dunedin **Child mean±SD age or age range at BL:** antenatal (wks gest NA), mothers mean age 32y	**Study design:** RCT **Quality rating:** Weak **Intervention duration:** Antenatal to infant age 18mo **Data collection:** BL – antenatal/at birth PI – age 18mo FU – age 2y	**Intervention condition:** FAB - 8 x contacts delivered by trained research staff for education/support re BF, N (x4) & PA Sleep - 2 contacts delivered antenatally & at 3 weeks Combination - received all of the above **Control condition:** Usual care – well child services **Setting:** Individual in-home & group	**Discretionary outcomes:** Ranked intake for spreads; cakes, cookies, puddings, confectionary, sweet snacks, & sweet cereals; sweet drinks; French fries, roast potato, & sweet potato; & savory snacks Intake of french fries & roast potato/sweet potato, sweet drinks **Measurement tool:** FFQ **Other outcomes:** HFE, PFP, FV provision & avail, avail of obesogenic foods, mealtime structure, core food intake, E & macronutrient intake	**Ranked intake of disc foods & bevs &;** **Intake of French fries, roast potato & sweet potato, & sweet drinks** Data not presented, but no significant group differences (FAB or combination vs Sleep only or control) reported	No group differences in avail of FV or obesogenic foods Group differences in favour of I relating to PFP
Helle et al, 2019 Early Food for Future Health Norway	**Sample:** N=718 mother-infant pairs **Recruitment:** Online & via child health clinics **Child mean±SD age or age range at BL:** 5.5mo	**Study design:** RCT **Quality rating:** Weak **Intervention duration:** Infant age 6 to 12mo **Data collection:** BL – age 3-5 mo PI – age 12mo	**Intervention condition:** 7 x monthly video clips, 3-5 minutes duration delivered via email, covering aspects of infant feeding such as appropriate foods, textures, taste preference development, responsive feeding, & cooking/recipes	**Discretionary outcomes:** Frequency of consumption of NC foods/drinks (times/day) **Measure:** FFQ **Other outcomes:** CEB, PFP, anthro, FV intake (frequency), homemade dinner, food variety score	**Frequency (times/day); Mean (SD)** *NC food/drinks* PI: I = 0.24(0.23), C = 0.22(0.21) **NS**	Group differences in favour of I relating to mealtime routines & FV intake & taste exposure

			Control condition: Usual care – well child services **Setting:** Online			
Louzada et al, 2012 N/A Brazil	**Sample:** N=500 mother-infant pairs **Recruitment:** Maternity ward of a major hospital **Child mean±SD age or age range at BL:** Infant birth	**Study design:** RCT **Quality rating:** Strong **Intervention duration:** Infant birth to 12 mo **Data collection:** BL – infant birth MI – age 6mo PI – age 12-16mo FU – age 3-4y & age 7-8y	**Intervention condition:** 9 x 40min student (undergrad N science) delivered counselling sessions, monthly for first 6mo, then every 2nd mo. Messages addressing infant feeding, PFP, N **Control condition:** Usual care – well child services **Setting:** Individual in-home	**Discretionary outcomes:** Lipid dense & sugar dense foods & bevs (kj/day) stratified by gender **Measure:** 1-2 x 24hr recalls **Other outcomes:** Anthro, lipid profile, FV intake	**Intake (kJ/day); Mean (SD)** BOYS *Lipid dense foods* PI: I = 95(201), C = 196(375), **p<0.05, Cohen's D = 0.34** 3-4y FU: I = 605(770), C = 818(923), **p<0.05 Cohen's D = 0.25** 7-8y FU: I = 870(761), C = 1000(864), **NS** *Sugar dense foods* PI: I = 54(169), C = 60(131), **NS** 3-4y FU: I = 365(256), C = 500(405), **p<0.05 Cohen's D = 0.40** 7-8y FU: I = 307(271), C = 371(360), **NS** GIRLS *Lipid dense foods* PI: I = 52(152), C = 181(369), **p<0.05 Cohen's D = 0.46** 3-4y FU: I = 682(746), C = 761(803), **NS** 7-8y FU: I = 780(728), C = 944(845), **NS** *Sugar dense foods* PI: I = 37(86), C = 74(151), **p<0.05 Cohen's D = 0.30** 3-4y FU: I = 455(415), C = 446(322), **NS** 7-8y FU: I = 319(220), C = 385(396), **NS**	
Magarey et al, 2016 NOURISH Australia	**Sample:** N=698 mother-infant pairs **Recruitment:** Maternity hospitals in Adelaide & Brisbane **Child mean±SD age or age range at BL:** 4.3±1.0mo	**Study design:** RCT **Quality rating:** Moderate **Intervention duration:** Infant age 4 to 15mo **Data collection:** BL - age 4mo	**Intervention condition:** 2 modules of 6 x 1-1.5hr Dietitian & Psychologist delivered education, at 4-7 & 13-15 mo, targeting child N, repeated/limited exposure of healthy /unhealthy food, PFP	**Disc food/bev outcomes:** 6mo, 2y & 3.5y FU: % daily E intake from disc food & non-milk sweet bevs (incl juice) **Measure:** 1 x 24hr recall **Other outcomes:** Anthro, FV intake, food preferences, CEB, PFP	**% daily E; Estimated Marginal Mean (SE)** *Disc food* 2y FU: I = 14.9(0.9), C = 15.9(0.8) 3.5y FU: I = 19.5(0.9), C = 19.4(0.9) 5y FU: I = 20.9(0.9), C = 21.7(0.9) Group x time **NS** *Non-milk sweet bevs* 2y FU: I = 3.0(0.5), C = 2.4(0.5)	Group differences in favour of I relating to FV score (by CDQ), preference for F & CEB

		FU - age 2y, age 3.5y & age 5y	**Control condition:** Usual care – well child services **Setting:** Group		3.5y FU: I = 2.0(0.5), C = 2.2(0.5) 5y FU: I = 2.0(0.5), C = 2.1(0.5) Group x time **NS**	
Schroeder et al, 2015 N/A US	**Sample:** N=292 parent-infant pairs **Recruitment:** Health centres from John Hopkins Community Physicians network **Child mean±SD age or age range at BL:** NR (shortly after infant birth)	**Study design:** CRCT **Quality rating:** Weak **Intervention duration:** Infant birth to 24mo **Data collection:** BL – NR PI – age 24mo	**Intervention condition:** 12 x educational brochures delivered & discussed by clinic staff (paediatricians, nurses) addressing N, PFP, PA, & parent N & PA **Control condition:** NR **Setting:** Individual	**Discretionary outcomes:** Soda, sweetened tea & punch (serves/day) **Measure:** FFQ **Other outcomes:** Anthro, PFP, milk intake	**Intake (serves/day)** *Soda* PI: NR, **p<0.006** *Sweetened tea* PI: NR, **p<0.014** *Punch* PI: NR, **p<0.021**	
Skouteris et al, 2014 MEND 2-4 Aus	**Sample:** N=201 parent-child pairs **Recruitment:** Community **Child mean±SD age or age range at BL:** 2.7±0.6y	**Study design:** RCT **Quality rating:** Weak **Intervention duration:** 10 wks, starting at child age 2.7y **Data collection:** BL – age 2.7y PI – 10 weeks FU – 6mo & 12mo	**Intervention condition:** 10 x 90min weekly workshops, delivered by trained program leaders, addressing N, PA, parenting & lifestyle behaviours. Children attended healthy snack, active play and creative play time **Control condition:** Wait-list control **Setting:** Group	**Discretionary outcomes:** Sweet drinks & high energy snack foods (servings consumed yesterday) **Measure:** FFQ **Other outcomes:** Anthro, FV, water & milk intake, PA, sedentary behaviour, CEB, neophobia	**Consumption (serves yest); Mean (SD)** *Sweet drinks* PI: I – 0.2(0.3), C = 0.4(0.6), **NS Cohen's D = 0.42** 6mo FU: I = 0.2(0.3), 0.3(0.4), **NS** 12mo FU: I = 0.3(0.4, C = 0.3(0.4), **NS** *High energy snack foods* PI: I = 0.9(0.8), C = 1.3(1.4), **p=0.02 Cohen's D = 0.35** 6mo FU: I = 1.0(0.8), C = 1.2(1.2), **NS** 12mo FU: I = 1.1(0.9), C = 1.2(1.4), **NS**	Group differences in favour of I relating to V intake & satiety responsiveness
van Griecken et al, 2017 E-Health4Uth Netherlands	**Sample:** N= 2102 mother-child pairs **Recruitment:** Youth Health Care program participants **Child mean±SD age or age range at BL:** ~14mo	**Study design:** CRCT **Quality rating:** Moderate **Intervention duration:** Child age 18 to 24mo **Data collection:** BL – age 14 mo FU – age 36mo	**Intervention condition:** 2 x web-based modules delivered at 18 and 24 mo of age with tailored online advice, & individual motivational interviewing session with a Youth Health Centre professional (nurse or physician)	**Discretionary outcomes:** Sweetened bev intake (glasses/day) **Measure:** Single **q**uestionnaire item **Other outcomes:** Breakfast consumption, PA, screen time	**Intake (glasses/day); Mean (SD)** *Sweetened bevs* 36mo FU: I = 2.10(1.28), C = 2.31(1.51), **NS**	

			addressing N, PA, screen time **Control condition:** Usual care – well child services **Setting:** Online & individual			
Watt et al, 2009; Scheiwe et al, 2010 Infant Feeding Peer Support Trial UK	**Sample:** N=312 mother-infant pairs **Recruitment:** Baby clinics in Camden and Islington **Child mean±SD age or age range at BL:** 10wks	**Study design:** RCT **Quality rating:** Strong **Intervention duration:** Infant age 3 to 12mo **Data collection:** BL – age 3mo FU – age 18mo & age 4-5y	**Intervention condition:** 9 x monthly home visits delivered by trained local mothers, addressing infant feeding/weaning, N **Control condition:** Usual care – well child services **Setting:** Individual in-home	**Discretionary outcomes:** Squash (cordial), ever consumed (y/n) **Measure:** Single questionnaire item **Other outcomes:** Anthro, FV, water & milk consumption, bottle use, oral health, maternal N knowledge & confidence	**Ever consumed (never); n(%)** *Squash (cordial)* 18mo FU: I = 65(63), C = 67(62), **NS** 4-5y FU: I = 40(73), C = 19 (41), **p=0.001**	
Wen et al, 2012 Wen et al, 2015 HBT Australia	**Sample:** N=667 mother-infant pairs **Recruitment:** Antenatal clinics **Child mean±SD age or age range at BL:** 24-34wks gestation	**Study design:** RCT **Quality rating:** Strong **Intervention duration:** Antenatal to child age 24mo **Data collection:** BL – antenatal/at birth PI – age 2y FU – age 3.5y & age 5y	**Intervention condition:** 8 x community nurse delivered education once antenatally, then at 3-6mo intervals to 24mo. Five key messages addressing infant feeding (BF, solids intro), N, PA **Control condition:** Usual care with 2 mailouts re child safety **Setting:** Individual in-home	**Discretionary outcomes:** Consumption (y/n) of chips/fries, sweet snacks, (PI only), salty snacks, confectionary (1.5 & 3y FU only), soft drink **Measure:** FFQ **Other outcomes:** Anthro, infant feeding, FV intake, PA, screen time, eating in front of tv, PFP, & maternal diet, screen time & PA	**Consumption (y/n); n (%)** *Chips/fries* PI: I = 219(86), C = 212(88), **NS** *Sweet snack every day* PI: I = 186(73), C = 186(77), **NS** *Salty snacks* PI: I = 166(65), C = 169(70), **NS** 3.5y FU: I = 154(73), C = 143(70), **NS** 5y FU: I = 125(65), C = 120(67), **NS** *Confectionary* 3.5y FU: I = 169(80), C = 163(80), **NS** 5y FU: I = 151(79), C = 153(86), **NS** *Soft drink* PI: I = 60(24), C = 64(26), **NS** 3.5y FU: I = 70(33), C = 59(29), **NS** 5y FU: I = 71(37), C = 70(39), **NS**	Group differences in favour of I relating to V intake & maternal V intake at PI

anthro = weight, BMI z-score, waist circumference etc; Bevs = beverages; BF = breastfeeding; BL = baseline; CEB = Child eating behaviour; Disc = discretionary; E = energy; FV = fruit & vegetable; HFE = Home Food Environment; MI = mid-intervention; mo = months; N = nutrition; NC = Non-core (discretionary); PA = physical activity; PFP = parental feeding practices; PI = post-intervention; SSB = non-milk sugar sweetened beverages; SCT = social cognitive theory; y = years

APPENDIX 2: ENERGY AND PROTEIN PLOTS BY TIME OF EATING OCCASION

Figure 1: Energy intake of 2-year-old Australian children, by time, demonstrating peaks in intakes at key mealtimes (n=544)

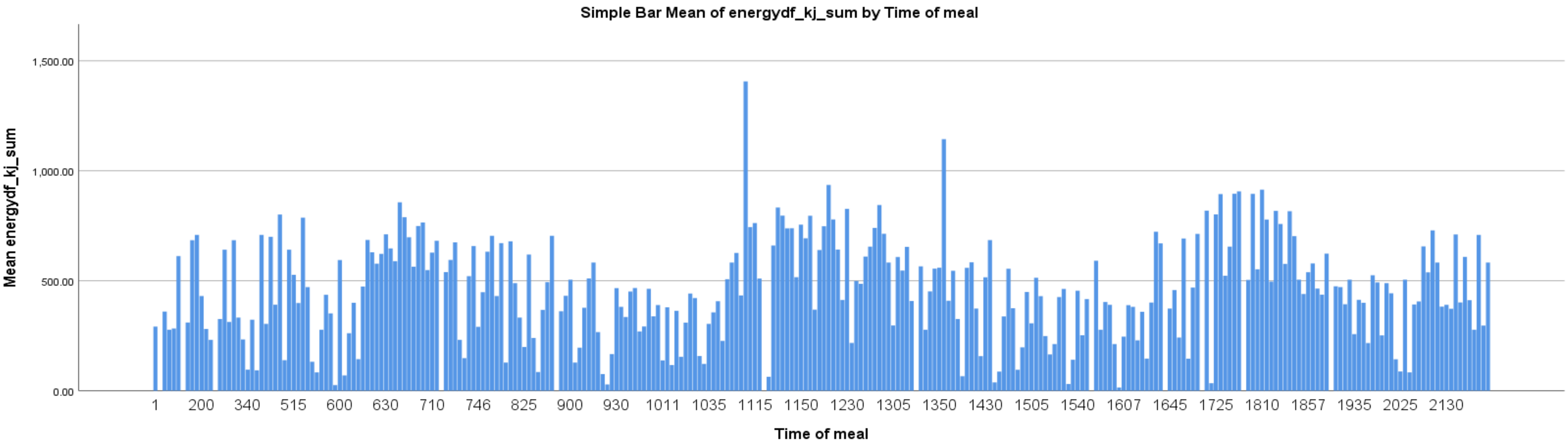
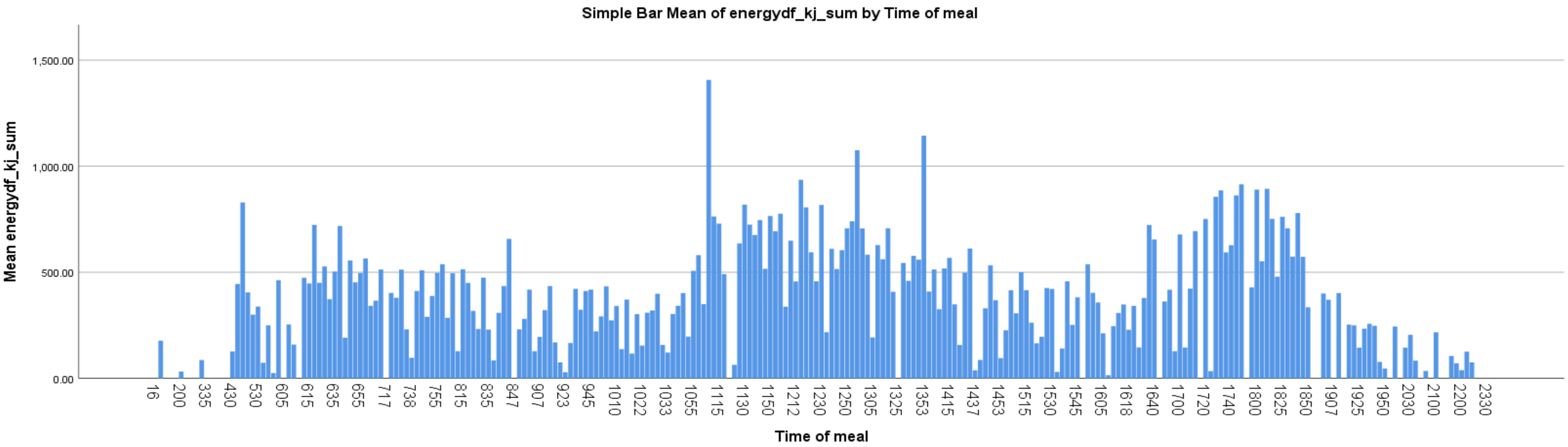


Figure 2: Energy intake (excluding milk) of 2-year-old Australian children, by time, demonstrating peaks in intakes at key mealtimes (n=544)



APPENDIX 3: REGRESSION OUTPUT TABLES, SENSITIVITY ANALYSES

SPSS OUTPUT TABLES: Sensitivity regression analyses of physical resources, family, parent and child factors, and intake of discretionary energy at MAIN MEALS AND SNACKS COMBINED in two-year-old Australian children, excluding participants with missing income data (n=509)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.198[a]	.039	.026	10.66120	.039	2.935	7	501	.005	
2	.229[b]	.052	.033	10.62031	.013	2.289	3	498	.078	
3	.251[c]	.063	.038	10.59352	.010	1.841	3	495	.139	
4	.375[d]	.141	.107	10.20573	.078	7.389	6	489	.000	
5	.388[e]	.151	.112	10.17865	.010	1.868	3	486	.134	
6	.411[f]	.169	.118	10.14295	.018	1.490	7	479	.169	1.883

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2335.503	7	333.643	2.935	.005[b]
	Residual	56944.265	501	113.661		
	Total	59279.768	508			
2	Regression	3109.888	10	310.989	2.757	.003[c]
	Residual	56169.879	498	112.791		
	Total	59279.768	508			
3	Regression	3729.555	13	286.889	2.556	.002[d]
	Residual	55550.212	495	112.223		
	Total	59279.768	508			
4	Regression	8347.081	19	439.320	4.218	.000[e]
	Residual	50932.687	489	104.157		
	Total	59279.768	508			
5	Regression	8927.739	22	405.806	3.917	.000[f]
	Residual	50352.028	486	103.605		
	Total	59279.768	508			
6	Regression	10000.488	29	344.844	3.352	.000[g]
	Residual	49279.279	479	102.879		
	Total	59279.768	508			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta		Lower Bound	Upper Bound
1	(Constant)	25.371	1.417		.000	22.587	28.155
	Mat_1_21hours	.281	1.166	.012	.810	-2.010	2.573
	Mat_21_35hours	1.919	1.262	.074	.129	-.561	4.399
	Mat_35plushours	-.895	1.769	-.024	.613	-4.371	2.580
	Pat_NotWork	-3.002	2.631	-.051	.254	-8.171	2.166
	Pat_1_35hours	-.925	1.644	-.026	.574	-4.156	2.306
	Pat_more40hours	-1.424	1.115	-.058	.202	-3.615	.767
	Income_sens	-5.160	1.398	-.170	.000	-7.907	-2.414
2	(Constant)	22.185	3.345		.000	15.613	28.758
	Mat_1_21hours	.377	1.183	.016	.750	-1.947	2.701
	Mat_21_35hours	2.414	1.320	.093	.068	-.180	5.007
	Mat_35plushours	-.569	1.819	-.015	.755	-4.142	3.005
	Pat_NotWork	-2.615	2.655	-.045	.325	-7.831	2.601
	Pat_1_35hours	-1.327	1.664	-.037	.426	-4.598	1.943
	Pat_more40hours	-1.662	1.117	-.068	.138	-3.857	.534
	Income_sens	-4.931	1.513	-.163	.001	-7.904	-1.958
	Parent partnered at T3	2.062	3.228	.030	.523	-4.280	8.404
	HEDU_pat_gps	-2.010	.975	-.093	.040	-3.926	-.094
	ChildHH_gps	1.243	1.022	.057	.225	-.766	3.252
3	(Constant)	25.669	4.814		.000	16.211	35.128
	Mat_1_21hours	.714	1.192	.030	.549	-1.628	3.055
	Mat_21_35hours	2.875	1.335	.111	.032	.253	5.497
	Mat_35plushours	-.218	1.827	-.006	.905	-3.808	3.373
	Pat_NotWork	-2.255	2.668	-.039	.398	-7.497	2.987
	Pat_1_35hours	-1.015	1.667	-.028	.543	-4.290	2.261
	Pat_more40hours	-1.748	1.117	-.072	.118	-3.943	.447
	Income_sens	-4.312	1.533	-.142	.005	-7.325	-1.300
	Parent partnered at T3	1.961	3.226	.029	.543	-4.377	8.299
	HEDU_pat_gps	-1.098	1.053	-.051	.298	-3.167	.971
	ChildHH_gps	1.571	1.065	.072	.141	-.521	3.662
	HEDU_mat_gps	-1.868	1.072	-.084	.082	-3.974	.237
	Mother's Age at Birth	-.147	.105	-.065	.163	-.353	.059
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.030	.093	.014	.750	-.153	.212
4	(Constant)	26.347	5.718		.000	15.112	37.582
	Mat_1_21hours	.643	1.155	.027	.578	-1.625	2.912
	Mat_21_35hours	1.964	1.301	.076	.132	-.592	4.520
	Mat_35plushours	-1.671	1.782	-.044	.349	-5.173	1.830

	Pat_NotWork	-1.098	2.591	-.019	.672	-6.188	3.993
	Pat_1_35hours	-.404	1.621	-.011	.803	-3.590	2.782
	Pat_more40hours	-1.967	1.084	-.080	.070	-4.097	.162
	Income_sens	-4.506	1.485	-.149	.003	-7.424	-1.589
	Parent partnered at T3	1.845	3.113	.027	.554	-4.272	7.961
	HEDU_pat_gps	-.961	1.023	-.044	.348	-2.970	1.049
	ChildHH_gps	.949	1.047	.044	.365	-1.108	3.007
	HEDU_mat_gps	-.879	1.061	-.040	.407	-2.963	1.204
	Mother's Age at Birth	-.082	.102	-.037	.423	-.283	.119
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.051	.090	.024	.575	-.127	.228
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	1.704	.833	.107	.041	.066	3.341
	FPSQ - Reward for eating mean subscale score (high score = bad)	1.718	.772	.119	.026	.202	3.234
	FPSQ - Covert restriction mean subscale score (high score = good)	-2.259	.555	-.181	.000	-3.349	-1.169
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.321	.548	-.027	.559	-1.397	.756
	FPSQ - Child Eats Same Food As Rest Of Family 3	.045	.405	.005	.911	-.750	.840
	Group allocation - 2 groups	-.883	1.044	-.038	.398	-2.935	1.169
5	(Constant)	25.012	17.946		.164	-10.250	60.274
	Mat_1_21hours	.747	1.153	.031	.517	-1.518	3.013
	Mat_21_35hours	2.277	1.309	.088	.083	-.294	4.848
	Mat_35plushours	-1.478	1.780	-.039	.407	-4.975	2.020
	Pat_NotWork	-1.652	2.599	-.028	.525	-6.760	3.455
	Pat_1_35hours	-.601	1.621	-.017	.711	-3.787	2.584
	Pat_more40hours	-2.001	1.082	-.082	.065	-4.126	.124
	Income_sens	-4.417	1.482	-.146	.003	-7.329	-1.505
	Parent partnered at T3	2.169	3.110	.032	.486	-3.942	8.279
	HEDU_pat_gps	-.843	1.021	-.039	.410	-2.850	1.164
	ChildHH_gps	.898	1.046	.041	.391	-1.156	2.953
	HEDU_mat_gps	-.955	1.059	-.043	.368	-3.035	1.126
	Mother's Age at Birth	-.109	.103	-.048	.291	-.311	.094
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.082	.091	.039	.371	-.098	.261
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	1.665	.831	.105	.046	.031	3.298
	FPSQ - Reward for eating mean subscale score (high score = bad)	1.689	.772	.117	.029	.173	3.205
	FPSQ - Covert restriction mean subscale score (high score = good)	-2.224	.554	-.179	.000	-3.313	-1.136
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.328	.549	-.027	.550	-1.408	.751
	FPSQ - Child Eats Same Food As Rest Of Family 3	.046	.407	.005	.910	-.754	.846
	Group allocation - 2 groups	-1.007	1.047	-.044	.337	-3.063	1.050
	Baby Gender	.881	.921	.041	.340	-.930	2.691
	years from days	.256	8.364	.001	.976	-16.178	16.689
	WHO 2006 BMI z score T3	-.989	.467	-.092	.035	-1.906	-.071
6	(Constant)	24.099	19.318		.213	-13.859	62.056
	Mat_1_21hours	.870	1.157	.036	.452	-1.403	3.143

