Extending Attention Span for Children with Attention Deficit Hyperactivity Disorder through a Webcam/Mouse Directed Attentive User Interface

by

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DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Othman Mohammed Asiry
9/11/2018

DEDICATION

This work is dedicated first and foremost to "ALMIGHTY GOD" for helping me in completing my PhD and giving me patience and wisdom throughout my whole journey. Secondly, to my lovely wife for her patience and sacrifices and to my two angels, my son Yazan and my daughter Layan. Thank you for being patient and understanding. Sorry for keeping you for weeks in boredom when I could not take you to parks or have a day out. I promise, I will make it up to you when I take this heavy load off my shoulders.

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LIST OF PUBLICATIONS

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ABSTRACT

School children are affected by Attention Deficit Hyperactivity Disorder, commonly known as ADHD, a neurobiological condition. The major symptom here is short attention span, which can negatively influence the academic performance of a child, specifically in those tasks which require more concentration.

In this work, we outline our research on extending the attention span of children with ADHD by investigating the effect of user interface colour schemes on the attention state of these children. This will help develop a computer application that adapts its user interface by incorporating multiple stimuli to capture the attention of the child. The proposed adaptive user interface is directed by an eye tracking device (webcam), which constantly monitors the user's attention state. A computer mouse is used as a second modality for tracking attention. A number of metrics were used in this study: number of fixations in the form of read words and the total time spent in reading the text. The results show that children with ADHD performed better in the presence of a colour scheme in general, specifically with a highlighting colour scheme, in comparison with no colour scheme. The contrast scheme was the second most effective for attention. The sharpening/blurring scheme helped the children keep engaged, but it was less effective than the highlighting and contrast schemes. Limitations of the study include small sample size, lack of female participants, limited age groups of the participants, and the venue of the study being only in a school setting. Future work could address these limitations by recruiting more participants, including female participants, across different age groups and in different settings. This work is based on the optimal stimulation theory which states that children with attention and hyperactivity disorders seek the optimum stimulation and attend to the task presenting extra stimulation.

1 INTRODUCTION

1.1 Introduction

Human life is hugely dominated by computer technologies, as they influence the way we learn things, communicate with other people and go about completing our tasks and missions every day. There are many devices and machines available to us that are computerized and that make our lives simpler. We can fulfill our objectives at greater speed and efficiency than ever before.

Those who have special needs can use assistive technologies to overcome hurdles they face in their everyday life. These assistive technologies can be used for the purposes of intervention and rehabilitation. Those who have ADHD can also make use of this technology.

For those with ADHD, Attentive User Interfaces (AUIs) can enhance engagement and attentions. Eye tracking devices support the design of AUIs to create an interface that is sensitive to user attention (T Selker, 2004; Vertegaal, 2003). In this work reported in this thesis, a high-resolution webcam, supplemented with a computer mouse, was used to monitor the attention state of children with ADHD.

1.2 Problem Statement

ADHD is a disorder commonly found in children and adolescents and is accompanied by academic problems. It is estimated that 3–5 % of school age children are affected by this disorder (Millichap, 2009). ADHD has three subtypes:

- ADHD-I is predominantly a condition of inattention. A child with this type of disorder exhibits six or more symptoms of inattention and less than six symptoms of hyperactivity/impulsiveness.
- ADHD-H is categorised by the observation of six or more symptoms of hyperactivity/impulsiveness and less than six symptoms of inattention.
- ADHD-C shows the combination of symptoms of the two other types.

Symptoms of ADHD include an inability to stand still, problems in being organised, failure to finish tasks and listening problems (Millichap, 2009). Boys are diagnosed three to nine times more often than girls (Kollins, Sparrow, & Conners, 2011). The symptoms of ADHD differ across lifespan. It has been found that young children show symptoms

of hyperactivity and impulsivity more often than inattention. It is also demonstrated that the symptoms become less intense as the child gets older (Biederman, Mick, & Faraone, 2000; Lahey et al., 1994).

Children with ADHD tend to lose focus after a short period of time and this lack of attention could lead to educational underachievement. Children with ADHD also lose their place in material they are currently reading (Glick, 2011; Rief, 2015, 2016; Robin, 1998). Some studies (Russell A Barkley, 1997) show that ADHD can be accompanied by other educational, behavioural and social problems. ADHD is associated with low academic achievement, poor school performance, retention in grade, school suspension and expulsion. Over 25 % of students with ADHD will go through grade retention, get enrolled in special education programs and fail to pass high school. They are also prone to be suspended or even expelled from school (R. A. Barkley, 2006; DuPaul & Power, 2008).

Children with ADHD are easily distracted by aspects of their surroundings that are vivid, moving, novel, colourful or salient (Copeland & Wisniewski, 1981; Radosh & Gittelman, 1981). This could lead to difficulties in sustained and selective attention, which is required when reading, listening to instructions or solving math problems.

Longitudinal studies (Rabiner, Coie, & Group, 2000) suggest that the academic impairment noticed in children with ADHD is mainly due to inattention-related symptoms, rather than symptoms of hyperactivity and impulsiveness. There is a strong connection between inattentive symptoms and poor academic performance (Willcutt & Pennington, 2000). Children who exhibit purely inattentive behaviour are likely to underachieve in reading (Mayer, 1999; Warner-Rogers, Taylor, Taylor, & Sandberg, 2000) and mathematics (Marshall, Hynd, Handwerk, & Hall, 1997; Raghubar et al., 2009). A study by Nelson, Benner, Lane, and Smith (2004) reported that 83 % of children with behavioural disorders achieve less in standardized reading skills.

1.3 Research Objectives

Motivated by the issues raised in the problem statement, the main objectives of this work are to investigate the effect of interface colour schemes on the attention state of children with ADHD and to design and develop a gaze-based AUI that adapts itself to the attention state of the child. The AUI uses an eye-tracking device (webcam) and a mouse to monitor the child's head/eyes and mouse pointer movements. This information is reported to an

application that can adapt its interface based on the attention state of the child. An Area of Interest (AOI) being looked at by a child adapts its appearance via a predefined colour scheme: highlighting, contrast or sharpening. The developed application aims at keeping children with ADHD engaged in a task for longer. This study is based on optimal stimulation theory which states that children with ADHD need extra stimulation to stay focused (S. Zentall, 1975). The movement of colour highlighting across text from left to right should help keep attention on the page rather than wandering elsewhere (Hecker, Burns, Katz, Elkind, & Elkind, 2002).

1.4 Research Hypotheses

This research developed two sets of hypotheses based on the impact of colour schemes on two metrics: number of read words and total time to complete a reading task. Each set of hypotheses contains null and alternative hypotheses. In inferential statistics, the null hypothesis is a well-known term that indicates that there is no connection between the two measured phenomena, while the alternative hypothesis indicates that there is a connection between the measured phenomena (Everitt, 1998).

1.4.1 Hypotheses regarding the effect of colour schemes on read words

1.4.1.1 Research H1 null hypothesis H_{01}

Colour scheme has no effect on the number of words read by children with ADHD, i.e., the mean of all schemes is equal:

$$\mu_{\text{no effect}} = \mu_{\text{colour\_scheme}}$$

To test this hypothesis, a paired t-test will be used to determine whether the different colour schemes have the same impact as the no effect condition in terms of the number of words read by children with ADHD.

14.1.2 Alternative H1 Hypothesis H_{a1}

The alternative hypothesis could be directional or nondirectional. In the case of directional, a one-tailed statistical test can be used and results in some variable A being greater or less than some other variable B. In the case of nondirectional, a two-tailed statistical test can be used that identifies whether variable A is not equal to variable B.

In this study, the alternative hypothesis is two-tailed (nondirectional) and, therefore, a two-tailed statistical test was used. The alternative hypothesis states that there is a statistically significant effect of the colour scheme on the number of words read by children with ADHD.

$\mu_{\text{no effect}} \neq \mu_{\text{colour\_scheme}}$

1.4.1.3 Research H2 null hypothesis H_{02}

The contrast scheme has no significant effect on the number of words read by children with ADHD.

1.4.1.4 Alternative H2 Hypothesis H_{a2}

The contrast scheme has a significant effect on the number of words read by children with ADHD.

1.4.1.5 Research H3 null hypothesis H_{03}

The highlighting scheme has no significant effect on the number of words read by children with ADHD.

1.4.1.6 Alternative H3 Hypothesis H_{a3}

The highlighting scheme has a significant effect on the number of words read by children with ADHD.

1.4.1.7 Research H4 null hypothesis H_{04}

The sharpening scheme has no significant effect on the number of words read by children with ADHD.

1.4.1.8 Alternative H4 Hypothesis H_{a4}

The sharpening scheme has a significant effect on the number of words read by children with ADHD.

1.4.1.9 Hypothesis testing

Hypotheses H_{02}, H_{a2}, H_{03}, H_{a3}, H_{04}, and H_{a4} are tested using one-way repeated measures ANOVA to identify the colour scheme(s) that has/have the most effect on the number of words read by children with ADHD.

1.4.2 Hypotheses regarding the effect of colour schemes on total time

1.4.2.1 Research H5 null hypothesis H_{05}

Colour scheme has no effect on the total time spent reading by children with ADHD; the mean of total time of all schemes is equal:

$\mu_{\text{no effect}} = \mu_{\text{colour\_scheme}}$

To test this hypothesis, a paired t-test will be used to determine whether the different colour schemes have the same impact as the no effect condition in terms of the total time spent in reading a text.

1.4.2.2 Alternative H5 Hypothesis H_{a5}

The alternative hypothesis states that there is a statistically significant effect of the colour scheme on the total time spent reading by children with ADHD.

$$\mu_{\text{no effect}} \neq \mu_{\text{colour\_scheme}}$$

1.4.2.3 Research H6 null hypothesis H_{06}

The contrast scheme has no significant effect on the total time spent reading by children with ADHD.

1.4.2.4 Alternative H6 Hypothesis H_{a6}

The contrast scheme has a significant effect on the total time spent reading by children with ADHD.

1.4.2.5 Research H7 null hypothesis H_{07}

The highlighting scheme has no significant effect on the total time spent reading by children with ADHD.

1.4.2.6 Alternative H7 Hypothesis H_{a7}

The highlighting scheme has a significant effect on the total time spent reading by children with ADHD.

1.4.2.7 Research H8 null hypothesis H_{08}

The sharpening/blurring scheme has no significant effect on the total time spent reading by children with ADHD.

1.4.2.8 Alternative H8 Hypothesis H_{a8}

The sharpening/blurring scheme has a significant effect on the total time spent reading by children with ADHD.

1.4.2.9 Hypothesis Testing

Hypotheses H_{06}, H_{a6}, H_{07}, H_{a7}, H_{08}, and H_{a8} are tested using one-way repeated measures ANOVA to identify the colour scheme(s) that has/have the most effect on the total time spent reading by children with ADHD.

1.5 Significance of the Study

As stated in the problem statement, children with ADHD have a problem with sustained attention (the ability to maintain attention). This study will investigate the effect of colour schemes on the attention of students with ADHD. The software application developed in this study will help children with ADHD sustain their attention and, consequently, will

help them perform better in reading tasks as proposed by the optimal stimulation theory (S. Zentall, 1975).

This study could benefit the following stakeholders:

1.5.1 Students

Students with ADHD will benefit from the outcomes through the incorporation of the most effective colour scheme on attention in their learning materials to help them pay attention and keep them engaged with information and instructions. Sustained attention plays an important role in learning and increasing sustained attention could help these children do better at school (L. B. Smith, Colunga, & Yoshida, 2010).

1.5.2 Teachers and instructors

As reported in the optimal stimulation theory (S. Zentall, 1975), children with ADHD need extra stimulation to increase their attention and decrease hyperactivity. Adding these colour schemes to learning and instruction materials will help set focus on the most relevant information that help students stay engaged in assigned tasks and decrease distraction.

1.5.3 Future researchers

This study will help shed light on the role of colour on the attention of children with ADHD and has the potential to open a door for more research. The outcomes and findings of this research will add to the literature in this field.

1.6 Contribution of the Research

The contribution made by this research is presented in the following subsections.

1.6.1 Theoretical contribution

This research aims at finding a link or relation between colour schemes and the attention state of children with ADHD. This was done by assessing attention state when applying colour schemes (highlighting, contrast and sharpening) and comparing it with the no colour scheme (black text on white background). Based on the conclusion drawn from analysis of the research data, there was a strong link between the presence of colour schemes and attention state of the child. This study is in support of, and an addition to, the Optimum Stimulation Theory, which states that children with ADHD need more stimulation to maintain their attention. This study used colour as a stimulation to help children to stay focused.

1.6.2 Methodological contribution

The study combined the double-pre-test post-test experimental design with the counterbalanced order to control for the maturity threat to the internal validity and the order effect. The study also used two methods to enhance and strengthen the validity: a subjective method using a questionnaire, and an objective method (non-self-report) by conducting experiments using a developed application. Another methodological contribution lies in the ability of applying the methods used in this study in other education areas with which these children find difficulties, such as mathematics or science.

1.6.3 Empirical and practical contribution

Children with ADHD have their attention span extended when colour schemes are used. The colour scheme is the independent variable and its effect on the attention state of the child is the dependent variable. Two measures were used to assess attention: the time spent reading text and the number of words read during the reading task. To the best of the researcher's knowledge, this is the first study using attentive user interface to assess the attention of children with ADHD, and this would be an addition to the body of knowledge in this area. One of the practical contributions is the insight gained from this research in understanding the role of colour on the attention process and how this could be used in developing more applications for children with special education needs in general and, in particular, children with ADHD.

1.7 Scope and Boundaries of the Study

The study focusses on investigating the effect of colour schemes on the attention state of primary school children diagnosed with ADHD in Saudi Arabia. The data was collected from a randomly selected city that has schools with inclusion programs for children with ADHD. The application developed to collect data for the study helps children stay focused when reading by applying colour effects to the presented text. The system counts the number of read words and total time with each of the colour schemes. The more words read and time spent, the more effective the used colour scheme. The study was conducted in a school setting. The participants of the study were primary school male students diagnosed with ADHD.

1.8 Limitations of the Study

Although the research has met its objectives, there are limitations. One of the limitations is the small sample size. The researcher did his best to get as many participants as

possible, however, due to cultural issues, some parents did not give permission for their children to participate in the study. In such a community, being a parent of a child with special needs is a critical issue. Another limitation of the study is that all participants were male. The researcher could not approach females to participate due to cultural restrictions that divide schools into male-only and female-only. Therefore, the results of the study should not be generalized for female ADHD children. More studies are needed, including both male and female ADHD children, to compare the results of this study with studies including female participants to assess whether gender has an effect on the findings.

1.9 Definition of Terms

ADD: Attention Deficit Disorder

ADHD: Attention Deficit Hyperactivity Disorder

ADHD-C: ADHD Combined subtype

ADHD-H: ADHD Hyperactivity/Impulsiveness subtype

ADHD-I: ADHD Inattention subtype

AOI: Area of Interest

AUI: Attentive User Interface

COACH: Cognitive Adaptive Help

DFD: Data Flow Diagram

DSM: Driver State Monitor

DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

ECS: Electronic Charts System

EEG: Electroencephalography

FACT: Functional Acuity Contrast Test

FAST: Focus and Saccade Tracking

FCFA: Frequent Change in Focus of Attention

FMT: Farnsworth-Munsell 100 Hue Test

MAGIC: Manual and Gaze Input Cascaded pointing

SBREC: Social and Behavioural Research Ethics Committee

SPSS: Statistical Package for the Social Sciences

SUITOR: Simple User Interest Tracker

UCD: User Centred Design

UML: Unified Modelling Language

UAT: User Acceptance Testing

1.10 Thesis Outline

To achieve the aims and objectives of the research, this thesis is organised as follows:

Chapter 1: This chapter has first set the background of the study as well as the rationale and motivation for conducting the study and then presented the hypotheses for the study, the significance of conducting the study, and the boundaries and limitations of the study.

Chapter 2: This chapter provides a review of the relevant literature. This includes the main pillar of the research, which is ADHD, by providing information describing what ADHD is, its subtypes and the main symptoms accompanying this disorder. Attentive User Interface (AUI) is then presented as a proposed solution to minimise the effect of inattentive behaviour resultant from ADHD. In AUIs, various colour schemes are used and their effect on attention is assessed. The role of tracking devices as diagnosis and intervention tools is illustrated by highlighting studies that have incorporated the tracking device for both purposes.

Chapter 3: This chapter presents the proposed solution to the research problem, which is the inattentiveness problem of children with ADHD. The chapter starts by highlighting the problem that sparks the proposed attention extending system. The requirements, used as the building blocks of the functions of the system, are gathered through user and system requirements. Visualisation of the system components, actors or stakeholders of the system along with the reaction and relationships between those entities is achieved using UML diagrams. Developing the interface of the system took place using low-fidelity and high-fidelity prototyping. The coding applied in developing this system is illustrated in the System Development and Coding section. Different levels of testing were applied as shown in the Unit and System Testing section. The system description and how it works are illustrated in this chapter.

Chapter 4: This chapter outlines the participating users, the methods employed, the stimuli presented to the subjects, sampling techniques to recruit participants, the ethics issues for recruiting the subjects, and, finally, the data collection methods and instruments and the procedures to validate those instruments.

Chapter 5: In this chapter, the collected data is analysed using statistical software to draw conclusions and then interpret the results. The analysed data is presented and reported in the form of tables and graphs.

Chapter 6: This chapter discusses the results of the study, concludes the work conducted in this study and suggests future direction. It also points out the limitations of the research.

1.11 Summary

This chapter has highlighted the background and the rationale for conducting this study, the aim and the objectives, and the hypotheses. It has pointed out the significance of this study, and the scope and limitations. In the background section, the problems faced by children with ADHD were discussed. The benefits to be gained from this study were then illustrated in the significance section. Each study has its boundaries and scope that narrow it down to a specific domain and area. The limitation section detailed those of this study.

2 LITERATURE REVIEW

2.1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a common neurobiological condition affecting school-age children. One of the main symptoms is short attention span, which is a key factor of poor academic performance, especially in tasks requiring a high amount of concentration time. This thesis has outlined a research plan for extending the attention span of children with ADHD by designing and developing a computer software application that adapts its user interface by incorporating multiple stimuli. The proposed Adaptive User Interface (AUI) is directed by a webcam/mouse, which constantly monitors the user's attention state. Presenting traditional tasks in a computerised format has been shown to benefit children with ADHD (Shaw & Lewis, 2005).

Attention is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources (Anderson, 2005). Attention has been defined by James (1950) as something that possesses the mind, and gives it clarity, when it comes to picking one thought from several thoughts. It helps in focusing and concentrating and that is the essence of it. It helps in withdrawing from things, while it focuses on the one thing that needs attention.

2.2 Attention Deficit Hyperactivity Disorder (ADHD)

ADHD is the name given to signify a formative disorder observed in youngsters or children that includes deficiencies in behavioural restraint, maintenance of concentration, struggle against diversion, and control of a person's movement related to circumstantial demands, i.e., conditions of hyperactivity or impatience. In the last century, many instances have been observed of issues such as hyperactivity disorder or hyperkinetic response among children and a lack of ability to consistently concentrate, whether it is with hyperactivity or without it (R. Barkley & Murphy, 2011). There are three subtypes of ADHD: pre-dominantly inattentive, ADHD-I; pre-dominantly hyperactive and impulsive, ADHD-H; and combined subtype, ADHD-C. Each subtype has symptoms as listed in Table 2. 1 (Millichap, 2009).

Table 2. 1: Symptoms of ADHD subtypes

ADHD-I	ADHD-H	ADHD-C
Failure to maintain attention	Cannot wait for turn in speech or in line	Symptoms of both ADHD-I and ADHD-H
Easily distracted	Cannot stand still	
Forgetful and loses things	Always in a hurry	
Disorganised	Talks a lot	
Seems to not listen when being spoken to	Fidgety	
Makes thoughtless mistakes	Cannot play quietly	
Avoids doing tasks requiring effort	Answers without pre-thinking	

The relation between ADHD and academic underachievement is well documented in the literature (Russell A Barkley, 2014; Bigorra, Garolera, Guijarro, & Hervás, 2016; Hinshaw, 1992; Mash & Dozois, 2003; S. S. Zentall, 1993). The academic areas affected by the symptoms of ADHD include reading, writing and mathematics (Barry, Lyman, & Klinger, 2002). Symptoms of inattentive behaviour usually affect the student's ability to pay attention to task instructions, shifting from one activity to another and forgetting to complete given tasks (Mash & Barkley, 2003). The more severe the symptoms are, the more impact on the academic achievement (Barry et al., 2002).

Spira and Fischel (2005) reported that children with pure inattentive symptoms usually do not complete given tasks since they lack the persistence to finish them. There is a strong relationship between inattentiveness and student achievement in reading. Inattentiveness reduces the student's ability to do well in reading (Rowe & Rowe, 1992).

Fowler and Cross (1986) investigated the influence of inattentiveness and academic achievement. They found that preschooler's attention problems persist through grade one and two and that affects their achievement in reading and math, even though their parents did not report a significant relationship between inattentiveness and reading at home. This could be related to the lack of uniqueness in reports and assessment devices. Boys with attention problems were found to have poor reading fluency, comprehension and overall reading ability compared to girls with attention deficit (Pham, 2016). Children at the age

of 12 years with dominant inattention are at more risk of poor academic achievement than hyperactive children, based on teachers ratings and official exams in reading, writing and mathematics (Salla et al., 2016).

Robin (1998) states that those students who have attention deficit problems have trouble with their short-term memory and will read the same paragraph over and over. The repetition makes reading difficult. Rief (2016) suggested using a bookmark to help children locate their position while reading since they easily lose their location. Moreover, Glick (2011) indicated that children with ADHD usually fail to recall which step comes next or are unable to find their location while reading a passage. The same condition is reported in children with dyslexia. Golden Robert N. (2010) reported that children with dyslexia have the same problem of losing their location and skipping words or lines when they are reading. Using colour could help a reader keep track of their place while reading and this may help with their inattentiveness to the text (Hecker et al., 2002).

2.3 Types of Attention

Selection and attending to specific information within a surrounding is governed by two factors: the features of the stimuli (colour, onset, movement or luminance) and the goal of the observer (Folk, Remington, & Johnston, 1992; Warner, Juola, & Koshino, 1990; Yantis & Jonides, 1990). Selective attention is controlled in two ways: stimuli-driven, also known as bottom-up, or goal-driven, also known as top-down (Bundesen, Habekost, & Kyllingsbæk, 2005; Turatto & Galfano, 2001; J. M. Wolfe, 1994).

2.3.1 Sustained attention

Sustained attention is refered to as "the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, nonarousing qualities would otherwise lead to habituation and distraction to other stimuli" (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). It is the ability to attend to a certain stimulus for a period of time while ignoring distracting stimuli (Shalev, Ben-Simon, Mevorach, Cohen, & Tsal, 2011).

Children with ADHD are found to have difficulties in maintaining their attention for a prolonged time (Holmes et al., 2010; Huang-Pollock, Karalunas, Tam, & Moore, 2012). L. B. Smith et al. (2010) reported that efficient learning depends on the ability to maintain attention on a task, and sustained attention is crucial for accumulating knowledge and applying it in new areas of learning. There is a strong relationship between sustained attention and learning performance (C. M. Chen & Huang, 2014; Steinmayr, Ziegler, & Träuble, 2010). Adding colour to simple vigilance and copying tasks was reported to

improve sustained attention and decrease hyperactivity of children with ADHD (S. S. Zentall, Falkenberg, & Smith, 1985; S. S. Zentall & Kruczek, 1988). A study conducted by Stern and Shalev (2013) investigated the effect of text spacing and presentation type on sustained attention. The results showed that there is a connection between double-spacing and increased sustained attention. Moreover, there is also a connection between the presenting type (computer screen) and enhanced sustained attention. The authors recommended conversion of school printed material into digital forms to be presented on computer screens. In this study, adding colour to the given task and presenting it in digitized format may help in improving the sustained attention of students with ADHD. This claim is based on the previous studies reported in this section.

2.3.2 Selective attention

Selective attention refers to "the ability to focus processing on relevant features and objects while ignoring irrelevant features and objects" (Bundesen, 1990; Bundesen & Habekost, 2008). It is the ability to select what to attend to when presented with several options (Calmels, Berthoumieux, & Fabienne d'Arripe-Longueville, 2004). There is inconstistency among studies concerning this kind of attention in chidren with ADHD. On the one hand, some studies reported that children with ADHD can not selectively attend to one stimuli and ignore others (Booth et al., 2005; dos Santos Assef, Capovilla, & Capovilla, 2007; Gomarus, Wijers, Minderaa, & Althaus, 2009). On the other hand, some studies reported that this type of attention is intact and those children with ADHD are comparable with their peers (Heaton et al., 2001; Huang-Pollock, Nigg, & Carr, 2005; Koschack, Kunert, Derichs, Weniger, & Irle, 2003). Hazell et al. (1999); Mason, Humphreys, and Kent (2004); Mason, Humphreys, and Kent (2003) all reported that the selective attention ability, including visual search, is intact in children with ADHD. DeShazo Barry, Klinger, Lyman, Bush, and Hawkins (2001), reported that children with ADHD have impairement in sustained attention but not in selctive attention. The inconsitency in the results regarding selective attention may be due to the use of different approaches and methods in assessing selective attention.

2.3.3 Divided Attention

Divided attention refers to "the ability to share or divide attention among multiple sources of information" (Sturn, 1996). Studies investigating this type of attention concluded that children with ADHD have no problem finishing tasks requiring divided attention like the Trail Making Test Part B (TMT B), which requires dividing attention between two

stimlui, but they took longer compared with a control group (Boucugnani & Jones, 1989; Pasini, Paloscia, Alessandrelli, Porfirio, & Curatolo, 2007; Shue & Douglas, 1992). Other studies found that they complete the task in the same amount of time as their peers but they sacrifice accuracy (Grodzinsky & Diamond, 1992; Holmes et al., 2010). On the other hand, some studies suggested that children with ADHD find difficulties in undertaking dual tasks, swiching from one task to another is costly with one of the tasks being affected (Cepeda, Cepeda, & Kramer, 2000; Fuggetta, 2006). However, this impairment was not found in a recent study (Inasaridze & Bzhalava, 2010).

2.4 Attentive User Interface (AUI)

This study employs an AUI to apply a colour scheme to the interface to draw the attention of children with ADHD and help them in working on a task at hand for a longer period. An AUI is an interface that senses the user's attention and uses that as a primary input (T Selker, 2004; Vertegaal, 2003). They are "systems that pay attention to what users do so that they can attend to what users need" (Maglio, Matlock, Campbell, Zhai, & Smith, 2000). Dirican and Gokturk (2009) defined the AUI as a computing system that is sensitive to user's cognitive resources with attention being foremost. An attentive gaze directed interface can help in enhancing the attentive state of the user in three ways: minimizing the load on visual attention, improving its capacity and guiding user attention (Toet, 2006).

An AUI is part of what is known as Attention Aware Systems. Mana and Mich (2013) developed an attention aware system to detect the attention state of children using different inputs such as posture, gestures, and voice in addition to tracking facial features. Using attention grabbing approaches are recommended, including the use of colour to get the attention of the inattentive child. The application developed in this study uses an AUI to help children stay engaged in the task they are undertaking.

Maglio et al. (2000) developed the Simple User Interest Tracker (SUITOR), which is considered to be one of the first Attentive Information Systems to track the attention of the user via approaches like eye tracking and web browsing history. EyeWindows, which was developed by Fono and Vertegaal (2005), is another application that adapts its interface according to where the user is looking. If the user is looking at one of the presented windows, that window will be zoomed to its maximum size while the other windows will appear as thumbnails. The application applies another modality to assure that the selection of a window does not happen by mistake. The user has to press a key

on the keyboard to confirm the selection. Okoshi, Nakazawa, and Tokuda (2014) proposed Attelia, a software system that detects user attention in real time when using a smartphone. This software used machine learning to detect when to show notifications to the user by sensing a breakpoint in user activity. Bolt (1981) developed a technique to augment user attention where multiple movies are played at the same time. Each movie has sound and when the user looks at one of the movies, its sound is increased, and the sound of other movies is decreased. Additionally, if the user continues gazing at that movie, it will convert to full screen mode. MAGIC is another example of an attentive system in which the mouse pointer follows the user's gaze position (Zhai, Morimoto, & Ihde, 1999). The natural behaviour of user's eyes can be tracked using an eye tracking device and images can be shown to the user based on his/her attentional state. Some indicators are used to detect the attention level of the user such as blinking, opening and closing of the eyes and gazing or staring at one position (T Selker, Burleson, Scott, & Li, 2002). Qvarfordt and Zhai (2005) developed an attentive application called iTourist that adapts its interface according to what the user is looking at. When the application senses that the user is gazing at a position on the map, some changes are made to the interface.

There is a type of attentive interface, called contingent interfaces, which increase in resolution according to the gazing behaviour of the user. When the user is looking at certain positions on the display, the resolution of that position is increased while the resolution of other parts is decreased. The system uses eye tracking to tell where the user is looking (Reingold, Loschky, McConkie, & Stampe, 2003). Holman, Vertegaal, Sohn, and Cheng (2004) proposed an Electronic Charts System (ECS) Display, a 50" plasma monitor, which presents artwork. When the user focusses on a part of the display, that part is highlighted while the other parts are darkened. Attentive TV is a device that depends on the attention of the user in playing or pausing a show. When the device senses that there is no user, it pauses. When the user re-engages, it plays from the point the user stopped watching (J. Shell et al., 2003; Shell, Vertegaal, & Skaburskis, 2003). FreezeFrame is a technique developed by Dostal, Kristensson, and Quigley (2013) that depends on the attention of the user to make changes on a multi-monitor display. When a user is working on two monitors, and he/she shifts from display one to display two, the eye tracking device notices and freezes display one, turning it black and white. When the user looks back at display one again, the display is un-frozen and continues showing in colour. Popout Prism is a technique that directs user attention to the results of a search by

placing them in enlarged, coloured boxes (Suh, Woodruff, Rosenholtz, & Glass, 2002). The attention can be tracked and then used to adapt the content of the interface of a small display screen depending on the time spent on map objects (Kiefer & Giannopoulos, 2015). SwitchBack is an application based on Focus and Saccade Tracking (FAST) using the front-facing camera to track eye movement across the screen to help users of smart phones and tablets to resume the task they were working on before a distraction. The application highlights the line the user was reading in a body of text and presents to the user when he/she resumes attention to the screen. This could help him/her in resuming the task (Mariakakis, Goel, Aumi, Patel, & Wobbrock, 2015). Barbuceanu, Antonya, Duguleana, and Rusak (2011) proposed a new form of attentive interface with visual comprehension capabilities to identify user intention and to help him/her accomplish the interactivity processes such as object and task selection.

2.5 Eye tracking and ADHD

In the application developed for this study, the participant's eye movememt was tracked using a webcam to tell where the user is gazing in order to apply a colour scheme to the attentive interface. Eye tracking is a technique used to tell where the user is looking or at what object on the screen he/she is engaging with. Applications developed to be used with eye tracking devices can be classified as diagnostic, intervention, or both (Weede & Heisterkamp, 2018). This section reviews the literature to find works that have used eye tracking techniques as diagnostic or intervention tools.

2.5.1 Eye Tracking as a Diagnostic Tool

Eye tracking can be used for diagnosis and for intervention purposes. Deans, O'Laughlin, Brubaker, Gay, and Krug (2010) used an eye tracking device to track the eye movements of chidren with ADHD and learning disorders in order to have a good understanding of the underlying deficit that causes reading difficulties noticed in children with ADHD. Eye tracking is used in developmental research as a tool to diagnose children with some disorders like ADHD, dyslexia and autism. Pishyareh, Tehrani-Doost, Mahmoodi-Gharaie, Khorrami, and Rahmdar (2015) used eye tracking technology to invetigate the role of emotional processing on sustained attention of children with ADHD-C depending on the number and duration of fixations. Children were asked to view images containing emotional and neutral scenes. The results showed that children with ADHD are more attracted to images with unpleasant emotional scenes. In the same way, Serrano, Owens, and Hallowell (2015) applied eye tracking to record the viewing paterns of chidren with

and without attention deficit. The data was then used to compare the viewing patterns of the two groups. Results suggested that chidren with ADHD spend less time viewing an image but take longer to respond, and this suggests that attention has its effect on the emotions of children with ADHD. An eye tracker was employed by Türkan, Amado, Ercan, and Perçinel (2016) to compare the ability of children with and without ADHD to detect any changes or differences between original images and altered versions of the images. The eye movements were recorded using eye tracking devices. The results showed that children with ADHD underperformed compared with children without ADHD.

2.5.2 Eye Tracking as an Intervention Tool

Eye tracking devices can also be incorporated in applications developed for the purpose of helping children with ADHD. Al-Shathri, Al-Wabil, and Al-Ohali (2013) developed an application aiming at helping children with ADHD to maintain their attention for longer periods and to ignore distraction. Eye patterns (eye movements across the screen) were observed via the use of an eye tracking device. Attentive I is a cognitive therapy game developed to enhance visual attention and to develop memory skills for subjects with ADHD and Attention Deficit Disorder (ADD). The gaze enables the user to control objects on the screen with their eyes. The game also provides experts with reports for the sake of monitoring user progress (AlOmar, 2012). Weede and Heisterkamp (2018) developed a diagnostic and intervention system to help children with ADHD to overcome reading difficulties with training sessions. Users with reading difficulties usually find it difficult following lines. The system helps the user to fix their eyes on a specific location in the text in order to help in reducing the time spent reading and to help the user become a speed reader. The system uses eye fixation and duration as indicators of attention. Ghasemi (2009) ran a study to assess the influnce of eye fixation and a tracking exercise to enhance the attention and listening of children with ADHD.