Mat_21_35hours	2.432	1.312	.094	.064	-.146	5.010
Mat_35plushours	-1.370	1.779	-.036	.441	-4.865	2.125
Pat_NotWork	-1.484	2.604	-.025	.569	-6.601	3.633
Pat_1_35hours	-.685	1.624	-.019	.673	-3.876	2.505
Pat_more40hours	-2.177	1.085	-.089	.045	-4.308	-.046
Income_sens	-4.745	1.483	-.157	.001	-7.658	-1.831
Parent partnered at T3	3.283	3.142	.048	.297	-2.890	9.456
HEDU_pat_gps	-.900	1.022	-.041	.379	-2.907	1.108
ChildHH_gps	1.081	1.050	.050	.304	-.983	3.145
HEDU_mat_gps	-1.254	1.065	-.056	.240	-3.348	.839
Mother's Age at Birth	-.090	.104	-.040	.390	-.294	.115
Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.041	.094	.020	.663	-.143	.225
FPSQ - Reward for behaviour mean subscale score (high score = bad)	1.651	.858	.104	.055	-.035	3.337
FPSQ - Reward for eating mean subscale score (high score = bad)	1.702	.785	.118	.031	.160	3.244
FPSQ - Covert restriction mean subscale score (high score = good)	-2.137	.556	-.171	.000	-3.229	-1.045
FPSQ - Overt restriction mean subscale score (high score = bad)	-.510	.573	-.042	.374	-1.637	.617
FPSQ - Child Eats Same Food As Rest Of Family 3	-.009	.446	-.001	.984	-.885	.867
Group allocation - 2 groups	-1.238	1.052	-.054	.240	-3.305	.829
Baby Gender	.842	.935	.039	.369	-.996	2.679
years from days	-1.681	8.385	-.009	.841	-18.158	14.796
WHO 2006 BMI z score T3	-.798	.478	-.074	.095	-1.736	.141
Food responsiveness mean score	-.456	.975	-.028	.640	-2.372	1.460
Enjoyment of food mean score	-.091	1.166	-.005	.938	-2.382	2.201
Satiety responsiveness + slowness in eating combined mean score	2.590	1.124	.128	.022	.381	4.799
Food fussiness mean score	-.413	.940	-.026	.661	-2.259	1.434
Emotional overeating mean score	1.879	1.153	.085	.104	-.386	4.144
Emotional undereating mean score	-1.040	.590	-.084	.079	-2.200	.119
Desire to drink mean score	-.091	.588	-.007	.877	-1.246	1.064

SPSS OUTPUT TABLES: Sensitivity regression analyses of physical resources, family, parent and child factors and intake of discretionary energy at MAIN MEALS in two-year-old Australian toddlers excluding participants with missing income data (n=509)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.180[a]	.032	.019	8.12242	.032	2.388	7	501	.021	
2	.263[b]	.069	.050	7.99113	.037	6.533	3	498	.000	
3	.278[c]	.077	.053	7.97966	.008	1.477	3	495	.220	
4	.368[d]	.136	.102	7.77037	.058	5.504	6	489	.000	
5	.382[e]	.146	.107	7.74873	.010	1.912	3	486	.127	
6	.404[f]	.164	.113	7.72267	.018	1.469	7	479	.176	2.002

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1102.779	7	157.540	2.388	.021[b]
	Residual	33052.867	501	65.974		
	Total	34155.647	508			
2	Regression	2354.279	10	235.428	3.687	.000[c]
	Residual	31801.368	498	63.858		
	Total	34155.647	508			
3	Regression	2636.496	13	202.807	3.185	.000[d]
	Residual	31519.150	495	63.675		
	Total	34155.647	508			
4	Regression	4630.493	19	243.710	4.036	.000[e]
	Residual	29525.153	489	60.379		
	Total	34155.647	508			
5	Regression	4974.871	22	226.131	3.766	.000[f]
	Residual	29180.775	486	60.043		
	Total	34155.647	508			
6	Regression	5588.291	29	192.700	3.231	.000[g]
	Residual	28567.355	479	59.640		
	Total	34155.647	508			

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound
1	(Constant)	15.861	1.080		.000	13.740	17.983
	Mat_1_21hours	-.267	.889	-.015	.764	-2.013	1.478
	Mat_21_35hours	1.246	.962	.063	.196	-.644	3.135
	Mat_35plushours	-.255	1.348	-.009	.850	-2.902	2.393
	Pat_NotWork	-.539	2.004	-.012	.788	-4.477	3.398
	Pat_1_35hours	-1.363	1.253	-.050	.277	-3.824	1.099
	Pat_more40hours	-1.424	.850	-.077	.094	-3.093	.246
	Income_sens	-3.259	1.065	-.142	.002	-5.351	-1.166
2	(Constant)	12.515	2.517		.000	7.570	17.461
	Mat_1_21hours	-.240	.890	-.013	.788	-1.988	1.509
	Mat_21_35hours	1.718	.993	.087	.084	-.234	3.669
	Mat_35plushours	-.028	1.369	-.001	.984	-2.717	2.661
	Pat_NotWork	-.111	1.998	-.003	.956	-4.036	3.813
	Pat_1_35hours	-1.821	1.252	-.067	.147	-4.281	.640
	Pat_more40hours	-1.728	.841	-.093	.040	-3.380	-.077
	Income_sens	-2.889	1.139	-.126	.011	-5.126	-.652
	Parent partnered at T3	2.586	2.429	.050	.288	-2.186	7.358
	HEDU_pat_gps	-2.778	.734	-.168	.000	-4.219	-1.336
	ChildHH_gps	1.192	.769	.072	.122	-.319	2.704
3	(Constant)	14.421	3.626		.000	7.296	21.546
	Mat_1_21hours	-.016	.898	-.001	.986	-1.780	1.748
	Mat_21_35hours	2.013	1.005	.102	.046	.037	3.988
	Mat_35plushours	.183	1.377	.006	.894	-2.521	2.888
	Pat_NotWork	.117	2.010	.003	.954	-3.831	4.066
	Pat_1_35hours	-1.599	1.256	-.059	.203	-4.067	.868
	Pat_more40hours	-1.779	.842	-.096	.035	-3.432	-.126
	Income_sens	-2.466	1.155	-.107	.033	-4.735	-.196
	Parent partnered at T3	2.489	2.430	.048	.306	-2.285	7.263
	HEDU_pat_gps	-2.148	.793	-.130	.007	-3.706	-.589
	ChildHH_gps	1.372	.802	.083	.088	-.203	2.948
	HEDU_mat_gps	-1.335	.807	-.079	.099	-2.921	.252
	Mother's Age at Birth	-.087	.079	-.051	.274	-.242	.069
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.027	.070	.017	.702	-.111	.164
4	(Constant)	17.206	4.354		.000	8.651	25.760
	Mat_1_21hours	-.068	.879	-.004	.939	-1.795	1.660
	Mat_21_35hours	1.298	.990	.066	.191	-.648	3.244

	Mat_35plushours	-.877	1.357	-.031	.518	-3.543	1.788
	Pat_NotWork	.960	1.972	.022	.627	-2.916	4.835
	Pat_1_35hours	-1.060	1.235	-.039	.391	-3.485	1.366
	Pat_more40hours	-1.959	.825	-.106	.018	-3.580	-.338
	Income_sens	-2.563	1.130	-.112	.024	-4.784	-.342
	Parent partnered at T3	2.330	2.370	.045	.326	-2.327	6.986
	HEDU_pat_gps	-2.136	.779	-.130	.006	-3.666	-.606
	ChildHH_gps	.999	.797	.061	.211	-.568	2.565
	HEDU_mat_gps	-.734	.808	-.043	.364	-2.320	.853
	Mother's Age at Birth	-.055	.078	-.032	.479	-.209	.098
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.039	.069	.025	.568	-.096	.174
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	.875	.634	.072	.168	-.371	2.122
	FPSQ - Reward for eating mean subscale score (high score = bad)	1.152	.588	.105	.050	-.002	2.307
	FPSQ - Covert restriction mean subscale score (high score = good)	-1.438	.422	-.152	.001	-2.268	-.608
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.285	.417	-.031	.495	-1.105	.534
	FPSQ - Child Eats Same Food As Rest Of Family 3	-.281	.308	-.041	.363	-.886	.325
	Group allocation - 2 groups	-.875	.795	-.050	.272	-2.438	.687
5	(Constant)	11.345	13.662		.407	-15.499	38.189
	Mat_1_21hours	.022	.878	.001	.980	-1.703	1.747
	Mat_21_35hours	1.554	.996	.079	.119	-.403	3.512
	Mat_35plushours	-.752	1.355	-.026	.579	-3.414	1.911
	Pat_NotWork	.536	1.979	.012	.786	-3.352	4.424
	Pat_1_35hours	-1.235	1.234	-.046	.318	-3.660	1.190
	Pat_more40hours	-1.972	.823	-.106	.017	-3.590	-.355
	Income_sens	-2.515	1.128	-.109	.026	-4.732	-.298
	Parent partnered at T3	2.548	2.367	.049	.282	-2.103	7.200
	HEDU_pat_gps	-2.049	.778	-.124	.009	-3.577	-.521
	ChildHH_gps	.976	.796	.059	.221	-.588	2.541
	HEDU_mat_gps	-.784	.806	-.046	.331	-2.367	.800
	Mother's Age at Birth	-.074	.078	-.043	.346	-.228	.080
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.064	.069	.040	.360	-.073	.200
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	.847	.633	.070	.181	-.397	2.091
	FPSQ - Reward for eating mean subscale score (high score = bad)	1.111	.587	.101	.059	-.043	2.265
	FPSQ - Covert restriction mean subscale score (high score = good)	-1.418	.422	-.150	.001	-2.247	-.590
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.268	.418	-.029	.521	-1.090	.553
	FPSQ - Child Eats Same Food As Rest Of Family 3	-.257	.310	-.037	.407	-.867	.352
	Group allocation - 2 groups	-1.004	.797	-.057	.208	-2.570	.562
	Baby Gender	.400	.701	.024	.568	-.978	1.778
	years from days	2.763	6.367	.019	.664	-9.747	15.274
	WHO 2006 BMI z score T3	-.799	.356	-.098	.025	-1.497	-.100
6	(Constant)	12.957	14.708		.379	-15.943	41.857

Mat_1_21hours	.119	.881	.007	.893	-1.612	1.849
Mat_21_35hours	1.734	.999	.088	.083	-.229	3.697
Mat_35plushours	-.662	1.354	-.023	.625	-3.323	1.999
Pat_NotWork	.591	1.983	.013	.766	-3.305	4.487
Pat_1_35hours	-1.266	1.236	-.047	.306	-3.695	1.163
Pat_more40hours	-2.141	.826	-.115	.010	-3.764	-.518
Income_sens	-2.752	1.129	-.120	.015	-4.970	-.534
Parent partnered at T3	3.415	2.392	.066	.154	-1.285	8.115
HEDU_pat_gps	-2.115	.778	-.128	.007	-3.644	-.586
ChildHH_gps	1.132	.800	.069	.157	-.439	2.704
HEDU_mat_gps	-1.000	.811	-.059	.218	-2.594	.594
Mother's Age at Birth	-.062	.079	-.036	.435	-.218	.094
Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.044	.071	.028	.538	-.096	.184
FPSQ - Reward for behaviour mean subscale score (high score = bad)	.879	.653	.073	.179	-.405	2.163
FPSQ - Reward for eating mean subscale score (high score = bad)	1.258	.598	.115	.036	.083	2.432
FPSQ - Covert restriction mean subscale score (high score = good)	-1.340	.423	-.142	.002	-2.172	-.509
FPSQ - Overt restriction mean subscale score (high score = bad)	-.305	.437	-.033	.485	-1.163	.552
FPSQ - Child Eats Same Food As Rest Of Family 3	-.446	.339	-.065	.189	-1.112	.221
Group allocation - 2 groups	-1.118	.801	-.064	.163	-2.692	.456
Baby Gender	.219	.712	.013	.758	-1.180	1.618
years from days	1.150	6.384	.008	.857	-11.395	13.695
WHO 2006 BMI z score T3	-.703	.364	-.086	.054	-1.418	.011
Food responsiveness mean score	-.174	.742	-.014	.815	-1.632	1.285
Enjoyment of food mean score	.037	.888	.003	.967	-1.708	1.782
Satiety responsiveness + slowness in eating combined mean score	1.860	.856	.121	.030	.178	3.541
Food fussiness mean score	-.757	.715	-.063	.290	-2.163	.648
Emotional overeating mean score	1.168	.878	.069	.184	-.556	2.892
Emotional undereating mean score	-1.038	.449	-.111	.021	-1.921	-.155
Desire to drink mean score	-.198	.448	-.021	.659	-1.077	.682

SPSS OUTPUT TABLES: Sensitivity regression analyses of physical resources, family, parent and child factors and intake of discretionary energy at SNACKS in two-year-old Australian toddlers, excluding participants with missing income data (n=508)

Model Summary

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.165[a]	.027	.013	5.95686	.027	1.991	7	500	.055	
2	.180[b]	.032	.013	5.95828	.005	.921	3	497	.431	
3	.198[c]	.039	.014	5.95501	.007	1.182	3	494	.316	
4	.289[d]	.084	.048	5.85213	.044	3.920	6	488	.001	
5	.297[e]	.088	.047	5.85510	.005	.835	3	485	.475	
6	.323[f]	.104	.050	5.84589	.016	1.218	7	478	.291	1.909

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	494.542	7	70.649	1.991	.055[b]
	Residual	17742.097	500	35.484		
	Total	18236.639	507			
2	Regression	592.592	10	59.259	1.669	.085[c]
	Residual	17644.047	497	35.501		
	Total	18236.639	507			
3	Regression	718.325	13	55.256	1.558	.093[d]
	Residual	17518.314	494	35.462		
	Total	18236.639	507			
4	Regression	1523.886	19	80.205	2.342	.001[e]
	Residual	16712.753	488	34.247		
	Total	18236.639	507			
5	Regression	1609.788	22	73.172	2.134	.002[f]
	Residual	16626.851	485	34.282		
	Total	18236.639	507			
6	Regression	1901.276	29	65.561	1.918	.003[g]
	Residual	16335.363	478	34.174		
	Total	18236.639	507			

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound
1	(Constant)	9.575	.792		.000	8.019	11.131
	Mat_1_21hours	.562	.652	.042	.390	-.720	1.844
	Mat_21_35hours	.425	.706	.030	.547	-.962	1.812
	Mat_35plushours	-.798	.989	-.038	.420	-2.741	1.145
	Pat_NotWork	-3.180	1.470	-.098	.031	-6.068	-.292
	Pat_1_35hours	-.215	.919	-.011	.815	-2.021	1.590
	Pat_more40hours	-.383	.624	-.028	.540	-1.608	.843
	Income_sens	-2.149	.781	-.128	.006	-3.685	-.614
2	(Constant)	8.919	1.877		.000	5.231	12.607
	Mat_1_21hours	.692	.664	.052	.298	-.613	1.996
	Mat_21_35hours	.565	.741	.039	.446	-.891	2.021
	Mat_35plushours	-.563	1.021	-.027	.582	-2.568	1.443
	Pat_NotWork	-3.209	1.489	-.099	.032	-6.135	-.283
	Pat_1_35hours	-.234	.934	-.012	.803	-2.069	1.601
	Pat_more40hours	-.330	.627	-.024	.599	-1.562	.902
	Income_sens	-2.395	.849	-.143	.005	-4.063	-.727
	Parent partnered at T3	-.095	1.811	-.003	.958	-3.653	3.463
	HEDU_pat_gps	.882	.548	.073	.108	-.194	1.958
	ChildHH_gps	.323	.574	.027	.574	-.805	1.451
3	(Constant)	10.507	2.706		.000	5.189	15.824
	Mat_1_21hours	.847	.670	.064	.207	-.470	2.164
	Mat_21_35hours	.775	.751	.054	.302	-.699	2.250
	Mat_35plushours	-.400	1.027	-.019	.697	-2.418	1.619
	Pat_NotWork	-3.035	1.500	-.094	.044	-5.982	-.088
	Pat_1_35hours	-.095	.937	-.005	.919	-1.937	1.747
	Pat_more40hours	-.368	.628	-.027	.558	-1.603	.866
	Income_sens	-2.117	.862	-.126	.014	-3.811	-.423
	Parent partnered at T3	-.138	1.813	-.004	.939	-3.701	3.425
	HEDU_pat_gps	1.289	.592	.107	.030	.125	2.453
	ChildHH_gps	.480	.599	.040	.423	-.697	1.657
	HEDU_mat_gps	-.810	.603	-.066	.180	-1.994	.374
	Mother's Age at Birth	-.069	.059	-.056	.241	-.185	.047
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.015	.052	.013	.773	-.088	.118
4	(Constant)	10.317	3.281		.002	3.871	16.764
	Mat_1_21hours	.785	.663	.059	.236	-.516	2.087
	Mat_21_35hours	.486	.746	.034	.515	-.980	1.953

	Mat_35plushours	-.885	1.022	-.042	.387	-2.893	1.123
	Pat_NotWork	-2.501	1.485	-.077	.093	-5.419	.418
	Pat_1_35hours	.085	.930	.004	.927	-1.742	1.912
	Pat_more40hours	-.372	.622	-.027	.550	-1.594	.850
	Income_sens	-2.137	.852	-.127	.012	-3.810	-.464
	Parent partnered at T3	-.161	1.785	-.004	.928	-3.669	3.346
	HEDU_pat_gps	1.413	.587	.117	.016	.260	2.566
	ChildHH_gps	.185	.601	.015	.759	-.997	1.366
	HEDU_mat_gps	-.301	.608	-.024	.621	-1.496	.894
	Mother's Age at Birth	-.040	.059	-.032	.501	-.155	.076
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.020	.052	.017	.701	-.082	.122
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	.809	.478	.092	.091	-.130	1.748
	FPSQ - Reward for eating mean subscale score (high score = bad)	.435	.443	.054	.327	-.435	1.305
	FPSQ - Covert restriction mean subscale score (high score = good)	-1.014	.318	-.147	.002	-1.639	-.389
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.151	.314	-.023	.630	-.769	.466
	FPSQ - Child Eats Same Food As Rest Of Family 3	.266	.233	.053	.253	-.191	.724
	Group allocation - 2 groups	-.628	.599	-.049	.296	-1.805	.550
5	(Constant)	16.199	10.328		.117	-4.094	36.491
	Mat_1_21hours	.806	.664	.061	.225	-.498	2.110
	Mat_21_35hours	.584	.753	.041	.439	-.896	2.064
	Mat_35plushours	-.797	1.024	-.038	.437	-2.810	1.215
	Pat_NotWork	-2.702	1.495	-.083	.071	-5.640	.236
	Pat_1_35hours	.038	.933	.002	.967	-1.794	1.871
	Pat_more40hours	-.398	.623	-.029	.523	-1.621	.825
	Income_sens	-2.089	.853	-.124	.015	-3.764	-.413
	Parent partnered at T3	-.042	1.789	-.001	.981	-3.556	3.473
	HEDU_pat_gps	1.454	.588	.121	.014	.299	2.609
	ChildHH_gps	.149	.602	.012	.805	-1.035	1.332
	HEDU_mat_gps	-.336	.609	-.027	.581	-1.533	.861
	Mother's Age at Birth	-.051	.059	-.041	.393	-.167	.066
	Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.030	.052	.026	.568	-.073	.133
	FPSQ - Reward for behaviour mean subscale score (high score = bad)	.798	.478	.090	.096	-.142	1.738
	FPSQ - Reward for eating mean subscale score (high score = bad)	.448	.444	.056	.314	-.425	1.320
	FPSQ - Covert restriction mean subscale score (high score = good)	-.995	.319	-.144	.002	-1.621	-.369
	FPSQ - Overt restriction mean subscale score (high score = bad)	-.173	.316	-.026	.584	-.794	.448
	FPSQ - Child Eats Same Food As Rest Of Family 3	.244	.235	.048	.299	-.217	.706
	Group allocation - 2 groups	-.631	.603	-.049	.296	-1.815	.553
	Baby Gender	.473	.530	.039	.373	-.570	1.515
	years from days	-3.151	4.812	-.029	.513	-12.605	6.304
	WHO 2006 BMI z score T3	-.299	.269	-.050	.267	-.827	.229
6	(Constant)	10.691	11.140		.338	-11.198	32.581

Mat_1_21hours	.814	.667	.061	.223	-.498	2.125
Mat_21_35hours	.555	.757	.039	.464	-.932	2.043
Mat_35plushours	-.741	1.025	-.035	.470	-2.756	1.274
Pat_NotWork	-2.561	1.501	-.079	.089	-5.511	.388
Pat_1_35hours	-.008	.936	.000	.993	-1.847	1.831
Pat_more40hours	-.339	.626	-.025	.588	-1.568	.890
Income_sens	-2.145	.855	-.128	.012	-3.825	-.466
Parent partnered at T3	.039	1.811	.001	.983	-3.520	3.598
HEDU_pat_gps	1.495	.589	.124	.011	.337	2.652
ChildHH_gps	.174	.606	.014	.775	-1.018	1.365
HEDU_mat_gps	-.421	.614	-.034	.493	-1.628	.786
Mother's Age at Birth	-.046	.060	-.037	.441	-.164	.072
Mat BMI (kg/m2) at Time 1 (4-6 months post birth)	.016	.054	.013	.773	-.090	.122
FPSQ - Reward for behaviour mean subscale score (high score = bad)	.731	.495	.083	.140	-.241	1.704
FPSQ - Reward for eating mean subscale score (high score = bad)	.266	.453	.033	.556	-.623	1.156
FPSQ - Covert restriction mean subscale score (high score = good)	-1.001	.320	-.145	.002	-1.630	-.371
FPSQ - Overt restriction mean subscale score (high score = bad)	-.357	.330	-.053	.281	-1.006	.293
FPSQ - Child Eats Same Food As Rest Of Family 3	.430	.258	.085	.096	-.076	.936
Group allocation - 2 groups	-.741	.607	-.058	.222	-1.933	.451
Baby Gender	.655	.539	.054	.225	-.405	1.715
years from days	-3.253	4.833	-.030	.501	-12.750	6.244
WHO 2006 BMI z score T3	-.210	.275	-.035	.446	-.751	.331
Food responsiveness mean score	-.230	.562	-.025	.683	-1.334	.874
Enjoyment of food mean score	.230	.672	.023	.732	-1.091	1.551
Satiety responsiveness + slowness in eating combined mean score	.655	.648	.058	.313	-.619	1.929
Food fussiness mean score	.761	.542	.087	.161	-.303	1.825
Emotional overeating mean score	.648	.665	.053	.331	-.659	1.955
Emotional undereating mean score	.180	.341	.026	.598	-.491	.851
Desire to drink mean score	.045	.340	.006	.894	-.623	.713

APPENDIX 4: CO-AUTHORSHIP APPROVAL NOTICES

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Co-authorship Approvals for Higher Degree by Research Thesis for Examination

In accordance with Clause 5, 7 and 8 in the HDR Thesis Rules, a student must sign a declaration that the thesis does not contain any material previously published or written by another person except where due reference is made in the text or footnotes. There can be no exception to this rule.

a. Publications or significant sections of publications (whether accepted, submitted or in manuscript form) arising out of work conducted during candidature may be included in the body of the thesis, or submitted as additional evidence as an appendix, on the following conditions:

i. they contribute to the overall theme of the work, are conceptually linked to the chapters before and after, and follow a logical sequence
ii. they are formatted in the same way as the other chapters (i.e. not presented as reprints unless as an appendix), whether included as separate chapters or integrated into chapters
iii. they are in the same typeface as the rest of the thesis (except for reprints included as an appendix)
iv. published and unpublished sections of a chapter are clearly differentiated with appropriate referencing or footnotes, and
v. unnecessary repetition in the general introduction and conclusion, and the introductions and conclusions of each published chapter, is avoided.

b. Multi-author papers may be included within a thesis, provided:

i. the student is the primary author
ii. there is a clear statement in prose for each publication at the front of each chapter, recording the percentage contribution of each author to the paper, from conceptualisation to realisation and documentation, in accordance with the Research Publication, Authorship and Peer Review Policy, and
iii. each of the other authors provides permission for use of their work to be included in the thesis on the Submission of Thesis Form below.

c. Papers where the student is not the primary author may be included within a thesis if a clear justification for the paper's inclusion is provided, including the circumstances relating to production of the paper and the student's position in the list of authors. However, it is preferable to include such papers as appendices, rather than in the main body of the thesis.

A. STUDENT'S DETAILS (to be completed by the Student)

Name: Chelsea Emma Mauch Student ID: 2009666

Degree: Doctor of Philosophy College: Nursing and Health Sciences

Title of Thesis: Mobile apps for supporting healthy parental food provision: a user-centred approach informing a digital health intervention concept

B. CO-AUTHORSHIP APPROVALS (To be completed by the student and co-authors)

If there are more than four co-authors (student plus 3 others), only the three co-authors with the most significant contributions are required to sign below.

Please note: A copy of this page will be provided to the Examiners.

1. **Full publication Details** Mauch CE , Wycherley TP, Laws RA, Johnson BJ, Bell LK, Golley RK Mobile Apps to Support Healthy Family Food Provision: Systematic Assessment of Popular, Commercially Available Apps, JMIR I

Section of the thesis where the publication is referred to Chapter 3: A review of commercially available food provision apps

Student's Contribution to the publication:

Research Design 70 %

Data Collection and analysis 90 %

Writing and editing 80 %

Outline your (the student's) contribution to the publication:

Chelsea Mauch contributed to the conceptualisation of the research questions and led the research design, with input from her supervisory team.

She led the research, conducting all searches, data extraction, and app assessments.

She interpreted findings, prepared and edited the full draft manuscript prior to seeking feedback from co-authors

☐ I confirm that the details above are an accurate record of the student's contribution to the work.

Name of Co-Author 1: Professor Rebecca Golley Signed: Prof Rebecca Golley Digitally signed by Prof Rebecca Golley Date: 2020.09.07 17:22:39 +09'30' Date: 07/09/2020

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2. **Full publication Details** Commercially available apps to support healthy family meals: User-testing of app utility, acceptability and engagement

Section of the thesis where the publication is referred to Chapter 4: User-testing of parental food provision apps

Student's Contribution to the publication:

Research Design 80 %

Data Collection and analysis 90 %

Writing and editing 80 %

Outline your (the student's) contribution to the publication:

Chelsea Mauch conceptualised the research questions and study design, consulting with co-authors for expert input regarding data collection tools and methodologies. Chelsea managed the study, conducting recruitment and quantitative data collection, and oversaw the semi-structured interviews which were conducted by a Research Assistant. Chelsea analysed all data and consulted with co-authors on the conceptual model arising from qualitative data analysis. Chelsea drafted the full manuscript prior to seeking input from co-authors.

■ I confirm that the details above are an accurate record of the student's contribution to the work.

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APPENDIX 5: CHAPTER 3 PUBLICATION

Mauch CE, Wycherley TP, Laws RA, Johnson BJ, Bell LK, Golley RK. Mobile Apps to Support Healthy Family Food Provision: Systematic Assessment of Popular, Commercially Available Apps. JMIR Mhealth Uhealth. 2018; 6(12): e11867, accessed at https://mhealth.jmir.org/2018/12/e11867/

Original Paper

Mobile Apps to Support Healthy Family Food Provision: Systematic Assessment of Popular, Commercially Available Apps

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Abstract

Background: Modern families are facing conflicting demands on their time and resources, which may be at the detriment of child and family diet quality. Innovative nutrition interventions providing parents with behavioral support for the provision of healthy food could alleviate this issue. Mobile apps have the potential to deliver such interventions by providing practical behavioral support remotely, interactively, and in context.

Objective: This review aimed to identify and assess popular, commercially available food- and nutrition-related mobile apps that offer support for the provision of healthy family food by (1) describing app scope and characteristics, (2) assessing app quality, and (3) conducting a behavioral analysis of app content and features.

Methods: Searches in the Google Play Store and Apple App Store between August 2017 and November 2017 identified apps addressing the food provision process. Apps were included if they were applicable to parents or families, written in English, and with a user rating of ≥4 stars. Weight loss and diet monitoring apps and subscription apps with no free versions were excluded. App quality was assessed using the Mobile App Rating Scale (4 domains: engagement, functionality, aesthetics, and information). App content and features were extracted and behavior change techniques (BCTs) identified.

Results: Of the 2881 apps screened, 1.77% (51/2881) were included for assessment, comprising 23 recipe and recipe manager apps, 12 meal planning apps, 10 shopping list apps, 4 family organizers, and 2 food choice apps. Half (n=26) of the apps functioned primarily through user data input. Food choice and family organizer apps scored highest for app quality (mean 3.5 [SD 0.6] out of 5), whereas most apps scored well for functionality and poorly for engagement. Common app features with the potential to support healthy food provision included meal planners (n=26), shopping lists (n=44), and the ability to share app content (n=48). Behavioral support features mapped to relatively few BCTs (mean 3.9 [SD 1.9] per app), with *Adding objects to the environment* present in all apps, and 65% (33/51) including *Instruction on how to perform the behavior*.

Conclusions: Recipe and recipe manager apps, meal planning apps, and family organizers with integrated meal planning and shopping lists scored well for functionality and incorporated behavioral support features that could be used to address barriers to healthy food provision, although features were focused on planning behaviors. Future apps should combine a range of features such as meal planners, shopping lists, simple recipes, reminders and prompts, and food ordering to reduce the burden of the food provision pathway and incorporate a range of BCTs to maximize behavior change potential. Researchers and developers should consider features and content that improve the engagement quality of such apps.

(JMIR Mhealth Uhealth 2018;6(12):e11867) doi:10.2196/11867

KEYWORDS

diet; nutrition; family; mobile applications; behavior modification

Introduction

Background

Excessive consumption of energy-dense, nutrient-poor foods is a key cause of poor diet quality [1-4] and is contributing to the high prevalence of overweight and obesity globally [5-7]. In Australia, these foods are contributing 30% to 40% of the total daily energy intake of children and adolescents [2]. Similar figures have been reported in the United States and Canada, with children and adolescents consuming at least one-third of their daily energy intake in the form of energy-dense, nutrient-poor foods [4,8]. The increasing reliance on these generally highly processed foods may be in part because of the conflicting demands that the modern lifestyle places on the resources available for family food provision [9].

Food provision, encompassing the planning, purchasing, and preparation of food, requires significant time and both mental (eg, food preparation knowledge and planning skills) and physical (eg, food preparation facilities) resource [10-12]. The use of food coping strategies (such as meal planning, shopping list writing, use of convenience ingredients or preprepared meals, and seeking support) can enable families to overcome resource-related barriers to food provision (including time or income scarcity). Although some strategies, such as the purchase of fast or convenience food, occur at the detriment of diet quality [13-17], other strategies, such as meal planning and shopping list use, have been associated with healthier food preparation [13]. Nutrition interventions supporting the use of healthy food coping strategies are warranted and in fact desired by parents [18]. However, interventions supporting parents to improve their children's dietary intake are primarily focused on education rather than skill development and are of moderate effectiveness [19]. Addressing resource-related food provision barriers and supporting the adoption of healthy food coping behaviors may enhance the effectiveness of interventions to improve child and family diet quality [11,12,20].

Health interventions delivered by mobile apps have the potential to address resource-related barriers to healthy food provision by offering practical behavioral support, remotely, interactively, and in context [21]. The unique placement of mobile phones within our daily lives, along with technological advancements such as global positioning system, machine learning, and data tracking, means that apps are positioned to deliver ecological momentary interventions [21,22]. Although the initial time and monetary outlay for app development can be substantial, they are highly scalable, and with mobile phone ownership nearing saturation, they have the potential to reach a diverse population [23,24]. Furthermore, interventions can be personalized based on user input, which may improve user engagement and intervention fidelity [22,23]. The current popularity of health and nutrition-related apps in both the general public and in research, along with the opportunities that the technology provides, makes it an important platform to explore for future family nutrition interventions [23,25].

Reviews of Mobile Health Interventions and Commercially Available Apps

Reviews of nutrition-related mobile health interventions have examined their effectiveness in relation to behavioral and weight-related outcomes [26-29]. A meta-analysis of 12 diet and physical activity–focused app studies found that delivery of an intervention via a mobile app significantly reduced weight compared with controls (−1.04 kg, 95% CI −1.80 to −0.27 kg) [27]. Similarly, a systematic review found moderate evidence that diet and physical activity apps lead to improvements in health-related behaviors and outcomes (19 of 27 apps) [29]. However, these reviews have generally focused on apps for weight loss or diet monitoring, with limited relevance to family food provision [26-29].

A recent scoping review identified studies describing apps relevant to families, although the focus was primarily on apps supporting parent food practices (ie, responding to vegetable refusal and food portions) and monitoring of family members snack intake [30]. The same review identified a small subset (19%, 9/47) of mainly app development studies describing food access and food purchasing apps [30]. These apps were found to utilize environmental support features such as recipe suggestions and augmented reality tagging of products in the supermarket aisle [30]. Therefore, although there is evidence of the development of apps providing behavioral support for aspects of food provision, there is a paucity of published research exploring the use of apps for families that consider a range of food provision processes. To understand the potential role of apps in addressing a range of food provision processes, it is crucial to look toward existing, commercially available apps to support innovation in future research studies [23].

Reviews of apps in the commercial space have assessed app features and quality as well as identified the behavior change technique (BCT) content of nutrition, physical activity, and weight management apps targeting adults [31-33] and children [34,35]. These reviews found that there remains a need to enhance app quality and utilize behavior change theory in app development as important precursors to app effectiveness [31,33,34]. The focus of these apps on diet and weight-related outcomes (such as calorie counting and weight monitoring), rather than the behaviors leading to healthy dietary intake and weight, may limit their behavior change potential [33]. Similar to reviews of published app studies, commercial apps pertaining to food provision in a family context have yet to be explored. To ensure that current technological and behavior change potential in this area is fully understood, and to understand gaps in the commercial space, a review of existing, commercial apps addressing family food provision is required.

Objectives

Thus, the purpose of this review was to identify and assess popular, commercially available food and nutrition-related mobile apps that have the potential to offer behavioral support for the provision of healthy family food. Specifically, the objectives of this systematic assessment were to describe app scope and characteristics, assess app quality, and conduct a behavioral analysis of app content and features.

Methods

Search Strategy

Systematic searches were conducted in the Google Play Store and Apple App Store between August 2017 and November 2017. The search strategy was modeled on prior systematic assessments in similar fields of research [31,32,34,36]. Google Play searches were conducted on a personal computer in a Google Chrome Web browser without Google account log-in. App Store searches were performed using the app on an iPad, as the store does not include a search function when used on a personal computer [32]. Search terms relating to the food provision process were selected, and pilot searches in both stores resulted in the following primary terms being used to identify apps for inclusion:

- WHO: child, children, toddler, kid, kids, preschooler, family, families, and parent
- WHAT: nutrition, food, meal, menu, recipe, recipes, and diet
- HOW: planning, planner, shopping, supermarket, grocery, budget, cook, cooking, prep, and preparation

Terms were combined into groups reflecting the various stages of the food provision process, including meal planning; food budgeting; nutrition, food, and cooking knowledge; food purchasing; and meal preparation. Combinations of 2 to 3 words were then generated for each group (eg, meal planner and child meal plan), and the first combination from a group was entered, with the first 50 results being checked by title and description against the inclusion and exclusion criteria. This was repeated for subsequent search terms from that group until a term returned no new apps that met the inclusion criteria. The search was then deemed saturated for that group and the next group of search terms applied.

App Selection

Apps were included if they were applicable to parents with children, written in the English language, and had a user rating of at least four stars in the Google Play Store (to ensure that only popular, functional apps were reviewed) [31]. This limit was not applicable in the App Store as most apps had insufficient reviews to be given a star rating. All free, paid, and freemium apps were included, except where the app was subscription only with no freemium version. The following app types were excluded: (1) weight loss, diet monitoring, and calorie counter apps; (2) generic apps with only 1 food-related component (ie, personal organizers with a shopping list); (3) infant food and feeding apps; (4) apps focused on child feeding practices, electronic books, or magazines; and (5) recipe apps focused on unhealthy food (ie, cakes) or 1 key ingredient or cuisine. Apps were also excluded if their use was contingent upon involvement in a research study or a face-to-face component. The initial screen using these criteria was conducted using the app name, description, and screenshots of the app found within the stores. Approximately 10% of the screened apps (selected randomly, using the random number function within Microsoft Excel 2016) were checked by a second reviewer for correct inclusion and exclusion. Agreement was 93.7% (256/273), with discrepancies discussed and consensus reached [36].

Due to large numbers of similar and generic apps (eg, basic shopping list apps), a second and third screen was undertaken with additional exclusion criteria. At the second screen, apps with only 1 food-related component (ie, recipes only), less than 20 reviews in the Google Play store [34], and duplicates between stores were excluded. Apps were then grouped according to their primary purpose as described in the Google Play Store or App Store, and a third screen applied to ensure that the final sample provided good representation of the features available in such apps. Using the app description in the Google Play Store and App Store, apps were included if they had at least one unique feature not yet described in another app from that group of apps, or features in a unique combination.

Data Extraction and Assessment

Once all eligible apps were identified, an Apple iPad Mini Version 4 (Model A1550) and Lenovo Tab3 7 Essential (Model TB3-710F) were used to download apps for assessment. Where apps were *freemium* (ie, available for free but with some features only accessible with payment), the paid version was purchased, except where subscription was required. These apps were downloaded and assessed in the free version. Apps were used for a minimum of 10 min before any data extraction or assessment took place [37]. Reviewers used individual apps for a period of time (generally on a number of occasions) that was sufficient to familiarize themselves with the apps features and functionality. The time spent using apps varied because of the significant heterogeneity of the included apps. Data extraction was checked, and apps were assessed independently by a second reviewer in a random sample of 22% (11/51).

App Characteristics

App information including app and developer name, operating system availability, version, affiliations, cost structure, user rating and number of downloads (where available), and app scope (ie, target audience and behavior) was extracted into a purpose-designed Microsoft Excel 2016 spreadsheet. The primary direction of data into or out of the app was determined and described as input, output, or both. App content such as information, videos, images, and recipes were defined as *output*, whereas features requiring user input, such as entering items into shopping lists or meal planners, were defined as *input*.

App Quality

App quality was assessed using the Mobile App Rating Scale (MARS), an objective and reliable measure of the quality of health-related apps [37]. The domains assessed by the MARS tool include engagement, functionality, aesthetics, and information [37]. An optional domain regarding subjective app quality was not included in this study. Apps were rated between 1 and 5 for each of the criteria, with 4 mean domain scores and an overall mean score across all 4 domains being indicative of app quality (a score of 5 indicating the best performing apps). Both reviewers viewed a Web-based training video before app assessment [38]. Inter-rater reliability of the overall MARS score was tested on the sample of double-assessed apps using the two-way random effects intraclass correlation coefficient (ICC) [39]. The resulting ICC value of .74 indicated good inter-rater reliability [40].

App Content and Features

Data regarding app content and features were sorted into 2 distinct categories: (1) "Behavioral support content and features" and (2) "Technical features." "Behavioral support content and features" were those that may enable the performance of a behavior relating to the provision of healthy family food. "Technical features" did not offer behavioral support but were important to the overall functioning of the app. App content was then assessed for the presence of BCTs against the BCT taxonomy version 1 (BCTTv1) [41]. Both reviewers underwent Web-based training before coding [42]. The agreement between reviewers regarding the presence of BCTs was tested in the 11 double-assessed apps using kappa and prevalence adjusted and bias adjusted kappa (PABAK) and was near perfect (kappa mean 0.82 [range 0.66-1], PABAK 0.97 [range 0.94-1]) [43].

Statistical Analysis

Means (SD) for each MARS subscale and the overall MARS score were calculated using Microsoft Excel 2016 for each app. A summary score was calculated for each app type (ie, recipe and recipe managers, meal planners, shopping lists, family organizers, and food choice apps) along with an overall mean score for all apps. The mean (SD) number of BCTs per app and app type was calculated, and the total number of apps from each app type incorporating the BCT was presented graphically. The presence of behavioral content and features and technical features was tallied for each app type and for all apps.

Results

App Selection

A total of 2881 apps were screened across the Google Play Store and Apple App Store. The final number included for assessment was 51 (see Figure 1).

App Characteristics

Selected apps fell into 5 categories of app type: (1) recipe and recipe manager apps, which provided recipes or digital storage of recipes; (2) meal planning apps, which allowed the planning and recording of meals in advance; (3) shopping list apps, which allowed recording of grocery items for purchase; (4) family organizer apps, which included meal planners and shopping lists synced between family members; and (5) food choice apps, which provided nutrition or produce information to support food purchasing (see Multimedia Appendix 1 for app details and MARS scores).

Recipe and recipe manager apps were the most common app type in the sample (45%, 23/51), followed by meal planning apps (24%, 12/51). Almost all apps were developed by commercial enterprises, with the exception of 1 app developed by a government body and another by a nongovernment research institute in collaboration with a private health insurer. Approximately one-third (31%, 16/51) of apps were free to download and use (see Multimedia Appendix 2). The primary behavioral targets of the apps included food purchasing (90%, 46/51), meal preparation (76%, 39/51), meal planning (47%, 24/51), and food choice (10%, 5/51). Half (51%, 26/51) of the apps operated primarily on input from the app user, with shopping lists and family organizers being most reliant on user data input. Only one-quarter of apps incorporated both significant user data input along with app information output (25%, 13/51).

App Quality

The mean MARS score for app quality was highest for food choice apps and family organizer apps (mean 3.5 [SD 0.6] out of 5 for each), followed by recipe and recipe manager apps (mean 3.4 [SD 0.5]). Shopping list apps had the lowest overall MARS scores, with half of the apps scoring below 2.5 (for MARS scores by app type, see Table 1, and by individual app, see Multimedia Appendix 1). Engagement was the lowest scoring domain for each app type, with shopping lists and meal planners performing the worst. Most app types scored well for functionality (mean across all app types 3.6 [SD 0.7]).

App Content and Features

Behavioral Support Content and Features

App content and features relating to the provision of healthy family food are presented by app type (see Table 2, and for details by app, see Multimedia Appendix 2). Several common app features supported the use of key healthy food coping strategies, for example, meal planners, shopping lists, and social supports. Meal planners were the primary feature of all 12 meal planning apps and featured in around half of the overall sample (51%, 26/51). Shopping lists featured almost universally (86%, 44/51) and where incorporated into other app types (as opposed to a stand-alone shopping list app), they generally offered automated list generation. Similarly, almost all (94%, 48/51) apps included the ability to share app content by email and/or social media.

Recipes and recipe managers (the primary feature of recipe and recipe manager apps, n=23) were present in more than half of the overall sample (recipes 33/51, 65% and recipe managers 28/51, 55%). Food preparation skills instructions were uncommon (14%, 7/51) and included either text, image, or video-based instructions. Reminders and/or prompts were included in almost a third of apps (27%, 27/51). A small number of apps included general and produce-related nutrition information (16%, 8/51), whereas only 3 apps (6%) included the ability to purchase food for delivery.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram for popular, commercially available food and nutrition-related apps addressing parental food provision.

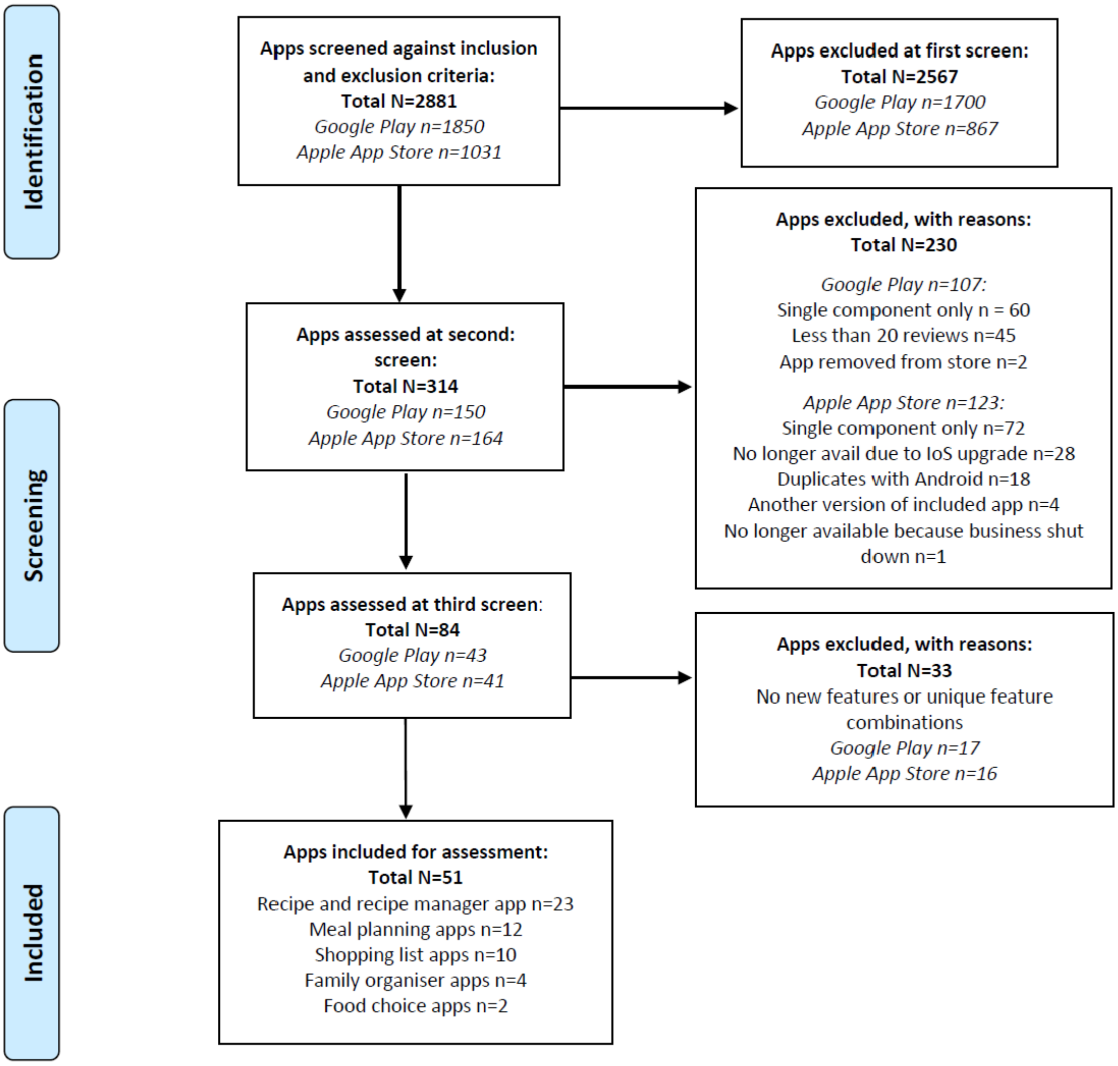


Table 1. Mean (SD) Mobile App Rating Scale (MARS) subscores and overall scores by app type.

MARS domain sub-scores and overall score	Recipe and recipe manager apps (n=23), mean (SD)	Meal planning apps (n=12), mean (SD)	Shopping list apps (n=10), mean (SD)	Family organizer apps (n=4), mean (SD)	Food choice apps (n=2), mean (SD)	All apps (N=51), mean (SD)
Engagement	2.7 (0.6)	2.5 (0.8)	2.1 (0.4)	3.2 (0.7)	2.7 (1.3)	2.6 (0.7)
Functionality	3.8 (0.6)	3.8 (0.7)	3.0 (0.9)	3.7 (0.6)	4.4 (0.2)	3.6 (0.7)
Aesthetics	3.6 (0.8)	3.2 (1.0)	2.9 (0.9)	3.7 (0.9)	2.8 (0.2)	3.3 (0.9)
Information	3.4 (0.4)	3.2 (0.6)	2.9 (0.5)	3.6 (0.5)	4.0 (0.7)	3.3 (0.6)
Overall score	3.4 (0.5)	3.1 (0.7)	2.7 (0.6)	3.5 (0.6)	3.5 (0.6)	3.2 (0.6)

Table 2. App behavioral support content and features presented by app type and across all apps

Behavioral support content or feature	Recipe and recipe manager apps (n=23), n (%)	Meal planning apps (n=12), n (%)	Shopping list apps (n=10), n (%)	Family organizer apps (n=4), n (%)	Food choice apps (n=2), n (%)	All apps (N=51), n (%)
Meal planners and meal plans	10 (44)	12 (100)	2 (20)	2 (50)	0 (0)	26 (51)
Shopping list	20 (87)	9 (75)	10 (100)	4 (100)	1 (50)	44 (86)
Social community or connectivity[a]	10 (44)	4 (33)	0 (0)	0 (0)	0 (0)	14 (27)
Other social supports[b]	23 (100)	11 (92)	9 (90)	4 (100)	1 (50)	48 (94)
Recipes	19 (83)	6 (50)	4 (40)	3 (75)	1 (50)	33 (65)
Recipe managers	13 (57)	6 (50)	7 (70)	2 (50)	0 (0)	28 (55)
Pantry or fridge manager	1 (4)	1 (8)	5 (50)	0 (0)	0 (0)	7 (14)
Food preparation skills instructions	6 (26)	1 (8)	0 (0)	0 (0)	0 (0)	7 (14)
Reminders and prompts[c]	4 (17)	4 (33)	5 (50)	1 (25)	0 (0)	14 (27)
Encouragement and incentives[d]	8 (35)	1 (8)	4 (40)	2 (50)	0 (0)	15 (29)
Produce purchasing information	0 (0)	0 (0)	0 (0)	0 (0)	1 (50)	1 (2)
Produce storage information	1 (4)	0 (0)	0 (0)	0 (0)	1 (50)	2 (4)
Produce nutrition information	1 (4)	1 (8)	1 (10)	0 (0)	2 (100)	5 (10)
Recipe nutrition information	6 (26)	3 (25)	1 (10)	0 (0)	0 (0)	10 (20)
Other nutrition information	2 (9)	1 (8)	0 (0)	0 (0)	0 (0)	3 (6)
Food purchase and delivery	1 (4)	1 (8)	1 (10)	0 (0)	0 (0)	3 (6)

[a]Community (with following), upload recipes or images, rate, review, like, and comment.