2.6 Head/Mouse Tracking

2.6.1 Predicting attention using a camera

Head or mouse tracking are used as proxies for attention. Head tracking can be used to detect the level of attention. Stiefelhagen (2002) used an omni-directional camera to track the faces of people around a meeting table and analysed their head poses to predict their focus of attention. Hu, Huang, and Ranganath (2005) used an algorithm to spot the attentive behavior of people with a frequent change in focus of attention (FCFA) from a

static video camera. They predicted any shift of attention by noticing changes in head pose. Voit and Stiefelhagen (2006) used multiple cameras in a smart room to estimate the head orientation of each person in the room to determine their focus of attention. They used neural networks to estimate head pose in each camera, then a Bayes filter was used to merge all estimates. The final result was used to determine the attention of the people in terms of who was looking at whom. Otsuka et al. (2008) used face direction as an indicator of visual attention of people in a meeting. Fu and Huang (2007) developed a head tracking system called "hMouse" to estimate head pose/motion. Head orientation was used to determine a user's locus of attention. It was used to identify the direction of attention and who or what the user was paying attention to in the surrounding (Stiefelhagen, Bernardin, Ekenel, & Voit, 2008).

Head tracking can be used to monitor the attention level of a driver of a vehicle. Ji and Yang (2002) developed a technique to estimate the attention and fatigue level of a driver based on face pose. They used a camera to detect the orientation of the driver's head. D'Orazio, Leo, Guaragnella, and Distante (2007) incorporated two indicators to detect the attention state of the driver: eye gaze and head pose. A single camera was used to predict alertness. The gaze and head pose were applied to identify when the driver was not paying attention to the road. Eye blinking and head rotation are determinants of driver attention (P. Smith, Shah, & da Vitoria Lobo, 2000). Toyota has developed a Driver Monitoring System that assesses the attention of the driver. They use a near-infrared (IR) camera placed on the steering column. It monitors the angle of the driver's head. If the head is shifted away from the road for a period, a warning is activated. Driver State Monitor (DSM), developed by Delphi, uses a single camera with two IR sources mounted on the dashboard facing the driver. It monitors eye and head pose to assess the distraction and fatigue level of the driver (Barr, Popkin, & Howarth, 2009). Murphy-Chutorian and Trivedi (2010) developed a head-pose estimation algorithm and 3-D tracking techniques integrated in a real-time system to estimate the attention level of the driver.

Stiefelhagen, Yang, and Waibel (2001) used an omni-directional camera to track faces of participants in a meeting and applied neural networks and Bayesian techniques to estimate the focus of attention based on head pose. Xu et al. (2015) developed a system called Turkergaze to predict gaze direction using a webcam. Papoutsaki et al. (2016) developed an online tracking tool called WebGazer that used a normal webcam to tell the

location of the user's gaze on a webpage in real time. Hwang, Wu, Lai, and Huang (2011) used a webcam to identify the attention of the user using face features: the eyes and the nose.

2.6.2 Predicting gaze position from cursor movement

J. Huang, White, and Buscher (2012) predicted gaze position from mouse cursor movement. M. C. Chen, Anderson, and Sohn (2001) found that gaze position is highly correlated to mouse position and suggested that a mouse could be used as an alternative device to an eye tracker. Guo and Agichtein (2010) conducted a study to investigate the relation between mouse pointer position and gaze position. They reported that both gaze and mouse position were correlated within a range of 100 pixels with an accuracy of about 77 %. Another study, run by A. Johnson, Mulder, Sijbinga, and Hulsebos (2012), found that the mouse is a good tool for assessing user attention. They concluded that 75 % of the data related to eye movement could be captured by using the mouse as a tracking tool. A study conducted by (Cooke, 2006) revealed that about 69 % of the time the gaze position corresponds to mouse position. As such, they considered the mouse to be a poor man's eye tracker. Navalpakkam et al. (2013) found that tracking the movements of a mouse pointer can predict a user's attention on a search page.

Arroyo, Selker, and Wei (2006) developed an application called MouseTrack that tracks the attention of the user by tracking the location of the mouse pointer. While the user reads text on the screen, the mouse is used to indicate where he/she is reading. Scheier and Weide (2015) concluded that the mouse could be used as another device, in addition to the eye tracker, to track the attention of users. A computer mouse is considered to be an inexpensive and pervasive means of tracking user attention by predicting where he/she is looking based on mouse pointer location (Johansen & Hansen, 2006). Owen (2001) suggested that a mouse could be a practical device to track user attention in both a lab setting and remotely at the user's site.

Ageev, Lagun, and Agichtein (2013) demonstrated that cursor data collected on search result landing pages could be used to extract text fragments that attract user attention and subsequently improve quality of search result summaries (snippets). Rodrigue, Son, Giesbrecht, Turk, and Höllerer (2015) used the (x,y) coordinates of recorded mouse movements to predict the attention state of the user on a graphical user interface. Xu, Sugano, and Bulling (2016) used a computational model to anticipate the user's visual attention on the graphical user interface using mouse movement and keyboard input as

indicators of the user attention. Demšar and Çöltekin (2017) suggested that a mouse could be used as a means of predicting the attention of the user by tracking the mouse pointer across the monitor.

2.7 Colour perception in ADHD

The inconsistency and the lack of consensus among researchers in the previous studies encouraged the researcher to conduct this study. The aim of this study is to find out the effect of colour on the attention state of children with ADHD using different colour schemes (highlighting with warm colours, creating a contrast between the text colour and its background, and sharpening the on-task information while blurring the off-task information).

There is inconsistency in the findings (S. Kim, Banaschewski, & Tannock, 2015) about colour deficiency in children with ADHD. Children with ADHD were found to perform poorly with blue–yellow perception but this is not the case with red–green (Banaschewski et al., 2006; Roessner et al., 2008). S. Kim et al. (2014) investigated the differences between males and females in regard to the ability to discriminate between different intensities of some hues. The finding showed that males with ADHD have no impairment in noticing various colour saturations of a specific hue in comparison with subjects in a control group. This is not the case with female subjects who find it hard to discriminate different saturations of the same hue when compared with non-ADHD female participants in a control group. However, this study has no female participants. The finding from S. Kim et al. (2014) did not report any deficit of colour saturation discrimination among male subjects.

Regarding contrast sensitivity, there is also inconsistency in results. Three studies were conducted to assess this perception in individuals with ADHD. Two of them found that there is no significant difference between ADHD groups and control groups. Only one of these studies reported a difference between the two groups of subjects (Fuermaier et al., 2017). In a study run by Bartgis, Lefler, Hartung, and Thomas (2009), Functional Acuity Contrast Test (FACT), a test used to evaluate the visual system to detect the beginnings of any disease, was used to investigate the relationship between inattention and hyperactivity symptoms and contrast sensitivity in children with and without ADHD. They found that contrast sensitivity deficit is significantly related to hyperactivity, rather than inattention, symptoms. They reported that children with ADHD dominant inattention type did not perform poorer in this test comparing to children without ADHD.

Banaschewski et al. (2006) used the Farnsworth-Munsell 100 Hue Test (FMT) that asked participants to rank colour in ascending or descending order based on fine differences in hue. The current study does not require defining the differences in hue.

Those studies that reported specific colour deficiency with ADHD children depended solely on finding difference in fine saturation of some hues. By conducting this study, the researcher wishes to add an entry to the debate about this issue. This study showed that children with ADHD performed better when the colour schemes were added to the reading task.

2.8 Colour Schemes

Changing colour schemes on the screen and providing highlighting tracking systems is useful for students who have learning disabilities and could be helpful for all learners who have difficulties managing a large amount of text at one time (Fichten et al., 2001). Three colour schemes implemented in this study are described in the following subsections.

2.8.1 Highlighting

Kercood and Grskovic (2009) conducted a study on the impact of highlighting on performance, accuracy and behavior of students with attention deficit while doing math computation tasks. Results reported that the computation accuracy improved and, at the same time, off-task behaviour decreased with the use of highlighting. S. S. Zentall (2006) proposed two strategies to enhance selective attention: first, to practice more on the intended task, and second, by highlighting the general structures of a task or task-related information (words, sentences, instructions). Ray (2006) reported that colour highlighting enhanced writing structures in writing tasks. S. S. Zentall (1985) showed that highlighting alternate lines with two colours enhanced the performance of children with attention deficit but has no effect on the performance of children without attention deficit.

Chi, Gumbrecht, and Hong (2007) reported that highlighting part of a text guides the attention to that part. In research conducted by V. S. Gier, Kreiner, and Natz-Gonzalez (2009), inappropriate use of text highlighting could impair reading comprehension. On the other hand, V. Gier, Kreiner, Hudnell, Montoya, and Herring (2011) compared the effect of three techniques: no highlight, appropriate highlighting and inappropriate highlighting. They found that the negative effect of inappropriate highlighting was cancelled out when applying an electronic highlighter.

Hughes and Lewis (2002) applied highlighting to direct attention in an open scene. They used an orange circle annotation with three levels of highlighting. The results showed that when the desired location in the scene is solely highlighted, the attention is directed to those locations. The detection ability is lower when non-desired locations are also highlighted. This result is used in this study by only highlighting part of the text with a warm colour (orange), as used in the study of Hughes and Lewis (2002), to direct the attention to that part. Highlighting of text attracts the attention to the word or words being read (Biancarosa & Griffiths, 2012).

2.8.2 Contrast

The second scheme used in this study is colour contrast. The contrast between text and background colours is found to draw attention to the text. Some research in colour and advertising suggest that a high level of contrast between text and background enhances readability (Bruce & Foster, 1982; Radl, 1980; Wang, Fang, & Chen, 2003). Hall and Hanna (2004) reported that a high contrast between text and its background increased the readability of webpages.

Proulx and Egeth (2008) investigated the effect of luminance contrast on attention. The participants were asked to watch a display containing bars and to press the right button of the mouse if a vertical target was present in the display and the left button if the target does not appear. There were two trials. The bars in the first trial were similar in luminance while the bars in the second trial had different luminance. The results showed that the participants pay more attention to high contrast than to low. The relationship between contrast and attention could be interpreted by the biased competition theory that states that our attention is biased toward some features of objects like luminance contrast and size. Our attention will be grabbed by an object with high contrast and is larger in size. Stimulus with high contrast is "easy to attend and hard to ignore" (Pashler, Dobkins, & Huang, 2004; Proulx & Egeth, 2008). It was found that areas with high contrast (luminance-contrast, colour contrast or orientation contrast) attract the attention (Einhäuser & König, 2003).

2.8.3 Sharpening-Blurring

Sharpening/blurring is used in this study by sharpening task information and blurring other areas to set the attention on the desired area of the display. Focus on a desired area is achieved by creating a perceptual distance between the sharpened (un-masked) and the blurred (masked) areas. This makes the important information 'pop out'. Darkening the

less important parts of the user interface directs attention to the most important information (Zhai, Wright, Selker, & Kelin, 1997). This technique (sharpening/blurring) is used in Microsoft Windows and Lotus Word Pro to make desired parts stand out. When the user chooses to quit, the background is blurred to make the dialogue box stand out.Ted Selker (1994) applied sharpening/blurring in an application called Cognitive Adaptive Help (COACH). Dialogues are masked (blurred) and only one step of the task is unblurred at a time to focus the attention on that step. BubbleView (Kim et al., 2017) is a technique that guides the user's visual attention using the mouse pointer position to reveal blurred images at their original resolution (sharpened).

Numerous studies have tried to identify features that can guide attention. The most specific features are colour, motion, orientation, and size (Vogel & Baudisch, 2007). Spotlight is a technique used by (Khan, Matejka, Fitzmaurice, & Kurtenbach, 2005) to direct user attention by darkening most of the display area and leaving only part brightly visible.

One method for directing the user's attention is by blurring the less relevant parts of the display, while the relevant information is displayed sharply (Kosara, Miksch, & Hauser, 2002). Pulling user attention to the information of interest in search results is done by highlighting search results while keeping non-results unhighlighted (Cockburn, Karlson, & Bederson, 2008). Kosara et al. (2002) applied a 'semantic depth of the field' technique for drawing the attention of users. Items on the interface that fulfill some criteria are pulled into focus while others are blurred.

2.9 Optimal Stimulation Theory and performance of children with ADHD

The optimal stimulation theory proposed by S. Zentall (1975) states that children with ADHD will show a hyperactivity behaviour when they are exposed to a task with low arousal or stimulation. Children with ADHD seek optimal visual and auditory stimulation. Tasks given to them should have extra stimualtion to fulfil this need. The hyperactivity and inattentiveness would be lessened in the presence of high sensory stimulation. "Stimulation typically improved academic productivity and reduced non-academic activity" (Vostal, Lee, & Miller, 2013). Children with ADHD may have the skills necessary for academic success, but they do not keep them up long enough on tasks in order to reveal those skills.

The task performance of children with ADHD was improved by adding a stimulant in the form of colours (Belfiore, Grskovic, Murphy, & Zentall, 1996). The number of correct addition problems increased when digits were coloured and motion was added to the mathematics task (Lee & Zentall, 2002). Children with ADHD were found to perform better than their peers when reading silently when using blue and red-coloured overlays (Iovino, Fletcher, Breitmeyer, & Foorman, 1998). Hecker et al. (2002) reported that college students diagnosed with ADHD read faster with less mind wandering when the text they read was highlighted using colour, and that also helped in tracking text from left to right. The performance and behavior of chidren with ADHD could be normalized through alternatvies suggested by S. S. Zentall (1993). One of these approaches is increasing task and environmental stimulation. S. S. Zentall and Kruczek (1988) reported that adding colour to relevant features improved the performance of children with ADHD. Increasing the stimulation by adding colours into routine tasks motivated children with ADHD to continue working on the given task (Kercood & Banda, 2012). The performance of hyperactive children was improved when adding colour to relevant details of the task (S. S. Zentall et al., 1985). S. S. Zentall and Dwyer (1989) found that when colour is added to a task, the performance of children with ADHD was equivalent to a control group. Their performance is poor when using only black and white colours and colours enhanced performance of repetitive tasks. Imhof (2004) reported that the quality of hand writing of children with ADHD improved with colour stimulation. This was explained due to the addition of an external stimulation to the task to regulate selective attention and improve graphomotor ability. In a study conducted by (S. S. Zentall, 1989), it was observed that hyperactive children out-performed their peers when presented a task with black letters first and then with coloured letters. Adding bright colour to relevant details of the task helps set focus on those details (Kercood & Grskovic, 2009). Iovino et al. (1998) stated that word recognition and reading comprehension of children with ADHD improved when using coloured overlays. Imhof (2004) concluded that the attention and writing skills of children with ADHD was enhanced when colour stimulation was used. For tasks that require attention to be paid, colours could be used to improve attentional ability (S. S. Zentall & Dwyer, 1989). The attention of ADHD children increased while their hyperactivity reduced when they used coloured letters to do copying tasks and tasks requiring awareness (S. S. Zentall, 1985; S. S. Zentall & Kruczek, 1988). Adding colour stimulants to the task enhances the performance of ADHD children when it is added after exposure to the traditional black letters on white

paper (S. S. Zentall, 1986, 1989; S. S. Zentall & Dwyer, 1989). For this reason, children are first presented with black text, and then presented with colour schemes. On the other hand, a study conducted by (Belfiore et al., 1996) found that colour did not improve sight-word learning. This study had only three participants and this may decrease the generalisation of its findings.

2.10 Summary

This chapter reviewed the literature on ADHD starting with the background of this disorder, its subtypes and the symptoms of each sutype. There are three diiferent types of attention: sustained, selcective and divided. There is inconsistency in the studies investigating the imparement of sustained and divided attention in children with ADHD. On the other hand, selective attention has been found to not affect these children. In the proposed work, to help these children sustain their attention for a longer period of time, an Attentive User Interface applies colour schemes (highlighting, contrast and sharpening) to attract children and help them stay attentive to the task at hand. In order to apply the colour effect, a webcam and a mouse are used to determine where the child is looking or engaging in order to apply the effect at that area. This work is based on the optimal stimulation theory which states that children with ADHD show less hyperactivity and perform better on tasks with extra stimulation.

3 ATTENTION EXTENDING SYSTEM

3.1 Introduction

Attention is a very limited resource and many stimuli in an environment compete to grab it. Children with ADHD have even more difficulty using this limited resource. They usually get distracted by irrelevant stimuli and lose their attention after a short period of time.

This chapter describes an attention extending system developed for this study to track the attention of a child and respond according to his/her attention state. The system needs to determine whether or not the user is paying attention to predefined Areas of Interest (AOIs). These areas represent task-related information (line of text). A user looking at these areas indicates that he/she is visually attentive to the task. The system will apply a colour scheme to the AOI that the user is attending to. Three colour schemes are used: highlighting the background of the AOI, applying colour contrast between the text and the background, and sharpening the AOI while blurring other areas. The design and development of the application is anchored in the analysis of the ADHD literature and the technology related to this field. The comments and recommendations of specialists and teachers that work closely with the children are also incorporated.

3.2 Reading Assistive Technologies

Technology plays a vital role as it can open new horizons for accessing education and can overcome obstacles to learning for children and adolescents with ADHD (Silverman, Iseman, & Jeweler, 2009). Assistive technology can provide a helping hand to individuals with difficulties. R. B. Lewis and Lewis (1998) defined assistive technology as "any technology which enhances the performance of individuals with disabilities". They stated that assistive technologies serve two functions: to empower individual's strengths and to compensate for their disabilities, and to help them perform better in assigned tasks. There are devices and tools to help people with special needs to achieve and perform their daily tasks.

A reading pen is one assitive technology used to help individuals with learning disabilities to decode words and enrich vocabulary. It converts text into voice (Schmitt, McCallum, Hennessey, Lovelace, & Hawkins, 2012). Read2Go is an application for an iPad that uses text-to-speech to read books aloud. It has features like changing word and background highlighting colours, reading speed and font size (Palmer, 2013; "Read2Go," 2018). Kurzweil is a piece of software that employs text-to-speech for students to read, highlight

read words and take notes (Engstrom, 2005). Voice Dream Reader is an application that converts digital text from different sources into voice. It contains many features to facilitate the reading experience including pausing, rewinding, changing reading speed, changing font type and size, highlighting words being read and changing colour for best readability ("Voice Dream," ; Voice Dream, 2013). Wiggleworks ("Wiggleworks" n.d.) is a piece of software designed for children to help them in reading, writing and language activities. It contains audio books in which the selected book is read aloud, or he/she can read the book with visual aids. The software uses highlighting in which words or whole lines are highlighted to provide a visual guide for the child to follow. iRead (2018) is an application targeting young children to master their reading skills. It merges technology with personalized learning and embedded assessment for motivating children to succeed. Reading Counts (Houghton Mifflin Harcourt (2018)) is another application to encourage young children towards independent reading with measurable and highly motivating literacy resources. Student Assistance for Learning from Text (SALT) (MacArthur and Haynes (1995)) is a software application developed to help students with learning difficulties and under-achieving students overcome their reading difficulties.

3.3 Requirement Specification

In order to build the functionality of the system, user needs and requirements are captured. The system functions must reflect and meet these requirements.

3.3.1 User Requirements

User requirements describe the needs and demands of the targeted users. In the case of ADHD users, the system should fulfil their needs and resolve their problems. The user requirements are gathered from the literature, including journals, books and other resources, concerning ADHD. The requirements reflect the problems and shortcomings faced by that group of children. These problems or shortcomings include:

- children with ADHD become inattentive after a short period time and get distracted.
- they lose the location of what they are currently reading
- they got bored with the traditional black text on white background

Therefore, the proposed system should provide a means of keeping them engaged for a longer period using various colour schemes to flag what they are currently reading

3.3.2 System Requirements

System requirements are descriptions of system functionality, the provided services, and the operational constraints, in more detail (Sommerville (2011). These requirements are divided into two categories: functional and non-functional requirements.

I- Functional requirements:

These are statements of services the system should provide, how the system should react to particular inputs, and how the system should behave in specific conditions. In some cases, the functional requirements may also clearly state what the system should not do (Sommerville (2011). According to Marsic (2012), functional requirements determine the system's expected behaviour and the effects it should produce in the problem domain. These requirements generally represent the main product features. The functions that the application provides are: estimate the engagement of the children, apply a colour scheme on a hovered AOI, record the number of read words and the total time in a database to be used later during data analysis.

II- Non-functional requirements

Non-functional requirements can be defined as any requirement that is not a function provided by the system. This could be accessibility, reusability, ease of use or simplicity. The system does not require the user to have technical background to use it. Children with ADHD get easily distracted. Therefore, the user interface design should have a minimum of elements so the user is not distracted by unnecessary visuals. The functions of the application are usable, meaning to say, they are easy to use and are learnable. The application is also extendable, it supports the ability to add more features in the future.

3.4 UML Diagrams

The Unified Modelling Language (UML) provides a standard way of visualizing the design of a system (Booch, Rumbaugh, & Jacobson, 2005). It is used to demonstrate requirements and the design of the proposed system. It was created first by the three amigos, Grady Booch, Ivar Jacobson and Jim Rumbaugh, and then moved into the Object Management Group (OMG) for ongoing development and maintenance. It provides a visual representation of the system showing the different components and how those components interact. Several types of diagram are used to illustrate the components of the system and their interaction.

3.4.1 Use Case Diagram

A use case represents an action performed by an actor (a user or another system) to achieve a certain task or function. Use cases help decompose a large system into manageable units that could be divided amongst multiple developers of the system. Use case diagrams (Figure

3. 1) show the main functions the system provides and the interactions between the actors and the cases. Actors could be the stakeholder that initiates the use case or just a role in the system rather than a person. An actor can be from within the system of interest or from outside the boundaries of the system, in which case it is referred to as a supporting actor that interacts with the functionality of the system. Use case diagrams show the scenario of how the functions of the system work in ways that help in understanding how the system behaves to achieve that functionality. It also shows how the actors are related to the use cases and how the use cases are related to each other. It is built based on the requirement specifications elicited from the anticipated users of the proposed system.

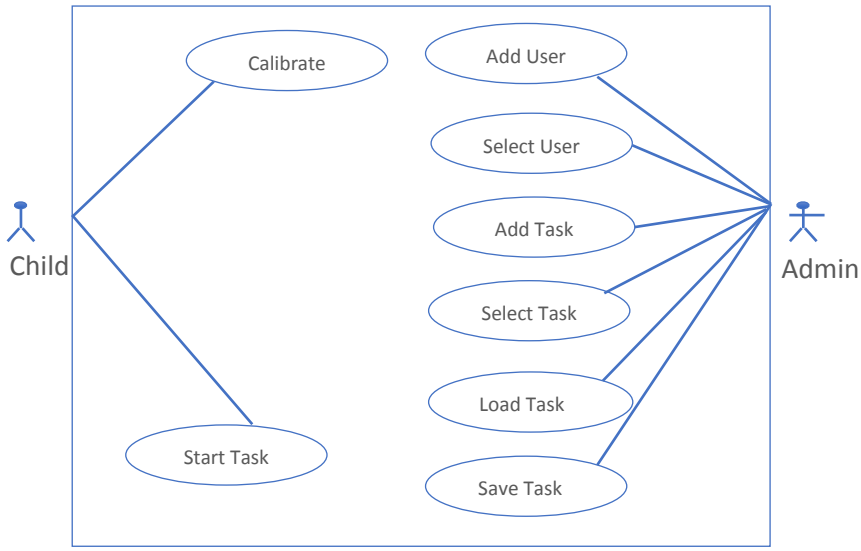


Figure 3. 1:Use Case Diagram

The Use Case Description (Table 3. 1 to Table 3. 8) is a step by step description of the interaction between the actor and the system. It also describes the interaction between the system and its surrounding in a textual form. Along with the use case diagram, the use case description forms the use case model. The use case description is documentation for the different use cases listed in the system giving information about the pre-conditions that need to be fulfilled before the start of the use case, the actors (persons or roles) and the post-conditions, which list the actions or conditions that should exist after the current use case is complete.

Table 3. 1: Use Case Description (Add user)

Use case	Description
Add user	Admin adds a child to work on the system
Actor	The Admin

Pre-condition	Make sure that the user does not exist in the database so as not to be duplicated.
Flow of events	1- Admin press "Add User" button. 2- The adding user page shows up 3- Admin enters user information 4- Admin presses "Save" button 5- The user information is saved in user database
Post condition	The user will be able to work on the system

Table 3. 2: Use Case Description (Select User)

Use case	Description
Select user	Admin selects a user from user's database
Actor	Admin
Pre-condition	The user should exist in user database
Flow of events	1- Admin open user database 2- The intended user is selected from the database. 3- The user information is shown on the screen.
Post condition	The user starts working on the system

Table 3. 3:Use Case Description (Add Task)

Use case	Description
Add Task	Admin adds a task to task database
Actor	Admin
Pre-condition	Check that the task does not exist in the database so as not to be duplicated.
Flow of events	1- Admin press "Add Task" button 2- The task information is entered 3- Admin presses "Save" 4- The task will be saved in the task database

Post condition	More tasks will be valid for users

Table 3. 4: Use Case Description (Select Task)

Use case	Description
Select task	The admin selects a task from task database
Actor	The admin
Pre-condition	The tasks should be loaded by the Admin
Flow of events	The task is shown to the user.
Post condition	The user starts working on the task

Table 3. 5: Use Case Description (Load Task)

Use case	Description
Load task	Admin loads the tasks for the user to select from them
Actor	Admin
Pre-condition	The task database should contain at least one task
Flow of events	1- Admin opens task database 2- Admin retrieves the tasks from the database 3- The tasks are shown to the admin
Post condition	The admin will be able to select a task

Table 3. 6: Use Case Description (Save Task)

Use case	Description
Save Task	Admin saves the tasks after the user finishes working on the task or the task becomes idle for a specific period of time
Actor	Admin

Pre-condition	The task finishes or becomes idle for a while.
Flow of events	1- Admin presses “Save Task” button 2- The task is saved in the task database
Post condition	The task database is updated

Table 3. 7: Use Case Description (Calibrate)

Use case	**Description**
Calibrate	The user calibrates the eye tracking device in order to get his/her eye characteristics
Actor	The child
Pre-condition	A user should be selected
Flow of events	1- The user follows some points that appear on the screen. 2- The eye tracking device obtains the eye characteristics. 3- These characteristics are saved in gaze database
Post condition	The user can start using the eye tracking device

Table 3. 8: Use Case Description (Start Task)

Use case	Description
Start task	The child begins working on the selected task.
Actor	The child
Pre-condition	A task should be selected
Flow of events	1- The user presses the “Start” button 2- He starts working. 3- His gaze is tracked

Post condition	The user's gaze behavior is saved into the gaze database

3.4.2 Context Diagram

As its name implies, this diagram (Figure 3. 2) shows the context in which the system works. It shows the entire system with its entities. In this diagram, the boundaries of the system are shown along with the interactions with its surrounding elements. Being aware of the surroundings or environment and the operational conditions has a vital role in the success or failure of the system. It shows the system as a whole without providing any details about the internal structure of the system. It has three components: the system, the terminator (which represents a function or an object), and the connectors that connect those terminators to the system. It is considered to be level 0 of the data flow diagram.

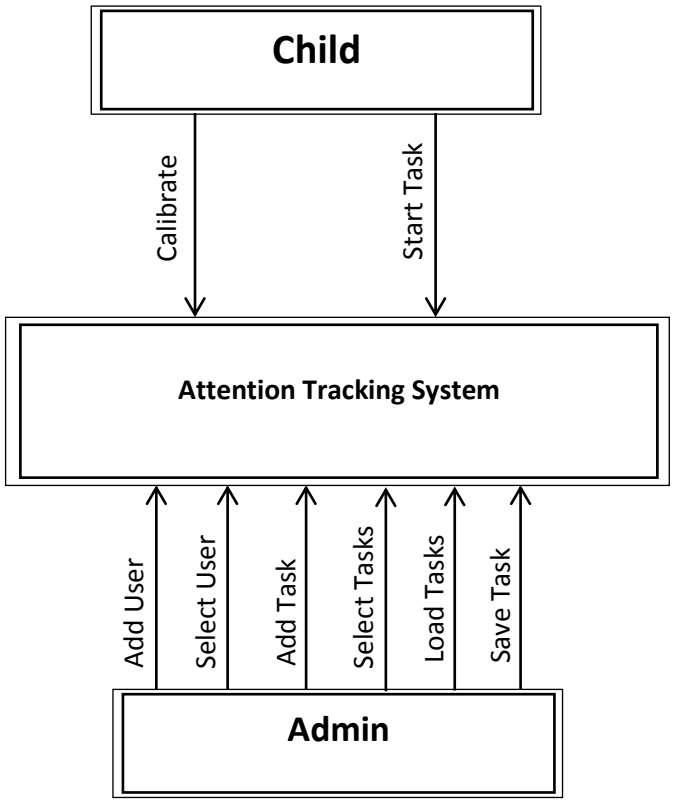


Figure 3. 2:Context Diagram

3.4.3 Data Flow Diagram (DFD)

Data flow diagrams (Figure 3. 3 and Figure 3. 4) show how data flows through the system. It is composed of four components: entities, data flow, storage and processes. The entities could be other systems, subsystems, departments, machines or the users of the system. It shows the

process and steps taken to transform the input data into output data. It is a visual representation of the flow of data through the different entities of the system with high level details. It is considered to be an expansion of the context diagram. It has several levels, each of which has more detail of the functionalities of the system.

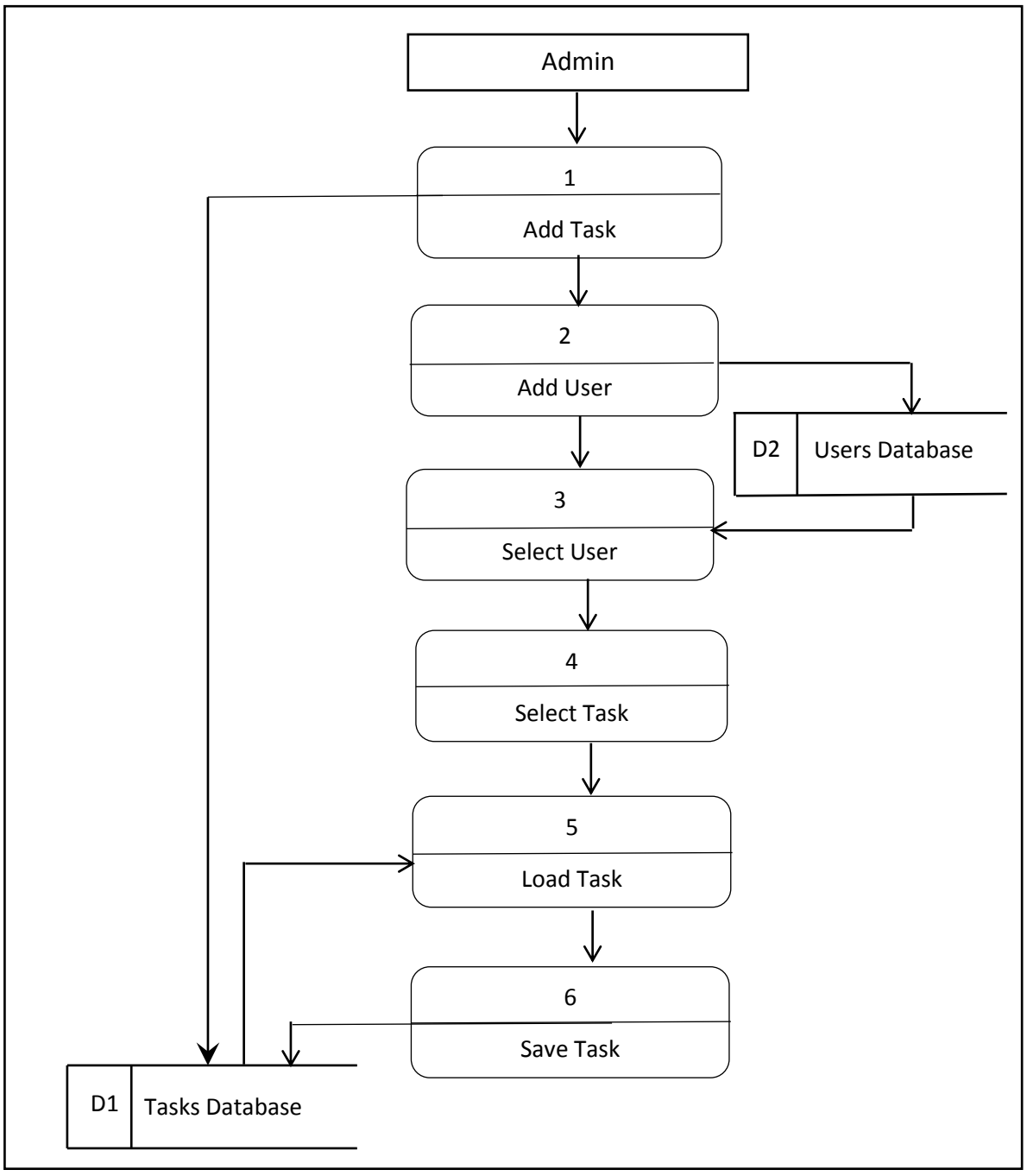


Figure 3. 3: Data Flow Diagram (Admin)

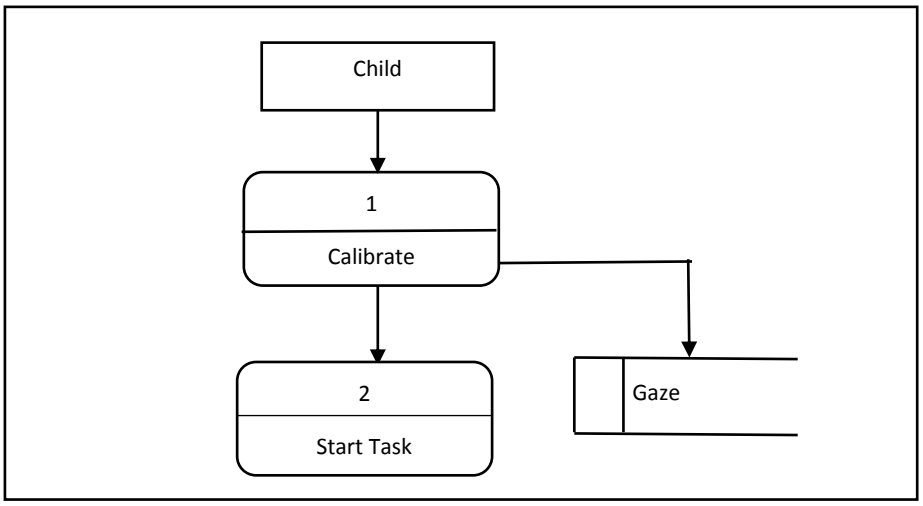


Figure 3. 4: Data Flow Diagram (Child)

3.4.4 Class Diagram

A class diagram (Figure 3. 5) shows the entities of the system in the form of classes. It shows the characteristics of the class objects in addition to the structural and behavioural features of the class. Each class has two components: methods (functions) that take place in the class and attributes (data) that are the properties that describe the class. The classes are connected through lines. The notation attached to the lines indicate the type of relation (one-to-one, one-to-many and many-to-many). It also shows the relationships between the different classes and the inheritance among the classes.

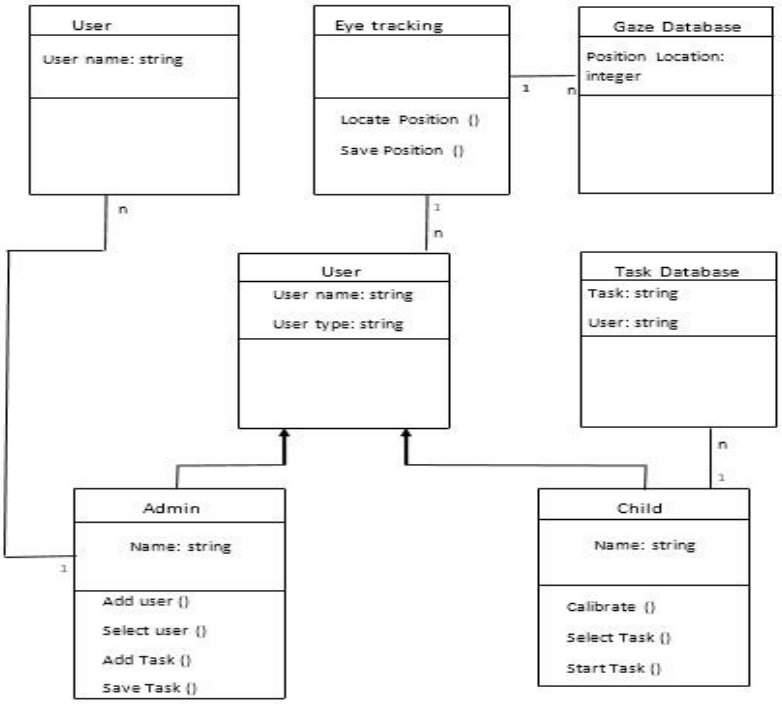


Figure 3. 5: Class Diagram

3.4.5 Sequence Diagram

This diagram (Figure 3. 6) illustrates the interaction between the objects of the system to accomplish a specific function and the order in which the interaction occurs. It also shows the messages exchanged between the objects of the system in carrying out the functionality of the proposed system. It consists of participants or the actor in the system, which could be an entity or an object. The messages show the communication between the objects of the system. A sequence diagram contains two axes: vertical represents time and horizontal represents the acting participant.

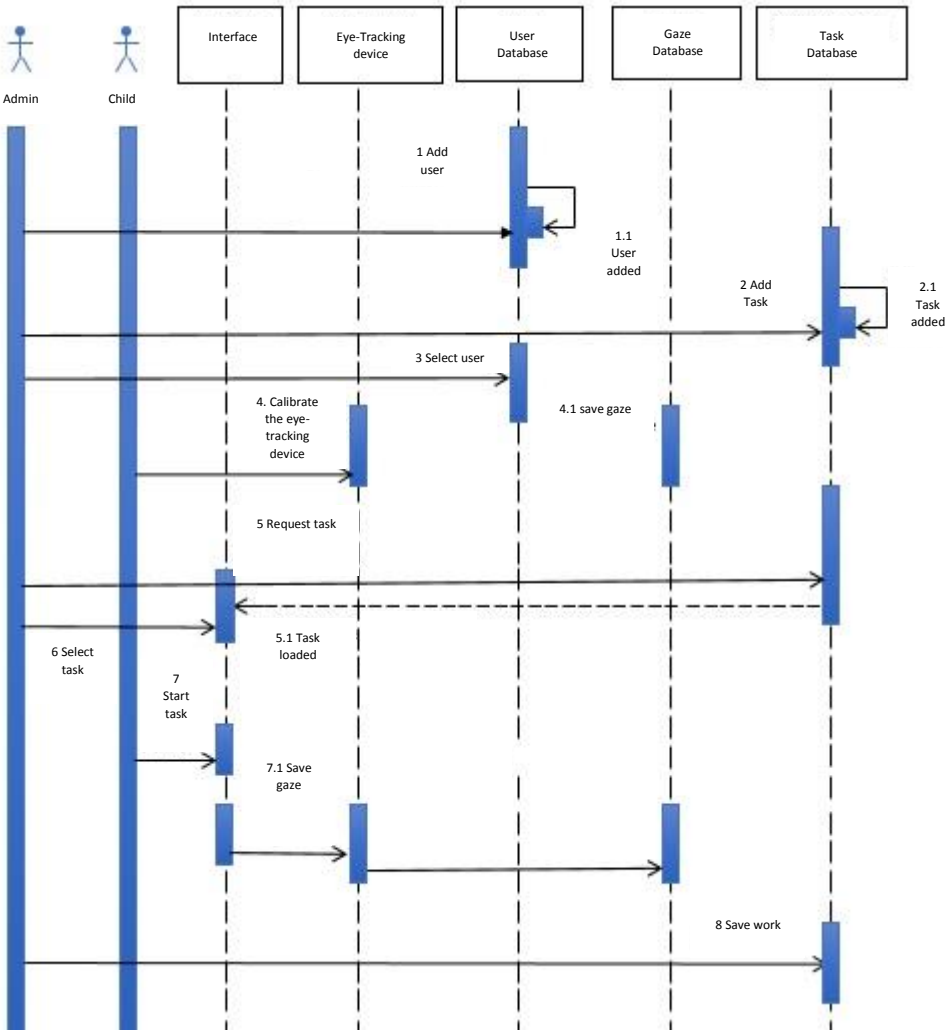


Figure 3. 6: Sequence Diagram

3.5 Interface Design

The design of the interface is based on standard guidelines for designing web pages and applications (United, 2006). Guidelines considered important for the developed system include:

- Guideline 6.1: Avoid cluttered displays
- Guideline 6.6: Optimize display density, there should be a minimum of items in the interface in order to minimise distractions
- Guideline 7.4: Provide feedback on User's location, this is applied through the use of colour scheme on the line and on the word under the mouse pointer to provide a bookmark for the reader's location in the display.

The developed application is intended to be used by children with ADHD, children who are easily distracted by the stimuli around them. The application was created to be as simple and easy as possible. Guidelines 6.1 Avoid cluttered displays and 6.6: Optimize display density are related, which emphasize the use of a minimum and non-condensed display. The interface was designed with minimum components, only necessary interface elements were added. This was done so the user is not distracted by many items on the display. The researcher avoided the use of drop-down or pop-up menus, list-boxes or tool-tips because they may distract the child. Animation was not used in the design as it was reported in some studies (Ford, Poe, & Cox, 1993) that it could distract children with ADHD. The lines of text were double-spaced to make the text non-condensed and make applying the effect easier. The number of buttons on the screen was minimised to keep the display simple. As mentioned in previous studies (Glick, 2011; Rief, 2015, 2016; Robin, 1998), children with ADHD tend to lose their reading location, guideline 7.4 (provide feedback on User's location) was taken into consideration by the location of gazed text being marked with a colour effect. The on-task information is highlighted, a colour contrast was made between the text and its background and by sharpening the desired information while blurring other information to help the child locate what they are currently reading.

Usually, the design and development of internet webpages or applications is done via the creation of prototypes using several approaches. Several prototypes are made to be as close to the final product as possible during the prototyping process (J. Lin, Newman, Hong, & Landay, 2000). Fidelity refers to how close the produced prototypes are to the

intended final products. The prototypes are classified as low-fidelity and high-fidelity (Rudd, Stern, & Isensee, 1996).

Prototypes that are similar to the final website or application are called High Fidelity prototypes and the less similar are called Low Fidelity. Sauer, Franke, and Ruettinger (2008) stated that a prototype can be described as a target of a system, that is compared with the actual model of the system and if it is reliable or not. The fidelity or reliability of the model or the prototype can be different; it ranges from a low fidelity simulation of the system, like a paper prototype, to full operational prototype. A full operational prototype is exactly like the real system to be developed. Prototyping helps in exploring user needs and requirements and the understanding gained is reflected in the development of a final product that meets these requirements.

3.5.1 Low Interface Fidelity

Low fidelity prototyping is used in the early stages of the development process to provide the big picture of user requirements and demands (Rudd et al., 1996). Low fidelity prototypes are an important tool for designers as well as developers to produce and test designs and solutions during early design phases (Beyer & Holtzblatt, 1997). Jakob Nielsen (2003) stated that discovering and addressing issues in a proposed design at an early stage has ten times the impact and is a hundred times cheaper than making and addressing changes at later stages when the implementation has started. To achieve this, a low fidelity prototype should be "quick to build and easy to use" (Virzi, Sokolov, & Karis, 1996). A low fidelity prototype is an ideal approach to discovering usability issues in the application such as information flow, terminology and the fulfilment of major user requirements (Snyder, 2003). It saves time and resources in early stages of the development cycle. Ignoring this process is costly and may threaten the entire development process (see Appendix A.1).

3.5.2 High Interface Fidelity

High fidelity is defined by Bonner and Van Schaik (1998, p. 253) as "where all or most of the functionality and often the form of the interface is fully represented". High fidelity prototypes are produced using the same techniques as those used in developing the final product. It is similar to the final product in terms of appearance and interactivity. The researcher used Visual Studio, which was used in developing the final product, in producing high fidelity prototypes. Implementing a high fidelity prototype is usually time consuming and requires a large amount of resources (Nissinen, 2015). A high fidelity

prototype illustrates the functionality of the product and resembles the final product in the sense that the user cannot tell the difference between the two versions (Nissinen, 2015) (see Appendix 0).

3.6 System Development and Coding

Visual Studio 2013 with C# was used to develop the application. The application was developed using an incremental approach (Figure 3. 7) in which the different functions of the application are added one by one until the application was fully built. This was to ensure that the current function is well designed and built before moving on to the next function. Each function was developed using the full software life cycle of design, testing and implementation. A User Centred Design (UCD) was used where the focus of the development was to meet the user needs and demands.

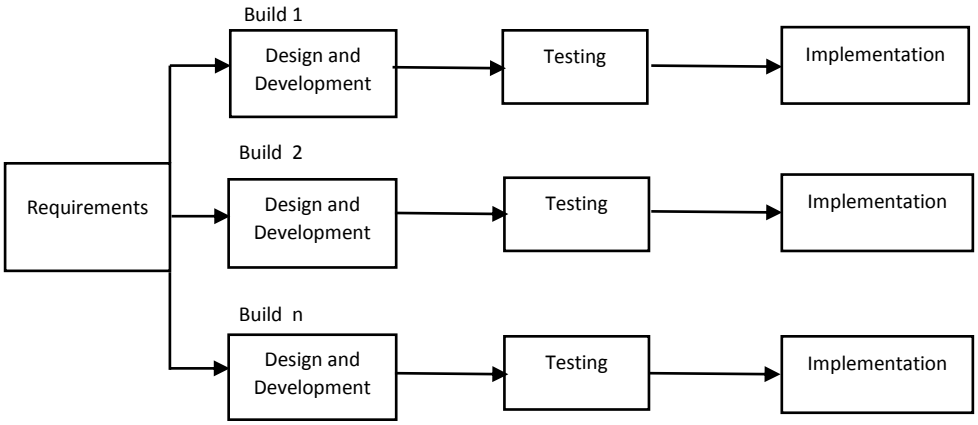


Figure 3. 7: Incremental Life Cycle model

3.7 Units and System Testing

Testing is vital in order to be certain that the system meets its functional and non-functional requirements. Testing consists of a sequence of tests from the parts to the whole, also known as bottom-up testing. Each unit is tested individually and then those units are integrated together and tested to check the interaction between them before the whole system with its various hardware and software is tested. The final stage is user acceptance testing with targeted users to check whether the developed system meets their needs and requirements. Figure 3. 8 illustrates the stages of testing.

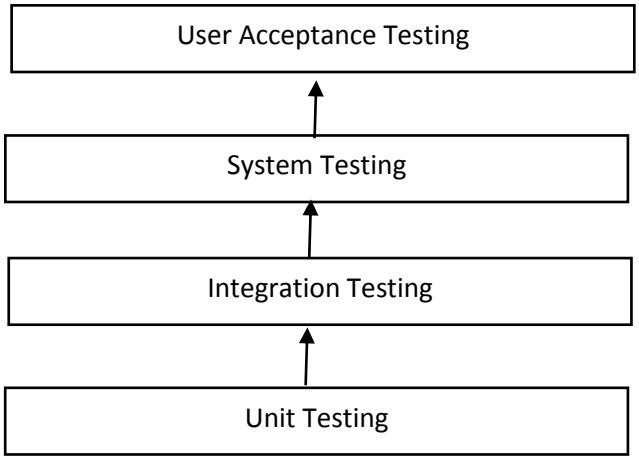


Figure 3. 8: Unit and system testing

3.7.1 Unit Testing

A unit is the smallest part of the software. It represents a function or a method in the system. Unit testing aims to test the separate parts of the system independent of other units of the system under development. The testing follows a bottom-up approach in which components at the lowest levels are tested first. The testing continues until all components at all levels are tested. This helps in finding bugs at early stages to avoid costly debugging at later stages as much as possible.

3.7.2 Integration Testing

After the units are tested individually and assured to work as intended, integration testing is next. Hardware and software components are combined and tested to evaluate the interaction between them. It's an intermediate phase between unit testing and system testing. The different functions of the application are merged together and the interaction between them is assessed to check if they perform as intended.

3.7.3 System Testing

System testing is conducted on a ready, integrated system to assess the system against its specifications and requirements. In this phase of testing, the interaction of various hardware and software components are tested to find any errors resulting from the interaction between the system components. This step is done every time a new build or a function is added to the developed application to ensure that the new function does not impact the extant functions.

3.7.4 User Acceptance Testing

User Acceptance Testing is the last phase of testing in which the intended users work on the developed system to assess whether the software meets user requirements. This stage

is important to find out whether the users are satisfied with the system or if it needs more development and modification. This stage judges the readiness of the system to be deployed. The developed application was tested in the pilot study by five ADHD children before administering it in the main study. They showed a willingness to work on the application for a longer time.

3.8 How the system works

When a child is gazing at any of the AOIs, which represent lines in the text, a predefined colour scheme is applied to the AOI. The word the child is currently reading is marked with a shade of the line colour. This helps the child to locate his/her position in the passage, which is important as indicated in studies that children with ADHD lose their position in text when reading (Glick, 2011; Rief, 2015, 2016; Robin, 1998).

The system implements three colour schemes.

- The text background is highlighted with three warm colours: red, orange and yellow.
- Three colour contrasts are used: red-green, orange-blue, and yellow-violet. A web contrast checker was used to gauge the contrast ratio of the selected colours.
- Two colours are used in the sharpening/blurring scheme: red and orange. The text colour is sharpened while the background is blurred to set focus on the sharpened text.

The system design, especially the choice of the three colour schemes and the selection of colours, is based on a rich body of literature (Bekdash, Asirvadam, Kamel, & Hutapea, 2015; Belfiore et al., 1996; Farley & Grant, 1976; Iovino et al., 1998; Kumi, Conway, Limayem, & Goyal, 2013) concerning children with ADHD and on the recommendations from specialists at the Department of Education and child developmental specialists who work closely with children with ADHD.

The system supports two interaction modalities: one using a webcam to track the eyes of the child while she/he is reading and the other using a mouse to control and move a mouse pointer on the screen. The webcam modality uses Camera Mouse, a free program that enables a user to control the mouse pointer on the screen by tracking the eye. It uses a child's eye as the tracking point and when the eye moves across the text, the mouse pointer moves with the eye accordingly (Betke, Gips, & Fleming, 2002). When the child stops at an AOI to read, a predefined colour scheme is applied to the whole line with a shade of line colour applied to the word the child is currently hovering on and reading,

as shown in Figure 3. 9. As the child reads, the system calculates the number of read words and time spent in each line and within the whole text.

Figure 3. 9: User interface with yellow highlighting scheme

In order to detect when the colour effect is to be applied, the mouse pointer has to fixate (stop) on some AOI for a certain time. During the pilot study, different dwell times were tested: 300 ms, 500 ms, 1000 ms, 1500 ms, 2000 ms and 2500 ms. It was found that using shorter dwell times resulted in many words being subject to colour effect during the saccades (when the eye is moving from one fixation to another). This is known as Midas Touch effect (Jacob, 1990), in which the effect or the selection happens without intention. To address this problem, there should be a dwell time before the effect is applied. On the other hand, using a longer dwell time somehow frustrated the child. During the pilot study, some of the participants stopped working on the application when the dwell time was 2500 ms. It was found that 1500 ms was the best dwell time to apply the effect on the AOI.

The mouse modality was used to address an issue where some ADHD children had difficulties in maintaining the webcam calibration. Design of this modality is based on the observation that some ADHD children often use the mouse pointer to flag their position in the text in order to help them locate where they are currently reading on a computer screen. Once the child stops at an AOI to read, as tracked by the mouse pointer, the system will undergo the same process as for the webcam modality to apply a colour scheme and record performance data.

To validate the accuracy of data collected by the system, the number of read words was compared against that recorded by a teacher. The teacher had the text the child was currently reading. When a word was read aloud by the child, the teacher crossed off that word. At the end of the session, the total number of read words was calculated and recorded in a log book. The teacher used a crayon when crossing words as it was found to produce less noise than a ballpoint pen or a pencil in our pilot studies.

3.9 Colour Schemes, Camera and Mouse Setup

The selection of colours is based on a body of literature (Bekdash et al., 2015; Belfiore et al., 1996; Farley & Grant, 1976; Iovino et al., 1998; Kumi et al., 2013). The researcher used a colour picker tool to select the colours used in this study, as seen in *Figure 3. 10* and *Figure 3. 11*.

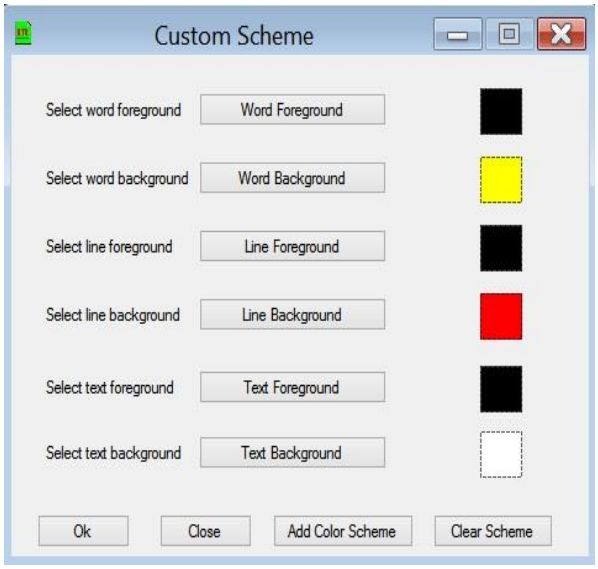


Figure 3. 10: selecting the colour scheme

Figure 3. 11: colour picker tool

It is worth mentioning that this feature is accessible to the researcher only in selecting the colour scheme used in the study; the users have no access to this feature.

Camera mouse (Betke et al., 2002) software was used to control the mouse over the screen. The process starts with selecting the webcam that will be used to track the eye of the user.

Figure 3. 12: Selecting a camera

Then the feature in the face to be tracked is selected. One of the eyes is selected as a tracking point.

Figure 3. 13:Selecting a feature to track

The next step is assigning the key(s) used to trigger the start and end of the tracking process. The ctrl key was assigned to start or end the process when pressed.

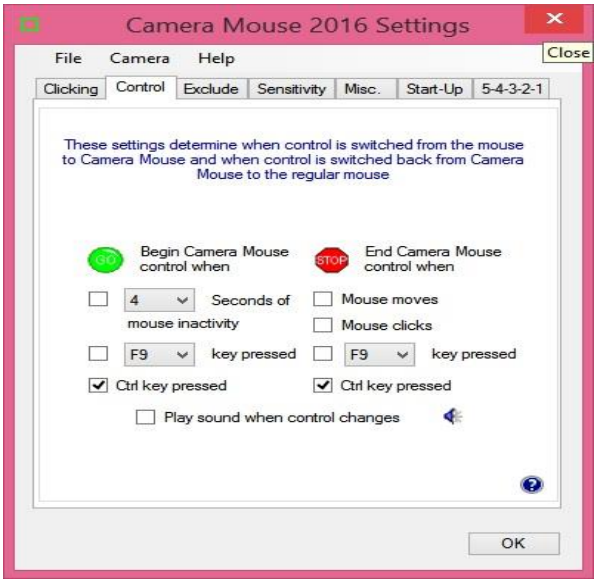


Figure 3. 14: Assigning the shortcut key

The sensitivity of the mouse pointer when controlled by the eye was set to medium to match that of the mouse pointer (Figure 3. 15 and Figure 3. 16)

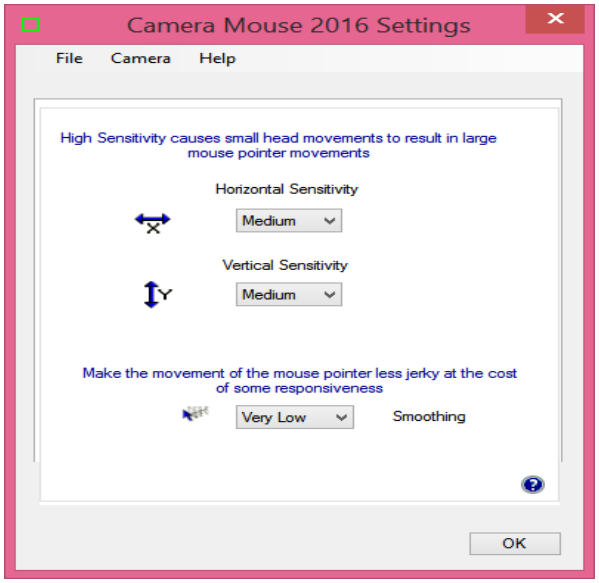


Figure 3. 15: Setting the camera

To improve the accuracy of the mouse pointer, the Enhance pointer precision check-box was ticked.

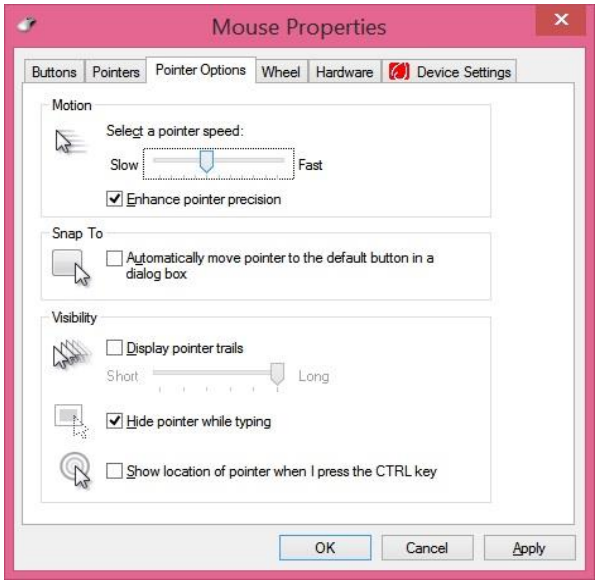


Figure 3. 16: Setting the mouse properties

3.10 Summary

This chapter introduced the software application developed for this study. The application aimed at assisting children with ADHD to be engaged with learning materials for a longer

period of time. The system is demonstrated in the how the system works section which provides some details about the features and colour schemes used to help children to be engaged and the modalities used to apply those schemes on the interface. Various UML diagrams were used to develop and illustrate the different functions of the application in a graphic representation. The units and the whole system functions were integrated and tested. Several trials were conducted to collect objective data needed to draw the conclusions.

4 EVALUATION

4.1 Participants

The participants of this study were 21 children diagnosed with ADHD recruited from a primary school with a program for children with ADHD in Jeddah, Saudi Arabia. They were aged 10–12 years old (mean 10.33, SD 0.65) and were diagnosed by a specialist at the Department of Education based on the DSM-5 criteria (Association, 2013). They were all male students since cultural issues make it hard for a male researcher to approach female students. Information packs were sent to parents containing information about the aim of the study and what their children would be asked to do. The parents of the participants were asked to sign a consent form allowing their children to take part in the study (see Appendix B7: Consent Form: Parents (English)). The parents and the children were informed that their identity would not be revealed and that the data collected would be for the purpose of the study only and would not be disclosed in publications.

Table 4. 1 provides a breakdown of the ages and school levels of the participants.

Table 4. 1: Frequencies and percentages of Demographics of Students Participating in the study

	Frequency	Percentage
	N = 21	N = 21
Age		
10	2	9.52
11	10	47.62
12	9	42.86
Grade		
4	3	14.28
5	9	42.86
6	9	42.86

School personnel were asked for the standardized test scores of participating students in their Arabic language subject to use as each participant's base academic performance.

4.2 Methods

There are two research approaches: deductive and inductive. The selection of one approach is a decision based on which approach answers the research question and accomplishes the research objectives (M. Saunders, Thornhill, Adrian, & Lewis, Philip, 2007). The deductive approach (Figure 4. 1) is used when the researcher would like to confirm or reject theories and hypotheses, while an inductive approach is used to construct a new theory (M. Saunders, Lewis, & Thornhill, 2009). This research is based on the optimal stimulation theory and, therefore, it follows that the deductive approach is used to formulate the research problem and test the hypotheses. It is an approach that is commonly used to test different types of theories. The main objective of the deductive approach is to draw a conclusion by confirming or rejecting the hypothesis and it is associated with the positivist paradigm (Crowther & Lancaster, 2009). illustrates the stages of the deductive approach.

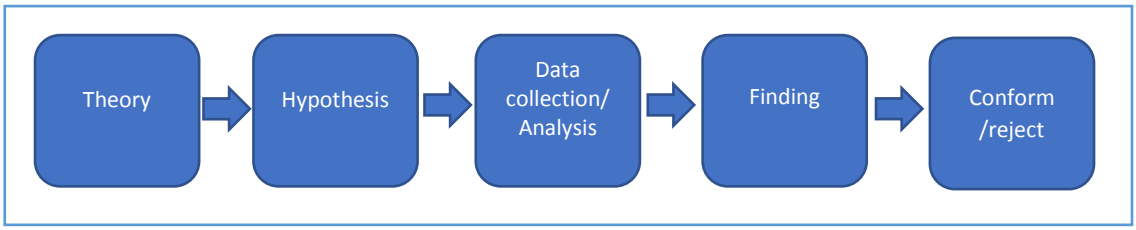


Figure 4. 1: The deductive approach (Trochim, 2005)

This study employs experimental repeated measures design in which all participants of the study were exposed to all levels of the intervention.

One-way repeated measures ANOVA was used to determine if the colour schemes have an effect on the total time and the number of words read from a text by children with ADHD. The independent variable of the experiment is the colour scheme and its effect on the dependent variable, the level of attention of the child, was assessed. The participants were exposed to all intervention levels. The order of the treatment was counterbalanced to control for the order effect (Field, 2009). The participants were assigned to three subgroups each with seven subjects, with the order of treatment different for each group. This was to make sure that the order in which the treatment was presented did not affect the results of the experiment. The participants were given breaks between trials to control for boredom and fatigue (Pan, Shell, & Schleifer, 1994).Table 4. 2 presents the order of treatment for each experiment subgroup.

Table 4. 2: The counterbalance of treatments across participants

Subgroup	Order of treatment							
Subgroup1 P1 – P7	Y-High	O-Sharp	R/G-Cont.	R-High	Y/V-Cont.	O-High	R-Sharp	O/B-Cont.
Subgroup2 P8 – P14	R/G-Cont.	O-Sharp	Y-High	R-Sharp	O-High	O/B-Cont.	R-High	Y/V-Cont.
Subgroup3 P15 – P21	Y/V-Cont.	R-Sharp	Y-High	R/G-Cont.	O-High	R-High	O-Sharp	O/B-Cont.
	R-High: Red Highlighting Y/V-Cont. Yellow Violet Contrast O-Sharp.: Orange Sharpening R-Sharp.: Red Sharpening O/B-Cont.: Orange/blue Contrast Y-High: Yellow Highlighting R/G- Cont.: Red/Green Contrast O-High: Orange Highlighting							

In order to select the participants of the study, inclusion criteria were established, as follows:

- Diagnosed with ADHD: the children participating in this study were diagnosed by specialists at the Department of Education according to DSM-5 criteria (Association, 2013), with no other disorder like learning disability or dyslexia. Children with ADHD in such inclusive schools are usually diagnosed annually or when there is a need for another diagnosis. The study started in the second month of the school calendar and, therefore, the diagnosis was considered up to date.
- The ability to read: the children at schools with classes and programs for children with ADHD are enrolled from year one. They have had extensive training to minimize reading difficulties accompanying ADHD. They are not speed readers, but they can read. They have no difficulties in reading but they lack the ability to persist and finish reading tasks. Spira and Fischel (2005) reported that children with pure inattentive symptoms usually do not complete a given task; they lack the persistence to finish.
- No visual problems: to control for vision issues that may have an influence on the interventions or the results, children participating in this study were checked by ophthalmologists to ensure that they have no vision problems. Glasses may cause

undesired reflection (Y. Huang, Kong, & LI, 2013) and this may affect the quality of the data. Children wearing glasses were excluded.

Several trials were conducted for the purpose of collecting objective data. The aim of the experimental research was to ensure that the change in the dependent variable is due to the manipulation of the independent variable.

4.3 Experiments

4.3.1 Experiment settings

The trial was conducted in a 7x5 metre resources room with no pictures or posters on the walls (Kercood, Zentall, & Lee, 2004). The resources room is located on level two of the school to provide a calm environment. The window blinds were drawn to control the reflection of the sun on the monitor. The observer (class teacher) sat beside the student but slightly behind so as not to encourage conversation (Pernice & Nielsen, 2009). The working area was clear of paper, pens or any other unnecessary material that may have encouraged the student to move, which may affect calibration (Pernice & Nielsen, 2009). The student sat on a chair adjusted in height to stay in a position facing the centre of the monitor. The distance between the user and the monitor was about 60 centimetres. The chair was stationary with no wheels and did not swivel or roll (Pernice & Nielsen, 2009).

A dual-screen set-up was used in which the researcher monitored the session from another monitor that showed the same content the user was working on. The resources room had many working spaces separated by high partitions (cubicles). The student and the teacher were sitting in one workspace while the researcher was sitting in another. This was intended to allow the student to behave normally. The researcher did not interfere through the process of the trials unless there was a technical issue or to save session data after the participant had finished their task.

The session began by welcoming the participants, thanking them for taking part in the study, telling them that their participation was highly appreciated and that they were free to work on the system as much as they liked and to feel free to stop at any time. They were asked to stay comfortable and to minimize movements to maintain calibration. Then, the calibration process started by asking them to look straight at the monitor and telling them that a green rectangle will surround their eyes in the image and that will be used for the duration of the session (see Figure 4. 3). The calibration screen was hidden from the user during task execution, but still used in the background to confirm ongoing

calibration. Before the experiment, the child had a training session to become familiar with the system. After that, the trials started.

4.3.2 Experiment Design

The experiments followed the one-group, double-pretest-posttest design (see Figure 4.2). In this design, two readings or measurements were taken before applying the intervention or the treatment, then applying the treatment and taking more readings. The participants were assigned to three subgroups. All participants were exposed to all levels of the independent variable (colour scheme). Two readings were taken for every participant and they were the baseline from which the readings from applying the colour schemes were compared. After taken the baseline reading, the colour schemes were applied in counterbalanced order to eliminate the order effect that may distort the results. With each colour scheme applied, the time spent reading the text and the number of read words were recorded. This kind of design is used to minimise the effect of maturation and regression to mean that is considered a threat to internal validity. These threats are usually present with the single-pretest-posttest design. Adding another pretest minimises the likelihood that the effect observed in the dependent variable is solely due to factors other than the manipulation of the independent variable. If the difference between the posttest and the second pre-test score is similar to the difference between the second and the first test, then the observed effect is likely caused by factors other than the manipulation of the intervention (Eliopoulos et al., 2004; Salkind, 2010; Shadish, Cook, & Campbell, 2002). This design is also called dry-run because it illuminates the biases that may exist in assessing the effects of the treatment from second pre-test and the post test. It is simulating what would happen in the null case.

This design has been used in previous studies, for example in a study conducted by Marin, Sabogal, Marin, Otero-Sabogal, and Perez-Stable (1987) to investigate the effects of a culturally appropriate smoking cessation information campaign for Hispanics. Two pre-tests were conducted before the campaign and then a post test was conducted. Results showed that information levels after the campaign were higher than before it and also higher than the difference between the first and the second pre-tests.

In this study the no effect scheme (the absence of the colour schemes) was applied twice and readings were taken and considered the baseline, then every scheme was applied in a random way. Every time the scheme was applied, its effect was measured.