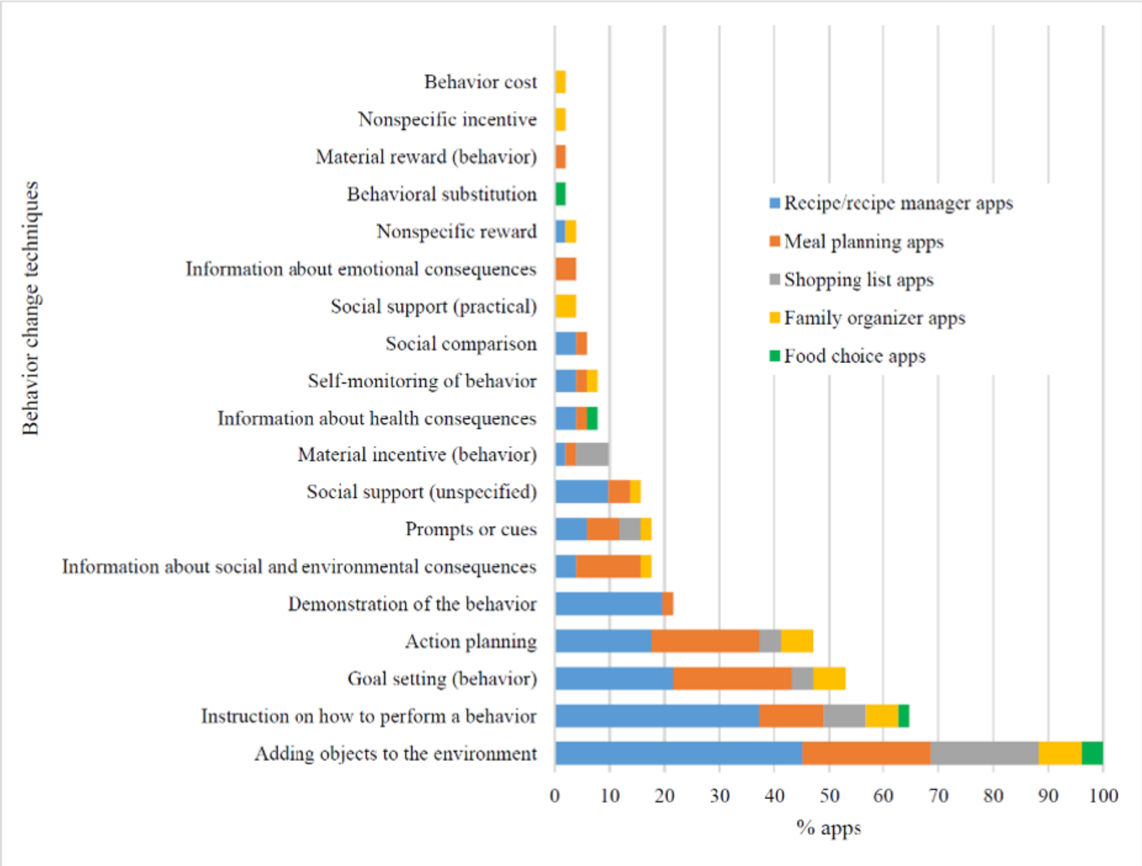
[b]Sharing to social media, sending via email, shared calendar, and private texting.

[c]Recipe suggestions on entering the supermarket, supermarket proximity alert, and reminders (to cook, plan meals, and shop).

[d]Positive messages, points, rewards, competitions, sales or discounts, and other notifications (eg, new content and offers).

Of 93 BCTs in the taxonomy, 19 were identified as being present across the 51 apps, with a mean (SD) of 3.9 (1.9) per app ranging from 1 to 10 (see Figure 2 and Multimedia Appendix 3). Family organizer apps followed by meal planning apps were identified as having the greatest number of BCTs (mean 5.5 [SD 3.1] and mean 4.8 [SD 1.9], respectively). Recipe and recipe manager apps included an average of 4 BCTs per app (mean 3.9 [SD 1.5]), whereas food choice apps and shopping list apps were identified as including the least number of BCTs (mean 2.5 [SD 0.7] and mean 2.3 [SD 0.8], respectively). The only BCT that was identified as being present across all apps was *Adding objects to the environment*. This was because of features such as shopping lists and meal planners that were thought to add objects to the environment that may subsequently enable a behavior relating to healthy food provision. Recipe and recipe managers commonly included the BCT *Instruction on how to perform the behavior* (83%, 19/23), owing to the inclusion of recipes with step-by-step instructions. Furthermore, 92% (11/12) and 83% (11/12) of meal planning apps included BCTs *Goal setting (behavior)* and *Action planning*, owing primarily to the ability to plan meals in advance.

Figure 2. Proportion of apps identified with Behavior Change Technique present, by mobile app type.



Technical Features

Technical features were grouped separately as they were unlikely to directly support behavior but remained important to the overall functioning and engagement of the mobile apps (Table 3 and Multimedia Appendix 2). Two-thirds of apps (69%, 35/51) allowed some level of personalization, such as a customized recipe display based on food preferences, dietary requirements, or number of serves required. More than half of all apps (57%, 29/51), predominantly recipe and recipe manager apps, included practical features such as cooking timers, unit converters (ie, cups to milliliters), voice input of data, hands free commands, and automatic screen lock to prevent the device from sleeping while the app is in use. A little over half of the apps allowed syncing between devices and cloud backup (59%, 30/51 and 57%, 29/51, respectively).

Table 3. Technical features presented by app type and across all apps.

Technical feature	Recipe and recipe manager apps (n=23), n (%)	Meal planning apps (n=12), n (%)	Shopping list apps (n=10), n (%)	Family organizer apps (n=4), n (%)	Food choice apps (n=2), n (%)	All apps (N=51), n (%)
Personalization[a]	20 (87)	9 (75)	4 (40)	1 (25)	1 (50)	35 (69)
Practical features[b]	17 (74)	4 (33)	7 (70)	1 (25)	0 (0)	29 (57)
Syncing between devices	12 (52)	6 (26)	8 (80)	4 (100)	0 (0)	30 (59)
Cloud backup	14 (61)	5 (42)	7 (70)	3 (75)	0 (0)	29 (57)
User or family profile[c]	7 (30)	3 (25)	0 (0)	3 (75)	0 (0)	13 (25)
Miscellaneous and optional purchases[d]	4 (17)	2 (17)	5 (50)	2 (50)	0 (0)	13 (25)
Search and display options[e]	19 (83)	5 (22)	8 (80)	4 (100)	1 (50)	37 (73)
Other input options[f]	6 (26)	6 (26)	10 (100)	3 (75)	1 (50)	26 (51)
Requires log-in	12 (52)	6 (26)	7 (70)	3 (75)	0 (0)	28 (55)
Web access required	21 (91)	10 (83)	5 (50)	4 (100)	2 (100)	42 (82)

[a]Food preferences, dietary requirements, favorites lists, scale recipes to serves required, and add notes or rating to recipes (private).

[b]Prevents device from sleeping, voice command, audio reading, hands free, smart watch compatible, cooking timers, and unit conversions.

[c]Individual profile or profile of individual family members or family as a whole.

[d]To-do lists and optional purchases (eg, hard copy cookbook and cooking equipment).

[e]Search functions, for example, by ingredient, recipe name, and category (eg, vegetarian), and novel search functions, for example, by shaking device and by photo.

[f]Common items lists, history or recurring items, barcode scanners, add images, coupons, and loyalty cards.

Discussion

Principal Findings

This review identified and assessed commercially available food and nutrition-related mobile apps addressing family food provision. Most apps provided behavioral support for the use of healthy food coping strategies, although supports were biased toward planning behaviors, which may appeal to some but not all users. App features and content mapped to relatively few BCTs, with the higher quality family organizer apps, meal planning apps, and recipe and recipe manager apps incorporating the greatest number of techniques, respectively. Recipe and recipe manager apps, meal planning apps, and family organizers with integrated meal planning and shopping lists were found to be highly functional with regards to their performance and ease of use and incorporated a range of behavioral support features that could be used to address barriers to healthy food provision, such as time scarcity and cognitive load.

App Characteristics and Quality

The majority of apps targeted meal planning and shopping list use, both considered healthy food coping strategies [13]. Although these food coping strategies are associated with healthier food preparation practices, they are best suited to those more inclined to plan [15]. Few apps effectively addressed food coping strategies such as preparing meals with few ingredients on hand, utilizing healthy convenience foods (ie, frozen or canned products and meal box kits), or seeking support. Furthermore, observed features often required extensive data input (eg, recipe managers and family organizers), which may be a barrier to app engagement or use [44].

Although most apps were generally functional in terms of their performance, ease of use, navigation, and gestural design, their low ratings for the engagement domain of the quality assessment was a concern, given this is a key predictor of long-term use [23]. A recent review of 11 weight loss apps addressing food-purchasing behavior reported similar findings [33], whereas, others have identified concerns regarding information quality and highlighted the need for evidence-based content [34]. However, as the information within the apps assessed in this review was mostly limited to recipes or food skills, the information quality rating is less relevant. The evidence base of such apps should be in their delivery of behavioral supports, to ensure that they have a positive influence on the food provision process.

Behavioral Analysis

Mobile app behavioral supports such as shopping lists, meal planners, and recipe managers have the advantage of delivering BCTs in the real world, when behaviors are likely to occur, thus improving the chance of positively shaping behavior [21,22]. However, the number of BCTs identified in the present sample of apps was lower compared with similar reviews of weight loss and general nutrition apps [31,34], reflecting the development of these apps for commercial purposes rather than for behavior change or health promotion. This indicates significant scope for increasing the behavior change potential of future apps in this space.

There were a number of app types and features that should be considered in the development of future evidence-based, behavioral change theory–driven apps targeting food provision in families. Meal planning apps and features, supporting the formation of intentions to prepare a healthy meal, were identified as including the second largest mean number of BCTs. Most notably, they incorporated *Goal Setting (behavior)* and *Action Planning*. The 2 meal planning apps with the highest MARS scores and largest number of BCTs allowed the user to outsource some aspects of the planning and purchasing process. One included automated meal plans and shopping lists produced using an internal bank of recipes, whereas the other offered meal box kit ordering and delivery. These apps could be suitable for those not naturally inclined to plan and willing to relinquish some decision making regarding meals. However, inadequate personalization, complex recipes, and the high cost associated with ingredients and box kits may be barriers to the widespread use of such apps.

Shopping lists as a stand-alone app type generally failed to offer more than the conventional paper and pen method, so it was unsurprising that they performed poorly on all domains of the MARS and mapped against very few BCTs. Where shopping lists were incorporated into other app types and allowed automatic list generation through recipes, they have the potential to reduce the time burden associated with shopping list writing. Linking to Web-based grocery ordering would add a further efficiency; however, this feature was surprisingly uncommon, only being incorporated into 2 of 51 apps.

Another feature with the potential to increase efficiencies relating to food purchasing is the ability to sync grocery lists between family members (ie, a shared shopping list). This feature could be utilized to share the mental and physical load of planning and purchasing food. Family organizers generally offered the ability to share such tasks among family members but most were expensive (eg, up to Aus $69.99 per year subscription), requiring an ongoing subscription to access such features. Furthermore, they required significant data input and are likely suited to those with established planning skills.

Few apps incorporated timely reminders and prompts, which is a missed opportunity to take advantage of mobile apps ability to offer ecological momentary intervention [22]. If used appropriately (ie, not overwhelmingly) and timed to coincide with the performance of food-related behaviors, reminders and prompts in the form of push notifications could act to reduce the mental load of the food provision process. Supermarket proximity alerts and reminders of the planned evening meal were effective, albeit uncommon, examples of such push notifications, delivering the BCT *Prompts and cues*.

Most of the apps assessed provided limited information, generally in the form of recipes and food skills, which is consistent with the move toward more data input style apps. This content was associated with *Instruction on how to perform a behavior* and where video or image content was included, *Demonstration of the behavior*. However, most apps providing recipes or food skills were not focused on healthy food preparation or use of healthy food coping strategies (ie, utilizing frozen or canned foods, cooking from few ingredients), and few directly targeted families. Nutrition information delivered in the context of food purchasing, such as in 1 reviewed app that suggested healthier alternatives to scanned products, may be more likely to support behavior change than generic nutrition information. However, it is possible that the way information is presented and the functionality of the app delivering it determines its efficacy in changing behavior; For example, the convenience of the information (ie, barcode scanners for searching) and the pairing of recipes with relevant food skills videos, hands free commands, single directions displayed per page, and text to speech functions.

Review Strengths and Limitations

Although the search strategy of this review was systematic and based on similar reviews of commercial apps for nutrition and weight management [31,32,34], it was limited by the lack of standard methodology for searching commercial mobile app stores. Lack of standardized search methods and limited and variable information provided in app descriptions made it difficult to ensure all eligible apps were captured, particularly high-quality apps. There were also limitations relating to the use and interpretation of the MARS score. The information quality domain was limited to assessing the accuracy of the app description and the credibility of the app developer in the absence of assessable information and should, therefore, be interpreted with caution. Moreover, although family organizer apps and food choice apps scored the highest MARS ratings, they were based on only 4 and 2 apps, respectively. Finally, the coding of BCTs was limited to features and content that could be accessed or viewed within the assessment period. Therefore, some push notifications may have been overlooked, whereas lengthy blogs within apps were excluded from detailed analysis.

Despite its limitations, this review assessed a large number of apps and provides unique information about their behavior change potential by not only describing and assessing app scope, characteristics, and quality but also through a behavioral analysis of app content and features. Reviewer training, along with the use of a second reviewer in a 20% sample, improves the objectivity and accuracy of the data extracted and assessed in this review. The present target group is families, but the findings have applications to food planning, purchasing, and preparation behaviors more generally.

Implications for Practice and Future Research

The findings of this review suggest that recipe and recipe manager apps, family organizer apps, and meal planning apps should be explored as viable options for nutrition promotion interventions. Future apps should combine a range of behavioral support features such as meal planners, shopping lists, simple recipes, reminders and prompts, and food ordering to reduce the burden of the food provision process and maximize behavior change potential. Consideration of food coping strategies other than meal planning, or the incorporation of skills training, prompts, and encouragement to plan meals, would make these apps applicable to people less inclined to plan. Although particular attention should be paid to personalization features, they should also provide a level of automation that reduces the need for excessive data input. Finally, researchers and developers should be mindful of the needs of modern families and consider the engagement qualities of such apps to ensure their effectiveness and longevity.

Conclusions

This review, assessing commercially available food and nutrition-related apps for family food provision, demonstrates that apps could be used to deliver behavioral support for healthy food coping strategies. Future apps should include a wider range of features and BCTs to promote engagement and improve the behavior change potential of such apps.

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Authors' Contributions

CEM led the research, under the supervision of RKG, TPW, RAL, and LKB guiding study design and search strategy. CEM conducted all searches, data extraction, and app assessment, with BJJ undertaking double screening and assessment. CEM drafted the manuscript, with all authors contributing to the interpretation of results and reviewing of drafts. All authors read and approved of the final manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Included app details and Mobile App Rating Scale scores.

[PDF File (Adobe PDF File), 21KB - mhealth_v6i12e11867_app1.pdf]

Multimedia Appendix 2

App content and features.

[PDF File (Adobe PDF File), 46KB - mhealth_v6i12e11867_app2.pdf]

Multimedia Appendix 3

Behavior change technique presence within apps, according to the behavior change technique taxonomy version 1.

[PDF File (Adobe PDF File), 21KB - mhealth_v6i12e11867_app3.pdf]

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Abbreviations

BCT: behavior change technique
BCTTv1: behavior change technique taxonomy version 1
ICC: intraclass correlation coefficient
MARS: Mobile App Rating Scale
PABAK: prevalence adjusted and bias adjusted kappa

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APPENDIX 6: APP DETAILS AND MOBILE APP RATING SCALE SCORES, DETAILED TABLE

Table 1: Included app details and Mobile App Rating Scale scores

App name (developer name)	Version[a]	Operating system[b]	App pricing structure (cost[c] in AUD)	Target behaviours: Meal planning	Food purchasing	Meal preparation	Food choice	MARS score (per MARS domain & overall) [d]: Engagement	Functionality	Aesthetics	Information quality	MEAN score
Recipe and recipe manager apps												
All recipes (Allrecipes.com, Inc)	6.5.2	I/A	Free		X	X		3.0	4.0	3.7	4.0	3.7
Big oven (BigOven.com)	5.6.17 - 5.7.23	I/A	Freemium (subscription)		X	X		3.0	3.8	3.7	3.5	3.5
Change4Life Smart Recipes (Public Health England)	3.0.3	I	Free	X	X	X	X	3.2	4.8	4.0	3.8	3.9
Cheftap (Mindframe Design, LLC)	4.0.0.415 - 4.0.0.424	I/A	Freemium (subscription)			X		2.6	3.3	3.3	3.5	3.2
Clean and Green Eating (Clean & Green Lifestyle)	2.0.2	I/A	Paid (4.49)		X	X		2.8	4.8	5.0	3.0	3.9
Cookbook recipes (Riafy Technologies)	11.16.26	A	Freemium (subscription)	X	X	X	X	2.4	3.0	3.3	3.0	2.9
Cookooz (Soft Venture)	1.2	I	Free	X		X		1.8	3.8	3.0	3.0	2.9
Copy me that (Copy me that)	1.0.0.2 - 3.0.1	I/A	Freemium (subscription)	X	X	X		3.2	3.0	2.7	3.5	3.1
Epicurious (Conde Nast Digital)	6.2.7	I	Free		X	X		3.6	4.3	4.7	3.5	4.0
Jamie Olivers Ultimate Recipes (Zolmo)	3.6.1	I	Paid (10.99)		X	X		3.0	4.3	4.3	3.5	3.8
Kitchen stories (Kitchen Stories)	7.2.1A	I/A	Free		X	X		3.6	4.5	5.0	3.5	4.2
My cookbook (Maadinfo Services)	5.0.34	I/A	Freemium (subscription)		X	X		3.2	3.8	3.7	4.0	3.7
My Recipe Book (Cross Forward Consulting, LLC)	3.3.4	I	Paid (0.99)		X	X		2.2	4.0	3.0	3.0	3.1
Nigella: The quick Collection (Random House)	1.9	I	Paid (5.99)		X	X		2.4	3.5	3.7	3.5	3.3
Paprika (Hindsight Labs LLC)	1.4.2	I/A	Paid (6.99)	X	X	X		2.2	3.5	3.0	3.5	3.1
Pepperplate (Pepperplate Inc.)	2.8	I/A	Free	X	X	X		1.8	3.8	2.3	3.0	2.7
Recipe book (Recipe Book)	6.0.3.4	A	Freemium (subscription)[e]		X	X		3.4	4.0	3.7	3.5	3.6
RecipeCloud (Jacob Hull)	3.1.6	I	Freemium (subscription)			X		2.4	4.0	4.0	3.0	3.4
Recipe keeper (Tudorspan)	3.13.3.0 - 3.15.2.0	I/A	Freemium (7.99)	X	X	X		2.6	4.0	4.0	4.0	3.7
VideoMeals (iCM Development Inc.)	2.2	I	Paid (4.49)		X	X		3.0	2.8	3.3	3.0	3.0
What's for dinner? (Snazzy Software, LLC)	2.1	I/A	Freemium (4.82)	X	X	X		2.0	2.8	1.7	2.5	2.2
What to cook? (Vitaly Kuz'menko)	2.1	I	Paid (1.49)	X	X	X		2.0	3.5	2.7	2.5	2.7
Yummly (Yummly)	1.9.5.3 - 1.9.6.4	I/A	Free		X	X		3.0	3.8	4.7	4.0	3.9
			MEAN (SD) MARS score for recipes and recipe managers:					2.7(0.6)	3.8(0.6)	3.6(0.8)	3.4(0.4)	3.4(0.5)
Meal planning apps												
Chef plan (Alberto Gasparin)	1.7.0	I/A	Paid (1.49)	X	X			1.6	4.0	3.0	2.0	2.7
Hello fresh (Hello Fresh)	2.18.2 - 2.25	I/A	Free[f]	X	X	X		3.4	4.3	4.7	4.0	4.1
Mealime (Mealime Meal Plans Inc)	1.6.6 - 1.7.5	I/A	Freemium (subscription)	X	X	X		4.0	4.0	4.7	4.0	4.2
Meal Planner Pal (Gregg Evans)	2.1	I	Freemium (1.49)	X	X			1.8	2.3	1.7	2.5	2.1
MealsUp (Benjamin Styles)	1.6.16	I	Freemium (2.99)	X	X	X		2.6	4.0	3.7	3.5	3.4
Menu Planner (InnovaDev, LLC)	4.05	I	Paid (4.49)	X	X	X	X	2.2	3.3	3.0	3.0	2.9
My family meal planner (My Family Meal Planner)	2.5	I/A	Paid (4.81)	X	X	X		1.6	4.0	2.3	3.0	2.7

App name (developer name)	Version[a]	Operating system[b]	App pricing structure (cost[c] in AUD)	Target behaviours: Meal planning	Food purchasing	Meal preparation	Food choice	MARS score (per MARS domain & overall) [d]: Engagement	Functionality	Aesthetics	Information quality	MEAN score
PlanBuyCook (Appetising Ideas Pty Ltd)	2.3.4	I	Paid (5.99)	X	X	X		3.4	4.8	4.0	3.5	3.9
Plateful (Happy Accident Apps)	1.4.5 - 1.4.6	I/A	Free	X				1.6	4.0	2.7	2.5	2.7
Recipe calendar (Harmonic Soft)	2.10 - 2.20	I/A	Freemium (4.99)	X	X	X		3.0	3.5	3.3	3.5	3.3
Today's Parent Mealtime (Rogers Media)	1.2	I/A	Free	X	X	X		3.0	4.3	3.7	3.5	3.6
Week menu (Bjorn Karlsson)	2.3.6	I	Paid (5.99)	X		X		2.0	3.3	2.0	3.0	2.6
							MEAN (SD) MARS score for meal planners:	2.5(0.8)	3.8(0.7)	3.2(1.0)	3.2(0.6)	3.1(0.7)
Shopping list apps												
AnyList (Purple Cover Inc)	5.8	I	Freemium (subscription)		X			3.0	4.3	3.7	3.5	3.6
Grocery king (Pocket Labs)	2.66 - 2.75f	I/A	Freemium (6.99)		X			2.2	2.8	3.7	3.0	2.9
Grocery List (Dmitry Polevoy)	6.4	I	Paid (1.99)		X			1.6	1.3	2.0	1.7	1.6
Grocery tracker (easicorp)	11.22 - 11.34	A	Freemium (6.42)	X	X			1.8	2.0	2.7	3.0	2.4
H-E-B (H-E-B)	2.4.0	I/A	Free		X	X		2.2	4.0	3.7	3.0	3.2
Lister (Lister Studios)	5.6.20	A	Free		X			2.4	4.0	3.7	3.0	3.3
Mighty shopping list (Mighty Pocket)	4.0.151	A	Freemium (3.99)	X	X			1.8	2.8	2.0	3.0	2.4
Out of milk (Out of milk)	8.3.0_816	I/A	Free		X	X		2.0	3.3	3.7	3.5	3.1
Scan2List (MidCentury M109edia Inc.)	10.6.702	I	Freemium (subscription)		X			2.0	2.8	2.3	2.5	2.4
Shopping List Ease (inMarket Media, LLC)	2.36	I	Freemium (2.99)		X			1.8	3.3	1.7	2.5	2.3
							MEAN (SD) MARS score for shopping lists:	2.1(0.4)	3.0(0.9)	2.9(0.9)	2.9(0.5)	2.7(0.6)
Family organizer apps												
Cozi (Cozi Inc.)	9.2.5610 - 9.3.5757	I/A	Freemium (subscription)	X	X	X		3.2	4.0	3.3	4.0	3.6
Organizer To-Do (Yadahome.com LLC)	3.10	I	Freemium (14.99)[g]		X	X		2.4	2.8	2.67	3.0	2.7
OurHome (OurHome)	3.13.2	I/A	Free		X	X		4.0	4.0	4.7	4.0	4.2
Picniic (Picnic Labs Inc.)	1.10 - 1.16	I/A	Freemium (subscription)		X	X		3.0	4.0	4.0	3.5	3.6
							MEAN (SD) MARS score for family organizers:	3.2(0.7)	3.7(0.6)	3.7(0.9)	3.6(0.5)	3.5(0.6)
Food choice apps												
FoodSwitch (The George Institute for Global Health)	2.1	I/A	Free		X		X	3.6	4.5	3.0	4.5	3.9
Perfect produce (SparkPeople)	1.0	A	Free		X	X	X	1.8	4.3	2.7	3.5	3.1
							MEAN (SD) MARS score for food choice apps:	2.7(1.3)	4.4(0.2)	2.8(0.2)	4.0(0.7)	3.5(0.6)
							OVERALL MEAN (SD) MARS ratings:	2.6(0.7)	3.6(0.7)	3.3(0.9)	3.3(0.6)	3.2(0.6)

a Ranges are included where various versions of apps may have been assessed over the course of the study
b A = available on Android, I = available on iOS
c Cost only included where a paid / premium version was purchased and assessed, and the cost was a one-off payment, as per inclusion criteria
d Range 1-5, 5 indicating a higher quality app
e Payment for ad removal only
f App free to use, with optional meal box kit purchases
g Option to pay by subscription