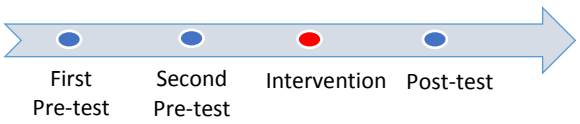


Figure 4. 2 :Experiment Design

4.3.3 Task and Procedure

There are several tasks, each assessing the effect of one colour scheme. In each task a different text is presented to the user (each text was similar in terms of word count and level of difficulty) (Nilsson, Soli, & Sullivan, 1994). The session started by calibrating the webcam (see Figure 4. 3). The child was asked to look at the centre of the screen. One feature (the eye) was selected as a tracking point to track eye movements and to tell where the user was gazing. The length of the experiments could range from two to four minutes. When the calibration was done, the child was presented with a trial text and asked to read it. This step is important as it gives an indication of how the child will perform in the main trials. Children were randomly assigned an intervention order (Table 4. 2).

The students in inclusion schools have extensive programs to minimize reading difficulties usually related to ADHD. Therefore, the researcher asked the school personnel to reveal the student's reading level to have an idea of the student's reading skills. In order to minimize the effect of reading proficiency as a confound variable the student's reading level was assessed before including the students in the study.

Figure 4. 3: Calibrating the webcam (Camera Mouse User Manual, 2016)

4.3.4 Stimuli

The students were asked to read aloud an Arabic text presented on a 22-inch screen. The text was presented with each of the three colour schemes in addition to being presented with no effect—plain black text on a white background—which served as the baseline for comparison. The font size was large enough to be easily read. Several experiments were conducted to assess the effect of each colour scheme on attracting the attention of the children. Randomization was adopted to counterbalance the order effect.

The text used as the stimuli was taken from a grade three Arabic language textbook and were examined by the students' teachers to make sure that the texts were similar in terms of length and difficulty (Riedel, Klaassen, Deutz, van Someren, & van Praag, 1999). In each trial, a different text was presented to the participants per Nilsson et al. (1994) who stated that in the repeated measures design, each experiment has different material. In contrast, independent design (between subjects) can use one material for all groups as the material is seen only one time by each group.

The stimuli were modified in appearance by applying the three colour schemes being tested. The length of text in each trial differed slightly. The number of read words was divided by the total number of words in the text to produce the percentage of read words. Each reading task took from two to four minutes.

4.3.5 Measures

Metrics used to measure engagements were: number of fixations in each AOI (number of words in each line), total number of fixations (total number of read words in all text), fixation duration, which is the total time spent in an AOI (total time in each line), and total fixation duration (total time spent in reading the text). Those metrics are found to be indicators of user engagement (Bylinskii & Borkin, 2015).

The number of read words and the total time were the measurements of the study and were measured for the whole text (total number and time of fixations). The application counted the number of read words and total time in the whole text. The number of omitted errors (missed words) or read words has been used in previous studies as indicators of attention level of children with ADHD (Berger & Cassuto, 2014).

4.4 Sampling Methods and Technique

Choosing respondents for research is very important due to the impact this has on the findings. Therefore, sampling, which can be defined as identifying the subset of the

population to whom the questionnaires are given, is a primary concern. Sampling also means the selection of a group of people in a way that increases the ability of the research to answer every question (Tashakkori, 2009).

In quantitative research, a sample has to be obtained that best represents the whole population; this is why probability sampling techniques are used. As for qualitative research, when participants are to be selected, purposive sampling techniques are used; which can answer the research questions and generate desired data (Graff, 2016).

If the methodology, instrumentation, and sampling strategy used are appropriate, then the quality of the research can be determined (L. Cohen, 2007). Sampling techniques are used in order to select a sample (Kothari, 2004). There are two major categories of sampling techniques: probability and non-probability sampling (M. Saunders et al., 2009). There are inherent benefits with probability sampling techniques, which is why it is a consideration for this study; the benefits include time saving, cost saving and accuracy (Lawrence, 2007). Simple random, systematic, stratified random and cluster samplings are some classifications of probability sampling (M. Saunders et al., 2009).

When each subject has an equal chance of being chosen from a population, then that is probability sampling. A random number table or a random mechanism is used for the purpose of choosing specific units that can be included in the sample (Lohr, 2009; M. Saunders et al., 2009). Probability sampling can be further classified as simple random, systematic, stratified random and cluster sampling (M. Saunders et al., 2009). When the chance of selecting each case is not equal, it is a non-probability sampling technique. Purposive sampling, convenience sampling, snowball sampling and quota sampling are types of non-probability sampling technique. In this study probability sampling technique (clustering) was used to select the participants

4.5 Sample Size

According to Gall, Borg, and Gall (1996), a sample of thirty cases is required in correlational research. On the other hand, a sample of fifteen cases is needed in a causal-comparative and experimental methodology. In this study a sample of twenty-one children diagnosed with ADHD were recruited.

4.6 Data Collection

There are two types of data in this study: primary data, which is collected using research instruments (questionnaire and experiments), and secondary data collected through reviewing the literature in the research field.

Factors impacting the data collection process include cost, time and resources (Pandey & Pandey, 2015). Saudi Arabia is a big country. The distance between cities can be thousands of kilometres. Collecting data from multiple cities is costly and time consuming. Therefore, one city was randomly selected to collect data from schools with an ADHD program.

Dedicated programs designed for children with ADHD are in their infancy and only five cities in all of Saudi Arabia have schools with such programs. In each of these cities, one or two schools have inclusion programs. Among the sampling techniques mentioned in Section **Error! Reference source not found.**, multistage random sampling, a form of c lustering, was used for recruiting the participants of the study. In the first stage, one city was randomly selected. In the second stage, schools with special programs for ADHD in this city were selected. It happened that the city selected in the first stage only had one school with an inclusion program for ADHD. In this school, all students with ADHD were selected. Some students' parents did not allow their children to participate in the study. According to Kumar (2011), if the number of refusals is small, it should not make the sample non-representative.

4.7 Human Subjects Ethics approval

The participants in this study were a priority and their anonymity was preserved. Their willingness to participate in this study was maintained throughout via the right to withdraw from the study at any time without consequences. Their safety and wellbeing was a big concern and participating in the study would not cause any harm to them in any way. Zoltán Dörnyei and Taguchi (2009) demonstrate the rights of the participants when participating in a study: there should be no harm, they have the right to accept or reject answering any questions, their identity should not be revealed, and they have the right to withdraw at any time with no consequences. The collected data should be used only for the purpose of the study. The information collected from this study was saved to a secured folder and the researcher was the only one able to access this information.

The study included human participants. Therefore, approval was sought from the Flinders University Social and Behavioural Research Ethics Committee (SBREC) before data

collection. Approval 7199 was granted on the 19th of May 2016 (Appendix B1: FINAL APPROVAL NOTICE). The researcher adhered to the guidelines and ensured that the participants and their caregiver were fully informed of the nature of the study and the steps and procedures to be included. The researcher sought their permission to participate by obtaining signatures on consent forms. They were given information containing details about the study. They were also given contact information of the researcher and the supervisor in case they needed further information or to clarify any point.

4.7.1 Approval to collect field data

The researcher also received permission from the Ministry of Education in Saudi Arabia to collect data from primary schools with programs for children with ADHD (Appendix B2: Approval to Collect Field Data). This included a permission from the special education sector at the department. This approval was important to allow contact with the schools' personnel and staff to seek their help in facilitating the study and coordination of the data collection process. The school management was given a copy of this permission to keep for their records. They were given the information pack and the data collection procedure was explained to them in order that they had a full understanding of the study.

4.8 Data collection Instruments

Data collection instruments are the tools (questionnaires, experiments, interviews, and focus groups) used to collect research data from the participants. In this study, two instruments were used: questionnaires and an experiment to gather the needed data from the subjects.

4.8.1 Questionnaire

A questionnaire can be defined in different ways. Questionnaires are like forms, filled by participants, after which information that is personal and demographic related is obtained (Creswell, 2008). Another definition defines questionnaire as a form, that gives numeric information or quantifiable information about the attitudes, trends and opinions of the population; this is done when a sample is selected from the population (Creswell, 2009). According to Zoltán Dörnyei and Taguchi (2009), questionnaire is an instrument through which participants are asked to respond to questions. In open ended questions, participants write their experiences, whereas in close-ended questions, respondents select the best answer.

The Likert scale is what started the close-ended questions (Likert, 1932). According to Tashakkori (2009), one of the most commonly used scales in research studies is the Likert

scale. This scale is used for the purpose of measuring the level of agreement or disagreement and to analyse the responses given by respondents in the questionnaire. The main purpose of using this scale is to obtain quantitative data. According to Z Dörnyei ; Zoltán Dörnyei and Taguchi (2009), the reason why the Likert scale is used so much is because it is a reliable measure and it can be easily used and for different purposes. Research carried out by Teddlie and Tashakkori (2009) reveals that close-ended questions are used more than open-ended questions, because responses through close-ended questions can be easily collected and quickly analysed.

There are two methods of delivery when it comes to survey based data collection. Kitchenham and Pfleeger (2002); Knapp and Kirk (2003) categorised these methods into supervised and unsupervised surveys. In a supervised survey, the respondent answers questions in the presence of the researcher. An unsupervised survey sees the user self-reflect and the researcher only distributes and collects the survey.

There are limitations and disadvantages with questionnaires. The individual questions can be complicated for respondents to make sense of if there are too many words or if they have too much repetition. In these situations, respondents may not be able to answer some questions, they can become bored, or are unable to make sense of some questions (Zoltán Dörnyei & Taguchi, 2009). However, there are advantages with questionnaires as well. According to Zoltán Dörnyei and Taguchi (2009), information can be collected in less time if the questionnaires are constructed correctly. Even when it takes a lot of time to enter data, questionnaires can be processed easily with the help of computer programs. Questionnaires make it less of a hassle for researchers, and make the whole process cost effective (Zoltán Dörnyei & Taguchi, 2009).

This research made use of two questionnaires: one for the students and one for the teachers. U Sekaran (2003) suggested that a questionnaire should be clear and understandable for the target respondents. They also stressed that the translated version should accurately match the original. Therefore, two-way translation methods (Bailey, 2008) were used to make sure the translated version matched the original. The questionnaire was developed in Arabic and then translated by a professional translator into English. The English version was sent to another professional translator to translate it back into Arabic. The original Arabic version and the one translated from English to Arabic were then compared. After another round, both translations

matched. The questionnaire was sent to Arabic teachers, child development consultants and a panel of ADHD specialists at the Department of Education who work closely with those children, to make sure that the wording was suitable and the structure of the questionnaire was clear and easy to understand. Their comments and suggestions were considered, and the questionnaire was revised accordingly.

A) Student Questionnaire

A questionnaire was used to assess the effect of colour schemes on the attention level of the children. This questionnaire was conducted after the children finished working on the application. The questionnaire used a 3-point Likert scale. Such a scale has been used in some research involving children (Goodman, 1997; Kovacs, 1992; V. Wolfe, 1996) and, in specific, children with ADHD (Owen, 2001).

The questionnaire had eight questions each with a three-point scale presented using smiley faces, as was used in previous work concerning children with ADHD (Allen et al., 2018; Bosenberg, Thomas, Lopez, Kokinsky, & Larsson, 2003; Denham & Auerbach, 1995; Owen, 2001; Wong & Baker, 1988).

The internal consistency of the questionnaire is the most important issue when the researcher uses a Likert scale to measure dimensions of phenomena under investigation (Gliem & Gliem, 2003).

B) Teacher Questionnaire

The teachers were surveyed to assess the usability of the software application developed to assess the impact of colour scheme on student attention. J Nielsen and Molic (1998) describe usability as a degree to which software can be used by some consumers, to achieve quantified objectives effectively, efficiently and with satisfaction. This is done in a quantified context. It is the test and procedure to assess the product against the user goals and requirements.

There are several tools and questionnaires to assess the usability of websites or applications. Among them are Post-Study System Usability Questionnaire (PSSUQ) (James R Lewis, 1992), Purdue Usability Testing Questionnaire (PUTQ) (H. X. Lin, Choong, & Salvendy, 1997), Questionnaire for User Interaction Satisfaction (QUIS) (Chin, Diehl, & Norman, 1988) and System Usability Scale (SUS) (Brooke, 1996).

System Usability Scale is considered quick, reliable, low cost and produces a single score that is easily understood by both expert and non-expert users.

SUS was developed by John Brooke in 1996. It contains ten items, each having five Likert response options. The individual items are meaningless on their own. These responses range from Totally Disagree to Totally Agree. The higher the score, the better the usability of the system. SUS scores range from 0 to 100. Scores above 73 indicate good usability and scores above 85 represent excellent usability (Sauro, 2011b). Tullis and Stetson (2004) conducted a study to assess the usability of two websites using five usability questionnaires: SUS, Computer System Usability Questionnaire, Questionnaire for User Interaction Satisfaction and two other questionnaires. The results show that the SUS produces the most reliable results with samples of different sizes. The SUS produced reliable results with a sample of 12–14 participants. Marco, Penichet, and Gallud (2013) assessed the usability of a tool called Drag & Share, a collaborative tool enabling the synchronization and sharing of files in real time. To do so, they asked a group of subjects to work on Moodle in two different ways: one with the use of the Drag & Share tool and the other without the tool. The findings showed that using the tool resulted in a SUS score of 89.5 and without the tool the score was 46.75. They show that the SUS confirms the usability of the Drag & Share.

In this study, SUS was administered to assess the usability of the developed application. Changing the wording of a system usability questionnaire is an accepted practice in the SUS and doesn't affect its reliability and validity (Sauro, 2011a). In line with Finstad (2006), during the pilot study, the participating teachers found the word "cumbersome" hard to understand. When it was replaced with the word "awkward", it was fully understood.

Normally, the SUS is administered directly after the participants work on the desired system and have accomplished some tasks. This is to ensure that the subjects can recall their experience from when they worked on the system so that they can give a good judgement of the system (McLellan, Muddimer, & Peres, 2012). With this guidance, the SUS was administered directly after the teachers had worked on the application. Some studies (Bangor, Kortum, & Miller, 2008; Orfanou, Tselios, & Katsanos, 2015) have concluded that SUS is a valid and reliable tool even for a small sample size.

A SUS score is quantitative in nature and is easy to understand even by non-experts. However, SUS does not indicate an acceptable usability score. Therefore, Bangor et al. (2008) produced a scale for an acceptable SUS score. This scale is illustrated in Table 4. 3.

Table 4. 3: Interpretation of System Usability Scales scores

Score	Meaning
85 – 100	The system is highly usable
70 – 84	Excellent
50 – 69	Good with some usability issues
< 50	The system is not acceptable

The data collected by administering the SUS questionnaire is analysed and the results reported in the data analysis chapter.

4.8.2 Experiments

An experiment can be described as a pragmatic procedure that arbitrates competing models or hypotheses. The aim of experimental research is to know whether a treatment has an influence on a result. There are different experiments, like true experiments, where the subjects are assigned to treatment conditions randomly. There are quasi-experiments, which make use of non-randomized assignments (G. Keppel, 1991). Researchers and scientists describe experiments as types of studies in which two or more groups or conditions are randomly assigned (Barker & Pistrang, 2015).

The main aim of the quantitative experimental research is to find evidence, which will yield a good conclusion about whether a treatment can cause a particular output or not. A representative sample should be used in such a procedure; controlled conditions should be used, so that the conclusion is generalized and can be used for a larger population (Lindgren, 2012). The result obtained is random if the experiments are performed randomly. There is the need for a plan so that only relevant information is obtained (Lundstedt et al., 1998). In the case of true experiments, a researcher tries to make a causal relationship between variables. This is achieved through manipulation of the independent variable so that the impact on dependent variables can be assessed (Shuttleworth, 2009).

The researcher determines the research design. The experimental designs are characterized through manipulation and control over the independent variable, which is called a treatment or intervention (Uma Sekaran, 1992). The aim of experimental research is to find out if a specific treatment has an impact over an outcome or not (Creswell, 2009). As per Creswell (2014), an experimental design when used in a quantitative research, tests the influence of treatment or even intervention on an outcome. The experimental research is carried out to find out about causal relationships. Through observation, it can be determined if the results of an independent variable can change the dependent variable (M. Saunders et al., 2009).

Manipulation is used in this collection of research designs, along with controlled testing. This is done to understand the causal processes and manipulation is carried out on one or more variables so that their impact on dependent variables can be assessed (Blakstad, 2008).

According to Kothari (2004), experimental studies, which are also known as hypothesis-testing research studies, are the ones where the researcher tests the hypotheses of a causal relationship. This causal relationship is between variables and such a study decreases bias and becomes more reliable. It will also allow inferences to be made about causality. It can be described as a study of the relationships between variables can be manipulated as well as measured. The scientific method gives more exact, accurate and reliable results and is similar to an observation that takes place under controlled conditions.

4.9 Instruments Validity and Reliability

Validity can be defined as "the extent to which data collection method or methods accurately measure what they were intended to measure" (M. Saunders, Thornhill, Adrian, & Lewis, Philip, 2007, p. 614). Reliability is refered to as "the dependability or consistency of the measure of a variable" (W Lawrence Neuman & Robson, 2007, p. 373). In like manner, M. Saunders, Thornhill, Adrian, & Lewis, Philip (2007, p. 149), defined reliability as "the extent to which your data collection techniques or analysis procedures will yield consistent findings".

4.9.1 Reliability and Validity of Student questionnaire

The reliability of the student questionnaire was assessed using Cronbach's alpha as an indicator of the internal consistency of the questionnaire. Two methods were used to assess the validity of the questionnaire: face validity and construct validity.

4.9.1.1 Face validity

Face validity is considered "a basic and a very minimum index of content validity" (U Sekaran, 2003). Mooi (2011) defines it as "an absolute requirement for a variable to be valid and refers to whether a variable reflects what you want to measure". Face validity, according to Graff (2016) is "the extent to which an instrument looks as if it is measuring the attribute it is supposed to measure".

The questionnaire was constructed by the researcher in Arabic and then translated to English by professional translators. It was presented to three Information Technology PhD students who were fluent in both English and Arabic to check the wording and to provide comments and suggestions. It was checked by a research statistician at the University of Jeddah to evaluate and suggest the proper statistical approach. In the pilot study stage, the questionnaire was presented to a child development consultant at King Faisal Specialist Hospital and research centre and a panel of psychological advisors at the Department of Education.

To check whether the wording was easy to understand for children at this age, it was checked by Arabic language teachers who teach students to find any unclear or ambiguous words or sentences. The child developmental specialist suggested that the questionnaire use a three-point Likert scale as the children would have difficulty answering the five-point Likert scale. The specialist stated that they would not be able to tell the difference between agree and strongly agree, and between strongly disagree and disagree of the five-point scale. This advice was heeded, and the questionnaire used a three-point Likert scale.

The questionnaire was then tested during the pilot study by five children from the target domain to identify any difficulties or words and sentences that were hard to comprehend. The comments and suggestions from all parties were taken into consideration and the questionnaire was revised accordingly to make sure that the questionnaire was clear and understandable to the children (M. Saunders et al., 2009). Testing the questionnaire at the pilot study stage is an important aspect to "refine the questionnaire so that respondents will have no problems in answering the questions and there will be no problems in recording the data" (M. Saunders et al., 2009).

4.9.1.2 Construct Validity

M. Saunders et al. (2009) describes construct validity as the extent to which the presence of constructs that you want to measure, are measured with the help of measurement questions. In this study, the construct validity was assessed using two approaches convergent and discriminant validity as suggested by Hair (2010).

I- Convergent validity

Bhattacherjee (2012) defined convergent validity as "the closeness with which a measure relates to (converges on) the construct that it is purported to measure". It assesses the extent to which two variables measuring the same concept are correlated to each other (Hair, 2010). Items in the same measure fulfil the convergent validity when they are highly correlated to each other (Kline, 2011). The result of this test shows that the items of each colour scheme are highly correlated with each other.

II- Discriminant Validity

Discriminant validity is the degree to which one construct differs from another construct (Hair, 2010). Campbell and Fiske (1959) showed the importance of conducting discriminant and convergent validity when investigating the validity of a test. The discriminant validity is met when the test of one concept is not highly correlated with another test that is meant to assess a different concept. It is an indicator to tell the difference between one construct and another within a model (Ghadi, Alwi, Bakar, & Talib, 2012).

The results of this test are detailed in the data analysis and results chapters. These results indicate that the items of the highlighting scheme are strongly related to each other but not to the items of contrast and sharpening, the same applies to the items of the contrast and sharpening.

4.9.2 Reliability and Validity of Teacher SUS questionnaire

Although many studies have concluded that SUS is highly reliable (Bangor et al., 2008), a reliability assessment was performed for this study. As reliability is commonly assessed using Cronbach's alpha (Orfanou et al., 2015), this method was employed to assess the internal consistency of SUS. Bougie (2013) reported that reliability is acceptable if Cronbach's alpha value is greater than 0.7. The validity of the questionnaire was assessed using Pearson correlation.

4.9.3 Reliability and Validity of the Experiments

Reliability of the experiment means that the experiment produces similar results when repeated. The application was tested in several occasions: first by a group of the researcher's colleagues in the faculty, during the pilot study by main stream students, and then by some students in the target population. The application showed similar results each time it was tested.

According to Cook (2009) "validity refers to whether the experiment used the measures it claims to". There are two kinds of validity related to experimental research, internal validity and external validity (Campbell, 1986). Internal validity is the degree to which the results are related to the manipulation of the independent variable rather than other uncontrolled factors (Salkind, 2008). Burns N (1993) defined internal validity as "the extent to which the effects detected in the study are a true reflection of reality, rather than being the result of the effects of extraneous variables". Behi and Nolan (1996) stated that "an experiment is said to have an internal validity when all possible extraneous variables have been controlled".

External validity, on the other hand, can be defined as "a property that allows research findings to be generalized to a larger population" (Ondercin, 2011). Thomas (2005), defined it as "the generalizability or representativeness of experimental effects or program treatment".

4.9.3.1 Threats to experiment internal validity

Robinson and Neutons (1987) stressed that it is not easy to control extraneous variables outside laboratory settings. An experimenter tries to control or hold constant those variables that may have an impact on the outcome of the experiment other than the manipulation of the independent variable (G. W. Keppel, T. D., 2004). Successful experiments apply procedures and steps to control or decrease as many of these threats as possible (Polit DF, 1991).

I- History

This is an unexpected event that may take place during the course of the study which may affect the outcome (Burns N, 1993). An example of this could be an unpleasant event that happens during the study between the pre- and post-stages and may influence the results of the study. Participants of this study were told to stop participating if they were experiencing or going through unpleasant incidents.

II- Instrumentation

This threat can be due to the instruments, the researcher or the observer. The researcher may have an effect on the results through being tired, bored or may make participants behave in certain ways. The participants may respond in ways to please the researcher. To overcome the effect of the observer, during the trials, the researcher sat in a separate cubicle and watched the trial from another monitor. The participants were not aware of the presence of the researcher. The application was tested by a group of the researcher's colleagues across several sessions, each with different users, to find any malfunctions or issues related to accuracy. It was also tested by students from the main stream and five students with ADHD in the pilot study for the same reason. Every time, it yielded the same results.

III- Statistical regression

The researcher may select only those participants with a very high or low score at the pre-test stage, which can cause what is called a statistical regression in which the scores tend to move toward the mean rather than to extreme highs or lows in the following tests. The participants of this study were average readers with academic scores neither very high nor very low, in addition the double pre-test post design minimizes the effect of this threat.

IV- Selection

The selection threat is likely to happen in the between-subjects design in which there could be a bias in the assigning of participants to the experimental or control group. In within-subjects design, which was employed in this study, there is only one group. Despite that, selection bias could be seen in the allocation of participants to the different levels of the treatment. In this study, participants were randomly assigned to the various levels of the treatment to control for the selection bias.

V- Mortality

Campbell and Stanley (1963) defined mortality as "differential loss of respondents from comparison groups". Some participants may drop out of a study for different reasons, making the groups unbalanced in terms of number of participants. In this study, repeated

measures design was used in which all participants underwent all treatment levels. If a participant dropped out, he or she would not be exposed to some levels of the treatment and this produces a threat to the internal validity of the experiment. Two participants dropped out of this study and their data was excluded during the data analysis stage.

VI- Maturation

Maturation happens as a natural change. When people get older, some biological or psychological changes take place. Those changes could happen during the course of a research activity that spans a period of time. To prevent this from threating the internal validity of the experiment, double pre-tests were conducted to show whether the changes observed in the dependent variable are purely due to the manipulation of the independent variable.

4.9.3.2 Threats to experiment external validity

According to Ondercin (2011), there are three threats to the external validity of an experiment that may affect the generalizability of the findings: non-representative samples, an artificial laboratory environment and testing effects. To address these threats, the school was randomly selected for conducting the study out of several schools that offer similar programs to children with ADHD. The researcher did his best to simulate a real situation where children are in their familiar environment with their teacher without unnecessary interference from the researcher during the study. Furthermore, the sequence of the experiments was randomized to counterbalance the testing effect.

Frankfort-Nachmias (2000) stated that researchers need to make a trade-off between the internal validity and external validity when designing the research. In some circumstances, the researcher may sacrifice the external validity in favour of maintaining the internal validity of the experiment (Ondercin, 2011).

4.10 Controlling for extraneous variables

Confounding variables are defined as "the variables that correlate (positively or negatively) with both the dependent variable and the independent variable" (Carneiro, 2005). They are extraneous variables that may influence the dependent variable and confound with the independent variable. In order to ensure that the experiments have internal validity the researcher made a best effort to predict and control the extraneous variables that may confound with the independent variable by holding them constant across all treatments or

intervention levels. The table below lists those variables and how their effects were controlled.

Variable	How it was dealt with
Experiment time	The experiments were conducted in the same time frame between 9am and 11am. The students were randomly assigned to time slots within this timeframe.
Student health condition	The parents were informed to notify the researcher through school personnel if their children were not well on the day of the trial.
Computer usage experience	The students were given training on how to use the application. The application design was made as simple as possible so that it can be easily used by children without much experience with computers.
Hunger	The classes in Saudi Arabia start early, at 7:00 am. The time of the experiments came after breakfast, when the children have had their food.
Natural factors	The venue in which the trials were conducted was adapted to minimize the effect of natural factors like noise or direct sunlight. The resources room, located on level two of the school, was used to minimise the noise. The blind was down to control for the reflection of the sunlight on the webcam.

The researcher took these approaches to control for extraneous variables that could be confounding (Buring, 1987):

- Randomization: the participants were randomly assigned to the treatments. It is worth mentioning that all participants were still exposed to all treatment levels.
- The participants were randomly assigned to the experiments.
- Restriction/exclusion: participation in this study was restricted to some criteria (see inclusion criteria on page 50). Those who did not adhere to the criteria were excluded from the study.

4.11 Summary

This chapter presented the evaluation part of the study by introducing the participants of the study and the sampling techniques used to identify the population from which data would be obtained. It also highlighted the methods for conducting the study.

Experimental setting and design are detailed. The stimuli, in the form of text with different colour effects, was presented to the participants to assess the effect of those colour schemes on attention level. This study used the number of read words as a measure to assess the attention of the children. The chapter also introduced the instruments used to collect the data. Validity and reliability are very important aspects in order to proceed to data analysis with confidence. There are many threats that may affect the internal and external validity of the results. These were discussed in the instrument validity. This study deals with human subjects, more specifically, children with special needs, and this required getting ethics approval to deal with those children. Two permissions were granted before approaching the children: an approval from Flinders University Social and Behavioural Research Ethics Committee and from the Ministry of Education in Saudi Arabia.

5 DATA ANALYSIS AND RESULTS

5.1 Introduction

This chapter presents the analysis of the quantitative data collected using two instruments: questionnaires and experiments. The reliability and validity of the data were assessed and screened for missing data, data normality, and outliers. This chapter contains two types of data: descriptive and inferential. The research data was analysed using IBM's Statistical Package for the Social Sciences (SPSS V.22), which is a well-known computer program that helps in preparing, analysing and reporting results in the form of tables and graphs.

5.2 Data screening

Pallant (2011) comments on the data screening process by saying that it is a very important process. Errors that occur during data entry need to be identified and addressed before conducting the main analysis. The aim of this process is to check the data against missing data, outliers and normality (Hair, 2010; Newton, 2013; Pallant, 2011). It is a crucial process since missing data, normality or outliers could affect the quality of the data if they are not properly dealt with.

5.2.1 Missing Data

Missing data represents information or items with no entry. This could be due to misunderstanding of the item, the item may discuss a sensitive issue that the participant did not want to answer or may be related to fatigue or lack of knowledge. Researchers use various techniques to deal with missing data, including: deletion and single imputation (Baraldi & Enders, 2010; Meade & Craig, 2012). The missing values could affect the data analysis and this could be a critical issue for some of the analysis techniques (the researcher intended to use ANOVA to analyse the data and missing values in some of the groups could ruin the results). Respondents with missing values were deleted from the analysis so as to not affect the validity of the results (Hair, 2010). In this study, two participants decided to withdraw from the study and their data were excluded from the data analysis making the study of twenty-one participants.

5.2.2 Test of normality

Data normality is a prerequisite and an assumption of many statistical analyses (William Lawrence Neuman, 2011). This process is taken into consideration in this study as there are many statistical analyses that require the data to be normally distributed.

5.2.2.1 Data normality for the application data

There are many approaches to assess data normality. Skewness and kurtosis are the most important indicators (Tabachnick & Fidell, 2007). Skewness can be seen as "the measure of the symmetry of a distribution; in most instances the comparison is made to a normal distribution" (Joseph F. Hair et al., 2010, p. 36), while kurtosis is "the measure of the peakiness or flatness of a distribution when compared with a normal distribution" (Joseph F. Hair et al., 2010, p. 35).

For the data to be normally distributed, the values of the skewness and kurtosis should be in the range -2.00 and +2.00 (William Lawrence Neuman, 2011). As shown in Table 5.1, the values of skewness fall between -.864 and + .491, while the values of kurtosis fall between -1.00 and +1.087, which comply with the accepted range of values of ±2.00, indicating the data is normally distributed.

Table 5.1: Normality test results for application data (number of read words)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
NE_Cam	21	61.33	70.83	66.7200	2.87756	-.419	.501	-.680	.972
cont_Cam	21	76.27	87.06	82.9343	3.35906	-.693	.501	-.606	.972
High_Cam	21	71.15	89.36	83.6286	4.57979	-.862	.501	1.087	.972
sharp_Cam	21	72.49	87.83	80.9667	3.81734	-.075	.501	-.209	.972
NE_Mouse	21	72.06	82.67	77.7757	2.97566	-.156	.501	-.695	.972
cont_Mouse	21	85.29	95.54	91.6771	3.15372	-.406	.501	-.988	.972
high_Mouse	21	88.53	96.25	93.4800	2.27672	-.864	.501	.242	.972
sharp_Mouse	21	86.63	96.45	90.8995	3.12203	.491	.501	-1.000	.972
Valid N (listwise)	21								

As shown in Table 5.2, the values of skewness fall between -.891 and + .387, while the values of the kurtosis fall between - 1.103 and +.318, which also comply with the accepted range of values of ±2.00, indicating the data is normally distributed.

Table 5.2: Normality test results for application data (the total time)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
t_NE_cam	21	92.00	106.25	99.9143	4.16324	-.491	.501	-.544	.972
t_cam_cont	21	121.03	137.15	127.042	4.69923	.350	.501	-.878	.972
t_cam_high	21	120.29	136.86	129.880	4.94520	-.571	.501	-.800	.972
t_cam_sharp	21	121.14	129.15	124.723	2.41510	.321	.501	-.919	.972
t_NE_mouse	21	110.30	126.01	119.131	4.34288	-.378	.501	-.422	.972
t_mouse_cont	21	130.96	145.87	140.043	4.85207	-.499	.501	-1.103	.972
t_mouse_high	21	135.00	147.00	142.649	3.47208	-.891	.501	.318	.972
t_mouse_sharp	21	132.61	146.33	138.949	4.41640	.387	.501	-1.099	.972
Valid N (listwise)	21								

5.2.2.2 Data normality for the questionnaire data

Again, for the data to be normally distributed, the values of the skewness and kurtosis should be in the range of -2.00 and +2.00 (William Lawrence Neuman, 2011). As shown in Table 5. 3 , the values of skewness fall between -.1.595 and + .199, while the values of the kurtosis fall between -1.768 and +1.895, which comply with the accepted range of values of ±2.00, indicating the data is normally distributed.

Table 5. 3: Normality test results of student questionnaire

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
The High contrast between the red text and background with shade of green colour makes text easier to read	**21**	**1**	**3**	**2.29**	**.902**	**-.635**	**.501**	**-1.518**	**.972**
The High contrast between the orange text and background with shade of blue colour makes text easier to read	**21**	**1**	**3**	**2.67**	**.577**	**-1.595**	**.501**	**1.895**	**.972**

The High contrast between the yellow text and background with shade of violet colour makes text easier to read	21	1	3	2.29	.784	-.576	.501	-1.078	.972
Highlighting part of the text with red make it easy to read	21	1	3	2.62	.669	-1.588	.501	1.428	.972
Highlighting part of the text with orange make it easy to read	21	1	3	2.24	.944	-.526	.501	-1.763	.972
Highlighting part of the text with yellow make it easy to read	21	1	3	2.57	.746	-1.464	.501	.652	.972
Sharpening part of the text with red colour make that part easy to read	21	1	3	2.00	.837	.000	.501	-1.579	.972
Sharpening part of the text with orange colour make that part easy to read	21	1	3	1.90	.889	.199	.501	-1.768	.972
Valid N (listwise)	21								

5.2.3 Outliers

Outliers are defined as observations that are substantially different from the other observations (i.e., an extreme value) on one or more characteristics (variables) (Hair, 2010). It is a score that differs from the rest of the data (Field, 2009). An outlier could be an extreme value on one variable (a univariate outlier) or could be a combination of different scores on two or more variables (multivariate outliers) (Tabachnick & Fidell, 2007). It is a value that is well below or well above the other scores (Pallant, 2011).

Dealing with outliers is very important for maintaining data accuracy since outliers may distort the conclusion drawn from the analysed data. In order to check the data for outliers, this study used z-scores.

To find outliers in the data, z-scores are calculated and then compared to the accepted range of ±3.29, as suggested by Tabachnick and Fidell (2007). Table 5. 4Table 5. 5Table 5. 6 show that all the z-scores for the student questionnaire and application data fall in the range of ±3.29, indicating that there are no outliers.

Table 5. 4: Univaraite outliers test for Questionnaire Data

Z-score Items	Minimum	Maximum
The High contrast between the red text and background with shade of green colour makes text easier to read	-1.42	+.79
The High contrast between the orange text and background with shade of blue colour makes text easier to read	-2.88	+.58
The High contrast between the yellow text and background with shade of violet colour makes text easier to read	-1.64	+.91
Highlighting part of the text with red make it easy to read	-2.42	+.57
Highlighting part of the text with orange make it easy to read	-1.31	+.81
Highlighting part of the text with yellow make it easy to read	-2.11	+.57
Sharpening part of the text with red colour make that part easy to read	-1.21	+1.10
Sharpening part of the text with orange colour make that part easy to read	-1.01	+1.23

Table 5. 5: Univaraite outliers test for the number of read words Data

Z-score Items	Minimum	Maximum
No Effect Webcam	- 1.87	+ 1.43
Contrast Webcam	- 1.98	+ 1.23
Highlighting Webcam	-2.72	+ 1.25
Sharpening Webcam	-2.22	+1.8
No Effect Mouse	-1.92	+1.64
Contrast Mouse	-2.03	+1.22
Highlighting Mouse	-2.17	+1.22
Sharpening Mouse	-1.37	+1.78

Table 5. 6: Univaraite outliers test for the total time spent Data

Z-score Items	Minimum	Maximum
t_No Effect Webcam	-1.90	+1.52
t_Contrast_Webcam	-1.28	2.15
t_Highlighting Webcam	-1.94	1.41
t_Sharpening Webcam	-1.48	1.83
t_No Effect Mouse	-2.03	1.58
t_Contrast Mouse	-1.87	1.20

t_Highlighting Mouse	-2.20	1.25
t_sharpening_Mouse	-1.44	1.67

5.3 Reliability and Validity

Reliability and validity of the research instruments are very important issues (Bryman, 2015; B. Johnson, & Christensen, L., 2013; Mertens, 2014). Pandey and Pandey (2015), described reliability as "the consistency throughout a series of measurements". Price, Chiang, and Jhangiani (2015) mentioned that there are three types of reliability assessment commonly used: test-retest reliability, internal consistency and inter-rater reliability. In this study, the internal consistency approach was used to assess the reliability of the scale used in the questionnaires. The most commonly used method to assess the internal consistency of a scale is Cronbach's alpha coefficient (Cronbach, 1951). The threshold value of 0.7 is the minimum accepted for internal reliability (Bryman, 2015; Pallant, 2016). Churchill Jr (1979) explained the meaning of different Cronbach's alpha coefficient values: around 0.9 represents an excellent internal consistency, around 0.8 represents a very good internal consistency and around 0.7 represent a good internal consistency. Values greater than .95 are not desirable as this indicates a redundancy among items (Streiner, 2003).

5.3.1 Reliability test results of student questionnaire

The internal consistency of the questionnaire is the most important issue when using Likert scale questions to measure dimensions of the phenomena under investigation.

The researcher developed a scale to measure students' assessment of which colour scheme helped them to read the text. The students were asked to evaluate the colour and their effects on their reading ability. The Cronbach alpha for the eight items was .724 (Table 5. 7), which, according to Churchill Jr (1979), is a good value demonstrating questionnaire internal consistency.

Table 5. 7: Reliability test of the student questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.724	.736	8

5.3.2 Reliability Test Results of Teachers' Questionnaire

The researcher also used the System Usability Scale (SUS) to gather reliable statistical data from teachers to score their opinions about the usability of the application. Cronbach's alpha of the SUS was .907, (Table 5. 8), which represent an excellent internal consistency (Churchill Jr, 1979). The student and teacher Cronbach's alpha scores meet conventional standards for scale reliability. As a result, the researcher proceeded to use the two scales in the study.

Table 5. 8 :Reliability test of teachers' questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.907	.911	10

5.3.3 Validity Testing of the Student Questionnaire Data

Validity is a measure to assess whether the research instrument (in this case the student questionnaire) is valid or not. An instrument is said to be valid if it measures what is supposed to measure. The validity is assessed using two approaches: face validity (discussed in Section 4.9.1.1) and convergent/discriminant validity.

5.3.3.1 Convergent Validity

Convergent validity assesses the extent to which two variables measuring the same concept are correlated to each other (Hair, 2010). Principal component analysis with Varimax rotation was employed to find these questionnaire components and their factor loading. Any value with a factor loading >= .5 is an indicator of convergent validity (Hair, 2010; Raubenheimer, 2004).

As can be seen in Table 5.9, the items of the highlighting scheme are highly correlated with each other .928, .861 and .865 (component 1). The same applies for the contrast scheme items .803, .784 and .846 (component 2) and the sharpening/blurring scheme items .907 and .877 (component 3). Therefore, the convergent validity of the questionnaire is accomplished.

Table 5.9: Components of Student Questionnaire

Color Scheme	Components		
	1	*2*	*3*
The High contrast between the red text and background with shade of green color makes text easier to read	.323	.803	-.353
The High contrast between the orange text and background with shade of blue color makes text easier to read	.016	.784	.223
The High contrast between the yellow text and background with shade of violet color makes text easier to read	-.031	.846	.103
Highlighting part of the text with red make it easy to read	.928	.057	.038
Highlighting part of the text with orange make it easy to read	.861	.094	.066
Highlighting part of the text with yellow make it easy to read	.865	.026	.245
Sharpening part of the text with red color make that part easy to read	.165	.092	.907
Sharpening part of the text with orange color make that part easy to read	.113	.039	.877

5.3.3.2 Discriminant validity

Discriminant validity is the degree to which one construct differs from another construct (Hair, 2010). The results of this test are shown in Table 5.9, which indicates that the items of the highlighting scheme are strongly related to each other but not to the items of contrast and sharpening. The same applies to the items of the contrast and sharpening/blurring. Therefore, discriminant validity is achieved.

5.3.4 Validity Testing of Teachers Questionnaire

To check the validity of the teacher questionnaire, the Pearson Coefficient of Correlation was calculated to measure the correlation between each item and the total score of corresponding scale, some of them were significant at a level of 1 % and some at 5 %. The correlation range is between r = .595 to .932, which indicates how the item correlates with the scale overall. The items correlate at moderate to strong validity for the scale under investigation (Hinkle DE, 2003), as seen in Table 5. 10 below.

Table 5. 10: Teachers questionnaire validity test

Correlations

		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Q1	Pearson Correlation	1	.557*	.454	.758**	.424	.361	.496	.188	.434	.699**	.689**
	Sig. (2-tailed)		.039	.103	.002	.131	.205	.072	.519	.121	.005	.006
	N	14	14	14	14	14	14	14	14	14	14	14
Q2	Pearson Correlation	.557*	1	.398	.817**	.345	.843**	.503	.636*	.646*	.719**	.889**
	Sig. (2-tailed)	.039		.159	.000	.227	.000	.067	.014	.012	.004	.000
	N	14	14	14	14	14	14	14	14	14	14	14
Q3	Pearson Correlation	.454	.398	1	.651*	.370	.327	.294	.329	.350	.596*	.603*
	Sig. (2-tailed)	.103	.159		.012	.192	.254	.307	.251	.219	.025	.023
	N	14	14	14	14	14	14	14	14	14	14	14
Q4	Pearson Correlation	.758**	.817**	.651*	1	.531	.643*	.616*	.408	.497	.937**	.932**
	Sig. (2-tailed)	.002	.000	.012		.051	.013	.019	.147	.071	.000	.000
	N	14	14	14	14	14	14	14	14	14	14	14
Q5	Pearson Correlation	.424	.345	.370	.531	1	.549*	.309	.244	.736**	.469	.624*
	Sig. (2-tailed)	.131	.227	.192	.051		.042	.282	.401	.003	.091	.017
	N	14	14	14	14	14	14	14	14	14	14	14
Q6	Pearson Correlation	.361	.843**	.327	.643*	.549*	1	.206	.559*	.800**	.563*	.798**
	Sig. (2-tailed)	.205	.000	.254	.013	.042		.480	.038	.001	.036	.001
	N	14	14	14	14	14	14	14	14	14	14	14
Q7	Pearson Correlation	.496	.503	.294	.616*	.309	.206	1	.172	.243	.588*	.599*
	Sig. (2-tailed)	.072	.067	.307	.019	.282	.480		.556	.402	.027	.024
	N	14	14	14	14	14	14	14	14	14	14	14
Q8	Pearson Correlation	.188	.636*	.329	.408	.244	.559*	.172	1	.586*	.436	.595*
	Sig. (2-tailed)	.519	.014	.251	.147	.401	.038	.556		.028	.119	.025
	N	14	14	14	14	14	14	14	14	14	14	14
Q9	Pearson Correlation	.434	.646*	.350	.497	.736**	.800**	.243	.586*	1	.407	.716**
	Sig. (2-tailed)	.121	.012	.219	.071	.003	.001	.402	.028		.149	.004
	N	14	14	14	14	14	14	14	14	14	14	14
Q10	Pearson Correlation	.699**	.719**	.596*	.937**	.469	.563*	.588*	.436	.407	1	.902**
	Sig. (2-tailed)	.005	.004	.025	.000	.091	.036	.027	.119	.149		.000
	N	14	14	14	14	14	14	14	14	14	14	14
Total	Pearson Correlation	.689**	.889**	.603*	.932**	.624*	.798**	.599*	.595*	.716**	.902**	1
	Sig. (2-tailed)	.006	.000	.023	.000	.017	.001	.024	.025	.004	.000	
	N	14	14	14	14	14	14	14	14	14	14	14

5.3.5 The Usability of the Application

The usability of the application was assessed using the System Usability Scale (described in Section 4.8.1). The scores from each teacher are listed in Table 5. 11 and visualised in Figure 5. 1. The mean score is 74.29 which indicates that the system is good in terms of usability.

Table 5. 11: System Usability Scale scores of the teachers

Teachers	**Score**
Teacher 1	57.5
Teacher 2	85
Teacher 3	85
Teacher 4	67.5
Teacher 5	67.5
Teacher 6	80
Teacher 7	80
Teacher 8	85
Teacher 9	77.5
Teacher 10	67.5
Teacher 11	72.5
Teacher 12	70
Teacher 13	72.5
Teacher 14	72.5
Minimum score	57.5
Maximum score	85
Mean	74.29
Std. Deviation	8.17

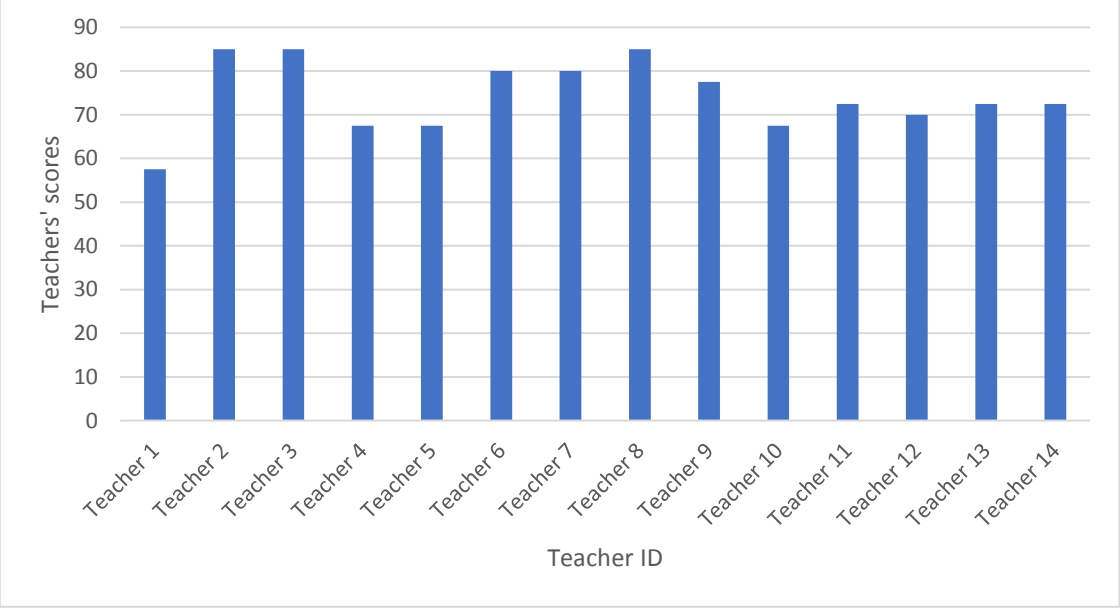


Figure 5. 1: System Usability Scale scores of the teachers

5.4 Descriptive Analysis

Descriptive analysis is the analysis of the demographic and personal information of the respondents. This was conducted after the data was screened for normality, outliers, and missing data. Table 5. 12 shows the demographic data of the 21 participants of the study.

Table 5. 12: Demographic data of the participants

	Frequency N = 21	Percentage N = 21
Age		
10	2	9.52
11	10	47.62
12	9	42.86
Grade		
4	3	14.28
5	9	42.86
6	9	42.86

5.4.1 Age

The age of the participants ranged between 10 and 12 years old, with most (10 students, 47.62 %) of the participants aged 11 years old, followed by 12 year old (9 students, 42.86 %), and 10 year old (2 students, 9.52 %).

5.4.2 Grade

The participants were enrolled in years 4, 5 and 6. The number of students from years 5 and 6 were equal (9 students, 42.86 %) and the number of students in year 4 was 3 (14.28 %).

5.5 Paired Samples t-test

To test this study's hypotheses (see Section 0), paired samples t-test, which is also called dependent-means t-test, was used. The paired samples t-test is used when there are two experimental conditions and the same participants undergo both conditions (Field, 2013). This test was conducted to determine if there was any difference in performance between the no-effect (pre-test) condition and when applying colour schemes on the text (post-test condition).

5.5.1 Assumptions of paired t-test

For the paired t-test to be valid, a number of assumptions must be met. Those assumptions are:

Assumption #1: The dependent variable should be at the interval or ratio level (continuous), and scores (percentage of words and the total spent time) of no effect, sharpening, highlighting and contrast being numerical. This assumption is met.

Assumption #2: No significant outliers. This assumption is accepted (see Section 5.2.3).

Assumption #3: Distribution of the dependent variable must be normal. Normal distribution is observed in the scores of no effect, sharpening, highlighting and contrast (see Sections 5.2.2.1 and 5.2.2.2).

Assumption #4: The independent variable should be composed of two categorical "related groups" or "matched pairs". There are two related groups: the averaged No Effect (pre-test 1 and pre-test 2 were averaged) and the averaged colour schemes (the highlighting, contrast and sharpening were averaged).

5.5.2 Comparing No Effect and Colour Scheme on number of read words

A paired-samples t-test was conducted to compare the number of read words in the no effect and colour scheme conditions (see Section 0, hypotheses H_{01} and H_{a1}) when using the webcam. Tables 5.13 and 5.14 present the results. There was a significant difference between the scores for the colour schemes (M=82.51, SD=3.10) and the no effect (M=66.72, SD=2.88) conditions: $t(20) = 22.13$, $p < 0.01$. These results show that colour schemes have an effect on the number of read words by children with ADHD. When the schemes are applied, those children perform better and read more words compared to the no effect condition. This rejects the null hypothesis (H_{01}) and supports the alternative hypothesis (H_{a1}).

Table 5. 13: Paired samples t-test statistics (Avg_webcam & No effect- number of words)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Avg_Webcam	82.5098	21	3.10164	.67683
	No_Effect_webcam	66.7200	21	2.87756	.62793

Table 5. 14: Paired samples test results

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Avg_Webcam - No_Effect_webcam	15.78984	3.26928	.71342	14.30168	17.27800	22.133	20	.000

Another paired-samples t-test was conducted to compare the number of read words with the no effect and colour scheme conditions (hypotheses H_{01} and H_{a1}) using a mouse. Results are presented in Tables 5.15 and 5.16. There was a significant difference between the scores for the colour schemes (M=92.02, SD=1.74) and no effect (M=77.78, SD=2.98) conditions: $t(20) = 20.97$, $p < 0.01$. These results show that colour schemes have an effect on the number of read words by children with ADHD. When the schemes are applied, the children perform better and read more words compared to the no effect condition. Again, this supports the alternative hypothesis (H_{a1}).

Table 5. 15: Paired samples t-test statistics (Avg_Mouse & No effect- number of words)

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Avg_Mouse	92.0189	21	1.73605	.37884
	No_Effect_Mouse	77.7757	21	2.97566	.64934

Table 5. 16: Paired samples test results

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Avg_Mouse - No_Effect_Mouse	14.24317	3.11264	.67923	12.82632	15.66003	20.969	20	.000

5.5.3 Comparing No Effect and Colour Scheme on total time

To test hypotheses H_{05} and H_{a5} (see Sections 0), paired samples t-test was conducted to determine if there was any difference in total time between the no effect (pre-test) condition and when applying colour schemes on the text (post-test condition).

A paired-samples t-test was conducted to compare the total time in the no effect and colour scheme conditions when using the webcam. Results are presented in Table 5. 17 and Table 5. 18. There was a significant difference between the scores for the colour schemes (M=127.22, SD=2.85) and the no effect (M=99.91, SD=4.16) conditions: t(20)

= 29.14, $p < 0.01$. These results show that colour schemes have an effect on the total time spent by children with ADHD. When the schemes are applied, those children engaged for a longer time compared to the no effect condition. This supports the alternative hypothesis (H_{a5}).

Table 5. 17: Paired samples t-test statistics (Avg_Webcam & No effect- total time)

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	t_Avg_cam	127.2152	21	2.84655	.62117
	t_NE_cam	99.9143	21	4.16324	.90849

Table 5. 18: Paired samples test results

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	t_Avg_cam - t_NE_cam	27.30	4.29344	.93691	25.35	29.25530	29.14	20	.000

Another paired-samples t-test was conducted to compare the total spent time with the no effect and colour scheme conditions using a mouse. Results are available in Table 5. 19 and Table 5. 20. There was a significant difference between the scores for the colour schemes (M=140.55, SD=2.44) and no effect (M=119.13, SD=4.34) conditions: t(20) = 27.65, $p < 0.01$. These results show that colour schemes have an effect on the total time spent by children with ADHD. When the schemes are applied, the children engaged for longer time compared to the no effect condition. This also supports the alternative hypothesis (H_{a5}).

Table 5. 19: Paired samples t-test statistics (Avg_Mouse & No effect- total time)

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	t_Avg_mouse	140.5470	21	2.43640	.53167
	t_NE_mouse	119.1313	21	4.34288	.94769

Table 5. 20: Paired samples test results

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	t_Avg_mouse - t_NE_mouse	21.42	3.55	.7745	19.80010	23.03120	27.65	20	.000

5.6 One-way Repeated Measures ANOVA

To test hypotheses H_{02}, H_{a2}, H_{03}, H_{a3}, H_{04}, H_{a4}, H_{06}, H_{a6}, H_{07}, H_{a7}, H_{08} and H_{a8}, one-way repeated ANOVA was conducted to identify which colour scheme had the greatest effect on the attention level of children with ADHD.

5.6.1 Assumptions of repeated measured ANOVA test

For the one-way repeated ANOVA to be valid, a number of assumptions need to be checked.

Assumption #1: the dependent variable must be continuous (interval or ratio). Scores (read words and the total time) of no effect, sharpening, highlighting and contrast are numerical. This assumption is accepted.

Assumption #2: No significant outliers. This assumption is accepted (see Section 5.2.3).

Assumption #3: Distribution of the dependent variable must be normal. Normal distribution is observed in the scores of no effect, sharpening, highlighting and contrast (see Section 5.2.2).

Assumption #4: Sphericity or the differences in variances of related groups must be equal. This is based on Mauchly's test or the corrections done by tests like Greenhouse Geisser or Huynh-Feldt tests. This assumption is accepted because Mauchly's *p* value is not significant, i.e., no difference is observed between the groups (see Table 5. 21 and Table 5. 33).

5.6.2 Research Hypotheses

The hypotheses for this research postulate that applying colour schemes to read text has an effect on the attention level of children with ADHD.

H2: The contrast scheme has an effect on the number of read words by children with ADHD

H3: The highlighting scheme has an effect on the number of read words by children with ADHD

H4: The sharpening scheme has an effect on the number of read words by children with ADHD

H6: The contrast scheme has an effect on the total time spent by children with ADHD

H7: The highlighting scheme has an effect on the total time spent by children with ADHD

H8: The sharpening scheme has an effect on the total time spent by children with ADHD

One-way repeated measures ANOVA was conducted to compare the effect of colour schemes (independent variable) on attention (dependent variable) of children with ADHD using three types of colour schemes: highlighting, contrast and sharpening. This has been used to accept or reject the null hypothesis H_0 that states that:

H_0: No effect = highlighting = contrast = sharpening.

If the null hypothesis is rejected, then we can accept the alternative hypothesis H_A:

H_A: No effect ≠ highlighting ≠ contrast ≠ sharpening,

which suggests that at least one of the schemes has statistically significant effect on the attention of children with ADHD.

5.6.3 WebCam (number of words)

One-way repeated-measures ANOVA with a within-subjects factor (contrast, highlighting, sharpening) using a webcam was performed. Mauchly's test indicated that an assumption of sphericity is plausible ($\chi^2(2) = .973$, $p = .615$), the values of p should be > .05 for the assumption of sphericity to be met (Field, 2013)

The results indicate that the webcam has a significant main effect on the number of read words by the children with ADHD ($F(2, 40) = 4.46$, $p = .018$, $\eta_p^2 = .18$), Table 5. 23. That is, the number of words read by the children differed significantly across the use of the three colour schemes. The eta squared value shows that 18 % of variance is accounted for by the effect of the colour scheme, which, according to (Cohen, 1988), is considered a significant effect.

Table 5. 21:Mauchly's test of Sphericity for the webcam

Mauchly's Test of Sphericity[a]

Measure MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
webCam	.950	.973	2	.615	.952	1.000	.500

Table 5. 22:Descriptive statistics for schemes with the webcam

Descriptive Statistics

	Mean	Std. Deviation	N
Contrast_webcam	82.9343	3.35906	21
Highlighting_webcam	83.6286	4.57979	21
Sharpening_webcam	80.9667	3.81734	21

Table 5. 23: Test of within subjects effect for the webcam

Tests of Within-Subjects Effects

Measure MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
webCam	Sphericity Assumed	80.075	2	40.038	4.456	.018	.182
	Greenhouse-Geisser	80.075	1.905	42.036	4.456	.020	.182
	Huynh-Feldt	80.075	2.000	40.038	4.456	.018	.182
	Lower-bound	80.075	1.000	80.075	4.456	.048	.182
Error(webCam)	Sphericity Assumed	359.385	40	8.985			
	Greenhouse-Geisser	359.385	38.099	9.433			
	Huynh-Feldt	359.385	40.000	8.985			
	Lower-bound	359.385	20.000	17.969			

Post-hoc tests using the Bonferroni correction revealed that there was a significant difference in the scores between highlighting (M = 83.63, SD = 4.58) and sharpening (M = 80.97, SD = 3.82) effects on number of read words (p = .013) to the favour of highlighting (Table 5. 22, Table 5. 24 and visualized in Figure 5. 2).

Table 5. 24: Pairwise comparison test

Pairwise Comparisons

Measure MEASURE_1

(I) webCam	(J) webCam	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.694	1.004	1.000	-3.317	1.928
	3	1.968	.938	.147	-.484	4.419
2	1	.694	1.004	1.000	-1.928	3.317
	3	2.662*	.824	.013	.509	4.815
3	1	-1.968	.938	.147	-4.419	.484
	2	-2.662*	.824	.013	-4.815	-.509

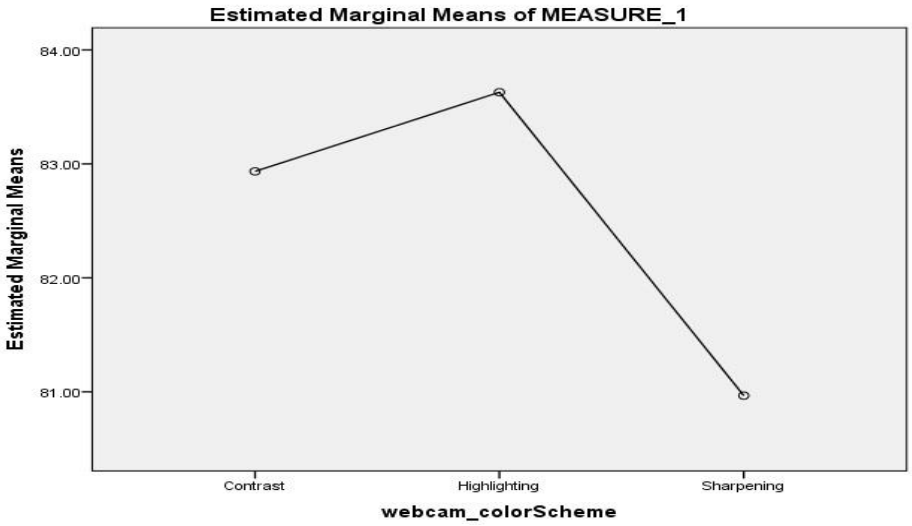


Figure 5. 2: Estimated marginal means of read words with webcam

5.6.4 Mouse (number of words)

One-way repeated measures ANOVA with a within-subjects factor (contrast, highlighting, sharpening) using a mouse was performed. Mauchly's test (Table 5. 25) indicated that an assumption of sphericity is plausible ($\chi^2(2) = 3.22$, $p = .20$) with the values of $p > .05$ for the assumption of sphericity to be met (Field, 2013).

Table 5. 25: Mauchly's test of Sphericity for the mouse

Mauchly's Test of Sphericity[a]

Measure attention

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Mouse_Tech	.844	3.222	2	.200	.865	.940	.500

The results indicate that the mouse effect has a significant main effect on the number of read words by the children with ADHD ($F(2, 40) = 4.65$, $p = .015$, $\eta_p^2 = .19$) (Table 5. 26). That is, the number of read words by the children differed significantly with the use of the three colour effects. The eta squared value shows that 19 % of variance is accounted for by the colour scheme effect, which is again considered a significant effect (Cohen, 1988).

Table 5. 26: Test of within subjects effect for the mouse

Tests of Within-Subjects Effects

Measure attention

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Mouse_Tech	Sphericity Assumed	73.597	2	36.798	4.648	.015	.189
	Greenhouse-Geisser	73.597	1.730	42.539	4.648	.020	.189
	Huynh-Feldt	73.597	1.879	39.164	4.648	.017	.189
	Lower-bound	73.597	1.000	73.597	4.648	.043	.189
Error(Mouse_Tech)	Sphericity Assumed	316.698	40	7.917			
	Greenhouse-Geisser	316.698	34.602	9.152			
	Huynh-Feldt	316.698	37.584	8.426			
	Lower-bound	316.698	20.000	15.835			

Table 5. 27: Descriptive statistics for schemes with the mouse

Descriptive Statistics

	Mean	Std. Deviation	N
Contrast_mouse	91.6771	3.15372	21
Highlighting_mouse	93.4800	2.27672	21
sharpening_mouse	90.8995	3.12203	21

Post hoc tests using the Bonferroni correction revealed a significant difference in the scores between the effect of highlighting (M = 93.48, SD = 2.28) and sharpening (M = 90.90, SD = 3.12) on the number of read words (p = .008) to the favour of highlighting, (Table 5. 27 and Table 5. 28 and visualized in Figure 5. 3).

Table 5. 28: Pairwise comparison test

Pairwise Comparisons

Measure attention

(I) Mouse_Tech	(J) Mouse_Tech	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-1.803	.798	.106	-3.888	.283
	3	.778	1.025	1.000	-1.899	3.454
2	1	1.803	.798	.106	-.283	3.888
	3	2.580*	.758	.008	.599	4.562
3	1	-.778	1.025	1.000	-3.454	1.899
	2	-2.580*	.758	.008	-4.562	-.599

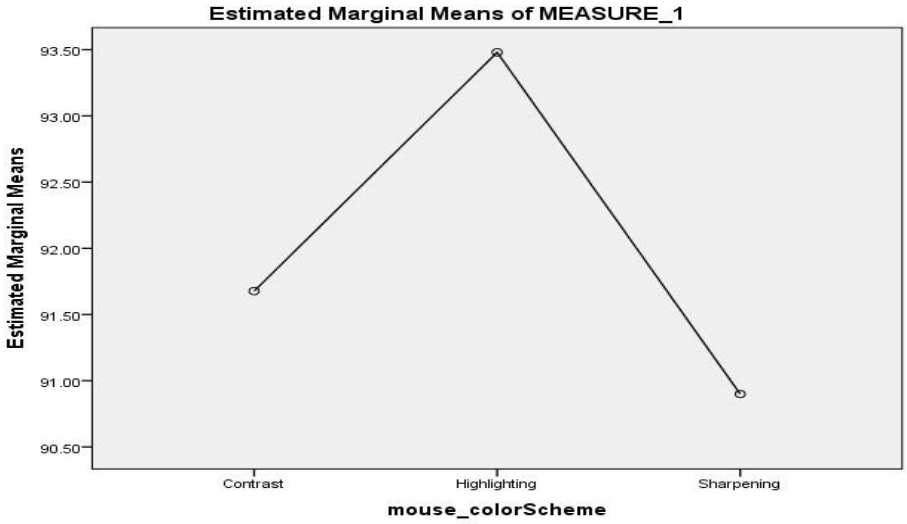


Figure 5. 3: Estimated marginal means of read words with mouse

5.6.5 WebCam (total time)

One-way repeated measures ANOVA with a within-subjects factor (contrast, highlighting, sharpening) using a webcam was performed. Mauchly's test (

Table 5. 29) indicated that an assumption of sphericity is plausible ($\chi^2(2) = 4.32$, $p = .115$) (Field, 2013).

Measure: time_spent_using_cam

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time_webcam_scheme	**.796**	**4.324**	**2**	**.115**	**.831**	**.897**	**.500**

Table 5. 29: Mauchly's test of Sphericity for the webcam

Measure: time_spent_using_cam

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time_webcam_scheme	**.796**	**4.324**	**2**	**.115**	**.831**	**.897**	**.500**

The results indicate that the webcam effect has a significant main effect on the number of read words by the children with ADHD ($F(2, 40) = 9.98$, $p < .01$, $\eta_p^2 = .33$) (Table 5. 30). That is, the time spent by the children differed significantly with the use of the three colour effects. The eta squared value shows that 33 % of variance is accounted for by the colour scheme effect, which is again considered a significant effect (Cohen, 1988).

Table 5. 30: Test of within subjects effect for the webcam

Measure: time_spent_using_cam

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time_webcam_scheme	Sphericity Assumed	**280.149**	**2**	**140.074**	**9.983**	**.000**	**.333**
	Greenhouse-Geisser	**280.149**	**1.662**	**168.583**	**9.983**	**.001**	**.333**
	Huynh-Feldt	**280.149**	**1.794**	**156.164**	**9.983**	**.001**	**.333**
	Lower-bound	**280.149**	**1.000**	**280.149**	**9.983**	**.005**	**.333**
Error(time_webcam_scheme)	Sphericity Assumed	**561.239**	**40**	**14.031**			
	Greenhouse-Geisser	**561.239**	**33.24**	**16.887**			
	Huynh-Feldt	**561.239**	**35.88**	**15.643**			
	Lower-bound	**561.239**	**20.00**	**28.062**			

Post hoc tests using the Bonferroni correction revealed a significant difference in the scores between the effect of highlighting (M = 129.88, SD = 4.95) and sharpening (M = 124.72, SD = 2.42) on the number of read words ($p < .01$) to the favour of highlighting, (Table 5. 31 and Table 5. 32 and visualized in Figure 5. 4).