APPENDIX 7: APP CONTENT AND FEATURES, DETAILED TABLE

Table 2: Content and features of the 51 included apps

		BEHAVIORAL SUPPORT CONTENT AND FEATURES																TECHNICAL FEATURES									
App name	Primary data direction	Food preparation skills instructions	Food purchasing info	Recipe nutrition info	Produce storage info	Produce nutrition info	Other nutrition info	Recipes	Recipe managers	Food purchase & delivery	Shopping list	Pantry / fridge manager	Reminders & prompts	Social community / connectivity	Other social supports	Meal planners & meal plans	Encouragement & incentives	User / family profile	Personalisation	Practical features	Miscellaneous & optional purchases	Search & display options	Other input options	Requires login	Web access required	Syncing between devices	Cloud back-up
Recipe and recipe manager apps																											
All recipes	Input & output	X		X				X			X(a)		X	X	X			X	X	X		X			X	X	X
Big oven	Input & output							X	X(a)		X(a)		X	X	X		X	X	X			X	X		X		X
Change4Life Smart Recipes	Output	X		X			X	X			X(a)				X	X	X		X			X			X[b]		
Cheftap	Input							X	X(a)						X				X	X		X		X[c]	X	X	X
Clean and Green Eating	Output			X				X			X(a)				X		X		X		X	X			X[b]		
Cookbook recipes	Input & output						X	X	X(a)		X(a)		X	X	X	X		X	X	X		X		X	X		
Cookooz	Input							X	X(m)						X				X				X	X	X[b]		X
Copy me that	Input & output							X	X(a)		X(a)			X	X	X		X		X	X	X		X	X	X	X
Epicurious	Output	X						X			X(a)		X		X		X		X	X	X	X		X	X		
Jamie Olivers Ultimate Recipes	Output	X						X			X(a)				X		X		X	X		X	X		X		
Kitchen stories	Output	X		X	X	X		X			X(a)			X	X	X	X		X	X				X	X		
My cookbook	Input								X(a)		X(a)			X	X				X	X		X	X	X	X		
My Recipe Book	Input							X	X(a)		X(a)				X				X	X		X		X[b]	X	X	X
Nigella: The quick Collection	Output	X						X			X(a)				X				X	X		X					
Paprika	Input										X(a)				X	X			X	X		X		X[b]	X	X	X
Pepperplate	Input								X(m[d])		X(a)				X	X			X	X		X	X	X	X[b]	X	X
Recipe book	Input & output			X				X	X(m)		X(a)			X	X		X	X	X	X		X			X	X	X
RecipeCloud	Input & output							X	X(a)					X	X		X	X	X	X		X		X	X	X	X
Recipe keeper	Input							X	X(a)		X(a)				X	X			X			X			X		
VideoMeals	Output							X			X(a)			X	X	X			X	X		X		X		X	X
What's for dinner?	Input							X	X(m)		X(a)				X	X				X					X[b]	X	X

					BEHAVIORAL SUPPORT CONTENT AND FEATURES															TECHNICAL FEATURES							
App name	Primary data direction	Food preparation skills instructions	Food purchasing info	Recipe nutrition info	Produce storage info	Produce nutrition info	Other nutrition info	Recipes	Recipe managers	Food purchase & delivery	Shopping list	Pantry / fridge manager	Reminders & prompts	Social community / connectivity	Other social supports	Meal planners & meal plans	Encouragement & incentives	User / family profile	Personalisation	Practical features	Miscellaneous & optional purchases	Search & display options	Other input options	Requires login	Web access required	Syncing between devices	Cloud back-up
What to cook?	Input								X(a[e])		X(a)	X(a)			X	X				X		X	X		X[b]	X	X
Yummly	Input & output			X				X		X	X(a)			X	X			X	X		X			X	X	X	X
	TOTAL	6	0	6	1	1	2	19	13	1	20	1	4	10	23	10	8	7	20	17	4	19	6	12	21	12	14
Meal planning apps																											
Chef plan	Input										X(m)				X	X							X		X[b]		
Hello fresh	Output			X			X	X		X				X	X	X	X	X	X					X	X	X	
Mealime	Input & output							X			X(a)				X	X		X	X	X		X		X	X	X	
Meal Planner Pal	Input										X(a)		X		X	X					X		X		X[b]		
MealsUp	Input								X(m)		X(a)		X		X	X							X	X	X	X	X
Menu Planner	Input					X			X(a)		X(a)	X(m)		X	X	X			X	X		X	X	X	X[b]	X	X
My family meal planner	Output			X				X			X(a)				X	X			X								
PlanBuyCook	Input & output	X						X	X(m)		X(a)				X	X			X	X	X	X	X				X
Plateful	Input								X(m)				X			X			X						X		
Recipe calendar	Input & output			X				X			X(a)		X	X	X	X		X	X	X				X	X	X	X
Today's Parent Mealtime	Output							X	X(m)		X(a)			X	X	X			X			X		X	X		X
Week menu	Input								X(m)						X	X			X			X	X		X	X	X
	TOTAL	1	0	3	0	1	1	6	6	1	9	1	4	4	11	12	1	3	9	4	2	5	6	6	10	6	6
Shopping list apps																											
AnyList	Input							X	X(a)		X(a)		X		X				X	X		X	X	X	X	X	X
Grocery king	Input								X(m)		X(a)	X(a)	X		X					X		X	X	X	X[b]	X	X
Grocery List	Input					X					X(m)	X(m)										X	X				
Grocery tracker	Input										X(m)	X(m)			X	X						X	X			X	
H-E-B	Input & output			X				X		X[f]	X(a)				X		X		X	X	X	X	X	X	X	X	X
Lister	Input								X(m)		X(a)		X		X		X			X			X			X	X
Mighty shopping list	Input								X(m)		X(a)	X(a)			X	X			X	X	X		X	X			
Out of milk	Input & output							X	X(a[e])		X(a)	X(m)			X		X		X	X	X	X	X	X	X	X	X
Scan2List	Input							X	X(m)		X(m)		X		X				X		X	X	X	X[b]	X	X	X
Shopping List Ease	Input								X(m)		X(m)		X		X		X			X	X	X	X	X[b]		X	X
	TOTAL	0	0	1	0	1	0	4	7	1	10	5	5	0	9	2	4	0	4	7	5	8	10	7	5	8	7
Family organizer apps																											

App name	Primary data direction	BEHAVIORAL SUPPORT CONTENT AND FEATURES																				TECHNICAL FEATURES					
		Food preparation skills instructions	Food purchasing info	Recipe nutrition info	Produce storage info	Produce nutrition info	Other nutrition info	Recipes	Recipe managers	Food purchase & delivery	Shopping list	Pantry / fridge manager	Reminders & prompts	Social community / connectivity	Other social supports	Meal planners & meal plans	Encouragement & incentives	User / family profile	Personalisation	Practical features	Miscellaneous & optional purchases	Search & display options	Other input options	Requires login	Web access required	Syncing between devices	Cloud back-up
Cozi	Input							X	X(a)		X(a)				X	X		X		X	X	X	X	X	X[b]	X	X
Organizer To-Do	Input							X			X(a)				X	X	X				X	X	X		X[b]	X	
OurHome	Input										X(a)		X		X		X	X				X	X	X	X	X	X
Picniic	Input & output							X	X(a[e])		X(a)				X			X	X			X		X	X[b]	X	X
	TOTAL	0	0	0	0	0	0	3	2	0	4	0	1	0	4	2	2	3	1	1	2	4	3	3	4	4	3
Food choice apps																											
FoodSwitch	Output					X					X(m)				X							X	X		X[b]		
Perfect produce	Output		X		X	X		X											X						X		
	TOTAL	0	1	0	1	2	0	1	0	0	1	0	0		1	0	0	0	1	0	0	1	1	0	2	0	0

(a) = autopopulated e.g. recipe content clipped from the web, ingredients from recipes sent to shopping list; (m) = manual data input by text, image, barcode

a No apps addressed automatic motivation

b Required for emailing, sharing, syncing and/or cloud back-up only

c Only allows up to 15 recipes without login, 100 with login

d Can be imported via online content but only via website (manual entry only in app)

e Recipes not imported – weblink saved and recipe viewed via internal browser

f Ordering can only occur via website, but is linked to groceries selected within the app

Reminders & prompts = Recipe suggestions on entering the supermarket, supermarket proximity alert, reminders (to cook, plan meals, shop)

Social community / connectivity = Community (with following), upload recipes/images, rate, review, like, comment

Other social supports = Sharing to social media, sending via email, shared calendar, private messaging

Encouragement & incentives = Positive messages, points, rewards, competitions, sales/discounts, other notifications (e.g. new content, offers)

User / family profile = Individual profile or profile of individual family members / family as a whole

Personalization = Food preferences, dietary requirements, favourites, try or make lists, scale recipes to serves required, add notes or rating to recipes (private)

Practical features = Prevents device from sleeping, voice command, audio reading, hands free, smart watch compatible, cooking timers, unit conversions

Miscellaneous & optional purchases = To-do lists, optional purchases (e.g. hard copy cookbook, cooking equipment)

Search & display options = Search functions e.g. by ingredient, recipe name, category, novel search functions e.g. by shaking device, by photo

Other input options = common items lists, history/recurring items, barcode scanners, add images, coupons, loyalty cards

APPENDIX 8: BEHAVIOUR CHANGE TECHNIQUE PRESENCE IN APPS, DETAILED TABLE

Table 1: Behaviour change technique presence within the 51 included apps, according to the behaviour change technique taxonomy version 1

App name	1.1 Goal setting (behav)	1.4 Action planning	2.3 Self-mon of behaviour	3.1 Social support (unspec)	3.2 Social support (prac)	4.1 Instr on how perform behav	5.1 Info about health cons	5.3 Info about soc & envir cons	5.6 Info about emot cons	6.1 Demo of the behaviour	6.2 Social comparison	7.1 Prompts/cues	8.2 Behav substitution	10.1 Material incentive behav	10.2 Material reward behav	10.3 Non-specific reward	10.6 Non-specific incentive	12.5 Add objects to the envir	14.1 Behaviour cost	No. of BCTs per app
	BEHAVIOR CHANGE TECHNIQUE																			
Recipe and recipe manager apps																				
All recipes				X		X				X		X		X		X		X		7
Big oven	X			X		X												X		4
Change4Life Smart Recipes			X			X	X	X		X								X		6
Cheftap	X		X			X		X										X		5
Clean and Green Eating						X												X		2
Cookbook recipes	X	X				X	X			X		X						X		7
Cookooz	X	X				X												X		4
Copy me that	X	X		X		X												X		5
Epicurious						X				X	X	X						X		5
Jamie Olivers Ultimate Recipes						X				X								X		3
Kitchen stories						X				X	X							X		4
My cookbook																		X		1
My Recipe Book						X												X		2
Nigella: The quick Collection						X				X								X		3
Paprika	X	X																X		3
Pepperplate	X	X																X		3
Recipe book				X		X				X								X		4
RecipeCloud				X		X												X		3
Recipe keeper	X	X				X												X		4
VideoMeals	X	X				X				X								X		5
What's for dinner?	X	X				X												X		4
What to cook?	X	X																X		3
Yummly						X				X								X		3
											Mean (SD) no. of BCTs identified in recipe and recipe manager apps:									3.9 (1.5)
Meal planning apps																				
Chef plan	X	X						X										X		4
Hello fresh	X	X				X			X	X	X			X	X			X		9
Mealime	X		X	X		X		X	X									X		7

App name	1.1 Goal setting (behav)	1.4 Action planning	2.3 Self-mon of behaviour	3.1 Social support (unspec)	3.2 Social support (prac)	4.1 Instr on how perform behav	5.1 Info about health cons	5.3 Info about soc & envir cons	5.6 Info about emot cons	6.1 Demo of the behaviour	6.2 Social comparison	7.1 Prompts/cues	8.2 Behav substitution	10.1 Material incentive behav	10.2 Material reward behav	10.3 Non-specific reward	10.6 Non-specific incentive	12.5 Add objects to the envir	14.1 Behaviour cost	No. of BCTs per app
	BEHAVIOR CHANGE TECHNIQUE																			
Meal Planner Pal	X	X										X						X		4
MealsUp	X	X						X				X						X		5
Menu Planner	X	X																X		3
My family meal planner						X	X	X										X		4
PlanBuyCook	X	X				X												X		4
Plateful	X	X						X										X		4
Recipe calendar	X	X		X		X		X				X						X		7
Today's Parent Mealtime	X	X				X												X		4
Week menu	X	X																X		3
Mean (SD) no. of BCTs identified in meal planning apps:																				4.8 (1.9)
Shopping list apps																				
AnyList						X												X		2
Grocery king												X						X		2
Grocery List																		X		1
Grocery tracker	X	X																X		3
H-E-B						X								X				X		3
Lister																		X		1
Mighty shopping list	X	X																X		3
Out of milk						X								X				X		3
Scan2List						X												X		2
Shopping List Ease												X		X				X		3
Mean (SD) no. of BCTs identified in shopping list apps:																				2.3 (0.8)
Family organizer apps																				
Cozi	X	X			X	X												X		5
Organizer To-Do	X	X				X												X		4
OurHome	X	X	X	X				X				X				X	X	X	X	10
Picniic					X	X												X		3
Mean (SD) no. of BCTs identified in family organizer apps:																				5.5 (3.1)
Food choice apps																				
FoodSwitch													X					X		2
Perfect produce						X	X											X		3
No. of food choice apps incorporating BCT:																				2.5 (0.7)
TOTAL no. of apps incorporating BCT:	27	24	4	8	2	33	4	9	2	11	3	9	1	5	1	2	1	51	1	3.9 (1.9)

APPENDIX 9: CHAPTER 4 MANUSCRIPT UNDER REVIEW

Original paper

Commercially available apps to support healthy family meals: User-testing of app utility, acceptability and engagement

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Abstract

Background:

Parents juggling caregiving and paid employment encounter a range of barriers in providing healthy food to their families. Mobile apps have the potential to help parents in planning, purchasing and preparing healthy family food. The utility and acceptability of apps to support parents is unknown. User perspectives of existing technology, such as commercially available apps can guide the development of evidence informed apps in the future.

Objective:

This study aimed to determine the feasibility of existing, commercially available apps for supporting healthy food provision practices of working parents.

Methods:

Working parents (n=133) were recruited online and completed a 10-item COM-B self-evaluation survey assessing their needs in relation to the provision of healthy family meals. Five apps were selected for testing, including a meal planning app, recipe app, recipe manager app, family organizer app and barcode scanning app. Survey items were mapped to app features, with a sub-sample of parents (n=67) allocated two apps each to trial simultaneously over 4-weeks. A semi-structured interview exploring app utility and acceptability, and an online survey including the System Usability Scale and the user version of the Mobile App Rating Scale (uMARS), followed app testing. Interview data were analyzed using a theoretical thematic approach.

Results:

Survey participants (n=133; age 34$\pm$4 years) were mainly mothers (n=130/133; 98%) and partnered (n=122/133; 92%). Participants identified a need for healthy recipes (n=109/133; 82% agreed/strongly agreed), and time for food provision processes (n=107/133; 80%). Engagement quality was the lowest rated domain of the uMARS (mean/app 3.0-3.7 of maximum 5). The family organizer, requiring a high level of user input, was rated the lowest for usability (median(IQR) 48(34:73)). In the interviews, participants weighed up the benefits of the apps (i.e. time saving) against the effort involved in using them in determining their acceptability. Organization was a sub-theme emerging from interviews, associated with the use of meal planners and shopping lists. These features were used in-time, as behavior was occurring.

Conclusions:

Meal planning apps and features promoting organization present feasible, time saving solutions to supporting healthy food provision practices. The incorporation of automated planning features will ensure that apps have a wider application and do not add to the time burden of food provision. The behavior change potential of food provision apps may lie in their ability to be integrated into everyday life, promoting healthy food provision in-time.

Keywords: Diet; Nutrition; Family; Mobile Applications; Behavior Modification

Introduction

Suboptimal dietary intake is a major public health concern due to its role in the development non-communicable diseases (NCDs) [1]. In 2016, NCDs were responsible for 70% of the worlds deaths [2]. Key dietary risk factors for NCDs include inadequate intake of vegetables, fruit and wholegrains, and excessive intake of energy dense, nutrient poor foods, also termed discretionary choices [1]. Ninety percent of Australian adults do not meet the recommended daily serves of vegetables and more than a third of daily energy intake is from discretionary choices [3]. Similar trends have been seen internationally [4, 5]. Poor dietary patterns start young and persist over time. Australian children's diet quality mirrors adult patterns by 4-8 years of age [3, 6]. Supporting parents' to provide healthy food to themselves and their families will improve population diet quality.

There has been a trend toward greater female workforce participation in modern households [7, 8]. In Australia in 2019, 70% of mothers in dual-parent households were working, while 60% of mothers in single-parent households were working [7]. Parents juggling caregiving and paid employment experience a range of barriers in providing healthy food to their families. The COM-B system [9] describes three key conditions that interact to enable a behavior (B) to occur, namely – capability (C), opportunity (O) and motivation (M). Parent focused nutrition interventions to date have tended to target capability (e.g. knowledge and skills) and motivation (e.g. confidence in supporting child health) [10]. However opportunity-related enablers such as adequate time for food provision are important and promote resilience against the broader unhealthy food environment [11, 12]. It is therefore important to consider a range of enablers relevant to the planning, purchasing and preparation of food in the development of future nutrition interventions.

The time and staff-intensive nature of traditional face-to-face interventions make them impractical in a resource scarce health promotion environment. Mobile apps offer advantages over face-to-face interventions, such as the delivery of interventions in everyday situations [13]. A review identified 51 commercially available apps that addressed the planning, purchasing and preparation of food [14]. The review found that meal planning, family organizer and recipe manager apps incorporated features promoting organization that could address potential barriers to healthy meal provision such as time scarcity and cognitive load [14]. However app content generally mapped to relatively few behavior change techniques (BCTs) and was not targeted toward healthy eating in a family context [14].

The next step to understanding the behavioral potential of these types of apps and features in a family food provision context is to gain insights from target users. User perspectives can inform the design of evidence-based apps that are informed by user context and needs [15-17]. This study sought user perspectives on commercially available apps to inform future app development or refinement [18]. It aimed to determine the feasibility of existing, commercially available apps and app features for supporting healthy food provision practices in working parents by exploring;

1. The utility of apps and app features to support the planning, purchasing and preparation of food
2. The acceptability of apps and app features, in terms of quality, usability, functionality, and engagement

Methods

Study design

This feasibility study was conducted between February and June 2019 using a mixed methods design. Participants completed a baseline survey, with a sub-sample undertaking a four-week app testing period followed by another survey and semi-structured interview. Five apps were selected for testing based on a prior review of commercially available apps [14]. Selected apps represented key content and features of interest identified in the prior review. They rated well for quality compared to similar apps (Table 1), were available in a free or freemium format, and were available on Apple and Android operating systems.

Table 1. Mobile App Rating Scale (MARS) quality score, BCTs and key content and features of the apps selected for testing [14]

App	MARS quality score	Key content & features of interest	No of BCTs	BCTs linked with app content & features[a]
Meal planning app	4.2	Recipes – personalized based on preferences Meal planning – automated or manual Shopping list – automatically generated from recipe content	7	1.1 Goal setting (behavior) 2.3 Self-monitoring of behavior 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behavior 5.3 Information about social & environmental consequences 5.6 Information about emotional consequences 12.5 Adding objects to the environment
Recipe manager app	3.7	Recipe storage – automatic population from online or manual entry Meal planning – manual Shopping list – automatically generated from recipe content	4	1.1 Goal setting (behavior) 1.4 Action planning 4.1 Instruction on how to perform the behavior 12.5 Adding objects to the environment

Recipe app	4.2	Recipes – text, photo and video Food preparation skills – text, photo and video	4	4.1 Instruction on how to perform the behavior 6.1 Demonstration of the behavior 6.2 Social comparison 12.5 Adding objects to the environment
Barcode scanning app	3.9	Product specific nutrition information – generated via barcode scanner	2	8.2 Behavioral substitution 12.5 Adding objects to the environment
Family organizer app	4.2	Shopping list – synced between users Family calendar – personalized tasks and reminders	10	1.1 Goal setting (behavior) 1.4 Action planning 2.3 Self-monitoring of behavior 3.1 Social support (unspecified) 5.3 Information about social & environmental consequences 7.1 Prompts/cues 10.3 Non-specific reward 10.6 Non-specific incentive 12.5 Adding objects to the environment 14.1 Behavior cost

a BCTs with numbers according to the Behavior Change Technique Taxonomy Version 1

Study sample and recruitment

Eligibility criteria included being a single or partnered parent in paid employment, with themselves or their partner having returned to work from a period of parental leave in the last 6 months. Other eligibility criteria included being based in Australia and the main food gatekeeper of the household. Individuals who did not own an Apple or Android mobile device with internet access or whose partner was not in paid employment were excluded.

Recruitment was via Facebook and flyers posted around a university campus and in childcare centres. These recruitment channels had been utilized successfully in prior research [19-21]. Online baseline survey completion constituted consent for the survey only. Participants provided contact details at the end of the survey to indicate interest in app testing. Consent for app testing was by return email, with reminders sent to non-responders until recruitment and app allocation goals (at least 10 participants per app) were met. Ethics approval was provided by the Flinders University Social and Behavioral Research Ethics Committee (approval no. 8211).

App testing

Ten baseline questions modelled on the COM-B self-evaluation survey [22] exploring the perceived enablers of healthy food provision, were mapped to the apps for testing (see Multimedia Appendix 1). Participants were each assigned two of the five mobile apps for testing, based on their responses to the baseline questions. This allowed the allocation of apps on the basis of need. The allocation of two apps allowed participants to envisage how complementary content and features could be combined. Consenting participants were contacted via telephone or email for app allocation and set up, and emailed a checklist of tasks to complete in each app [21]. They were encouraged to use both of the apps as little or as much as they wished during the following 4 weeks.

Follow-up

At the completion of the 4-week app testing period, participants were emailed a link to the follow-up survey, with one to three reminder emails sent to non-responders. Following receipt of the follow-up survey, participants were contacted by telephone to conduct a semi-structured interview (until data saturation was reached). Participants involved in app testing were provided with a meal-kit or grocery voucher to the value of $85 AUD in compensation for their time.

Data collection

Baseline survey

Demographic survey items included parent age, gender, highest level of education, relationship status, household income, work hours, partner's work hours (if applicable), and the number and age of children in the household. Diet quality measures were adapted from the validated Short Food Survey [23], and included questions relating to fruit and vegetable (2 items) and discretionary choice intake (10 items). For discretionary choice items, frequency of consumption (i.e. daily, weekly, monthly) was followed by a question regarding the number of times it was usually consumed (e.g. twice, 3 times).

The 10 COM-B self-evaluation items (see Multimedia Appendix 1) were rated on a 7-point likert scale from strongly disagree (1) to strongly agree (7) [22]. Scores from the two items mapping to each app were summed, with participants allocated the two apps receiving the highest aggregate score. Where an app was not allocated to at least 10 participants, some participants were allocated these apps despite a lower COM-B score, to ensure that adequate data was collected for each app.