Table 5. 31: Descriptive statistics for schemes with the webcam

Descriptive Statistics

	Mean	Std. Deviation	N
t_cam_cont	127.0424	4.69923	21
t_cam_high	129.8800	4.94520	21
t_cam_sharp	124.7233	2.41510	21

Table 5. 32: Pairwise comparison test

Pairwise Comparisons

Measure: time_spent_using_cam

(I) time_webcam_scheme	(J) time_webcam_scheme	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	**-2.838**	**1.356**	**.148**	**-6.381**	**.706**
	3	**2.319**	**1.171**	**.185**	**-.741**	**5.379**
2	1	**2.838**	**1.356**	**.148**	**-.706**	**6.381**
	3	**5.157***	**.893**	**.000**	**2.824**	**7.490**
3	1	**-2.319**	**1.171**	**.185**	**-5.379**	**.741**
	2	**-5.157***	**.893**	**.000**	**-7.490**	**-2.824**

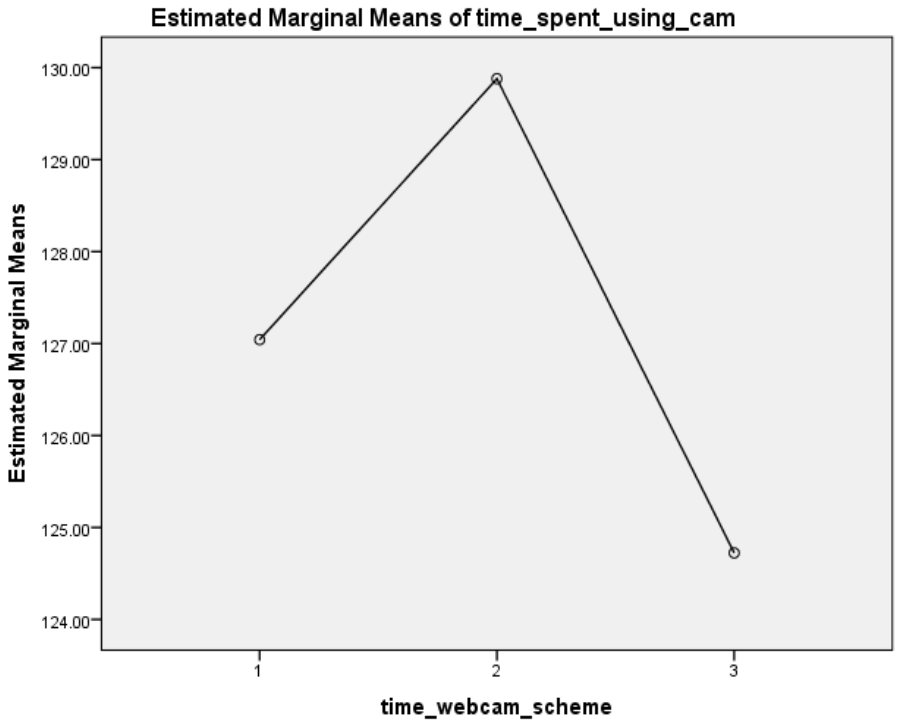


Figure 5. 4: Estimated marginal means of total time with webcam

5.6.6 Mouse (total time)

One-way repeated measures ANOVA with a within-subjects factor (contrast, highlighting, sharpening) using a webcam was performed. Mauchly's test (see Table 5. 33), indicated that an assumption of sphericity is plausible ($\chi^2(2)$ 1.34, p = .511).

Table 5. 33: Mauchly's test of Sphericity for the mouse

Mauchly's Test of Sphericity[a]

Measure: total_time_spent

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time_mouse_scheme	**.932**	**1.341**	**2**	**.511**	**.936**	**1.000**	**.500**

The results indicate that the mouse effect has a significant main effect on the number of read words by the children with ADHD (F(2, 40) = 4.07, p = .025, η_p^2=.17) (see Table 5. 34).

. That is, the total time spent by the children differed significantly with the use of the three colour effects. The eta squared value shows that 17 % of variance is accounted for by the colour scheme effect, which is again considered a significant effect (Cohen, 1988).

Table 5. 34:Test of within subjects effect for the mouse

Measure: total_time_spent

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time_mouse_scheme	Sphericity Assumed	**151.751**	**2**	**75.875**	**4.069**	**.025**	**.169**
	Greenhouse-Geisser	**151.751**	**1.872**	**81.047**	**4.069**	**.027**	**.169**
	Huynh-Feldt	**151.751**	**2.000**	**75.875**	**4.069**	**.025**	**.169**
	Lower-bound	**151.751**	**1.000**	**151.75**	**4.069**	**.057**	**.169**
Error(time_mouse_scheme)	Sphericity Assumed	**745.889**	**40**	**18.647**			
	Greenhouse-Geisser	**745.889**	**37.45**	**19.918**			
	Huynh-Feldt	**745.889**	**40.00**	**18.647**			
	Lower-bound	**745.889**	**20.00**	**37.294**			

Post hoc tests using the Bonferroni correction revealed a significant difference in the scores between the effect of highlighting (M = 142.65, SD = 3.47) and sharpening (M = 138.95, SD = 4.42) on the total time spent (p = .034) to the favour of highlighting (Table 5. 35 and Table 5. 36 and visualized in Figure 5. 5).

Table 5. 35: Descriptive statistics for schemes with the mouse

Descriptive Statistics

	Mean	Std. Deviation	N
t_mouse_cont	140.0429	4.85207	21
t_mouse_high	142.6490	3.47208	21
t_mouse_sharp	138.9490	4.41640	21

Table 5. 36: Pairwise comparison test

Pairwise Comparisons

Measure: total_time_spent

(I) time_mouse_scheme	(J) time_mouse_scheme	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	**-2.606**	**1.174**	**.114**	**-5.674**	**.461**
	3	**1.094**	**1.477**	**1.000**	**-2.765**	**4.953**
2	1	**2.606**	**1.174**	**.114**	**-.461**	**5.674**
	3	**3.700***	**1.330**	**.034**	**.226**	**7.174**
3	1	**-1.094**	**1.477**	**1.000**	**-4.953**	**2.765**
	2	**-3.700***	**1.330**	**.034**	**-7.174**	**-.226**

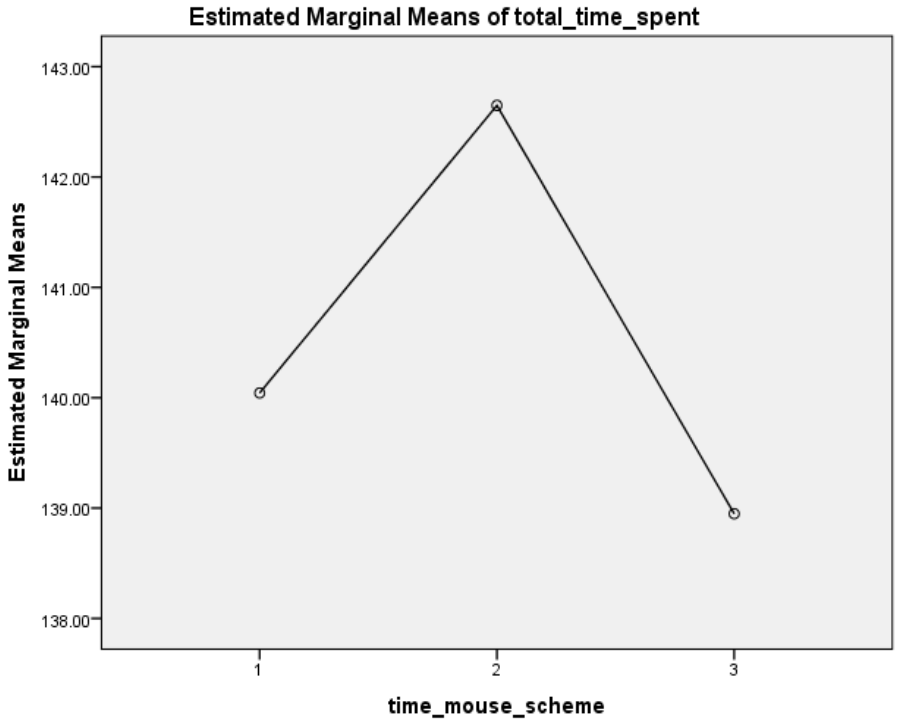


Figure 5. 5: Estimated marginal means of total time with mouse

Table 5. 37: Hypothesis Testing Summary

Hypothesis	Description	Confirmed	Rejected	Partially confirmed
Research H1 null hypothesis H01	*Colour scheme has no effect on the number of words read by children with ADHD*		√	
Alternative H1 Hypothesis H01	*There is a statistically significant effect of the colour scheme on the number of words read by children with ADHD*	√		
Research H2 null hypothesis H02	*The contrast scheme has no significant effect on the number of words read by children with ADHD.*		√	
Alternative H2 Hypothesis H02	*The contrast scheme has a significant effect on the number of words read by children with ADHD*	√		
Research H3 null hypothesis H03	*The highlighting scheme has no significant effect on the number of words read by children with ADHD*		√	
Alternative H3 Hypothesis H03	*The highlighting scheme has a significant effect on the number of words read by children with ADHD*	√		
Research H4 null hypothesis H04	*The sharpening scheme has no significant effect on the number of words read by children with ADHD*		√	
Alternative H4 Hypothesis H04	*The sharpening scheme has a significant effect on the number of words read by children with ADHD*			√
Research H5 null hypothesis H05	*Colour scheme has no effect on the total time spent reading by children with ADHD*		√	
Alternative H5 Hypothesis H05	*There is a statistically significant effect of the colour scheme on the total time spent reading by children with ADHD*	√		
Research H6 null hypothesis H06	*The contrast scheme has no significant effect on the total time spent reading by children with ADHD*		√	
Alternative H6 Hypothesis H06	*The contrast scheme has a significant effect on the total time spent reading by children with ADHD*	√		
Research H7 null hypothesis H07	*The highlighting scheme has no significant effect on the total time spent reading by children with ADHD.*		√	
Alternative H7 Hypothesis H07	*The highlighting scheme has a significant effect on the total time spent reading by children with ADHD*	√		
Research H8 null hypothesis H08	*The sharpening/blurring scheme has no significant effect on the total time spent reading by children with ADHD*		√	
Alternative H8 Hypothesis H08	*The sharpening/blurring scheme has a significant effect on the total time spent reading by children with ADHD*			√

5.7 Two-way Repeated Measures ANOVA (number of words)

A two-way repeated measures ANOVA was conducted to study the effect of interaction modalities (webcam and mouse) and colour schemes on the number of read words by the children with ADHD. Mauchly's test indicates that an assumption of sphericity was not violated ($\chi^2(2) = 5.947$, p = .051), see Table 5. 38.

Moreover, the results shows that there was nonsignificant interaction between modalities and colour schemes on the number of read words ($F(2, 40) = 2.49$, $p = .096$), see Table 5. 39. This reveals that there were nonsignificant differences between colour schemes on the number of read words caused by the different interaction modalities.

Table 5. 38: Mauchly's test of Sphericity

Mauchly's Test of Sphericity[a]

Measure MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Tech	1.000	.000	0	.	1.000	1.000	1.000
color_scheme	.899	2.029	2	.363	.908	.994	.500
Tech * color_scheme	.731	5.947	2	.051	.788	.844	.500

Measure: words

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
tech	Sphericity Assumed	**2848.293**	**1**	**2848.293**	**369.953**	**.000**	**.949**
	Greenhouse-Geisser	**2848.293**	**1.000**	**2848.293**	**369.953**	**.000**	**.949**
	Huynh-Feldt	**2848.293**	**1.000**	**2848.293**	**369.953**	**.000**	**.949**
	Lower-bound	**2848.293**	**1.000**	**2848.293**	**369.953**	**.000**	**.949**
Error(tech)	Sphericity Assumed	**153.981**	**20**	**7.699**			
	Greenhouse-Geisser	**153.981**	**20.000**	**7.699**			
	Huynh-Feldt	**153.981**	**20.000**	**7.699**			
	Lower-bound	**153.981**	**20.000**	**7.699**			
scheme	Sphericity Assumed	**144.391**	**2**	**72.196**	**4.801**	**.014**	**.194**
	Greenhouse-Geisser	**144.391**	**1.816**	**79.508**	**4.801**	**.017**	**.194**
	Huynh-Feldt	**144.391**	**1.987**	**72.656**	**4.801**	**.014**	**.194**
	Lower-bound	**144.391**	**1.000**	**144.391**	**4.801**	**.040**	**.194**
Error(scheme)	Sphericity Assumed	**601.556**	**40**	**15.039**			
	Greenhouse-Geisser	**601.556**	**36.321**	**16.562**			
	Huynh-Feldt	**601.556**	**39.746**	**15.135**			

	Lower-bound	601.556	20.000	30.078			
tech * scheme	Sphericity Assumed	9.281	2	4.640	2.491	.096	.111
	Greenhouse-Geisser	9.281	1.576	5.887	2.491	.110	.111
	Huynh-Feldt	9.281	1.688	5.497	2.491	.106	.111
	Lower-bound	9.281	1.000	9.281	2.491	.130	.111
Error(tech*scheme)	Sphericity Assumed	74.527	40	1.863			
	Greenhouse-Geisser	74.527	31.528	2.364			
	Huynh-Feldt	74.527	33.765	2.207			
	Lower-bound	74.527	20.000	3.726			

Table 5. 39: Test of within subjects effect

Table 5. 40: Descriptive statistics for schemes with the mouse

Descriptive Statistics

	Mean	Std. Deviation	N
cont_Cam	82.9343	3.35906	21
High_Cam	83.6286	4.57979	21
sharp_Cam	80.9667	3.81734	21
cont_Mouse	91.6771	3.15372	21
high_Mouse	93.4800	2.27672	21
sharp_Mouse	90.8995	3.12203	21

However, there was a significant main effect due to modality ($F(1,20) = 369.95$, $p < .01$, $\eta_p^2 = .95$), see Table 5. 39. This means that if we ignore all other variables (levels of colour effects), we will find there is a significant difference between the two modalities. The value of eta squared for effect size conveys that 95 % of effect on number of read words accounted for modality.

The estimated average of the webcam was ($M = 82.51$), and for the mouse it was ($M = 92.02$). According to the pairwise comparison there was a significant difference ($p < .01$) in favour of the mouse.

Additionally, there was a significant main effect of the colour scheme levels ($F(2, 40) = 4.8$, $p = .014$, $\eta p2 = .19$). This means that if we hold constant the effect of modality, there were significant differences among the three levels of colour scheme effects on the number of read words by the children with ADHD. The value of eta squared for effect size shows that 19 % of effect on number of read words is accounted for by colour scheme. The pairwise comparisons show that the significant difference exists between

highlighting (M = 88.55) and sharpening (M = 85.93) in favour of highlighting, (p = .005), see Table 5. 40,Table 5. 41 and Figure 5. 6.

Table 5. 41: Pairwise comparison

Measure: Number_of_words

(I) scheme	(J) scheme	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-1.249	.837	.454	-3.436	.939
	3	1.373	.960	.504	-1.134	3.879
2	1	1.249	.837	.454	-.939	3.436
	3	2.621*	.726	.005	.725	4.517
3	1	-1.373	.960	.504	-3.879	1.134
	2	-2.621*	.726	.005	-4.517	-.725

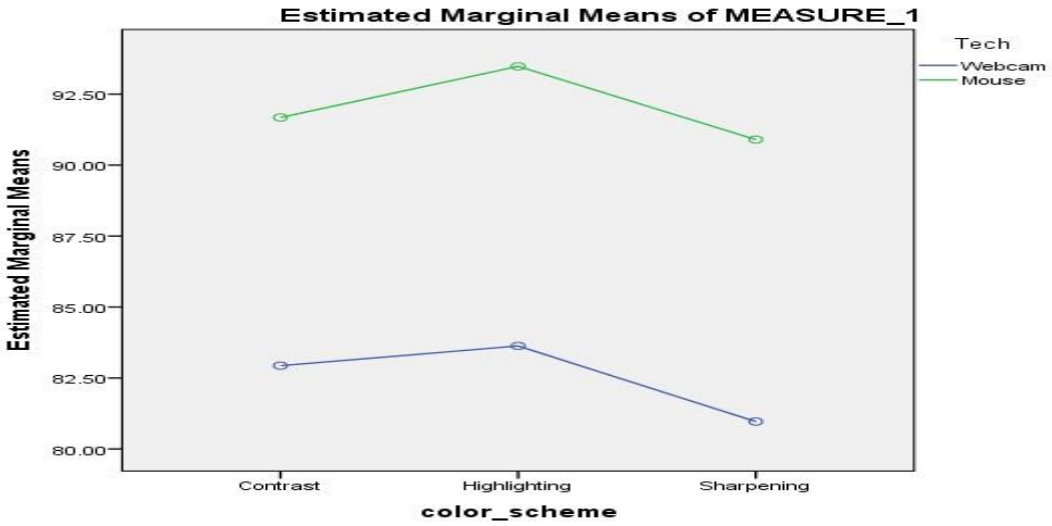


Figure 5. 6 : The interaction effect of webcam and mouse for the number of words

5.8 Two-way Repeated Measures ANOVA (time spent)

A two-way repeated measures ANOVA was conducted to study the effect of interaction modality and colour schemes on the time spent by the children with ADHD. Mauchly's test indicates that an assumption of sphericity was not violated ($\chi^2(2) = .277$, $p = .871$), Table 5. 42.

Moreover, the results show that there was nonsignificant interaction between modality and colour scheme on the time ($F(2, 40) = .443$, $p = .645$), see Table 5. 43. This reveals

that there were nonsignificant differences between colour schemes on the total time spent due to modality.

Table 5. 42: Mauchly's test of Sphericity

Mauchly's Test of Sphericity[a]

Measure: Total_time_spent

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Tech	1.000	.000	0	.	1.000	1.000	1.000
Scheme	.942	1.129	2	.569	.945	1.000	.500
Tech * Scheme	.986	.277	2	.871	.986	1.000	.500

Table 5. 43: Pairwise comparison

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Tech	Sphericity Assumed	**5598.667**	**1**	**5598.667**	**467.544**	**.000**	**.959**
	Greenhouse-Geisser	**5598.667**	**1.000**	**5598.667**	**467.544**	**.000**	**.959**
	Huynh-Feldt	**5598.667**	**1.000**	**5598.667**	**467.544**	**.000**	**.959**
	Lower-bound	**5598.667**	**1.000**	**5598.667**	**467.544**	**.000**	**.959**
Error(Tech)	Sphericity Assumed	**239.493**	**20**	**11.975**			
	Greenhouse-Geisser	**239.493**	**20.000**	**11.975**			
	Huynh-Feldt	**239.493**	**20.000**	**11.975**			
	Lower-bound	**239.493**	**20.000**	**11.975**			
Scheme	Sphericity Assumed	**419.031**	**2**	**209.516**	**11.540**	**.000**	**.366**
	Greenhouse-Geisser	**419.031**	**1.891**	**221.602**	**11.540**	**.000**	**.366**
	Huynh-Feldt	**419.031**	**2.000**	**209.516**	**11.540**	**.000**	**.366**
	Lower-bound	**419.031**	**1.000**	**419.031**	**11.540**	**.003**	**.366**
Error(Scheme)	Sphericity Assumed	**726.193**	**40**	**18.155**			
	Greenhouse-Geisser	**726.193**	**37.818**	**19.202**			
	Huynh-Feldt	**726.193**	**40.000**	**18.155**			
	Lower-bound	**726.193**	**20.000**	**36.310**			
Tech * Scheme	Sphericity Assumed	**12.868**	**2**	**6.434**	**.443**	**.645**	**.022**
	Greenhouse-Geisser	**12.868**	**1.971**	**6.527**	**.443**	**.642**	**.022**
	Huynh-Feldt	**12.868**	**2.000**	**6.434**	**.443**	**.645**	**.022**
	Lower-bound	**12.868**	**1.000**	**12.868**	**.443**	**.513**	**.022**
Error(Tech*Scheme)	Sphericity Assumed	**580.935**	**40**	**14.523**			
	Greenhouse-Geisser	**580.935**	**39.429**	**14.734**			
	Huynh-Feldt	**580.935**	**40.000**	**14.523**			

	Lower-bound	**580.935**	**20.000**	**29.047**

Table 5. 44: Descriptive statistics

	Mean	Std. Deviation	N
t_cam_cont	127.0424	4.69923	21
t_cam_high	129.8800	4.94520	21
t_cam_sharp	124.7233	2.41510	21
t_mouse_cont	140.0429	4.85207	21
t_mouse_high	142.6490	3.47208	21
t_mouse_sharp	138.9490	4.41640	21

Furthermore, there was a significant main effect due to modality ($F(1,20) = 467.54$, $p < .01$, $\eta_p^2 = .96$), Table 5. 43 . This means that if we ignore all other variables (levels of colour schemes), we will find there is a significant difference between the two interaction modalities. The value of eta squared for effect size conveys that 96 % of effect on the total time spent accounted for by modality.

The estimated average of the webcam was ($M = 127.22$), and for the mouse it was ($M = 140.55$). According to the pairwise comparison there was a significant difference ($p < .01$) in favour of the mouse modality.

Additionally, there was a significant main effect of the colour schemes ($F(2, 40) = 11.54$, $p < .01$, $\eta p2 = .37$), Table 5. 43. This means that if we hold constant the effect of modality, there were significant differences among the three levels of colour schemes on the time spent by the children with ADHD. The value of eta squared for effect size shows that 37 % of effect on the time spent was accounted for by colour scheme. The pairwise comparisons show that the significant difference existed between highlighting (M = 136.26) and sharpening (M = 131.84), (p = .008) in favour of highlighting, see Table 5. 44 , Table 5. 45 and Figure 5. 7.

Table 5. 45: Pairwise comparison

Measure: number_of_words

					95% Confidence Interval for Difference[b]	
(I) scheme_mouse	(J) scheme_mouse	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	**-1.803**	**.798**	**.106**	**-3.888**	**.283**

	3	.778	1.025	1.000	-1.899	3.454
2	1	1.803	.798	.106	-.283	3.888
	3	2.580*	.758	.008	.599	4.562
3	1	-.778	1.025	1.000	-3.454	1.899
	2	-2.580*	.758	.008	-4.562	-.599

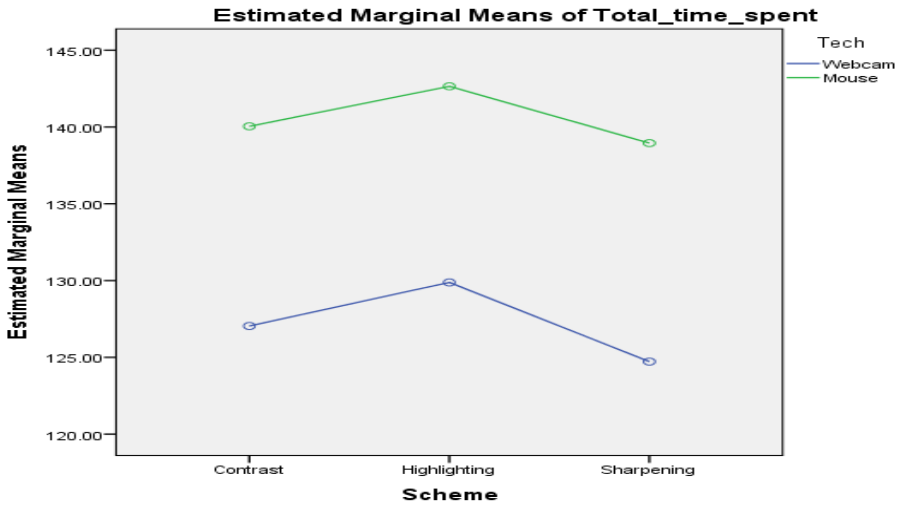


Figure 5. 7: The interaction effect of webcam and mouse for the total time

5.9 Assessing the effect of age and grade on the number of read words

The effects of age and grade on the number of read words using the two modalities are assessed in this section. The analysis of this section is based on (Pallant, 2011)

5.9.1 Finding if the participants' age has an effect on the number of words read by children with the use of webcam

Table 5. 46: Leven's test of Equality of error Variances

	F	df1	df2	Sig.
cont_Cam	.612	2	18	.553
High_Cam	4.398	2	18	.028
sharp_Cam	.054	2	18	.947

Table 5. 47: Box's Test of Equality of Covariance Matrices

Box's M	3.120
F	.419
df1	6
df2	2018.597
Sig.	.867

Table 5. 48 : Multivariate Tests

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Cam_Age_Words	Pillai's Trace	**.215**	**2.324[b]**	**2.000**	**17.000**	**.128**	**.215**
	Wilks' Lambda	**.785**	**2.324[b]**	**2.000**	**17.000**	**.128**	**.215**
	Hotelling's Trace	**.273**	**2.324[b]**	**2.000**	**17.000**	**.128**	**.215**
	Roy's Largest Root	**.273**	**2.324[b]**	**2.000**	**17.000**	**.128**	**.215**
Cam_Age_Words * AgeGroup	Pillai's Trace	**.158**	**.773**	**4.000**	**36.000**	**.550**	**.079**
	Wilks' Lambda	**.843**	**.760[b]**	**4.000**	**34.000**	**.559**	**.082**
	Hotelling's Trace	**.186**	**.742**	**4.000**	**32.000**	**.570**	**.085**
	Roy's Largest Root	**.179**	**1.615[c]**	**2.000**	**18.000**	**.226**	**.152**

A one-way repeated measures ANOVA with age as the between subjects factor was conducted. There was a nonsignificant effect for age on the number of words read by children with ADHD when using the webcam. Pillai's Trace = .158, F(4.36) = .773, p > .05, and Partial Eta Squared = .079 show that there was no effect for age on the number of read words by children with ADHD using a webcam, see Table 5. 48.

5.9.2 Finding if the participants' age has an effect on the total time spent by children with the use of webcam

Table 5. 49: Leven's test of Equality of error Variances

F	df1	df2	Sig.

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Age_webcam_time	Pillai's Trace	**.451**	**6.983[b]**	**2.000**	**17.000**	**.006**	**.451**
	Wilks' Lambda	**.549**	**6.983[b]**	**2.000**	**17.000**	**.006**	**.451**
	Hotelling's Trace	**.821**	**6.983[b]**	**2.000**	**17.000**	**.006**	**.451**
	Roy's Largest Root	**.821**	**6.983[b]**	**2.000**	**17.000**	**.006**	**.451**
Age_webcam_time * AgeGroup	Pillai's Trace	**.108**	**.512**	**4.000**	**36.000**	**.727**	**.054**
	Wilks' Lambda	**.892**	**.498[b]**	**4.000**	**34.000**	**.737**	**.055**
	Hotelling's Trace	**.121**	**.482**	**4.000**	**32.000**	**.748**	**.057**
	Roy's Largest Root	**.120**	**1.084[c]**	**2.000**	**18.000**	**.359**	**.107**

t_cam_cont	1.841	2	18	.187
t_cam_high	.585	2	18	.568
t_cam_sharp	.014	2	18	.986

Table 5. 50: Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices[a]	
Box's M	2.933
F	.394
df1	6
df2	2018.597
Sig.	.884

Table 5. 51: Multivariate Tests

A one-way repeated measures ANOVA with age as the between subjects factor was conducted. There was a nonsignificant effect for age on the total time spent by children with ADHD when using a webcam. Wilks' Lambda = .892, F(4.34) = .498, p > .05, and Partial Eta Squared = .055 show that there was no effect for age on the total time spent by children with ADHD using a webcam, see Table 5. 51.

5.9.3 Finding if the participants' age has an effect on the number of words read by children with the use of mouse

Table 5. 52: Leven's test of Equality of error Variances

	F	df1	df2	Sig.
cont_Mouse	3.536	2	18	.051
high_Mouse	1.461	2	18	.258
sharp_Mouse	.083	2	18	.921

Table 5. 53 : Box's Test of Equality of Covariance Matrices

Box's M	5.114
F	.686
df1	6
df2	2018.597
Sig.	.661

Table 5. 54: Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Mouse_Age_words	Pillai's Trace	.355	4.669[b]	2.000	17.000	.024	.355
	Wilks' Lambda	.645	4.669[b]	2.000	17.000	.024	.355
	Hotelling's Trace	.549	4.669[b]	2.000	17.000	.024	.355
	Roy's Largest Root	.549	4.669[b]	2.000	17.000	.024	.355
Mouse_Age_words * AgeGroup	Pillai's Trace	.039	.180	4.000	36.000	.947	.020
	Wilks' Lambda	.961	.171[b]	4.000	34.000	.952	.020
	Hotelling's Trace	.040	.162	4.000	32.000	.956	.020
	Roy's Largest Root	.037	.329[c]	2.000	18.000	.724	.035

A one-way repeated measures ANOVA with age as the between subjects factor was conducted. There was a nonsignificant effect for age on the number of words read by children with ADHD when using the mouse. Wilks' Lambda = .961, F(4.34) = .171, p > .05, and Partial Eta Squared = .020 show that the there was no effect of age on the number of read words by children with ADHD using a mouse, see Table 5. 54.

5.9.4 Finding if the participants' age has an effect on the total time spent by children with the use of mouse

Table 5. 55: Levene's Test of Equality of Error Variances

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Age_Mouse_time	Pillai's Trace	.191	2.005[b]	2.000	17.000	.165	.191
	Wilks' Lambda	.809	2.005[b]	2.000	17.000	.165	.191
	Hotelling's Trace	.236	2.005[b]	2.000	17.000	.165	.191
	Roy's Largest Root	.236	2.005[b]	2.000	17.000	.165	.191
Age_Mouse_time * AgeGroup	Pillai's Trace	.052	.239	4.000	36.000	.914	.026
	Wilks' Lambda	.948	.229[b]	4.000	34.000	.920	.026
	Hotelling's Trace	.055	.218	4.000	32.000	.926	.027
	Roy's Largest Root	.054	.485[c]	2.000	18.000	.624	.051

	F	df1	df2	Sig.
t_mouse_cont	.558	2	18	.582
t_mouse_high	.087	2	18	.917
t_mouse_sharp	1.264	2	18	.306

Table 5. 56: Box's Test of Equality of Covariance Matrices

Box's M	2.067
F	.277
df1	6
df2	2018.597
Sig.	.948

Table 5. 57: Multivariate Tests

A one-way repeated measures ANOVA with age as the between subjects factor was conducted. There was a nonsignificant effect for age on the total time spent by children with ADHD when using a mouse. Wilks' Lambda = .948, F(4.34) = .229, p > .05, and

Partial Eta Squared = .026 show that the there was no effect for the age on total time spent by children with ADHD using a mouse, see Table 5. 57.

5.9.5 Finding if the participants' school grade has an effect on the number of words read by children with the use of webcam

Table 5. 58: Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
cont_Cam	1.699	2	18	.211
High_Cam	4.668	2	18	.023
sharp_Cam	.276	2	18	.762

Table 5. 59: Box's Test of Equality of Covariance Matrices

Box's M	1.976
F	.261
df1	6
df2	1854.792
Sig.	.955

Table 5. 60 : Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Cam_Grade_words	Pillai's Trace	.323	4.049[b]	2.000	17.000	.036	.323
	Wilks' Lambda	.677	4.049[b]	2.000	17.000	.036	.323
	Hotelling's Trace	.476	4.049[b]	2.000	17.000	.036	.323
	Roy's Largest Root	.476	4.049[b]	2.000	17.000	.036	.323
Cam_Grade_words * Grade	Pillai's Trace	.161	.786	4.000	36.000	.542	.080
	Wilks' Lambda	.840	.774[b]	4.000	34.000	.550	.083
	Hotelling's Trace	.189	.758	4.000	32.000	.560	.087
	Roy's Largest Root	.185	1.664[c]	2.000	18.000	.217	.156

A one-way repeated measures ANOVA with grade as the between subjects factor was conducted. There was a nonsignificant effect for grade on the number of words read by children with ADHD when using a webcam. This is confirmed via Pillai's Trace = .161, F(4.36) = .786, p > .05, and Partial Eta Squared = .080, see Table 5. 60.

5.9.6 Finding if the participants' school grade has an effect on the total time spent by children with the use of webcam

Table 5. 61: Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
t_cam_cont	2.102	2	18	.151
t_cam_high	.802	2	18	.464
t_cam_sharp	.056	2	18	.946

Table 5. 62: Box's Test of Equality of Covariance Matrices

Box's M	2.831
F	.374
df1	6
df2	1854.792
Sig.	.896

Table 5. 63: Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Grade_webcam_time	Pillai's Trace	**.555**	**10.615[b]**	**2.000**	**17.000**	**.001**	**.555**
	Wilks' Lambda	**.445**	**10.615[b]**	**2.000**	**17.000**	**.001**	**.555**
	Hotelling's Trace	**1.249**	**10.615[b]**	**2.000**	**17.000**	**.001**	**.555**
	Roy's Largest Root	**1.249**	**10.615[b]**	**2.000**	**17.000**	**.001**	**.555**
Grade_webcam_time * Grade	Pillai's Trace	**.051**	**.237**	**4.000**	**36.000**	**.916**	**.026**
	Wilks' Lambda	**.949**	**.226[b]**	**4.000**	**34.000**	**.922**	**.026**
	Hotelling's Trace	**.054**	**.215**	**4.000**	**32.000**	**.928**	**.026**
	Roy's Largest Root	**.052**	**.469[c]**	**2.000**	**18.000**	**.633**	**.050**

A one-way repeated measures ANOVA with grade as the between subjects factor was conducted. There was a nonsignificant effect for grade on the total time spent by children with ADHD when using a webcam based on Wilks' Lambda = .949, F(4.34) = .226, p > .05, and Partial Eta Squared = .026, Table 5. 63.

5.9.7 Finding if the participants' school grade has an effect on the number of words read by children with the use of the mouse

Table 5. 64: Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
cont_Mouse	3.092	2	18	.070
high_Mouse	1.368	2	18	.280
sharp_Mouse	.184	2	18	.833

Table 5. 65: Box's Test of Equality of Covariance Matrices

Box's M	4.634
F	.613
df1	6
df2	1854.792
Sig.	.720

Table 5. 66: Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Mouse_Grade_ words	Pillai's Trace	.428	6.351[b]	2.000	17.000	.009	.428
	Wilks' Lambda	.572	6.351[b]	2.000	17.000	.009	.428
	Hotelling's Trace	.747	6.351[b]	2.000	17.000	.009	.428
	Roy's Largest Root	.747	6.351[b]	2.000	17.000	.009	.428
Mouse_Grade_ words * Grade	Pillai's Trace	.052	.241	4.000	36.000	.914	.026
	Wilks' Lambda	.948	.228[b]	4.000	34.000	.921	.026
	Hotelling's Trace	.054	.215	4.000	32.000	.928	.026
	Roy's Largest Root	.041	.372[c]	2.000	18.000	.694	.040

A one-way repeated measures ANOVA with grade as the between subjects factor was conducted. There was a nonsignificant effect for grade on number of words read by children with ADHD with the use of the mouse as Wilks' Lambda = .948, F(4.34) = .228, p > .05, and Partial Eta Squared = .026, see Table 5. 66.

5.9.8 Finding if the participants' school grade has an effect on the total time spent by children with the use of the mouse

Table 5. 67: Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
t_mouse_cont	.234	2	18	.794
t_mouse_high	.152	2	18	.860
t_mouse_sharp	.316	2	18	.733

Table 5. 68: Box's Test of Equality of Covariance Matrices

Box's M	1.454
F	.192
df1	6
df2	1854.792
Sig.	.979

Table 5. 69: Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Grade_mouse_time	Pillai's Trace	.295	3.559[b]	2.000	17.000	.051	.295
	Wilks' Lambda	.705	3.559[b]	2.000	17.000	.051	.295
	Hotelling's Trace	.419	3.559[b]	2.000	17.000	.051	.295
	Roy's Largest Root	.419	3.559[b]	2.000	17.000	.051	.295
Grade_mouse_time * Grade	Pillai's Trace	.071	.329	4.000	36.000	.856	.035
	Wilks' Lambda	.930	.312[b]	4.000	34.000	.868	.035
	Hotelling's Trace	.074	.295	4.000	32.000	.879	.036
	Roy's Largest Root	.053	.478[c]	2.000	18.000	.628	.050

A one-way repeated measures ANOVA with grade as the between subjects factor was conducted. There was a nonsignificant effect for grade on the time spent by children with ADHD when using a mouse, supported by Wilks' Lambda = .930, F(4.34) = .312, p > .05, and Partial Eta Squared = .035, see Table 5. 69.

5.10 Controlling for the threats of maturation and regression to the mean

The experiments follow the double-pretest-posttest design in which two pre-tests were conducted to minimize the effect of the maturation and regression threats. As mentioned

earlier, if the difference between the posttest and the second pretest is larger than the difference between the second and the first pretests, we conclude that the observed effect on the dependent variable is less likely due to the maturation or regression to the mean. Two paired samples t-tests were conducted to find the difference between the posttest and the second pre-test and the difference between the second and the first pretests.

Table 5. 70: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Avg_Cam	76.7152	21	2.89489	.63172
	Pre_Test2_Cam	68.0986	21	2.87317	.62698
Pair 2	Pre_Test2_Cam	68.0986	21	2.87317	.62698
	Pre_Test_Cam	65.3414	21	2.95349	.64450

Table 5. 71: Paired samples t-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Avg_Cam - Pre_Test2_Cam	**8.61667**	**2.18859**	**.47759**	**7.62043**	**9.61290**	**18.042**	**20**	**.000**
Pair 2	Pre_Test2_Cam - Pre_Test_Cam	**2.75714**	**.91386**	**.19942**	**2.34116**	**3.17312**	**13.826**	**20**	**.000**

As we can see in Table 5. 71, the difference between the mean of the posttest and the second pretest (8.62) is larger than the difference between the mean of the second and first pretests (2.76).

The same observation applies to the mouse as the difference between the mean of the posttest and the second pretest (13.183) is larger than the difference between the second and the first pretests (2.12), see Table 5. 73.

Table 5. 72: Paired Samples Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Avg_Mouse	92.0190	21	1.73536	.37869
	Pre_Test2_Mouse	78.8362	21	3.15794	.68912
Pair 2	Pre_Test2_Mouse	78.8362	21	3.15794	.68912

Pre_Test1_Mouse	76.7152	21	2.89489	.63172

Table 5. 73 :Paired samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Avg_Mouse - Pre_Test2_Mouse	**13.18286**	**3.40596**	**.74324**	**11.63248**	**14.73323**	**17.737**	**20**	**.000**
Pair 2	Pre_Test2_Mouse - Pre_Test1_Mouse	**2.12095**	**1.13482**	**.24764**	**1.60439**	**2.63752**	**8.565**	**20**	**.000**

5.11 Summary

This chapter introduced the procedures taken to ensure the suitability of data for further analysis. These procedures included data screening to check for missing data, assessing the normality of the data and finding outliers. Those steps are very important as failure to comply with these pre-requesties may lead to distortion of the results and misleading findings. To make sure that the data in hand are reliable and valid, internal consistency was conducted to assess the reliability of the data. Pearson correlation, convergence and discrimination were used to check the validity of the data. The aim of the this study is to assess the effect of the colour schemes on the attention span of children with ADHD. Therefore, one and two way repeated measures ANOVA were employed to check which one of the colour scheme(s) has the most effect on the attention of those children.

6 DISCUSSION AND CONCLUSION

6.1 Introduction

This chapter discusses the findings drawn from analysing the data of the research instruments: the questionnaires and the experiments. The discussion will relate the findings of this study to those of previous studies in the same domain of research. This study aims to investigate the effect of different colour schemes on the attention of children with ADHD and how these schemes may help those children stay focussed for longer periods of time and to finish the task in hand. As mentioned earlier, children with ADHD have difficulties in sustaining attention on assigned tasks. The optimal stimulation theory (S. Zentall, 1975) suggests that children with ADHD need extra stimulation in order to decrease hyperactivity and increase attention, and this is the theoretical framework of the study.

The study used two types of hypotheses: a null hypothesis that states that there is no difference in the mean of the different colour schemes and the baseline (no colour scheme); and an alternative hypothesis to use in case the null hypothesis was rejected due to finding a statistical significance resulting from the colour schemes. Pairwise comparison was conducted to find which colour scheme had the most effect on the attention of the students. The highlighting scheme was found to have the most effect, followed by the contrast scheme and the sharpening/blurring scheme, which, despite having the least effect, is still helpful in maintaining children's attention when it is compared to no effect.

Two modalities were used: webcam and mouse. Both helped the children locate their position in the text. This is important since children with ADHD usually lose their location when reading (Glick, 2011; Golden Robert N. , 2010; Rief, 2015, 2016; Robin, 1998). Results from the study indicate that the mouse performed better in terms of the number of words read and total time taken to finish reading.

Because of the small sample size used in this study, the results should be viewed as exploratory and, therefore, a larger follow-up study is recommended.

6.2 Discussion on the Student Questionnaire Findings

The participants of the study were twenty-one students in a primary school with an inclusion program for children with ADHD. Such programs are just emerging in schools

in Saudi Arabia with only a few schools with such programs in the entire kingdom. This, therefore, limited the number of available participants. The city, which was randomly selected, had only one school with dedicated programs for these children. Saudi Arabia is a very big country and the cities with such programs are distributed across a wide distance. To collect data from another city would have been difficult and costly.

A principal components analysis showed that the questionnaire had three components that corresponded to the three colour schemes tested: highlighting, contrast and sharpening/blurring. Items of the highlighting scheme are strongly related to component 1, contrast items are strongly related to component 2 and sharpening scheme items are strongly related to component 3.

The validity of the questionnaire was assessed using two approaches: face validity and construct validity. The reliability of the questionnaire was assessed by internal consistency, which is the commonly used approach. Cronbach's alpha value for the questionnaire was .724, which indicates that the questionnaire was reliable (Churchill Jr, 1979).

6.3 Discussion on the Student Experiments Findings

Several trials were conducted to assess the effect of colour schemes on the attention level of children with ADHD. The research considered internal and external validity and made every effort to control threats to validity so as to ensure that the effect on the dependent variable was solely due to the manipulation of the independent variable and that the results of the study can be generalized to a wider population.

The data analysis with one-way repeated measures ANOVA showed that colour scheme influenced the attention level of children with ADHD compared with no colour scheme. Children were able to stay focussed and did better on their reading tasks. The highlighting scheme had the most effect on attention, which is in line with other research (Chi et al., 2007) that has reported that the highlighting effect has an effect on the attention of children with ADHD. The results also showed that the contrast scheme influenced attention as well. This contradicts previous research (Silva & Frère, 2011) that has reported that contrast has no effect on the attention of children with ADHD. Despite the fact that the sharpening/blurring scheme had the least effect when compared with the highlighting and contrast schemes, it is still helpful when compared with no effect.

There were nonsignificant effects of age and school grade on both the number of words read and the total time spent, regardless of the modality used. This could be due to the minimal difference in age and grade. In future work, when recruiting participants from different age groups and school levels, the effect of age and grade will be assessed to determine if the difference in age and school grade affects the attention of children with ADHD.

6.4 Discussion on the Teachers Questionnaire Findings

In order to assess the usability of the application developed for this research, a questionnaire based on the System Usability Scale was administered to fourteen teachers who were asked to work with the application. A score of 74.29 was recorded, which is indicative of good usability. To the best of the researcher's knowledge, there is no Arabic version of the System Usability Scale. The wording of the questionnaire was slightly modified, which is common practice and does not affect the quality of the questionnaire (Sauro, 2011b).

Although the System Usability Score questionnaire has been reported to be highly reliable, the reliability of the questionnaire was assessed with the data gathered from surveying the teachers. The Cronbach's alpha value of .907 indicates that the questionnaire is highly reliable and is in line with a body of research that has showed that the SUS is reliable even with small samples. The validity of the questionnaire was assessed as well, with the values in the range r = .595 to r = .932. Research (James R. Lewis & Sauro, 2009) has suggested that the SUS has two dimensions: learnability, represented by items 4 and 10, and usability, presented by the other items. Items 4 and 10 had the highest scores, .932 and .902 respectively, which indicates that the system is highly learnable. This further means that the application is easy to learn and easy to work with. This complies with one of the goals of the developed application since it was intended to be used by children with no requirement for prior technical knowledge.

6.5 Implications of the study

6.5.1 On Theories

The study followed the deductive approach, which is best used when the researcher would like to prove or reject a theory or a hypothesis. The optimal stimulation theory (S. Zentall, 1975) was the backbone of the theoretical framework of this study. The findings of this study are in support—along with previous studies—of the optimal stimulation theory,

which states that children with ADHD need extra stimulation in learning materials in order to perform better.

6.5.2 On Practice

The findings of this study will be beneficial to stakeholders including students with ADHD and their teachers and instructors. Incorporating colour schemes into the learning materials could help these children.

The study applied the colour schemes in the reading area. However, children with ADHD have problems with other study areas, including mathematics. Colour scheme could be applied to mathematics learning by applying colour schemes to the mathematics operation or highlighting important parts of math word problems, making the important parts of the word problems more notable.

6.5.3 On Future Research in this area

This study examined the role of colours on the attention of children with ADHD. There are limited studies that examine specific colours on attention. The study applied three colour schemes, namely, highlighting, contrast and sharpening. The findings of this study may pave the way for more studies in the area on the role of the user interface colour schemes on the attention of children with ADHD.

6.6 Limitations and Future Research Directions

6.6.1 Small Sample Size

This study has some limitations, like other studies, and the first is the small sample size. Dedicated programs for students with special needs are in their early stages in Saudi Arabia and inclusion schools for students with ADHD are limited. Only five cities within Saudi Arabia had classes designed for those children. These cities are scattered across the country. Even in those cities, the number of students joining the schools is limited. Having a child with special needs is not a thing that everybody accepts in the society. Some parents don't allow their children to be enrolled in programs for children with ADHD. Therefore, the researcher had difficulties in finding a large number of participants. We hope, in time, that people's mindset will change and more parents will become aware of the importance of these special programs in helping their children overcome the difficulties they face.

6.6.2 Lack of Female Participants

The Saudi community is conservative and approaching females is not a socially accepted behaviour. The education system uses segregated schools in which there are schools for

girls only and others for boys only. The researcher could not obtain permission to include female participants in the study. The researcher suggested that more studies need to be conducted in the future including female participants to determine if gender has an effect on the results, by comparing the results from male subjects with those from female subjects.

6.6.3 The study was conducted in a school setting

The study was limited by the fact that it was conducted in a school setting. Every location has its own advantages and disadvantages. The school setting may differ from the home setting when the child is with his/her family. The presence of parents and siblings may have a positive or negative impact on the child and on his/her attention. Something worth mentioning is that, usually, the child is in school only in the day time and is at home in the afternoon or night time. The time when the child uses the application could affect his/her performance. Therefore, the researcher encourages the study be run in the future at home and at different times of the day.

6.6.4 Participants Age and Grade

The study was conducted in the primary school for grades four to six with students aged from ten to twelve years. There was no effect for the age and school grade on the results of the study. More studies are required to include students in other grades and ages. A larger difference in age could have an impact on the results.

6.6.5 The Application Operates on a Standalone Computer

The current application works on standalone computer and does not support a network. Future work would enable the application to work in the cloud and gather data from participants in remote locations.

6.7 The researcher's point of view

The journey of my PhD began in September 2013, and like everyone else, I was excited to live in a different culture. The western culture that I experienced, was difficult for me to cope with at first and I experienced what we call a culture shock.

Cultural shock and moving to a new place with new culture can be troublesome, because I have been used to a culture my whole life and it is not easy to change my ways. It can sometimes be frustrating and, at other times, motivating, but I think this challenging journey is worth the PhD. My friends who had studied here before were a huge help to me and made this transition much easier.

Like any other research, PhD research has its ups and down. I was prepared for it. I knew that there were going to be things that were difficult for me, but I also knew that I would learn many things on the way. I met new people, made friends and did lose some loved ones. The new ones that I met, were good to me and really helped me in my PhD research journey; they added value to my life. There were people who really helped me when two of my family members passed away and I realized that life is short. We don't know when we are going to lose a loved one, and the space that they leave behind, nobody else can ever occupy it. My elder sister and my aunt both lost their battle with cancer and that was a very dark time for me. I sometimes wish that I could have been their physician when they were battling with cancer, but I'm sure that they are at peace now.

One of reasons for doing my PhD research was my son. When he was diagnosed with ADHD, I felt more motivation as a parent to help him and the other children in the same situation. This motivation led me to be more focused on ADHD cases; children who are diagnosed with ADHD have a short attention span and this impacts not just their academic life, but everyday activities as well.

I met people and made friends here, and it really helped me in my journey. They really made my life easier, but as they finished their studies and returned back home, I do feel lonely, but I am thankful for what they have done for me.

As for my PhD research supervisor, he was a great help for me, as he was also a counsellor who helped me immensely in hard times. When I was stressed or depressed, he provided me with guidance and help. There were obstacles and frustrations that I faced on this journey of five years, but I really hope that these obstacles were worth the research that I have completed, and it will contribute towards the knowledge of other people. I also hope that this research opens doors for other research in this field.

If I could turn back time, I would be fair to my family and spend more time with them as the research took me away from them. On a few occasions I came home after spending a long time at the library to find my son or my wife in a state of hypoglycemia (a severe drop of blood glucose level), which is life threatening condition. I will never, never forgive myself if I lose one of them.

6.8 Conclusion

Children with ADHD have a limited focus span and they can easily get distracted by internal self-thoughts and external distractions in the environment. The optimal

stimulation theory states that children with ADHD need extra stimulation to persist with the task in hand. This study aimed at investigating the effect of interface colour schemes, as extra stimulation, on the attention level of children with ADHD. There were three colour schemes incorporated in the user interface to keep those children engaged for as long as possible. Different colour schemes were used in this study to pull the attention of the children and keep them engaged for a longer period. These effects were highlighting the on-task text with a warm colour (red, orange and yellow), creating a contrast between the text and its background by making the text a worm colour and its background a cool colour, or by sharpening the on-task text while blurring the off-task text. The researcher conducted experiments to find out which of these schemes had the greatest effect on the attention of the children. The schemes were incorporated in the presented text and the effects were assessed. Based on the results, it was found that adding stimuli in the form colour attracts the attention to the desired information. It was also found that the different schemes effect the attention to different levels. The highlighting scheme was the most effective scheme followed by the contrast scheme then the sharpening scheme. Setting the focus on the on-task information minimized the cognitive load on those children and help them to attend to the desired information.

The results showed that children, when using the webcam as the modality, completed 82.93% of the text with the contrast colour scheme, 83.63% with the highlighting scheme, and 80.97% with the sharpening/blurring colour scheme. On the other hand, when the mouse was used, they completed 91.68% of the text with the contrast scheme, 93.48% with the highlighting scheme, and 90.89% with the sharpening / blurring colour scheme. This shows that children with ADHD performed best with highlighting as a colour scheme and mouse as interaction modality.

6.9 Chapter Summary

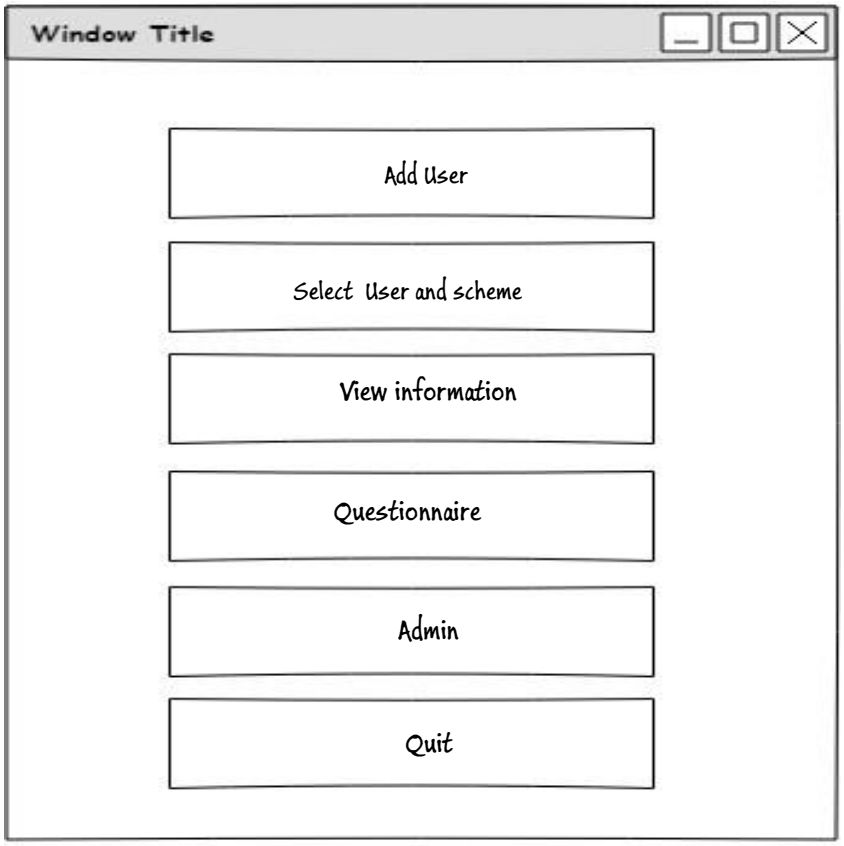
This chapter summarized the findings of the study, discussed the results of the student questionnaire, the experiments and the data of the teacher questionnaire. The chapter also presented the implications of the study from different aspects including the theoretical, practical and the future research. This chapter pointed out the limitations of the study and suggested future work needed to address these limitations.

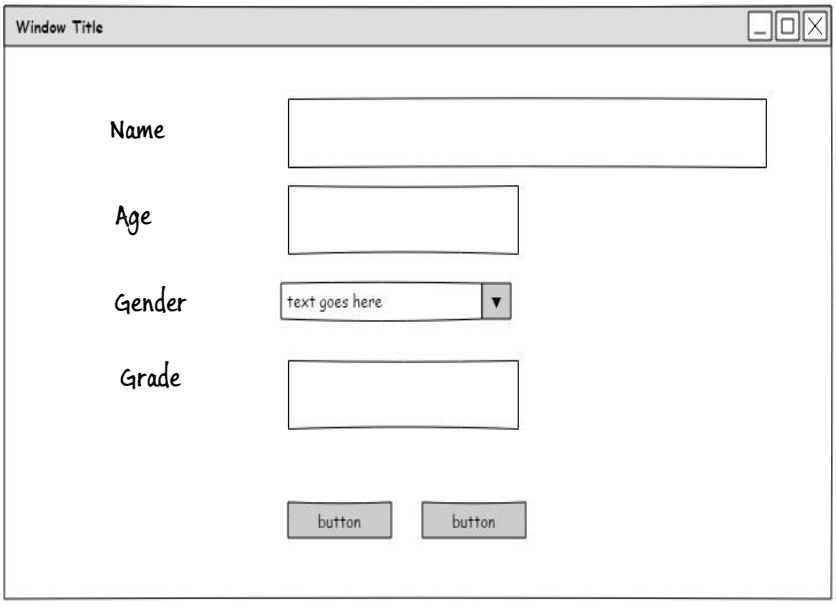
This research has shown that an adaptive user interface can provide a positive learning environment for children with ADHD. By tracking where a child is looking on a screen, using a webcam and/or mouse pointer, and applying a colour scheme to that area, children

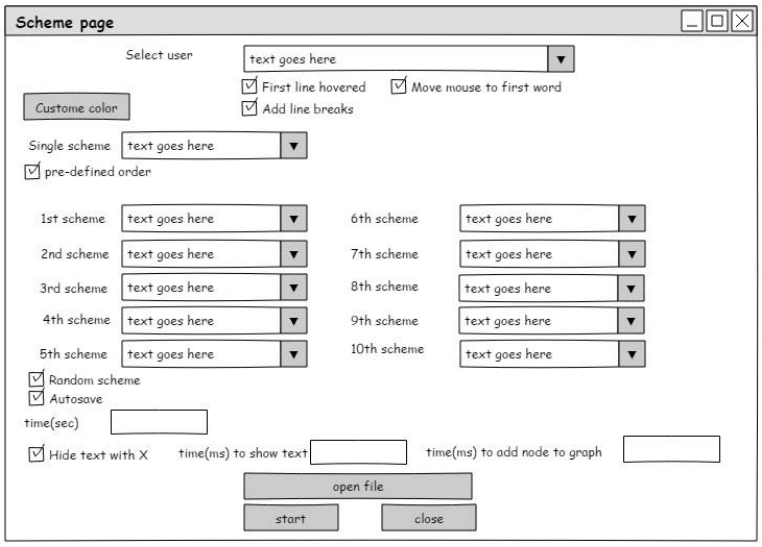
read more words and complete reading tasks compared with not applying a colour scheme. Of the schemes tested, highlighting words being read provided the greatest effect, followed by contrast, and then sharpening/blurring.

APPENDIX A : PROTOTYPE INTEFACE DESIGN

A.1 Low Fidelity Interface Design






Scheme page
Select user
text goes here
First line hovered
Move mouse to first word
Add line breaks
Custome color
Single scheme
text goes here
pre-defined order
1st scheme
2nd scheme
3rd scheme
4th scheme
5th scheme
6th scheme
7th scheme
8th scheme
9th scheme
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Random scheme
Autosave
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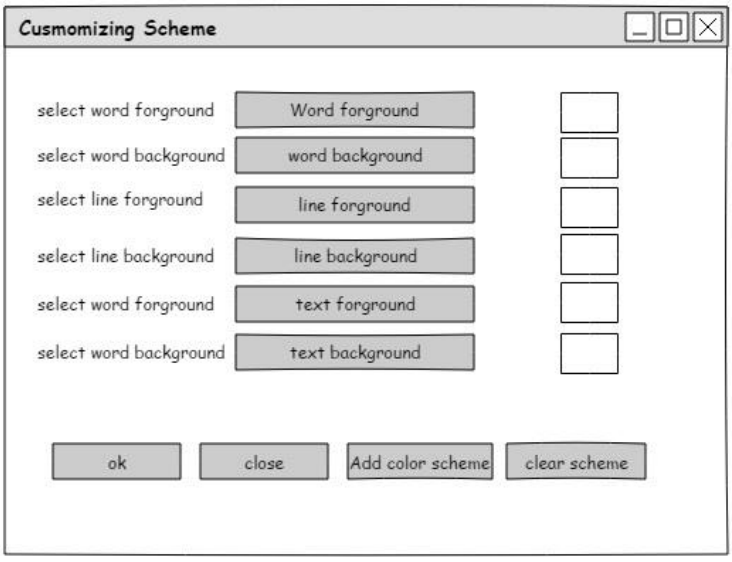
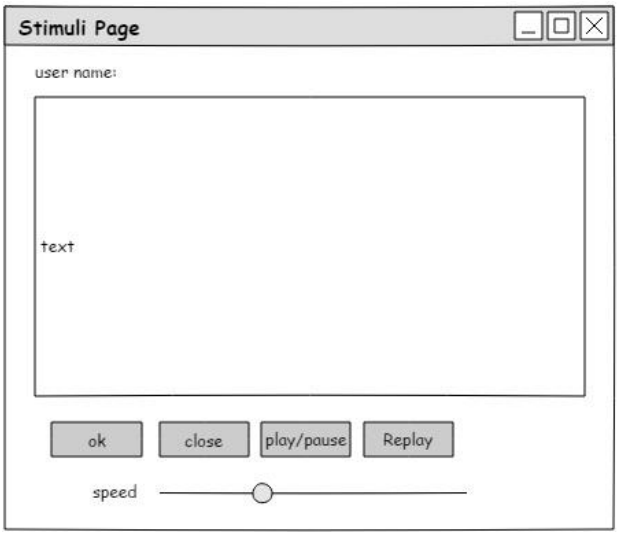
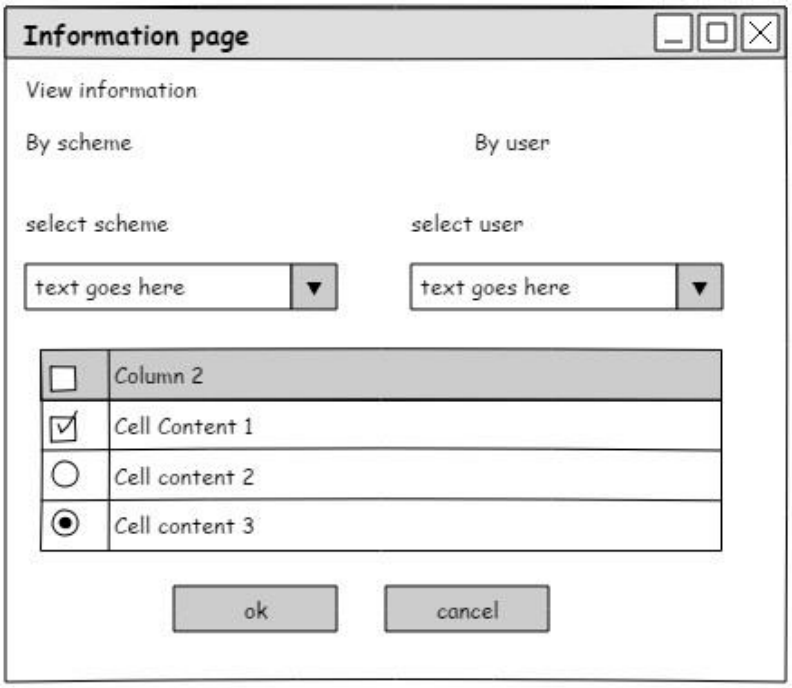
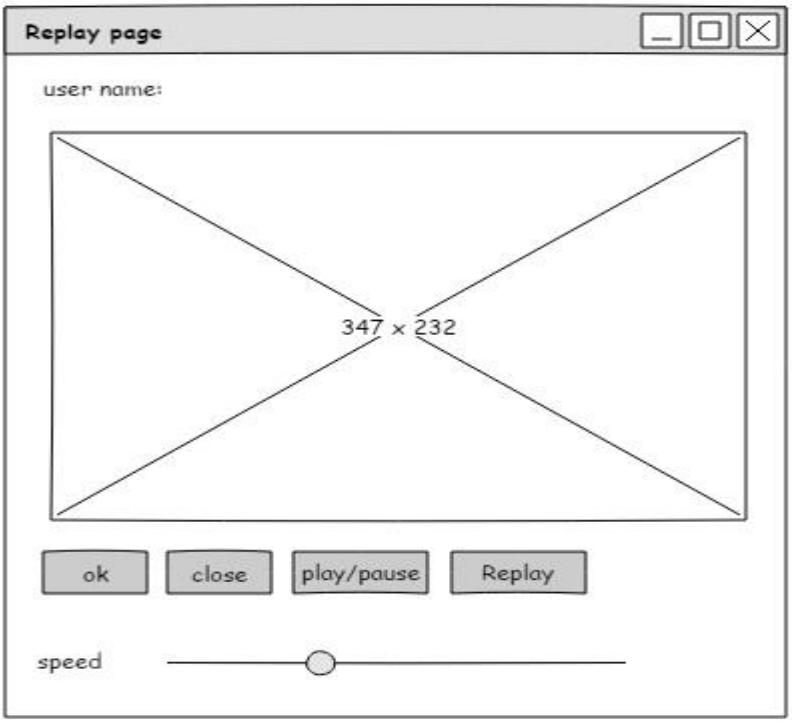
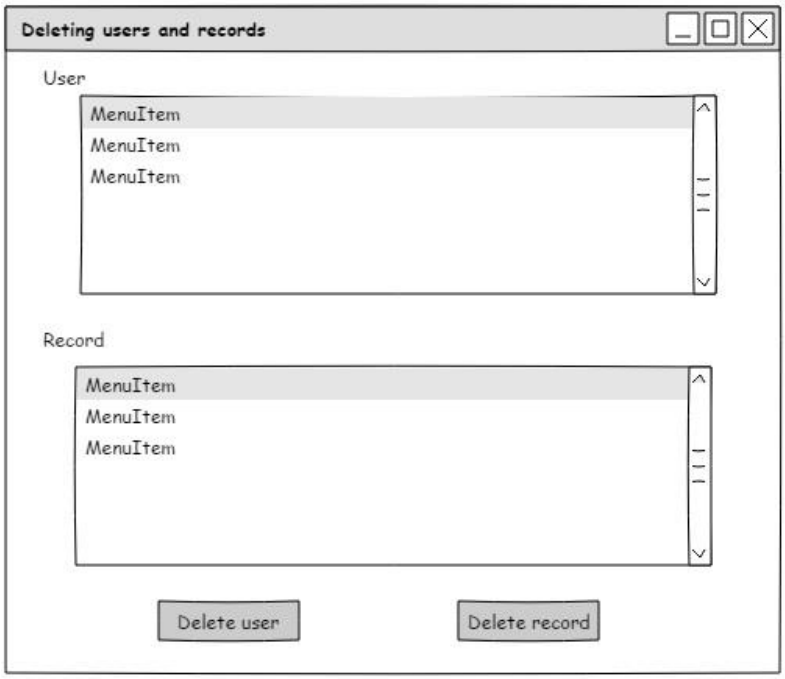
time(ms) to add node to graph
open file
start
close

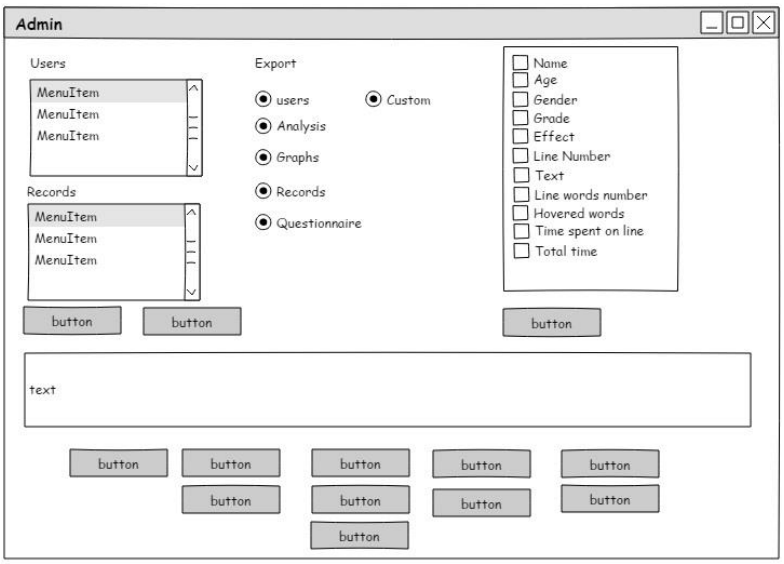

Cusmomizing Scheme
select word forground
Word forground
select word background
word background
select line forground
line forground
select line background
line background
select word forground
text forground
select word background
text background
ok
close
Add color scheme
clear scheme


Stimuli Page
user name:
text
ok
close
play/pause
Replay
speed

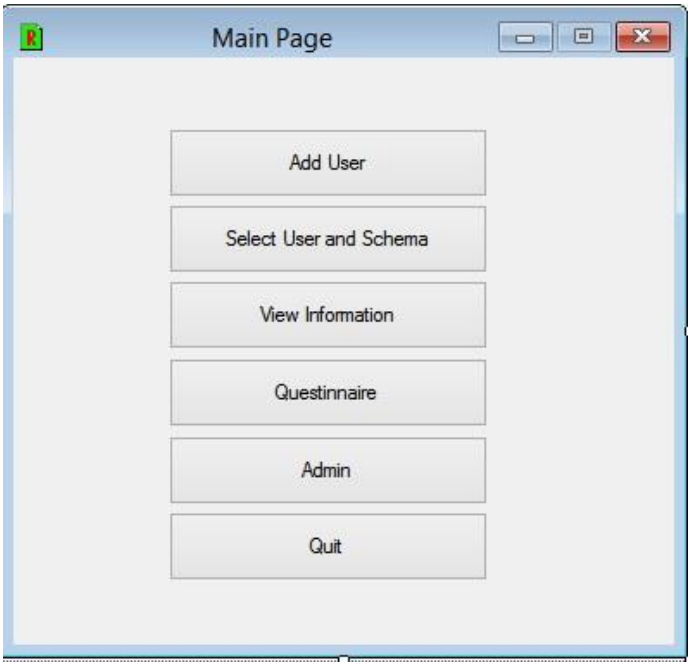

Information page
View information
By scheme
By user
select scheme
select user
text goes here
text goes here
Column 2
Cell Content 1
Cell content 2
Cell content 3
ok
cancel