Follow-up survey

Frequency of app use was measured in the follow-up survey for each of the four weeks using a four-point response scale (i.e. 'didn't use the app', 'once', '2-4 times' and '5 or more times'). Duration of app use was measured using a three-point response scale (i.e. 'less than 1 minute', '1-5 minutes', 'more than 5 minutes'). The System Usability Scale (SUS), a brief scale of 10 statements covering the complexity or ease of use of apps, was used to assess usability [24, 25]. Participants indicated their agreement on a 5-point scale from strongly disagree (1) to strongly agree (5). User-perceived app quality was measured via the user version of the Mobile App Rating Scale (uMARS) [26]. The 16-items making up the engagement, functionality, aesthetics and subjective quality subscales were included in the present study [26].

The information quality sub-scale was replaced with an item regarding app credibility as the apps contained minimal information and credibility has been shown to be important to app engagement [20].

Semi-structured interviews

Semi-structured interviews were conducted by a female research assistant with qualitative research experience and a research focus on family meals. The research assistant had no prior contact with participants. Three of the interviews were conducted by CEM, including a pilot interview and the two final interviews. Interviews took between 30 and 60 minutes and were audio-recorded with the participants' permission, using a speaker phone and audio-recorder. Interviews were transcribed verbatim by an independent company.

Interview questions addressed app feature and content acceptability, engagement and use of the apps, usefulness in addressing food provision, improvements required, and general suggestions for future app development. Questions were repeated for each of the two apps allocated. Questions were tested with the research assistant and piloted with one participant. As interviews were conducted, CEM listened to the audio and discussed progress with the research assistant. Once data saturation for an app or app combination was reached, determined by no new information emerging, participants testing those apps were only asked to complete the follow-up survey. Single parents and parents of a lower income were prioritized for interview in order to represent as diverse a sample as possible.

Data Analysis

Quantitative data

Quantitative data were analyzed using SPSS Version 22 (IBM, United States). Parental work hours were converted from continuous variables into groups (i.e. part-time = 1 to <35hrs/wk, full-time = 35+ hours) and combined to describe the family work schedule. Discretionary items were summed as total serves per day using age and gender specific adjustment factors [27]. Demographic data, diet quality and COM-B self-evaluation items were presented descriptively (e.g. n(%), mean(SD), and median(IQR) for COM-B items due to a positive skew in the data).

Follow-up data regarding self-reported frequency and duration of app use were calculated by app and presented descriptively as n(%). SUS scores were converted to a score out of 100 [24], with the median (IQR) score of the sample presented, due to a positive skew in the data. A median score below 50 was indicative of poor app usability, 50 to 70 was marginal, above 70 passable, and above 90 superior [25]. Scores for uMARS items were summed and averaged for each subscale, and across all items for the overall uMARS score.

Qualitative data

Transcriptions were coded using NVivo (QSR International) and analyzed using a theoretical thematic approach [28]. Coding took an inductive approach, with interview data initially sorted into groups based on the study objectives, interview questions and app characteristics. Coding was conducted by CEM, who organized data into major and minor themes and generated an initial conceptual model [28]. A meeting between co-authors was undertaken to discuss and refine themes, after which the final conceptual model with links back to quantitative data was ascertained. When presenting interview results, names have been changed to preserve anonymity.

Results

Sample characteristics

Figure 1 describes participant flow through the study. Participants completing the baseline survey (N=133) were mostly partnered (92%, 122/133) females (98%, 130/133). Two thirds (68%, 90/133) of households included one full-time working parent, and one part-time working parent. In most households (80% 106/133) the youngest child was less than 2 years of age, and 62% (80/133) included more than one child. Only 7% (9/133) of participants met the Australian guidelines for vegetable intake, while most (80%, 107/133) met the guidelines for fruit intake. Participants reported consuming 3.0 (SD 2.1) discretionary choice serves per day, excluding alcohol (Table 2). Compared to the baseline sample, participants completing interviews were more likely to have a university degree (78% 28/36 vs 62%, 83/133), be unpartnered (14%, 5/36 vs 8%, 11/133) and have an income below $70k AUD per annum (25%, 9/36 vs 19%, 25/133) (Table 2).

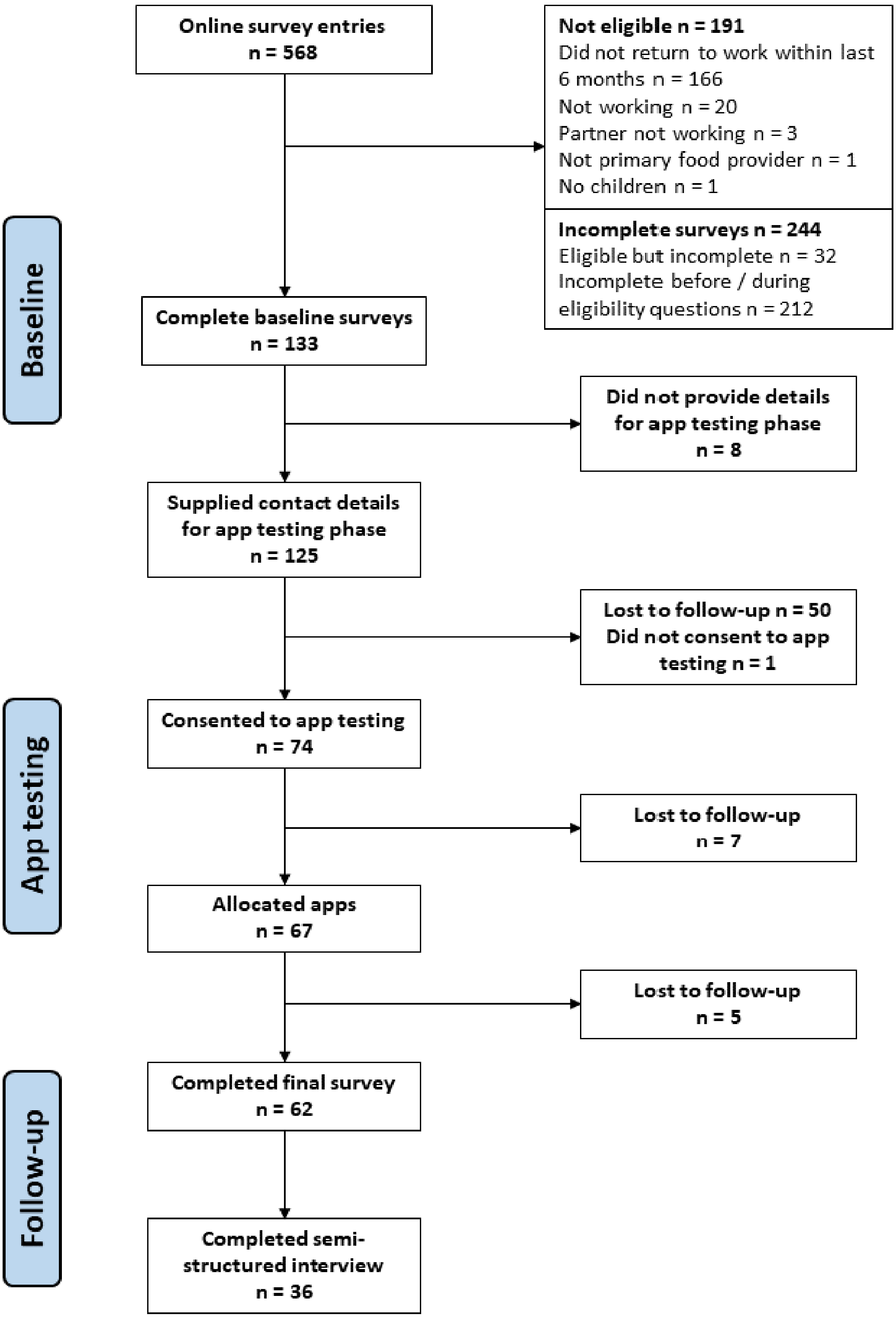

Figure 1. Flow of participants through the study

Table 2. Demographic characteristics of the survey sample at baseline, and the sample included in the qualitative analysis

Characteristic	Categories	Baseline survey data sample		Interview sub-sample	
		N	n (%) or mean (SD)	N	n (%) or mean (SD)
Age (years)		131[a]	33.8 (4.3)	36	33.6(4.3)
Gender	Female	133	130 (98)	36	35 (97)
	Male		3 (2)		1 (3)
Highest level of education	University	133	83 (62)	36	28 (78)
	No university		50 (38)		8 (22)
Relationship status	Partnered	133	122 (92)	36	31 (86)
	Single		11 (8)		5 (14)
No. of children	One child	130[a]	50 (39)	35[a]	13 (36)
	More than one child		80 (62)		22 (61)
Age of youngest child	Less than 2 years	133	106 (78)	36	29 (81)
	2-4 years		21 (16)		5 (14)
	5-12 years		6 (5)		2 (6)
Household income (gross per annum)	Less than $70k AUD	133	25 (19)	36	9 (25)
	$70k AUD or more		92 (69)		24 (67)
	Prefer not to say		16 (12)		3 (8)
Family work schedule	Both part-time	133	9 (7)	36	1 (3)
	Part-time & full-time		90 (68)		26 (72)
	Both full-time		23 (17)		4 (11)
	Single working parent		11 (8)		5 (14)
Vegetable intake (serves per day)	1 or less	133	26 (20)	36	8 (22)
	2-4		98 (74)		26 (72)

	5 or more		9 (7)		2 (6)
Fruit intake (serves per day)	Don't eat fruit	133	4 (3)	36	1 (3)
	1 or less		69 (52)		17 (47)
	2 or more		60 (45)		18 (50)
Discretionary intake (serves)[b]		118[a]	3.0 (2.1)	33[a]	3.0 (2.2)

a Numbers vary from 133 / 36 due to missing data
b Excluding alcohol

Table 3 presents the results of the COM-B self-evaluation items used to allocate apps. More than three quarters of participants suggested a need for more healthy recipes and meal ideas (82%, 109/133 agreed/strongly agreed, median 6 [IQR 6:7]) and time to plan, buy and prepare healthy meals (80% 107/133, median 6 [IQR 6:7]). Almost two thirds suggested a need for a better way of planning and recording meals and groceries (65% 87/133, median 6 [IQR5:6]), while food selection and cooking skills were not high priorities for this sample.

Table 3. COM-B self-evaluation item mean (SD) scores and proportion of sample responding agree or strongly agreed (N=133)

COM-B domain	COM-B item	Median (IQR) item score[a]	n (%) agreed/strongly agreed[b]
Capability	Have better food preparation and/or cooking skills	5 (3:6)	44 (33)
	Learn how to choose healthy food at the supermarket	5 (2:5)	30 (23)
	Learn how to plan healthy meals	6 (5:6)	72 (54)
Opportunity	Have more time to plan, buy and prepare healthy meals	6 (6:7)	107 (80)
	Have more healthy recipes and meal ideas	6 (6:7)	109 (82)
	Have guidance in choosing healthy food/meals	5 (4:6)	38 (29)
	Have a better way of planning and recording meals and groceries for the coming week	6 (5:6)	87 (65)
	Have more support or help from my partner/family	5 (4:6)	43 (32)
	Have more reminders to plan, shop or cook	5 (4:6)	43 (32)
Motivation	Have clear goals or plans toward preparing healthy meals	6 (5:6)	76 (57)

a 1 = strongly disagree to 7 = strongly agree
b Score of 6 or 7 (agreed / strongly agreed)

Follow-up data / interview data

Of the 67 participants allocated apps, 62 completed the follow-up survey, and 36 completed interviews (see Figure 1). Amongst those completing interviews, there were nine different combinations of apps allocated. The most common sets of apps allocated were the recipe manager and family organizer (n=7) or meal planning app (n=6), and the barcode scanning and recipe app (n=6). Figure 2 demonstrates the conceptual model of major and minor themes emerging from the semi-structured interviews and Table 4 provides examples of quotes relating to each sub-theme.

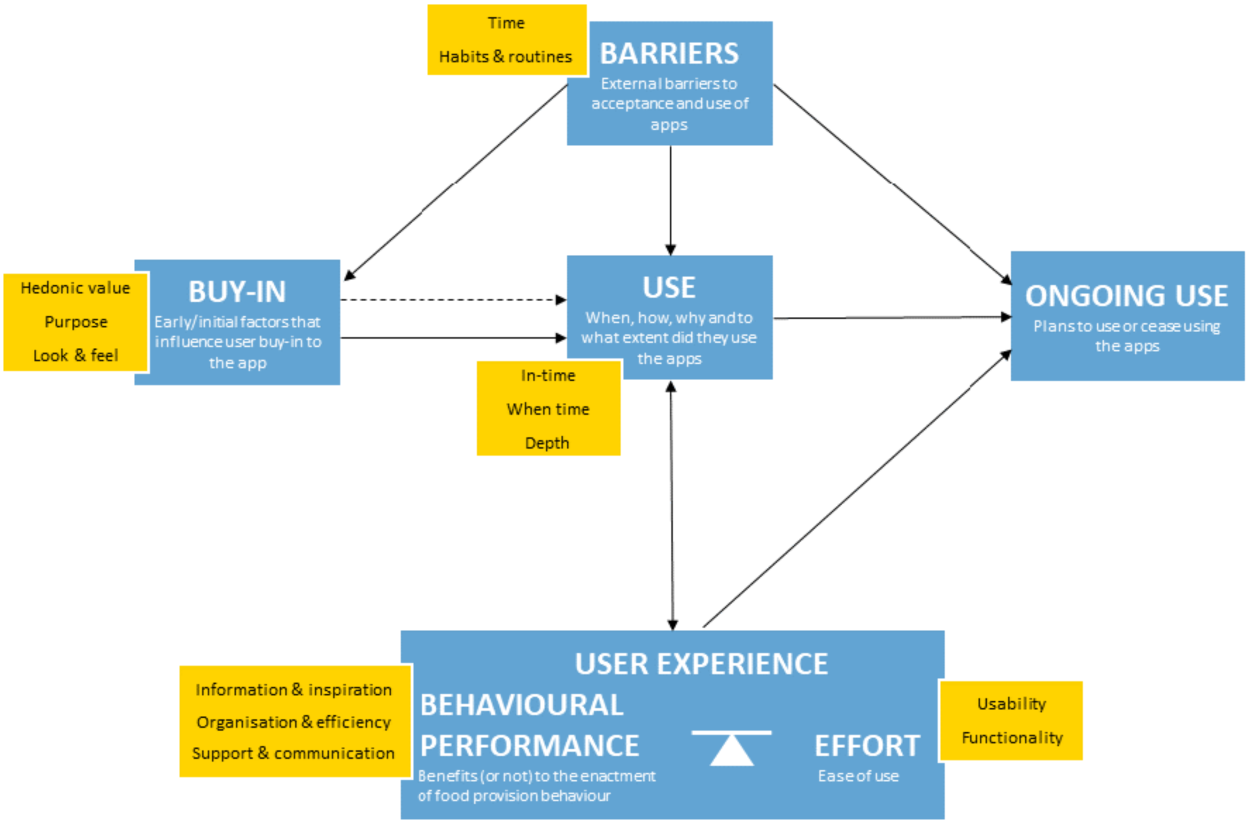

Figure 2. Conceptual diagram of major (blue) and minor themes (yellow) and how these may relate to ongoing use or disengagement with the app(s)

Table 4. Participants perspectives of app utility and acceptability, and their engagement with apps: major and minor themes, and illustrative quotes

Major theme	Minor theme	Illustrative quotes
Buy-in	Purpose	"(…) for probably what I was looking for which was meal planning, [meal planning app] was more appropriate." Mia, working 1 to <21 hrs/wk "…I think, it had a big overarching purpose but lots of, like, little purposes in there that just, kind of meant that you had to wade through more stuff to figure out what you wanted to use it for." Jo, working 21 to <35 hrs/wk
	Hedonic value	"…I hadn't even, um, really thought about the fact that there were apps out there to support with meal prep and healthy eating and all of that…" Harper, working 21 to <35 hrs/wk "…I didn't want to use the app. (…) I wasn't excited by it." Sophie, working 21 to <35 hrs/wk
	Look & feel	"…you'd like trust and you feel comfort in knowing that, you know, it just feels like a team of people has worked behind it…" Tiffany, working 21 to <35 hrs/wk
Use	In-time	"So we would (…) decide on the meals (…) then I would go grocery shopping (…) then I would put it away until I needed to cook every night." Blair, working 21 to <35 hrs/wk
	When-time	"…when the kids were sort of asleep (…) just looked up some recipes and that type of thing so – 'cause I just had some time to actually do it." Dianne, working 1 to <21 hrs/wk
	Depth	"I don't think I was even aware of it. (…) I don't think I even found that function." Bianca, working 21 to <35 hrs/wk
Barriers	Time	"I think, real or just perceived, I think, that's a, um, a time issue, I feel, like, (…) there's other things I should be doing…" Cora, working 21 to <35 hrs/wk
	Habits & routines	"… the app can be as brilliant as it is but if I'm not going to actually actively go out of my way to build that habit, (…) it's only as good as I'm going to make it." Sophie, working 21 to <35 hrs/wk "…I actually ended up changing jobs, like, right in the middle of, um, trialing the app. (…) I tried to settle back to just doing what was easy…" Harper, working 21 to <35 hrs/wk
User experience – Behavioral performance	Information & instructions	"…if I was, you know, tired or whatever, I might just turn to a freezer meal (…) whereas this kind of made me think, like making it from scratch and like, still find easy ways to get, you know, vegetables into my kids" Kathryn, working 1 to <21 hrs/wk

		"…aligned to the Australian (…) food guidelines (…) helping me, um, tick off how many serves I'm getting in each meal, something like that would be a nice bonus." Blair, working 21 to <35 hrs/wk
	Organization & efficiency	"…having the plan there it, sort of, I mean, it almost makes you more accountable (…) it really cuts out the excuses of, oh, I'm tired, we're running late, let's get a pizza." Cora, working 21 to <35 hrs/wk "Like, it took away the decisions, decisions I had to make, I think, I had already made them, and then, I didn't need to stress about it, basically." Blair, working 21 to <35 hrs/wk "Here's the recipe (…) adjust your shopping list (…) go through the, your supermarket of choice, get it delivered when you want, done." Fae, working 21 to <35 hrs/wk
	Support & communication	"…it would definitely be accessible across multiple devices. Um, so, you know, that, like, that everyone who's old enough and interested, in the family could contribute. (…) he wouldn't be constantly asking me every day, "What's for tea tonight?"" Brianna, working 35+ hrs/wk
User experience – Effort	Usability	"It's quick for meals and then the grocery, and then it comes up with a list and then you can cook it so that's what I like about it." Fae, working 21 to <35 hrs/wk
	Functionality	"I liked how it had allergies and ingredients that you liked and you disliked and how it had meal sizes, meal servings (…) you could really, like, make it for your family…" Fae, working 21 to <35 hrs/wk
Ongoing use		"…at least like once a week when I, because I do my grocery shopping usually once a week. So I'll probably sit down the night before and, you know, meal plan what we're going to have for that week." Kathryn, working 1 to <21 hr/wk "…I would do another week every couple of months on it when I was looking for inspiration." Lana, working 35+ hrs/wk

Buy-in

Early impressions of the apps appeared to be key to user buy-in and subsequent use. The alignment or fit of the apps purpose with participants self-identified needs was a sub-theme contributing to app buy-in. The clarity of the purpose of the app was equally important, with participants suggesting that an unclear or vague purpose was a turn-off. Although trying to do too much or serve too many purposes was equally problematic.

The look and feel of the apps was also important for buy-in and used to judge credibility and trustworthiness. The aesthetics quality subscale score of the uMARS aligned well with interview data, with the more visual apps (i.e. the recipe app, meal planning app and barcode scanning app) scoring higher on the subscale. The same three apps ranked the highest for perceived credibility (Table 5).

Table 5. Mean (SD) uMARS subscale scores, subjective quality score and total score by app (n=62)

		Subscale score[b]				Total uMARS score[b]	Subjective quality score[b]
App	n[a]	Engagement	Functionality	Aesthetics	Credibility		
Meal planning app	35	3.5 (0.5)	4.2 (0.5)	4.1 (0.6)	4.0 (0.8)	3.9 (0.5)	3.0 (0.9)
Recipe manager app	32	3.0 (0.7)	3.7 (0.9)	3.4 (0.6)	3.8 (0.8)	3.5 (0.6)	2.7 (1.1)
Recipe app	29	3.7 (0.6)	4.2 (0.6)	4.3 (0.5)	4.1 (0.7)	4.1 (0.4)	3.1 (0.9)
Barcode scanning app	12	3.6 (0.7)	4.2 (0.6)	4.0 (0.7)	4.3 (0.8)	4.0 (0.6)	3.4 (1.0)
Family organizer app	12	3.4 (0.8)	3.8 (0.7)	3.8 (0.7)	3.6 (0.5)	3.6 (0.6)	2.7 (1.1)

a n=4 participants completed the uMARS for only one app, due to a lack of use of the second app
b Scores range from 1 (low quality) and 5 (high quality) of subscales and for total score / subjective quality score

The hedonic value of apps, or the pleasure associated with their use, played a role in app buy-in. Novelty was important for some participants, who referred to apps as clever or different to what they were used to. However the lack of pleasure associated with use of these apps was an issue, particularly for those apps with little content. Two of the five engagement subscale items of the uMARS relate to the hedonic value of apps, namely the entertainment and interest qualities. Overall, the engagement subscale was the lowest scoring quality of the apps (Table 5), with the high input, low content apps again scoring the lowest on this domain.

Use

More participants reported using the apps at least once in the first week than in subsequent weeks (see Multimedia Appendix 2). The barcode scanning app was used most frequently over the testing period, with at least 7 of 12 participants allocated the app using it at least 2-4 times per week. Nine of the 12 users reporting spending 1-5 minutes at a time on the app. There was a rapid drop-off in use of the family organizer after the first week. There was also some decline in use of the meal planning app over time, however it was used for more than 5 minutes on each occasion by more than 22 of the 35 users.

Participants description of the timing and context in which they used the apps led to two key sub-themes, in-time and when-time. In-time use of apps, whilst planning meals, shopping or cooking, was purposeful or planned, and undertaken in order to achieve a task. When time use tended to be exploratory and took place in spare moments when it was convenient to do so. This use appeared to be for information or inspiration seeking, as opposed to functional tasks.

Another sub-theme of app use was the depth to which participants used the apps. During discussions of app features, some participants described not exploring the apps deeply enough to have knowledge of their content, features and functionality. This may have impacted upon participant perception of app utility, as some even described wanting features that were already present in the apps.

Barriers

Participants described external barriers impacting upon their acceptance and use of the apps, and on their ability to incorporate the apps as new behavioral strategies for food provision. Participants reported time scarcity as a barrier to app use, while others suggested they had more important priorities than using an app or changing their food provision behavior. Existing habits were also a key barrier to participants willingness and ability to use the apps. If participants already had established food provision habits, such as already planning meals in advance or writing a paper-based shopping list, they found it difficult to see the relevance of the app to them. Habits were described as difficult to change, with the formation of new habits with apps being seen as challenging. Sticking with recipes that are tried and tested tended to be the key fall back when there were major disruptions to their routine, such as a change of job.

User experience

Participant experience with the apps was organized under two major themes – the behavioral performance of the apps and the effort associated with use. Behavioral performance encompassed the contribution apps made to the performance of food provision behaviors, whilst effort referred to their ease of use and functionality. These aspects of the apps were weighed up against one another in determining app acceptability.

Behavioral performance

Participants found recipe content useful in providing inspiration for meals and encouraging variety. Some felt that this inspiration led to positive dietary change. Conversely, many felt that the recipes should be better tailored to families with young children, and include practical nutrition information focused on national guidelines. The barcode scanning app was found to be helpful for food selection, however only a relatively small sample indicated a need for such support.

The organization and efficiency aspects of the meal planning app and the recipe manager app were generally found to be positive, with participants discussing planning ahead, being prepared and feeling organized. Participants found automation features, such as automated shopping list generation useful. Planning was reported to reduce last minute decision making and shopping, and increase accountability. However, for those participants that already considered themselves planners, the apps were simply described as an alternative tool to utilise when undertaking established behaviors. A suggestion for enhancing the efficiency of the apps with automated shopping list generation was to integrate the shopping list with online shopping, allowing the completion of the process from planning to purchasing.

Support and communication features were mainly found in the family organizer app, which was not well accepted by study participants due to a perceived lack of relevance to families with young children. Regardless, around half of the sample were interested in syncing between devices so that other family members could contribute to food provision-related tasks.

Effort

Ease and simplicity of use was referred to in relation to the meal planning app, barcode scanning app and recipe app. The SUS scores aligned well with this finding, with the same three apps scoring above 70 (median[IQR] SUS score: meal planning app 78[68:88], barcode scanning app 79[56:90] and recipe app 80[58:89]) indicating a passable level of usability. The recipe manager app was also deemed to be passable (scoring 75[54:86]) despite receiving mixed reviews during the interviews. Conversely, the usability of the family organizer app was deemed poor (48[34:73]). Reasons provided during the interviews for finding the meal planning app, barcode scanning app and recipe app particularly easy to use was that they were more intuitive, self-explanatory and required very little input from the user. Participants also spoke about the accessibility and convenience of the technology and the streamlining of processes.

The functionality sub-theme of effort described the functioning of particular features of the apps. Participants liked the personalisation aspects of the apps, from modifying portion sizes to filtering recipes according to dietary requirements. Some participants suggested that the inclusion of recipe importing (a feature of the recipe manager app) in the meal planning app would enhance personalisation of content further. Similarly, although participants liked the automatic generation of lists, they preferred those that they could personalize or modify to their needs. While a major limitation reported by participants' regarding the barcode scanning app was the inability to utilise it whilst shopping online.

Ongoing use

Most participants reported that they would aim to use at least one of the apps periodically into the future, as required or when they had time. Those that found the apps particularly useful were clearer about their planned future use, while some articulated specific plans around further utilising the apps in different or extended ways.

Discussion

Summary of key findings

This study aimed to assess the feasibility of existing commercially available apps in supporting working parents to plan, purchase and prepare healthy family meals. Apps tested were found to enable in-time planning behavior, promoting organization and efficiency in the food provision processes. The effort involved in using these apps was a key influence on acceptability, and was weighed up against the perceived benefits of the apps. The balance between these two factors appeared to be key to the usefulness of these apps as tools to support food provision. The lack of family friendly recipe and nutrition content was a limitation to the utility of the apps in this sample of parents.

App utility

Organization resulting from planning features was perceived to reduce the time burden of food provision, confirming findings from a prior review of commercial apps [14]. Planning strategies for managing food provision were found to be used by working mothers experiencing time scarcity in qualitative research [29]. These same strategies have also been associated with a higher intake of vegetables and fruit in Australian women [30]. However planning may be challenging for those with less predictable work schedules, different family structures [31] and in those who are less inclined to plan [29]. Automated and streamlined planning features such as the generation of shopping lists from meal plans and recipes might make these apps more widely accepted and appealing even to the non-planner.

The use of planning features in-time, when food provision tasks were being undertaken, suggested that food provision apps are well placed to deliver support and content in-time and context [32]. Ecological Momentary Interventions (EMI) support individual behavior in everyday life outside of the research or clinic setting [13]. Evidence for EMI's in the app-based nutrition space is limited [32, 33], with the vast majority of research describing in-time dietary monitoring, assessment and feedback [34-36]. The integration of these apps into daily life may be key to their ability to modify or support behavior.

Inspiration was the main sub-theme arising from discussions regarding the apps with recipe content. Research investigating parental preferences for a food provision program targeting young children found that higher income, older and partnered participants were interested in creative cooking without recipes [37]. The present sample was similarly biased, perhaps explaining their use of recipe content for inspiration. Although the lack of family friendly recipes (i.e. recipes that are acceptable to children and adults alike) may have limited parents ability to use the recipes for anything other than inspiration.

Participants aptly suggested the need for more explicit nutrition content, such as serve based information linked to recipes. Prior work investigating parental preferences for an eHealth family healthy lifestyle program similarly found that parents preferred more practical nutrition information such as healthy portion sizes and recipes [38]. These findings suggest that although these apps may be able to capable of supporting the behavioral performance of food provision processes, their lack of practical nutrition content was a limitation to their utility in families in their present state.

App acceptability

Engagement and quality

Relatively few participants used the apps consistently and to the full extent intended in allocating them. Barriers to buy-in and use included time scarcity and existing habits. Time scarcity is a commonly cited barrier to healthy food provision behaviors [11, 12]. It is therefore unsurprising that time could also act as a barrier to the uptake of new digital solutions to food provision, especially when the use of such technology requires the formation of new habits [39]. Existing food provision habits are formed with repetition and practice, and can be difficult to break, particularly in a stable environment [40]. Prior research has similarly found that time and habits were key barriers to food provision behaviors and uptake of a meal planning app targeting low-income parents [41]. Aligning app use with everyday food provision tasks (such as meal planning), automation of key features and integration with services such as online shopping may alleviate the time burden of app use itself. Whereas positioning food provision apps as tools to support the maintenance of healthy habits during times of stress or disruption may reduce the need for new habit formation.

Consistent with prior work [14, 42], engagement quality was the lowest scoring uMARS subscale, particularly in those apps with minimal existing content. This is concerning, as user engagement is a major challenge to the efficacy and longevity of mHealth interventions [9]. The novelty of the apps was positive, as it is thought to play an early role in the hedonic value of technology [39]. Although familiarity with technology tends to reduce the pleasure derived from its novelty [39], speaking to the need for other qualities to promote ongoing engagement. As the enjoyment or pleasure associated with use of technology has been shown to be important to the usability, acceptance and use of apps [39, 43], enhancing this aspect should be a key consideration in the future. Features such as gamification might achieve this.

Usability and functionality

Participants in the present study weighed up the behavioral performance of the apps against the effort required to make use of them, with effort reflecting aspects of usability and functionality. According to the consumer version of the Unified Theory of Acceptance and Use of Technology (UTAUT2), the effort involved in technology use is thought to be a key predictor of intention to use, acceptance and actual use of technology [39]. Furthermore, the level of effort or the process involved in using technology may be more important to women [39], who made up the majority of participants in the present work. The greater acceptance of the apps requiring less user input suggests the need for careful consideration of the balance between effort and behavioral performance in future app development. This finding further strengthens the case for automated features and integration of apps with daily life, which has been shown to be a high priority for both digital health experts and consumers in addressing the usability of health-related apps [43].

Context and need

The present sample of parents identified a need for information in the form of healthy recipes and meal ideas, and for ways to reduce the time burden of food provision, rather than for support with food choice or food preparation skills. This may reflect the higher income and education level of the sample, which has been previously associated with greater food and nutrition knowledge, skills and confidence [44, 45]. A discrete choice experiment showed that older, higher income, partnered parents had a preference for meal planning and time-saving strategies, while younger, lower income, single parents preferred support with healthy cooking and nutrition [37]. Future research in households where needs are different could consider apps and app features that were less represented in the present work (e.g. apps focused on nutrition information and food preparation skills).

Strengths and limitations

Although this study does not assess dietary behavior change resulting from the use of these mobile apps, it does provide early evidence to support future app development and testing. This study's strength was in its mixed methods approach, including the allocation of apps based on need and the incorporation of rich qualitative data triangulated with quantitative findings. However, despite allocating apps according to need, they were not always deemed relevant or suitable. Parents testing the family organizer app felt that it was not relevant to families of young children, therefore the feedback regarding this app should be taken with caution. There were also limitations with regards to the sample population that may limit the generalizability of the findings. The sample was typically of high socioeconomic status, which may have led to a homogeneity in the results. However, effort was made to incorporate the voices of single parents and parents of lower socioeconomic status in the results. Irrespective of this sample bias, the vegetable, fruit and discretionary choice intake of the study sample reflected the eating habits of the broader Australian population [46, 47]. The present sample would therefore benefit from food provision related support much the same as the broader Australian population.

Implications for practice and future research

The behavior change potential of food provision apps may lie in their ability to be integrated into everyday life, promoting healthy food provision in-time and context. Meal planning apps with automated planning and shopping list preparation, and integration with online shopping and between users, may provide the nexus between dietary guidelines and healthy food provisioning, and enable planning behavior in those less inclined to plan.

Conclusion

This study has provided insights into the role of mobile apps in supporting parents to achieve healthy food provision in a whole of family context. Meal planning apps and features promoting organization present feasible, time saving solutions to supporting healthy food provision practices. The balance between effort and outcome should be at the core of app development in the future to ensure that the time burden of the technology itself does not outweigh the time saved in food provision processes. Attention must also be paid to the recipe and nutrition content, and engagement qualities of apps to ensure that they meet the needs of families whilst promoting positive behavior change.

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CEM led the study design, under the supervision of RAL, TPW, and RKG, and in consultation with IP and AJM. CEM conducted the research, with all co-authors contributing to the interpretation of results. CEM drafted the manuscript, with all co-authors reviewing drafts and reading and approving of the final manuscript.

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Conflicts of Interest

None declared

Abbreviations

BCTs: Behavior Change Techniques
COM-B: Capability, Opportunity, Motivation, Behavior model
SUS: System Usability Scale
uMARS: user version of the Mobile App Rating Scale
UTAUT2: consumer version of the Unified Theory of Acceptance and Use of Technology

Multimedia Appendix 1: Mapping of apps to COM-B items

Multimedia Appendix 2: Frequency and duration of app use

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APPENDIX 10: DETAILED SUMMARY TABLES OF APPS SELECTED FOR TESTING

Table 1: App information and MARS scores of the five tested apps

		Target behaviours				MARS app quality rating[a]				
App description	**App pricing structure**	**Meal planning**	**Food purchasing**	**Meal preparation**	**Food choice**	**Engagement**	**Functionality**	**Aesthetics**	**Information quality**	**MEAN score**
Recipe app	Free		X	X		3.6	4.5	5.0	3.5	4.2
Recipe manager app	Freemium	X	X	X		2.6	4.0	4.0	4.0	3.7
Meal planning app	Freemium	X	X	X		4.0	4.0	4.7	4.0	4.2
Family organiser app	Free		X	X		4.0	4.0	4.7	4.0	4.2
Barcode scanning app	Free		X		X	3.6	4.5	3.0	4.5	3.9

[a] Range 1-5, 5 indicating a higher quality app

Table 2: Features and content of the five tested apps

	BEHAVIORAL SUPPORT CONTENT AND FEATURES																			TECHNICAL FEATURES						
App description	**Food preparation skills instructions**	**Food purchasing info**	**Recipe nutrition info**	**Produce storage info**	**Produce nutrition info**	**Other nutrition info**	**Recipes**	**Recipe managers**	**Food purchase & delivery**	**Shopping list**	**Pantry / fridge**	**Reminders & prompts**	**Social community / connectivity**	**Other social supports**	**Meal planners & meal plans**	**Encouragement & incentives**	**User / family profile**	**Personalisation**	**Practical features**	**Miscellaneous & optional purchases**	**Search & display options**	**Other input options**	**Requires login**	**Web access required**	**Syncing between devices**	**Cloud back-up**
Recipe app	X		X	X	X		X			X(a)			X	X	X	X		X	X				X	X		
Recipe manager app							X	X(a)		X(a)				X	X			X			X			X		
Meal planning app							X			X(a)				X	X		X	X	X		X		X	X	X	
Family organiser app										X(a)		X		X		X	X				X	X	X	X	X	X
Barcode scanning app					X					X(m)				X							X	X		X[a]		

(a) = autopopulated e.g. recipe content clipped from the web, ingredients from recipes sent to shopping list; (m) = manual data input by text, image, barcode
a Required for emailing, sharing, syncing and/or cloud back-up only

Table 3: Behaviour Change Techniques of the five tested apps

App description	1.1 Goal setting (behaviour)	1.4 Action planning	2.3 Self-monitoring of behaviour	3.1 Social support (unspec)	4.1 Instruction on how to perform behaviour	5.3 Info about social & enviro consequences	5.6 Info about emotional consequences	6.1 Demonstration of the behaviour	6.2 Social comparison	7.1 Prompts/cues	8.2 Behavioural substitution	10.3 Non-specific reward	10.6 Non-specific incentive	12.5 Adding objects to the environment	14.1 Behaviour cost	TOTAL
Recipe app					X			X	X					X		4
Recipe manager app	X	X			X									X		4
Meal planning app	X		X	X	X	X	X							X		7
Family organiser app	X	X	X	X		X				X		X	X	X	X	10
Barcode scanning app											X			X		2

APPENDIX 11: ETHICS APPROVAL NOTICE

From: Human Research Ethics
To: Chelsea Mauch; Rebecca Golley
Subject: 8211 SBREC final approval notice (11 December 2018)
Date: Tuesday, 11 December 2018 3:04:22 PM

Dear Chelsea,

The Deputy Chair of the Social and Behavioural Research Ethics Committee (SBREC) at Flinders University considered your response to conditional approval out of session and your project has now been granted final ethics approval. Your ethics approval notice can be found below.

APPROVAL NOTICE

Project No.:	**8211**
Project Title:	Mobile apps to support healthy evening meal provision in working families: a feasibility study
Principal Researcher:	Ms Chelsea Mauch
Email:	chelsea.mauch@flinders.edu.au
Approval Date:	11 December 2018
Ethics Approval Expiry Date:	**31 December 2020**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided with the addition of the following comment(s):

Additional information required following commencement of research:

1. Permissions
   Please ensure that copies of the correspondence granting permission to display recruitment flyers, from relevant Private Child Care providers; and from the Deputy Vice-Chancellor (Research) Flinders University, are submitted to the Committee *on receipt.* Please ensure that the SBREC project number is included in the subject line of any permission emails forwarded to the Committee. Please note that data collection should not commence until the researcher has received the relevant permissions (item D8 and Conditional approval response – number 4, and Conditional approval response-additional information number 1).

RESPONSIBILITIES OF RESEARCHERS AND SUPERVISORS

1. Participant Documentation
Please note that it is the responsibility of researchers and supervisors, in the case of student projects, to ensure that:

- all participant documents are checked for spelling, grammatical, numbering and formatting errors. The Committee does not accept any responsibility for the above mentioned errors.

- the Flinders University logo is included on all participant documentation (e.g., letters of Introduction, information Sheets, consent forms, debriefing information and questionnaires – with the exception of purchased research tools) and the current Flinders University letterhead is included in the header of all letters of introduction. The Flinders University international logo/letterhead should be used and documentation should contain international dialling codes for all telephone and fax numbers listed for all research to be conducted overseas.
- the SBREC contact details, listed below, are included in the footer of all letters of introduction and information sheets.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project Number 'INSERT PROJECT No. here following approval'). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on 8201 3116, by fax on 8201 2035 or by email human.researchethics@flinders.edu.au.

2. Annual Progress / Final Reports

In order to comply with the monitoring requirements of the *National Statement on Ethical Conduct in Human Research (2007-Updated 2018)* an annual progress report must be submitted each year on the **11 December** (approval anniversary date) for the duration of the ethics approval using the report template available from the Managing Your Ethics Approval SBREC web page. *Please retain this notice for reference when completing annual progress or final reports.*

If the project is completed *before* ethics approval has expired please ensure a final report is submitted immediately. If ethics approval for your project expires please submit either (1) a final report; or (2) an extension of time request and an annual report.

Student Projects

The SBREC recommends that current ethics approval is maintained until a student's thesis has been submitted, reviewed and approved. This is to protect the student in the event that reviewers recommend some changes that may include the collection of additional participant data.

Your first report is due on **11 December 2019** or on completion of the project, whichever is the earliest.

3. Modifications to Project

Modifications to the project must not proceed until approval has been obtained from the Ethics Committee. Such proposed changes / modifications include:

- change of project title;
- change to research team (e.g., additions, removals, principal researcher or supervisor change);
- changes to research objectives;
- changes to research protocol;
- changes to participant recruitment methods;
- changes / additions to source(s) of participants;
- changes of procedures used to seek informed consent;
- changes to reimbursements provided to participants;
- changes / additions to information and/or documentation to be provided to potential participants;
- changes to research tools (e.g., questionnaire, interview questions, focus group questions);
- extensions of time.

To notify the Committee of any proposed modifications to the project please complete and submit the *Modification Request Form* which is available from the Managing Your Ethics Approval SBREC web page. Download the form from the website every time a new modification request is submitted to ensure that the most recent form is used. Please note that extension of time requests should be submitted prior to the Ethics Approval Expiry Date listed on this notice.

Change of Contact Details

Please ensure that you notify the Committee if either your mailing or email address changes to ensure that correspondence relating to this project can be sent to you. A modification request is not required to change your contact details.

4. Adverse Events and/or Complaints

Researchers should advise the Executive Officer of the Ethics Committee on 08 8201-3116 or human.researchethics@flinders.edu.au immediately if:

- any complaints regarding the research are received;
- a serious or unexpected adverse event occurs that effects participants;
- an unforeseen event occurs that may affect the ethical acceptability of the project.

Kind regards
Wendy Green

On behalf of Andrea Mather

Ms Andrea Mather (formerly Fiegert) **and Ms Rae Tyler**
Ethics Officers and Executive Officers, Social and Behavioural Research Ethics Committee

Ms Andrea Mather | Monday - Friday	T: +61 8201-3116 | E: human.researchethics@flinders.edu.au
Ms Rae Tyler | Monday, Wednesday and Friday mornings	T: +61 8201-7938 | E: human.researchethics@flinders.edu.au
A/Prof David Hunter | SBREC Chairperson	T: +61 7221-8477 | E: david.hunter@flinders.edu.au
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SBREC Website	Social and Behavioural Research Ethics Committee (SBREC)

Research Development and Support | Union Building Basement
Flinders University
Sturt Road, Bedford Park | South Australia | 5042
GPO Box 2100 | Adelaide SA 5001

APPENDIX 12: BASELINE SURVEY

Mobile apps for family meals study - Baseline survey

Landing page:
Thank you for your interest in our study exploring mobile apps for supporting healthy meals in working families.
This study is being conducted in two parts:

1. An initial survey (which follows this introduction)
2. A 4 week period where you will be asked to test mobile app(s), followed by a final online survey and telephone interview

This survey will take around 20 minutes to complete. Completing the survey only indicates your consent to the first stage of the study (the initial survey), and not the app testing stage of the study.

If you are interested in participating in the second stage of the study, please provide your name, email address and phone number at the end of the survey. We will then contact you with further details and a consent form to complete regarding the second stage of the study.
Please read the following information prior to completing the survey.

Participant information sheet (for all participants completing baseline survey):

INFORMATION SHEET
(for *all participants*)

Title: 'Mobile apps for family meals'

Researcher(s)

Mrs Chelsea Mauch
College of Nursing and Health Sciences
Flinders University
Tel: 8204 7075
Email: chelsea.mauch@flinders.edu.au

Professor Anthony Maeder
College of Nursing and Health Sciences
Flinders University

Dr Ivanka Prichard
College of Nursing and Health Sciences
Flinders University

Supervisor(s)

Associate Professor Rebecca Golley
College of Nursing and Health Sciences
Flinders University
Tel: 8201 5596

Dr Tom Wycherley
School of Health Sciences
University of South Australia

Dr Rachel Laws
School of Exercise & Nutrition Science
Deakin University

Dr Lucinda Bell
College of Nursing and Health Sciences
Flinders University

Description of the study
This study is part of the project titled 'Mobile apps for family meals'. This project will investigate the use of mobile apps to support working parents in planning, purchasing and preparing healthy meals. This project is supported by Flinders University, College of Nursing and Health Sciences.

Purpose of the study
This project aims to find out what working parents think of the usability, quality, and acceptability of a series of mobile apps found in commercial app stores. We also want to know when, how and in what situations parents use these apps, and if they find them useful in supporting them plan, purchase and prepare healthy meals.

What will I be asked to do?
You are invited to complete an online survey to find out about you and your family, how you currently manage the planning, purchasing and preparation of family meals, and what you think might make it easier to provide healthy meals to your family. We will use this information to choose some apps for you to test. At the end of the survey, you will be asked to provide your name, email address and phone number so that we can send you detailed information about the app testing stage of the study, and get your consent to be involved. Participation in any stage of this study is entirely voluntary.

Once you have provided consent to the app testing stage of the study, we will contact you by telephone to provide you with one to two mobile apps which we will ask you to use as you desire for a period of 4 weeks.

At the end of the 4 weeks, we will email you a link to a final survey, and contact you by telephone for an interview to find out what you thought of the app(s). The interview will take about 45 minutes. The interview will be audio recorded using a digital voice recorder to help with reviewing the results. Once recorded, the interview will be transcribed (typed-up) and stored as a computer file.

What benefit will I gain from being involved in this study?
The sharing of your experiences with the apps will help us to develop more effective apps for supporting healthy eating in families in the future. You will be able to keep the apps we provide you, and may find them useful in planning, preparing and purchasing meals for your family.

Will I be identifiable by being involved in this study?
In order to contact you to get your consent to the study, to provide you with the apps, and to conduct the interview, we will need your name and contact details. However, any identifying information will be removed and stored separately from your data once the study is complete, and your comments in the interview will not be linked directly to you. All information and results obtained in this study will be stored in a secure way, with access restricted to relevant researchers. You are also welcome to complete the initial survey anonymously, without providing your name and contact details, however this will exclude you from the app testing period.

Are there any risks or discomforts if I am involved?
We anticipate minimal risk from your involvement in this study, however, you may experience some discomfort in answering questions relating to personal information and how you manage the daily tasks of providing food to your family in the first survey. If any discomfort is experienced, you may choose not to answer those questions, or alternatively, contact the service listed below. If you have any concerns regarding anticipated or actual risks or discomforts, please raise them with the researcher.

Beyond Blue provides support for people experiencing depression and anxiety. Call 1300 224 636 or visit https://www.beyondblue.org.au/ for advice and support that may be accessed free of charge by all participants.

We also acknowledge that involvement in the app testing stage of the study will take some time, and we will compensate you for this burden as described below.

How do I agree to participate?
Participation is voluntary. You may refuse to answer any questions in the surveys or interview, and you are free to withdraw from the study at any time without effect or consequences. Completion of the following online survey does not imply that you have consented to being involved in the app testing and final survey / interview. We will send you further information and a consent form to sign and return only if you provide your details at the end of the survey.

Recognition of contribution / time / travel costs
If you choose to participate in the app testing stage of the study, in recognition of your contribution and time, you will be provided with a meal kit valued at $84, which is equivalent to two dinners for a family of four. Delivery of the meal kit will be arranged following the final interview.

How will I receive feedback?
On project completion, outcomes of the project will be given to all participants via email.

Thank you for taking the time to read this information sheet, and we hope that you will accept our invitation to be involved. Please click next to proceed with the survey.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number: 8211).

For more information regarding ethical approval of the project only, the Executive Officer of the Committee can be contacted by telephone on (08) 8201 3116, by fax on (08) 8201 2035, or by email to human.researchethics@flinders.edu.au

Eligibility screen:
The following questions will make sure that you are eligible for the study:
Please do not use the 'back' or 'forward' buttons in your browser, instead, use the buttons at the bottom of each screen.

Are you currently in paid employment? Y / N

Have you (or your partner) been on a period of parental leave (paid or unpaid) and returned to work within the last 6 months? Y / N

If you are in a relationship (married / defacto), is your partner also currently in paid employment? Y / N / N/A – I am a single parent

Are you the main person responsible for food provision in the household (i.e. planning meals, purchasing food, preparing meals)? Y / N

Do you own an Apple or Android mobile device (such as a smartphone, iPad or tablet) with internet access? Y / N

If answer N to any of the above questions:

Thank you for your interest in the Mobile apps for family meals study. Based on your previous response, you are not eligible for our study.

Would you like to be contacted about other opportunities to be involved in our research into apps for family meals?

Yes – please provide your name, phone number and email address.
No

Food management and coping strategies:
First, we would like to know about how you manage the process of planning, purchasing and preparing meals for your family, and any strategies you use to cope when you are busy. Take as long as you need to complete the questions. Remember that your answers will be kept confidential, and will only be used for research purposes.

1. Please indicate how much you agree with the following statements:

1 = Strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree

   a. I feel very competent in planning my families meals
   b. I feel very competent in choosing healthy and nutritious foods at the supermarket
   c. I feel very competent in cooking for my family

2. How often do you do the following?

1 = never, 2 = rarely, 3 = once per month, 4 = 2-3 times per month, 5 = once a week, 6 = more than once a week

a. Eat in a family restaurant / pub
b. Eat in a fast-food restaurant
c. Use delivery or quick take-away services
d. Buy convenience foods (such as frozen or pre-prepared meals)

3. How often do you do the following?

1 = Never, 2 = rarely, 3 sometimes, 4 = about half the time, 5 = most of the time, 6 = always

a. Plan meals in advance
b. Make / use a shopping list
c. Prepare meals with only a few ingredients
d. Prepare meals in advance
e. Double recipes, so that I have leftovers
f. Use online shopping
g. Use a meal kit delivery service
h. Use canned or frozen products in my cooking
i. Share responsibility with other family members for planning, shopping and cooking meals (moved from question 2 above)

4. Do you currently use any apps or websites that help you to plan, purchase and/or prepare meals for your family?
    a. Yes, please name: ___________
    b. No

Diet quality:

Now we would like to know about what YOU usually eat. In terms of "usually", it may be helpful to think about what you ate over the last week. To prompt your answers think about all meals, snacks and drinks as well as foods that are eaten at home and away from home.

Please read each question carefully as questions will ask:

- 'How many serves' – referring to how much you usually consume, or;
- 'How often' – referring to whether you eat a food always, usually, sometimes or never

5. How many serves of vegetables do you usually eat each day? One serve is equal to half a cup.
    a. Don't eat fruit
    b. Less than one serve
    c. One serve
    d. Two serves
    e. Three serves
    f. Four serves
    g. Five serves
    h. Six or more serves

6. How many serves of fruit (excluding juice) do you usually eat each day? One serve is equal to one medium piece of fruit.
    a. Don't eat vegetables
    b. Less than one serve
    c. One serve

d. Two serves
e. Three serves
f. Four serves
g. Five serves
h. Six or more serves

7. How often is the bread that you eat wholegrain/wholemeal?

Include high fibre white bread, wholegrain made from white flour with added seeds/grains, wholemeal bread, wholemeal/wholegrain made from wholemeal flour with added seeds and grains

a. Always
b. Usually
c. Sometimes
d. Never
e. Don't eat bread

8. What type of milk do you usually use?
   a. Whole / full cream (4%)
   b. Reduced fat (1-2%)
   c. Skim (less than 1%)
   d. Regular soy
   e. Reduced fat soy
   f. Don't use cow's milk or soy milk
   g. Other (please specify)________________

9. What type of spread do you usually use?

For example: on bread, biscuits or crackers

a. Butter
b. Table margarine (e.g. Country Gold Dairy Blend, Devondale spread)
c. Unsaturated margarine (e.g. Flora, MeadowLea, Olive Grove, Bertolli, Gold N Canloa, Logicol)
d. Don't use spread
e. Other (please specify)________________

Please read each question carefully as these next questions will be asked in 2 parts:

- 'How often' – asking whether you eat a food daily, weekly, monthly or never **AND**
- 'How many times' – asking how many times each day, week or month you usually eat the food

For example:

Takeaway pizza once one week and fish and chips once another week - this equals 2 times per month (select 'Each month', and write '2')

Soft drink every day and cordial 2 times per week – this equals 9 times per week (select 'Each week', and write '9')

10. How often do you usually have soft drink, cordial or sports drinks?

Include regular/sugar-sweetened and diet/artificially sweetened

a. Each day
b. Each week

c. Each month
d. Don't drink soft drink, cordial or sports drink

11. (If answered a-c) How many times (each day / each week / each month) do you usually have soft drink, cordial or sports drinks? *Include regular/sugar-sweetened and diet/artificially sweetened varieties*___________________

12. How often do you usually have fruit juice drinks?

Include fruit boxes, poppers or any fruit drink with added water or sugar. DO NOT include 100% fruit juice.

a. Each day
b. Each week
c. Each month
d. Don't drink fruit juice drinks

13. (If answered a-c) How many times (each day / each week / each month) do you usually drink fruit juice drinks? *Include fruit boxes, poppers or any fruit drink with added water or sugar. DO NOT include 100% fruit juice.*___________________

14. How often do you usually have meals or snacks from take away food stores?

This includes places like McDonalds, Hungry Jacks, Pizza Hut, KFC, Red Rooster, Fish/Chicken Shop or local take away food places and foods such as burgers, pizza, hot dogs, battered chicken or fish and chips.

a. Each day
b. Each week
c. Each month
d. Never

15. (If answered a-c) How many times (each day / each week / each month) do you usually have meals or snacks from take away food stores?

*This includes places like McDonalds, Hungry Jacks, Pizza Hut, KFC, Red Rooster, Fish/Chicken Shop or local take away food places and foods such as burgers, pizza, hot dogs, battered chicken or fish and chips.*___________________

16. How often do you usually eat potato gems, hot chips, hash browns, hot chips, French fries, wedges or fried potatoes?

Include home-made and purchased, baked and fried varieties

a. Each day
b. Each week
c. Each month
d. Don't eat any of the foods listed above

17. (If answered a-c) How many times (each day / each week / each month) potato gems, hot chips, hash browns, hot chips, French fries, wedges or fried potatoes.

*Include home-made and purchased, baked and fried varieties*___________________

18. How often do you usually eat savoury snacks such as crisps, pretzels or plain/flavoured crackers?

This includes potato crisps, corn chips, Jatz, Shapes and rice crackers

a. Each day
b. Each week
c. Each month
d. Don't eat any of the foods listed above

19. (If answered a-c) How many times (each day / each week / each month) do you usually eat savoury snacks such as crisps, pretzels or plain/flavoured crackers

This includes potato crisps, corn chips, Jatz, Shapes and rice crackers? ____________________

20. How often do you usually eat savoury pastries?

This includes pies, pasties, sausage rolls, Kransky Dogs and frankfurters wrapped in pastry.

a. Each day
b. Each week
c. Each month
d. Don't eat savoury pastries

21. (If answered a-c) How many times (each day / each week / each month) do you usually eat savoury pastries?

*This includes pies, pasties, sausage rolls, Kransky Dogs and frankfurters wrapped in pastry*____________________

22. How often do you usually have cakes, biscuits, buns, muffins and donuts? *Include ALL home-made and bought*

a. Each day
b. Each week
c. Each month
d. Don't eat any of the foods listed above

23. (If answered a-c) How many times (each day / each week / each month) do you usually have cakes, biscuits, buns, muffins and donuts? *Include ALL home-made and bought*____________________

24. How often do you usually eat snack type bars?

This includes muesli bars, fruit bars and breakfast cereal bars.

a. Each day
b. Each week
c. Each month
d. Don't eat snack type bars

25. (If answered a-c) How many times (each day / each week / each month) do you usually eat snack type bars?

*This includes muesli bars, fruit bars and breakfast cereal bars*____________________

26. How often do you usually eat chocolate or lollies?

Include all types of chocolate and both hard and soft lollies.

a. Each day
b. Each week
c. Each month

d. Don't eat chocolate or lollies

27. (If answered a-c) How many times (each day / each week / each month) do you usually eat chocolate or lollies?

*Include all types of chocolate and both hard and soft lollies*___________________

28. How often do you usually have ice-cream or ice-blocks?

This includes ice-blocks, ice-cream in a bowl or ice-creams on a stick.

a. Each day
b. Each week
c. Each month
d. Don't eat ice-cream or ice-blocks

29. (If answered a-c) How many times (each day / each week / each month) do you usually have ice-cream or ice-blocks?

*This includes ice-blocks, ice-cream in a bowl or ice-creams on a stick*___________________

Self-evaluation of enablers of healthy food provision:

Now we would like to know about what you think might help you to provide healthier meals to your family. Your responses here will enable us to choose an appropriate combination of apps for you to test.

What do you think it would take for you to provide healthier meals for your family?
I would need to......

1 = Strongly disagree, 7 = Strongly agree
Capability

a. Have better food preparation and/or cooking skills
b. Learn how to choose healthy food at the supermarket
c. Learn how to plan healthy meals
d. Have better strategies to manage the mental load of planning, purchasing and preparing healthy meals

Opportunity

e. Have more time to plan, purchase and prepare healthy meals
f. Have more healthy recipes and meal ideas
g. Have guidance in choosing healthy food and meals
h. Have a better way of planning and recording meals and groceries for the week
i. Have more support or help from my partner or other family members
j. Have more reminders to plan, shop or cook

Motivation

k. Have clear goals or plans toward preparing healthy meals

If there is something else that you think you need in order to provide your family with healthy meals, please describe:_________________________________

Demographics:

Finally, we would like to know a little about you and your family.

30. What is your date of birth? DD/MM/YYYY

31. What is your gender? M/F/Other

32. What is the highest level of education you have completed?
    a. Year 12 or less
    b. Certificate (e.g. Tafe or similar)
    c. Advanced diploma or diploma
    d. Bachelor degree and above

33. Which of the following best describes your relationship status?
    a. Married / defacto
    b. Single / never married
    c. Separated / divorced / widowed

34. What is your family's **combined** annual income before tax (including allowances and pensions)?
    a. $0 - $385 per week ($0 - $20 000 per year)
    b. $386 - $673 per week ($20 001 - $35 000 per year)
    c. $674 - $961 per week ($35 001 - $50 000 per year)
    d. $962 - $1346 per week ($50 001 - $70 000 per year)
    e. $1347 - $1923 per week ($70 001 - $100 000 per year)
    f. More than $1923 per week (more than $100 000 per year)
    g. I prefer not to say

35. What is your usual occupation? ____________________

36. How many hours do you work in a usual week? ___________

37. How many hours does your partner work in a usual week?____________ or N/A

38. Which of the following best describes your hours / shifts (tick all that apply)?
    a. Day (e.g. mostly between 9am-5pm)
    b. Morning shifts
    c. Afternoon shifts
    d. Night shifts
    e. Other (e.g. FIFO worker)____________

39. In a typical working week, do you mostly work:
    a. Weekdays
    b. Weekends
    c. Mixture of weekends and weekdays

40. If you need to change the time that you start or finish your workday, is it possible?
    a. Yes, I am able to work flexible hours
    b. Yes, with approval in special situations
    c. No, not likely

d. No, definitely not

41. How many children / dependents live with you (at least half of the time if shared custody arrangements are in place)? Place the number of children in the box next to the appropriate age group.
    a. Less than 2 year olds ______
    b. 2 – 5 year olds _______
    c. 5 – 12 year olds ________
    d. 12 – 18 year olds ________
    e. 18+ year olds_______

42. What types of child care do you use each week?

Please tick all that apply. If all of your children are in school, and you do not use any form of regular childcare, please tick 'none'.

a. Day care / child care centre
b. Family day care
c. Preschool / kindergarten
d. Occasional care
e. Gym, leisure or community care
f. After school care
g. Grandparent
h. Other relative
i. Nanny
j. Child's parent living elsewhere
k. Other (such as a neighbour), please describe_________
l. None

Before you submit this survey, if you have any questions, feedback or comments regarding this survey, please type in the box below.
____

If you would like to be involved in the app testing stage of the study, please tick yes below, and provide your name, email address and telephone number. We will then send you an email with further information regarding the study, along with a consent form for you to sign and return. After we receive your consent form, we will be in touch to allocate your app(s).

I am interested in the app testing stage of the study and would like to receive further information: Yes / No

(If yes) Please provide your name, email address and phone number below, and click 'Next' to finish the survey.
Name: __________________
Email: __________________
Phone: __________________

APPENDIX 13: FOLLOW-UP SURVEY

Mobile apps for family meals study – Follow-up survey

Thank you for participating in our study exploring mobile apps for supporting healthy evening meals in working families. This survey will ask questions about each of the apps you used, and should take no more than 20 minutes to complete.

In order to be able to link the information you provide us in this survey with your previous survey and your interview responses, please provide your full name below:
____

Please remember that regardless of how much you used the apps, and what you thought of the apps, we still want to hear from you! This will provide important information to support the development of apps for families in the future.

First we will ask you some questions about your use of the apps.

Self-reported app use:
The survey will ask about each of the apps you tested, one at a time. Start with one app, then the questions will be repeated for the second app later.

Please enter the name of the first app you tested:______________________

1. Did you use the app at least once? Y/N

If N, why not? __________________(then screen out)

2. How often did you use the app each week of the testing period?

Week 1 of app testing period:
   a. Didn't use the app
   b. Once
   c. 2-4 times
   d. 5 or more times

Week 2 of app testing period:
   a. Didn't use the app
   b. Once
   c. 2-4 times
   d. 5 or more times

Week 3 of app testing period:
   a. Didn't use the app
   b. Once
   c. 2-4 times
   d. 5 or more times

Week 4 of app testing period:

a. Didn't use the app
b. Once
c. 2-4 times
d. 5 or more times

3. When you used the app, on average how long did you use it for?
   a. Less than one minute
   b. 1-5 minutes
   c. More than 5 minutes

System Usability Scale:

Now we would like to know what you thought of the usability of the app.

1. Please indicate your agreement with the following statements:

1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree

a. I think that I would like to use this app frequently
b. I found the app unnecessarily complex
c. I thought the app was easy to use
d. I think that I would need the support of a technical person to be able to use this app
e. I found that the various functions in this app were well integrated
f. I thought that there was too much inconsistency in this app
g. I would imagine that most people would learn to use this app very quickly
h. I found the app very awkward to use
i. I felt very confident using the app
j. I needed to learn a lot of things before I could get going with this app

App quality assessment (uMARS):

Now we would like you to answer some questions about what you thought of the quality of the app.

Choose the answer that most accurately represents the quality of the app you are rating. All items are rated on a 5-point scale from "1. Inadequate" to "5. Excellent". Select N/A if the app component is irrelevant.

Engagement – fun, interesting, customisable, interactive, has prompts (e.g. sends alerts, messages, reminders, feedback, enables sharing)

1. Entertainment: Is the app fun/entertaining to use? Does it have components that make it more fun than other similar apps?
1 Dull, not fun or entertaining at all
2 Mostly boring
3 OK, fun enough to entertain user for a brief time (< 5 minutes)
4 Moderately fun and entertaining, would entertain user for some time (5-10 minutes total)
5 Highly entertaining and fun, would encourage repeat use

2. Interest: Is the app interesting to use? Does it present its information in an interesting way compared to other similar apps?
1 Not interesting at all
2 Mostly uninteresting
3 OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)
4 Moderately interesting; would engage user for some time (5-10 minutes total)
5 Very interesting, would engage user in repeat use

3. Customisation: Does it allow you to customise the settings and preferences that you would like to (e.g. sound, content and notifications)?
1 Does not allow any customisation or requires setting to be input every time
2 Allows little customisation and that limits app's functions
3 Basic customisation to function adequately
4 Allows numerous options for customisation
5 Allows complete tailoring the user's characteristics/preferences, remembers all settings

4. Interactivity: Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)?
1 No interactive features and/or no response to user input
2 Some, but not enough interactive features which limits app's functions
3 Basic interactive features to function adequately
4 Offers a variety of interactive features, feedback and user input options
5 Very high level of responsiveness through interactive features, feedback and user input options

5. Target group: Is the app content (visuals, language, design) appropriate for the target audience?
1 Completely inappropriate, unclear or confusing
2 Mostly inappropriate, unclear or confusing
3 Acceptable but not specifically designed for the target audience. May be inappropriate/ unclear/confusing at times
4 Designed for the target audience, with minor issues
5 Designed specifically for the target audience, no issues found

Functionality – app functioning, easy to learn, navigation, flow logic,and gestural design of app

6. Performance: How accurately/fast do the app features (functions) and components (buttons/menus) work?
1 App is broken; no/insufficient/inaccurate response (e.g. crashes/bugs/broken features, etc.)
2 Some functions work, but lagging or contains major technical problems
3 App works overall. Some technical problems need fixing, or is slow at times
4 Mostly functional with minor/negligible problems
5 Perfect/timely response; no technical bugs found, or contains a 'loading time left' indicator (if relevant)

7. Ease of use: How easy is it to learn how to use the app; how clear are the menu labels, icons and instructions?
1 No/limited instructions; menu labels, icons are confusing; complicated
2 Takes a lot of time or effort
3 Takes some time or effort

4 Easy to learn (or has clear instructions)
5 Able to use app immediately; intuitive; simple (no instructions needed)

8. Navigation: Does moving between screens make sense; Does app have all necessary links between screens?
1 No logical connection between screens at all /navigation is difficult
2 Understandable after a lot of time/effort
3 Understandable after some time/effort
4 Easy to understand/navigate
5 Perfectly logical, easy, clear and intuitive screen flow throughout, and/or has shortcuts

9. Gestural design: Do taps/swipes/pinches/scrolls make sense? Are they consistent across all components/screens?
1 Completely inconsistent/confusing
2 Often inconsistent/confusing
3 OK with some inconsistencies/confusing elements
4 Mostly consistent/intuitive with negligible problems
5 Perfectly consistent and intuitive

Aesthetics – graphic design, overall visual appeal, colour scheme, and stylistic consistency

10. Layout: Is arrangement and size of buttons, icons, menus and content on the screen appropriate?
1 Very bad design, cluttered, some options impossible to select, locate, see or read
2 Bad design, random, unclear, some options difficult to select/locate/see/read
3 Satisfactory, few problems with selecting/locating/seeing/reading items
4 Mostly clear, able to select/locate/see/read items
5 Professional, simple, clear, orderly, logically organised

11. Graphics: How high is the quality/resolution of graphics used for buttons, icons, menus and content?
1 Graphics appear amateur, very poor visual design - disproportionate, stylistically inconsistent
2 Low quality/low resolution graphics; low quality visual design – disproportionate
3 Moderate quality graphics and visual design (generally consistent in style)
4 High quality/resolution graphics and visual design – mostly proportionate, consistent in style
5 Very high quality/resolution graphics and visual design - proportionate, consistent in style throughout

12. Visual appeal: How good does the app look?
1 Ugly, unpleasant to look at, poorly designed, clashing, mismatched colours
2 Bad – poorly designed, bad use of colour, visually boring
3 OK – average, neither pleasant, nor unpleasant
4 Pleasant – seamless graphics – consistent and professionally designed
5 Beautiful – very attractive, memorable, stands out; use of colour enhances app features/menus

App credibility

13. Credibility of source: does the app seem to come from a credible source?
1 Suspicious source

2 Lacks credibility
3 Credibility of source is unclear
4 Possibly comes from a credible source
5 Definitely comes from a credible/specialised source

App subjective quality

14. Would you recommend this app to people who might benefit from it?
1 Not at all I would not recommend this app to anyone
2 There are very few people I would recommend this app to
3 Maybe There are several people I would recommend this app to
4 There are many people I would recommend this app to
5 Definitely I would recommend this app to everyone

15. How many times do you think you would use this app in the next 12 months if it was relevant to you?
1 None
2 1-2
3 3-10
4 10-50
5 >50

16. Would you pay for this app?
1 Definitely not
2
3
4
5 Definitely yes

17. What is your overall (star) rating of the app?
1 star - One of the worst apps I've used
2 stars
3 stars - Average
4 stars
5 stars - One of the best apps I've used

Do you have any further comments about the app?_______________________________

All of the above questions are then repeated for app no. 2

Thank you for completing the final survey, we will be in touch by telephone in the next few days to conduct the final interview and arrange your meal kit for delivery.

APPENDIX 14: INTERVIEW GUIDE

Mobile apps for family meals study – Interview guide

Introduction:
Hi this is ………… from the 'Mobile apps for family meals study'.
I am contacting you today to conduct the interview regarding the apps you have tested for us.
The interview will take between 45 and 60 minutes, is now a good time?

- → *Reschedule if required*

Purpose of the interview / clarification of topic under discussion:
The purpose of today's interview is to discuss your thoughts and opinions of the mobile apps you were allocated.
We will discuss what you thought of the apps, how you used the apps, how useful you found the apps and how you think they could be improved.

- → ****remind participants that regardless of whether they liked or disliked the apps or used them only once or daily, we still want their opinions / thoughts!*

At end of this phone call we will get some details to arrange the delivery of your Thomas Farms meal kit.

Format of the interview:
I will be recording the interview so that it can be transcribed into writing. This recording will only be listened to by study staff, and the company that transcribes the data for us. Your name will be stored separately from this data.
Please also remember that everything we discuss today is confidential, and if you wish to cease the phone call at any time, you are welcome to do so with no consequence.
And if you are unsure about a question I have asked, or if you would prefer not answer a question, please let me know.

Theme 1: App use and preference

1. We will start by talking about the app you preferred or used the most – was there one app you used or liked more than the other?

    - → *Try to maintain focus on the first app initially where possible. If however some themes are covered for the second app prior to formally commencing discussion about that app, they need not be repeated.*

******** IF NO (i.e. disliked both apps, or didn't use either much):***

2. Can you tell me about why you didn't use / like the app?

PROMPT: Was it due to the app itself? If so, what put you off?
PROMPT: Were there barriers to you using the app?

3. The first survey showed that in order to provide healthy meals to your family, you would like support with *insert relevant COM self-evaluation component here (i.e. plan your family's meals, learn how to choose healthy foods).* What were the main reasons the app couldn't or didn't help with this?

PROMPT: Were there problems with the app itself?
PROMPT: Were there barriers that prevented you using the app?
******** GO TO Theme 6***

Theme 2: App engagement (general and ecological momentary)

1. I see from your survey that you used the app……*(insert freq of use data)……*can you tell me a little more about this?

2. What did you mainly use the app for? When or in what situations did you use the app?

PROMPT: For example, did you use the app while undertaking tasks related to food (like shopping or cooking)?

Theme 3: General app and feature acceptability

1. Can you tell me what you thought of the app and its features?

→ *If needing to give examples of 'features', use those specific to the app i.e. what did you think of the shopping list function etc*
PROMPT: Did you generally like or dislike the app, and why?
PROMPT: Can you describe any features you **liked,** and why?
PROMPT: Can you describe any features you **disliked** and why?

Theme 4: Usefulness of the app in addressing self-identified COM-B needs

1. In what way, **if any**, did the app meet your needs in relation to…….*insert relevant COM self-evaluation component here?*

2. In what way, **if any**, has using this app changed the way you……. *insert relevant COM self-evaluation component here*?

    → *Repeat for each relevant COM-B component*

3. Will you use the app in the future, and if so, how?

→ *For example, in everyday life after the study? In a regular working week?*

4. Were there any other ways that the app impacted on you or your family, positively or negatively?

Theme 5: Family engagement
**********IF A DUAL-PARENT HOUSEHOLD***

1. What did other people in your family think of the app?

Theme 6: App improvements

1. If the developer of the app was to approach you for feedback, what would you say?

PROMPT: In what ways could the app be improved, **if at all**, to better support you to plan, buy and make healthy family meals?
PROMPT: In what ways could the app be improved, **if at all**, to work or function better?
PROMPT: In what ways could the app be improved, **if at all**, to encourage you to use it more?
PROMPT: In what ways could the app be improved, **if at all**, to encourage other family members to use it?

REPEAT FOR SECOND APP

Theme 7: Final feedback

1. Now that you've experienced these apps, what would you like to see if you were designing an app to help families to plan, buy and prepare healthy meals?

2. Is there anything else you'd like to say about the apps?

Incentive:
Now I will collect some details from you so that I can arrange delivery of your meal kit. The company through which we are ordering the meal kit can only deliver to Adelaide, Brisbane, Melbourne or Sydney – do you live in any of these cities?

*******IF NO:***
No worries, we can provide you with a digital supermarket voucher instead, which will be sent to your email address. Can I ask which type of voucher you prefer, Coles or Woolworths?
☐ Coles
☐ Woolworths
Great - you should receive the voucher in your inbox in about a week – let us know by email if you don't receive it or have any issues with it.

******IF YES:**
The meal kit is from a company called Thomas Farms, and will provide ingredients, along with recipes for 2 family meals. The meals are reasonably large, so should feed a family of 4-5, depending upon the age of the children.
These details will only be used to arrange delivery of the meal kit, and they will be provided directly to Thomas Farms.

Street address	
Suburb	
Postcode	
State	
Dietary requirements (e.g. no fish, vegetarian)	
Delivery instructions (e.g. leave by front door)	

Your estimated delivery date is…………*(second Monday AFTER this phone call)*

Future research:
There may be the opportunity to test further apps in the future, would you be interested and happy for me to keep your contact details for future research? We would contact you for consent to those studies separately and you would be under no obligation to say yes at that stage.

Thank you, and before I go, do you have any further questions?

APPENDIX 15: SELF-REPORTED FREQUENCY OF APP USE

Table 1: Self-reported frequency of app use over the 4-week app testing period, by app, and across the total sample (n=62)

Apps	N	Week	Didn't use the app	Once	2-4 times	5 or more times
			n (%)	n (%)	n (%)	n (%)
Meal planning app	35	1	5 (14)	15 (43)	14 (40)	1 (3)
		2	11 (31)	16 (46)	8 (22)	0 (0)
		3	15 (43)	7 (20)	12 (34)	1 (3)
		4	19 (54)	7 (20)	9 (25)	0 (0)
Recipe manager app	32	1	3 (9)	16 (50)	13 (41)	0 (0)
		2	11 (34)	9 (28)	12 (38)	0 (0)
		3	11 (34)	10 (31)	11 (34)	0 (0)
		4	16 (50)	10 (31)	5 (16)	1 (3)
Recipe app	29	1	4 (14)	9 (31)	13 (45)	3 (10)
		2	7 (24)	11 (38)	10 (35)	1 (3)
		3	9 (31)	12 (41)	6 (21)	2 (7)
		4	12 (41)	7 (24)	9 (31)	1 (3)
Barcode scanner app	12	1	2 (17)	3 (25)	3 (25)	4 (33)
		2	1 (8)	4 (33)	6 (50)	1 (8)
		3	2 (17)	3 (25)	4 (33)	3 (25)
		4	3 (25)	1 (8)	4 (33)	4 (33)
Family organiser app	12	1	0 (0)	5 (42)	4 (33)	3 (25)
		2	7 (58)	1 (8)	3 (25)	1 (8)
		3	6 (50)	2 (17)	3 (25)	1 (8)
		4	7 (58)	2 (17)	2 (17)	1 (8)