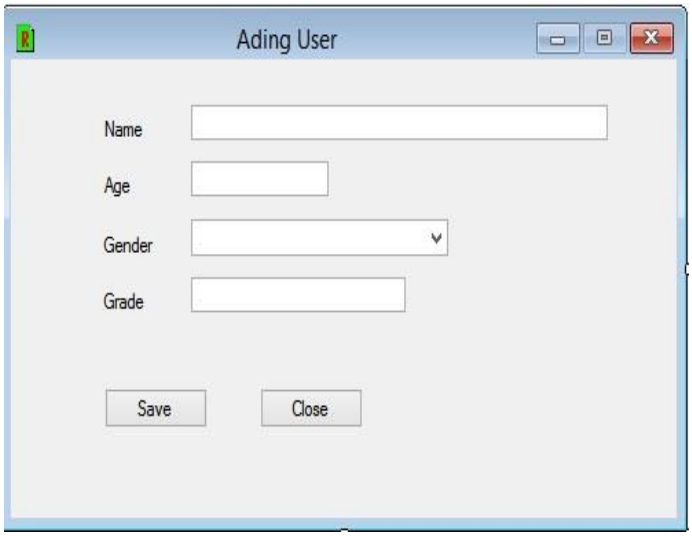

Replay page
user name:
347 x 232
ok
close
play/pause
Replay
speed

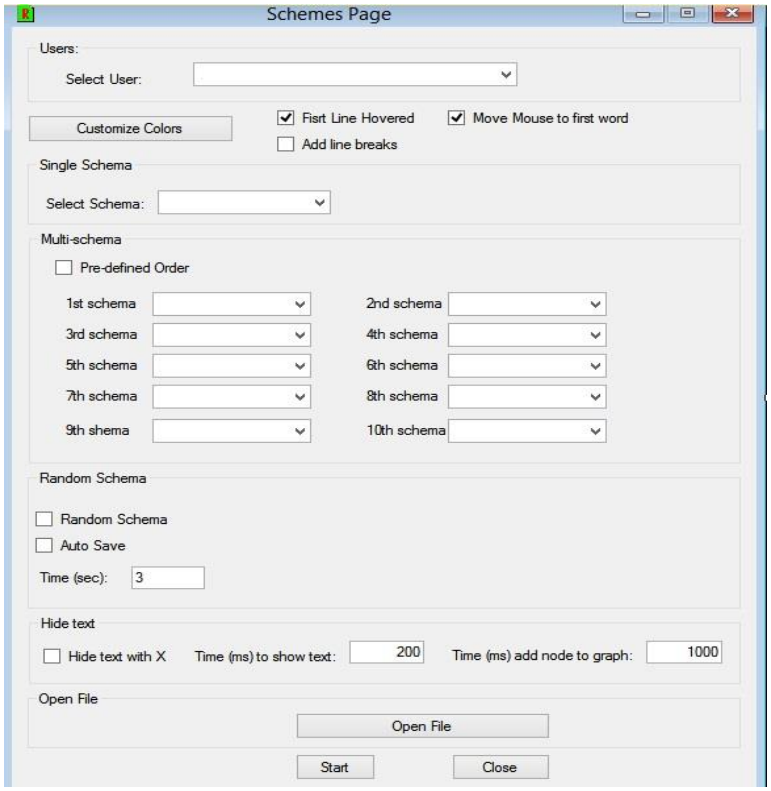

Deleting users and records
User
MenuItem
MenuItem
MenuItem
Record
MenuItem
MenuItem
MenuItem
Delete user
Delete record

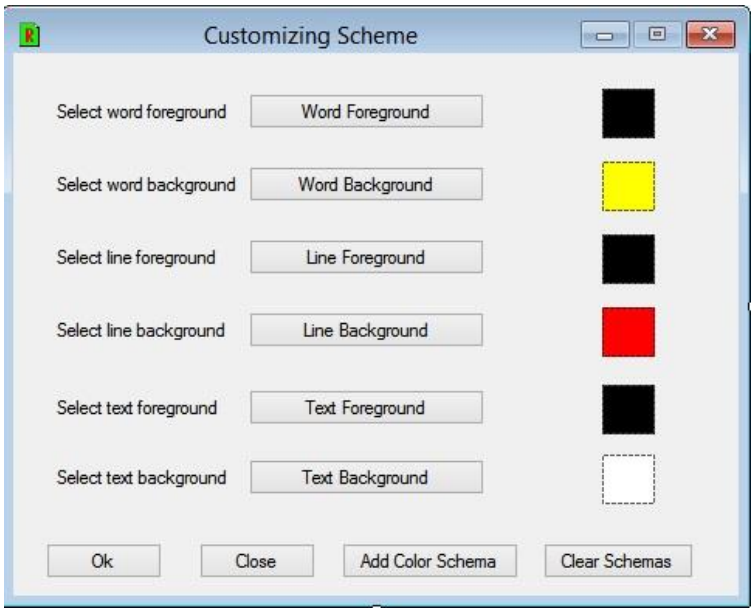

Admin
Users
MenuItem
MenuItem
MenuItem
Records
MenuItem
MenuItem
MenuItem
button
button
Export
users
Custom
Analysis
Graphs
Records
Questionnaire
Name
Age
Gender
Grade
Effect
Line Number
Text
Line words number
Hovered words
Time spent on line
Total time
button
text
button
button
button
button
button
button
button
button
button
button

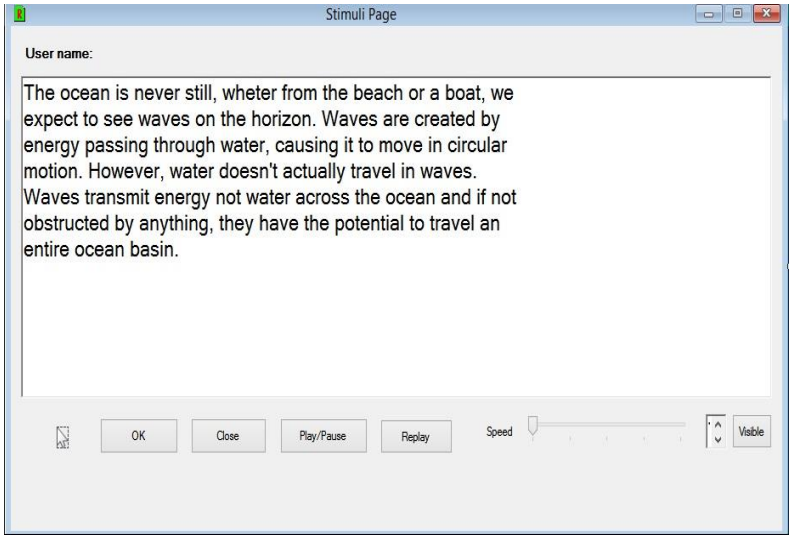
A.2 High Fidelity Interface Design

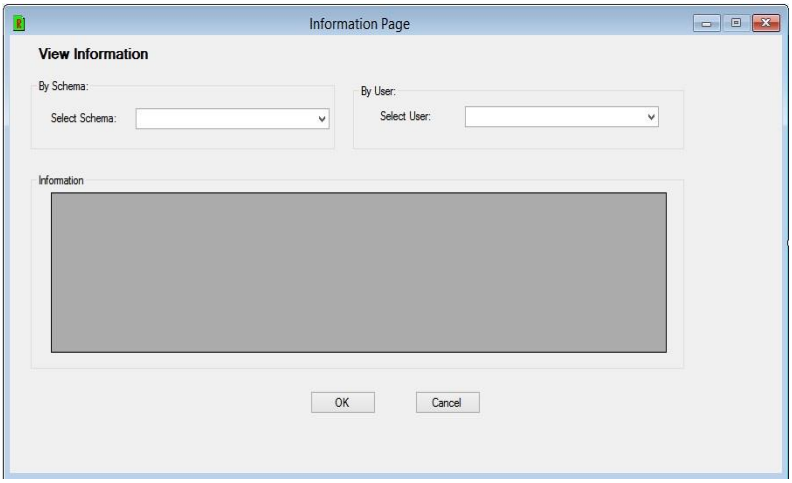


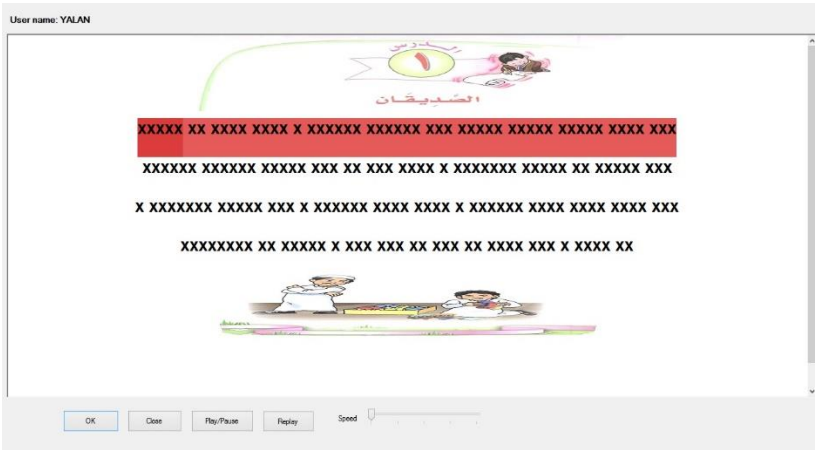



Schemes Page
Users:
Select User:
Customize Colors
Fisrt Line Hovered
Move Mouse to first word
Add line breaks
Single Schema
Select Schema:
Multi-schema
Pre-defined Order
1st schema
2nd schema
3rd schema
4th schema
5th schema
6th schema
7th schema
8th schema
9th shema
10th schema
Random Schema
Random Schema
Auto Save
Time (sec):
3
Hide text
Hide text with X
Time (ms) to show text:
200
Time (ms) add node to graph:
1000
Open File
Open File
Start
Close


Customizing Scheme
Select word foreground
Word Foreground
Select word background
Word Background
Select line foreground
Line Foreground
Select line background
Line Background
Select text foreground
Text Foreground
Select text background
Text Background
Ok
Close
Add Color Schema
Clear Schemas


Stimuli Page
User name:
The ocean is never still, wheter from the beach or a boat, we expect to see waves on the horizon. Waves are created by energy passing through water, causing it to move in circular motion. However, water doesn't actually travel in waves. Waves transmit energy not water across the ocean and if not obstructed by anything, they have the potential to travel an entire ocean basin.
OK
Close
Play/Pause
Replay
Speed
Visible


Information Page
View Information
By Schema:
Select Schema:
By User:
Select User:
Information
OK
Cancel


User name: YALAN
الصديقان
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xxxxxx xxxxxx xxxxx xxx xx xxx xxxx x xxxxxxx xxxxx xx xxxxx xxx
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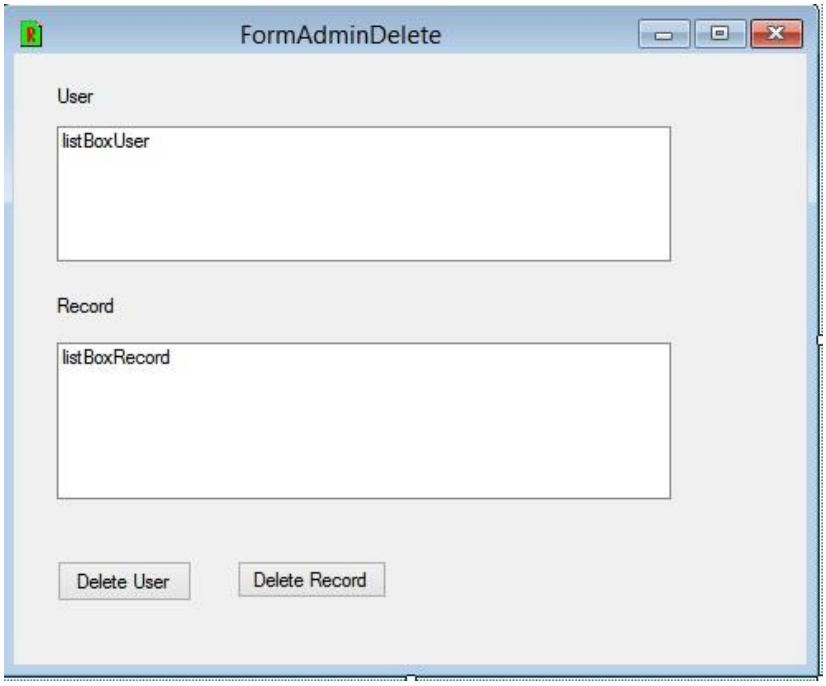
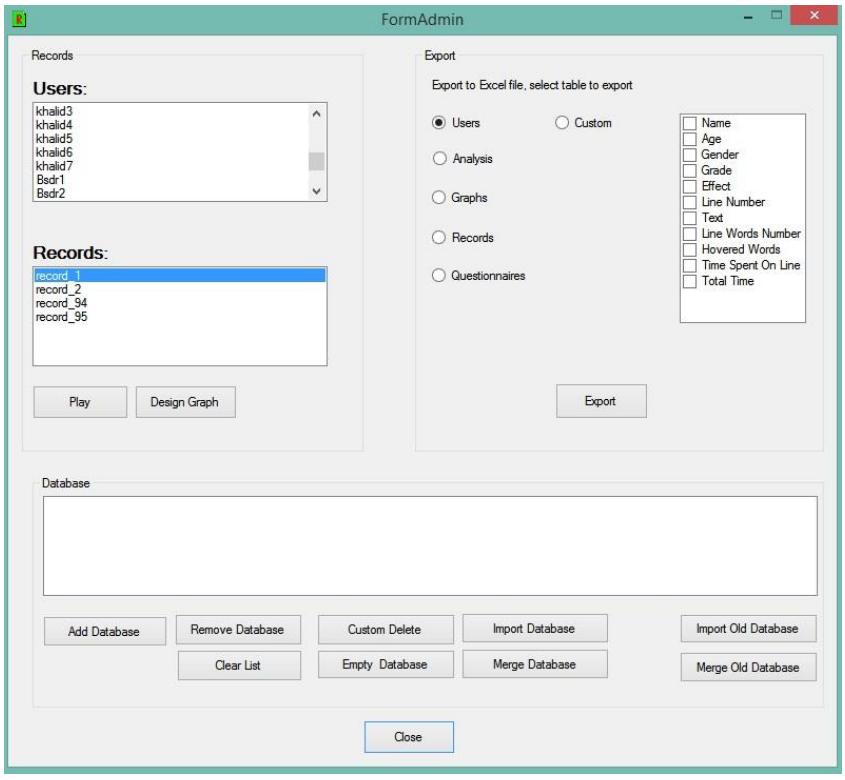
OK
Close
Play/Pause
Replay
Speed


FormAdminDelete
User
listBoxUser
Record
listBoxRecord
Delete User
Delete Record


FormAdmin
Records
Users:
khalid3
khalid4
khalid5
khalid6
khalid7
Bsdr1
Bsdr2
Records:
record_1
record_2
record_94
record_95
Play
Design Graph
Export
Export to Excel file, select table to export
Users
Custom
Analysis
Graphs
Records
Questionnaires
Name
Age
Gender
Grade
Effect
Line Number
Text
Line Words Number
Hovered Words
Time Spent On Line
Total Time
Export
Database
Add Database
Remove Database
Clear List
Custom Delete
Empty Database
Import Database
Merge Database
Import Old Database
Merge Old Database
Close

APPENDIX B: ETHICS APPROVAL DOCUMENTS

B1: FINAL APPROVAL NOTICE

Project No.:	**7199**
Project Title:	Extending Attention Span of ADHD Children through a Webcam/Mouse Directed Attentive User Interface
Principal Researcher:	Mr Othman Asiry
Email:	asir0016@flinders.edu.au
Approval Date:	19 May 2016
Ethics Approval Expiry Date:	**30 September 2018**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided.

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 (March 2007)* an annual progress report must be submitted each year on the **19 May** (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 **19 May 2017** 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 orhuman.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
Rae

Mrs Andrea Fiegert and Ms Rae Tyler
Ethics Officers and Executive Officer, Social and Behavioural Research Ethics Committee
Andrea - Telephone: +61 8 8201-3116 | Monday, Tuesday and Wednesday
Rae – Telephone: +61 8 8201-7938 | ½ day Wednesday, Thursday and Friday

Email: human.researchethics@flinders.edu.au
Web: Social and Behavioural Research Ethics Committee (SBREC)

Manager, Research Ethics and Integrity – Dr Peter Wigley
Telephone: +61 8 8201-5466 | email: peter.wigley@flinders.edu.au
Research Services Office |Union Building Basement Flinders University
Sturt Road, Bedford Park | South Australia | 5042
GPO Box 2100 | Adelaide SA 5001

CRICOS Registered Provider: The Flinders University of South Australia | CRICOS Provider Number 00114A
This email and attachments may be confidential. If you are not the intended recipient, please inform the sender by reply email and delete all copies of this message.

B2: Approval to Collect Field Data

المملكة العربية السعودية
وزارة التعليم
الإدارة العامة للتعليم بمحافظة جدة
إدارة التربية الخاصة بنين
معهد التربية الفكرية الأول للبنين بجدة

وزارة التعليم
Ministry of Education

الرقم : .....
التاريخ : / / ١٤ هـ
المرفقات : .....

افادة

تفيد ادارة معهد التربية الفكرية بأنه لا مانع لديها من اجراء الطالب/ عثمان محمد عثمان عسيري . لمشروع دراسته بالمعهد وذلك بعد مخاطبة الادارة العامة للتعليم بمحافظة جدة واخذ الموافقة ، وقد اعطي هذه الافادة بناءً على طلبه دون تحمل المعهد أي مسؤولية .

والله الموفق ، ،

مدير معهد التربية الفكرية للبنين بجدة
ناصر بن محمد الزهراني

وزارة التربية والتعليم
معهد التربية الفكرية الابتدائي الأول
الإدارة العامة للتربية والتعليم بمحافظة جدة

B3: Letter of Introduction (English)

School of Computer Science, Engineering and Mathematics

1284 South Road, Clovelly Park, SA 5042

GPO Box 2100

Adelaide SA 5001

Tel: 08 8201 7980

Date: 28 March 2016

LETTER OF INTRODUCTION

(For children, parents / caregivers and teachers)

Dear Participant, Parent / caregiver and Teachers,

This letter is to introduce Mr. Othman Asiry who is a doctorate student in the School of Computer Science, Engineering and Mathematics at Flinders University in Australia. He will produce his student card, which carries a photograph, as a proof of identity. Othman is undertaking research leading to the production of a thesis on the subject of " Extending Attention Span for Children with ADHD Through a Webcam/Mouse Directed Attentive User Interface."

He would like to invite you to assist with this project by agreeing to be involved in an experiment and completing a questionnaire, which covers certain aspects of this topic. No more than 30 minutes of your time would be required to answer the questionnaire. You may also be asked to participate in an experiment will take no more than 40 minutes.

Be assured that any information provided will be treated in the strictest confidence and none of the participants will be individually identifiable in the resulting thesis, report or other publications. You are, of course, entirely free to discontinue your participation at any time or to decline to answer particular questions.

Since Othman intends to record the eye movements for the experiments, he will seek your consent, on the attached form, to record your eye movements and use the recording in preparing the thesis, report or other publications, on condition that your name or identity is not revealed, and the recording will not be made available to any other person.

Any enquiries you may have concerning this project should be directed to me at the address given above or by telephone on (+61 8 82013969) or e-mail (Haifeng.shen@flinders.edu.au)

Thank you for your attention and assistance.

Yours sincerely

Dr. Haifeng Shen

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number 7199). 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

B4: Letter of Introduction (Arabic)

School of Computer Science, Engineering and Mathematics

1284 South Road, Clovelly Park, SA 5042

GPO Box 2100

Adelaide SA 5001

Tel: 08 8201 7980

خطاب مقدمة (من المشرف)

هذا الخطاب لتقديم السيد عثمان عسيري وهو طالب دكتوراه في كلية الحاسب الآلي، الهندسة والرياضيات في جامعة فلندرز في استراليا. سوف يقدم بطاقته الجامعية وهي تحتوي على صورة شخصية له ، كدليل هوية.

عثمان يقوم ببحث للوصول إلى نتائج خاصة باطروحته والتي بعنوان " زيادة زمن الانتباه لدى الاطفال ذوي فرط الحركة وتشتت الانتباه من خلال إجراء تغييرات على واجهة المستخدم باستخدام جهاز تعقب حركة العين".

سوف يكون في غاية الامتنان لو تفضلتم بالتطوع للمساعدة في هذا المشروع من خلال الموافقة على المشاركة في التجربة والاستبيان الذي يغطي جوانب مينة في هذا الموضوع . وهذا الامر لن يتطلب من وقتكم اكثر من ٤٠ دقيقة في التجربة ، ولا يزيد عن ٢٠ دقيقة في الاستبيان.

تأكد بأن أي من المعلومات المقدمة سيتم التعامل معها بسرية تامة ولن يتم تحديد هوية المشاركين بشكل فردي في نتائج الاطروحة، التقارير أو غيرها من المنشورات. وبالطبع يحق للمشارك التوقف عن المشاركة في أي وقت أو عدم الإجابة على أي من الأسئلة.

الباحث سوف يحتاج لتسجيل ومتابعة حركة العين أثناء القيام بالتجربة ، ويسعى للحصول على موافقتك وذلك بالتوقيع على النموذج المرفق، لاستخدام المعلومات المستخلصة من التجربة والاستبيان في إعداد الاطروحة ، التقارير أو غيرها من المنشورات شريطة الا يتم الكشف عن هويتك.

إذا كان لديك أي استفسار بشأن هذا المشروع يمكن أن توجهه لي على العنوان المذكور أعلاه أو عن طريق الهاتف رقم

61 8201 3969+ أو عن طريق البريد الاكتروني (haifeng.shen@fliners.edu.au) . عثمان يمكن الاتصال به عن طريق الهاتف رقم ٠٥٥٥٦٢٠٧٢٠ أو عن طريقالبريد الالكتروني (asir0016@flinders.edu.au).

أشكركم على اهتمامكم وساعدتكم.

تفضلوا بتقل فائق الاحترام

د. هايفنق شن

استاذ مساعد

كلية علوم الحاسب الآلي، الهندسة والرياضيات

جامعة فلندرز

تمت الموافقة على إجراء هذا البحث من قبل لجنة اخلاقيات البحوث الاجتماعية والسلوكية بجامعة فلندرز- مشروع رقم 7199

لمزيد من المعلومات حول الموافقة يرجى الاتصال بمسؤول اللجنة على الرقم 82013116 او على الفاكس رقم 82012035

أو البريد الالكتروني:

human.researchethics@flinders.edu.au

B5: Information sheet (English)

School of Computer Science, Engineering and Mathematics

1284 South Road, Clovelly Park, SA 5042

GPO Box 2100

Adelaide SA 5001

Tel: 08 8 8201 7980

Date: 28 March 2016

INFORMATION SHEET

(Parents)

Title: ‘‘Extending Attention Span for Children with ADHD through a Webcam/Mouse Directed Attentive User Interface’’

Investigators:

Othman Asiry

School of Computer Science, Engineering and Mathematics Flinders University

Ph: +966 555620720

Email: asir0016@flinders.edu.au

Supervisor (Principal Supervisor):

Dr. Haifeng Shen

School of Computer Science, Engineering and Mathematics Flinders University

Ph: +61 8 82013969

Supervisor (Associate Supervisor):

Dr. Paul Calder

School of Computer Science, Engineering and Mathematics Flinders University

Ph: +61 8 82012827

Description of the study:

This study is part of the project entitled " Extending Attention Span for Children with

ADHD through a Webcam/Mouse Directed Attentive User Interface." This project will investigate the effect of some factors (warm /cold colours, highlighting, Sharpening/ Blurring) on the attention and how these factors may extend the attention span for children with ADHD.

Purpose of the study:

This project aims to develop an application to help extending the attention span for children with Attention Deficit Hyperactivity Disorder (ADHD) by using an eye-tracking device to monitor the attention of ADHD children and make changes in an attentive user interface based on the attention state of the child.

What will your child be asked to do?

Experiment:

Your child may be invited to volunteer to participate in an experiment, he/she will be asked to work on application aiming to assess and improve the attention while read a passage of variant length.

During the experiment, the session will be monitored by an eye-tracking device to track the eye position on the screen; this will help to make some changes on the interface layout according the attention state. The data extracted will be saved for further data analysis. The length of the experiment will be 30-40 minutes.

Questionnaire:

After that, you will be asked to answer some questions in a questionnaire; this questionnaire will assess the design of the application. The questionnaire time would be 20-30 minutes.

Your child teacher will be involved in this process to simulate the real situation of the educational process.

What benefit my child gain from being involved in this study?

Your child participating in this study will help in investigating the factors that affect the attention, and the collected data will be used to develop an application to help ADHD children to pay attention for extended period. We are very keen to identify the interface elements that may attract or distract these children to minimize the distracting elements and enrich the attracting elements of the interface. The results of the study will help to tailor software helping ADHD children to be more focus.

Will my child be identifiable by being involved in this study?

Any personal information that may potentially identify the participant will be removed, and all the data is stored on a password-protected computer that only the researched have access to it.

To simulate the real educational process and make sure that all conditions are identical in the real daily educational process and this project, please be informed that your child teacher will be involved in this project.

Are there any risks or discomforts if my child involved?

There will be no risks or discomfort in your child involvement. However, if you have any concerns regarding anticipated or actual risks or discomforts, please raise them with the researcher. You can omit information by contacting the researcher within two weeks after the data has been collected. The researcher can be contacted by phone or by email.

How do I agree for my child to participate?

Participation is voluntary. Your child may answer 'no comment' or refuse to answer any questions, and he/she is free to withdraw from the experiment or questionnaire session at any time without effect or consequences. A consent form accompanies this information sheet. If you consent your child to participate, please read and sign the consent form.

How will I receive feedback?

Outcomes from the project will be summarized and given to you by the researcher if you would like to see them. Any concerns or questions regarding this research, please feel free to contact the researcher Mr. Othman by phone on (+966 555620720) or by email to (asir0016@flinders.edu.au) or the supervisor Dr. Haifeng Shen on (+61882013969) or by email (haifeng.shen@flinders.edu.au).

Thank you for taking the time to read this information sheet, and we hope that you will accept our invitation to be involved.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number 7199). 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

B6: Information sheet (Arabic)

School of Computer Science, Engineering and Mathematics

1284 South Road, Clovelly Park, SA 5042

GPO Box 2100

Adelaide SA 5001

Tel: 08 8201 7980

معلومات البحث

عنوان البحث

"زيادة زمن الانتباه لدى الاطفال ذوي النشاط الحركي وضعف الانتباه من خلال إجراء تغييرات في واجهة المستخدم باستخدام أداتي الكاميرا / الفأرة"

الباحث:

عثمان محمد عسيري

كلية علوم الحاسب، الهندسة والرياضيات

جامعة فلندرز

جوال: ٠٥٥٥٦٢٠٧٢٠

بريد الكتروني: asir0016@flinders.edu.au

المشرف الأكاديمي (الرئيسي)

د. هاينق شين

كلية علوم الحاسب، الهندسة والرياضيات

جامعة فلندرز

هاتف: ٨٢٠١٣٦٦٩

وصف الدراسة:

هذه الدراسة هي جزء من مشروع بحثي بعنوان "زيادة زمن الانتباه لدى الاطفال ذوي النشاط الحركي وضعف الانتباه باستخدام جهاز تتبع حركة العين " هذا المشروع سوف يكشف العناصر الموجودة في واجهة المستخدم والتي تؤثر على مستوى الانتباه زيادةً ونقصاناً، وسوف تستخدم البيانات المستخلصة من هذه الدراسة في تقليل أثر العناصر الموجودة في واجهة المستخدم والتي تقلل من مستوى الانتباه والتركيز على العناصر التي تزيد من مستوى الانتباه . هذه الدراسة مدعمة من جامعة فلندرز، كلية علوم الحاسب الآلي، الهندسة والرياضيات.

الغرض من الدراسة:

تهدف هذه الدراسة الى دراسة العناصر الموجودة في واجهة المستخدم والتي تؤثر على مستوى حالة الانتباه لدى الاطفال ذوي فرط الحركة وضعف الانتباه.

ماذا سوف يطلب منك:

التجربة:

قد تكون انت من المتطوعين للمشاركة في هذه الدراسة، سوف تقوم بالعمل على جهاز الحاسب سوف يعرض عليك مجموعة من النصوص سوف تقوم بقراءتها وخلال ذلك سوف يتم ملاحظة حركة العين باستخدام جهاز متابعة حركة العين وهذا الجهاز سوف يساعد على نعرفه حالة الانتباه لديك وسيتم اجراء تغيرات على واجهة المستخدم وفقاً لذلك. البيانات المستخلصة من الجهاز سوف تخزن على جهاز الجهاز من اجل عمل تحليل لهل فيما بعد. سوف تستغرق التجربة 15-20 دقيقة.

الاستبيان:

بعد الانتهاء من التجربة سوف يطلب منك تعبئة استبيان، هذا الاستبيان يقيس فاعلية وملائمة تصميم التطبيق الذي عملت في التجربة السابقة.

ما الفائدة التي سوف احصل عليها من خلال مشاركتي في هذه الدراسة:

مشاركتك في هذه الدراسة سوف تساعد على معرفة العوامل التي تؤثر على حالة الانتباه، البيانات سوف تساعد على تطوير تطبيق يساعد على زيادة زمن الانتباه الأطفال ذوي فرط الحركة وتشتت الانتباه. يتم ذلك عن طريق التركيز على العناصر التي تزيد من حالة الانتباه والتقليل من أثر العناصر الموجودة في واجهة المستخدم التي تشتت الانتباه.

هل سيتم الكشف عن هويتي إذا شاركت في هذه الدراسة:

سوف يتم إزالة أي معلومات تحدد هويتك، وسوف يتم تخزين البيانات في جهاز حاسب محمي بكلمة مرور، فقط الباحث سوف يطلع عليها، تعليقاتك لن تكون مرتبطة بك مباشرة.

هل هناك أي مخاطر أو مضايقات إذا كنت مشارك؟

لن يكون هناك أي مخاطر أو مضايقات في مشاركتكم، إذا لديك أي مخاوف بشأن مخاطر أو مضايقات متوقعة أو فعليه، يرجى ذكرها للباحث. يمكن للمشاركين حذف المعلومات عن طريق الاتصال بالباحث خلال اسبوعين بعد جمع البيانات. يمكن الاتصال بالباحث عن طريق الهاتف أم البريد الالكتروني.

كيف اوافق على المشاركة؟

مشاركتك طواعية، بإمكانك الإجابة 'لا تعليق' أو رفض الاجابة عن أي أسئلة، وبإمكانك الانسحاب من التجربة أو الاستبيان في أي وقت دون تأثير أو عواقب. نموذج الموافقة مصاحب لورقة معلومات البحث. من فضلك إذا كنت موافق على المشاركة يرجى قراءتها وتوقيع نموذج الموافقة.

كيف يمكنني الحصول على النتائج؟

سيتم تلخيص نتائج المشروع وتعطى لك من قبل الباحث إذا كنت ترغب الاطلاع عليها.

إذا كان لديك أي أسئلة أو استفسارات بشأن هذا البحث، لا تردد في الاتصال بالباحث عثمان عسيري عن طريق الجوال رقم ٠٥٥٥٦٢٠٧٢٠، أو عن طريق البريد الالكتروني (asir0016@flinders.edu.au)

أو المشرف د. هايفنق شن على الهاتف

+61 8201 3969 أو البريد الالكتروني (haifeng.shen@flinders.edu.au).

شكراً لأخذك الوقت الكافي لقراءة ورقة المعلومات هذه ونأمل بأن تقبل دعوتنا للمشاركة.

تمت الموافقة على إجراء هذا البحث من قبل لجنة اخلاقيات البحوث الاجتماعية والسلوكية بجامعة فلندرز- مشروع رقم 7199

لمزيد من المعلومات حول الموافقة يرجى الاتصال بمسؤول اللجنة على الرقم 82013116 او على الفاكس رقم 82012035

أو البريد الالكتروني:

human.researchethics@flinders.edu.au

B7: Consent Form: Parents (English)

School of Computer Science, Engineering and Mathematics

1284 South Road, Clovelly Park, SA 5042

GPO Box 2100

Adelaide SA 5001

Tel: 08 8201 7980

CONSENT FORM FOR PARTICIPATION IN RESEARCH

Research Title: "Extending Attention Span for Children with ADHD through a Webcam/Mouse Directed Attentive User Interface"

I.....

the parent /caregiver of

hereby consent him to participate as requested in the Information Sheet for the research project titled Extending Attention Span for Children with ADHD Through a Webcam/Mouse Directed Attentive User Interface.

1. I have read the information provided.

2. Details of procedures and any risks have been explained to my satisfaction.

3. I agree to have his eye movements data to be saved for further data analysis

4. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.

5. I understand that:

He may not directly benefit from taking part in this research.

He is free to withdraw from the project at any time and am free to decline to

answer particular questions.

While the information gained in this study will be published as explained, he will

not be identified, and individual information will remain confidential.

Whether he participate or not, or withdraw after participating, will have no effect

on my progress in my course of study, or results gained.

He may ask that the eye tracking be stopped at any time and that he may

withdraw at any time from the session or the research without disadvantage.

Parent / caregiver's signature Date

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name: Othman Asiry

Researcher's signature Date

I, the participant's caregiver whose signature appears below, have read a transcript of my participation and agree to its use by the researcher as explained.

Research Title: " Extending Attention Span for Children with ADHD Through a Webcam/Mouse Directed Attentive User Interface "

Parent / caregiver's signature Date

B8: Consent Form: Teacher (English)

Othman Mohammed Asiry
School of Computer Science, Engineering and Mathematics
Faculty of Science and Engineering
1284 South Road, Clovelly Park, SA 5042
GPO Box 2100

Date: 28 March 2016

Consent Form

(By Questionnaire - Teachers)

Research Title: "'Extending Attention Span for Children with ADHD through a Webcam/Mouse Directed Attentive User Interface'"

I.....

Being over the age of 18 years hereby consent to participate as requested in the Information Sheet for the research project titled "Extending Attention Span for Children with ADHD Through a Webcam/Mouse Directed Attentive User Interface."

6. I have read the information provided.

7. Details of procedures and any risks have been explained to my satisfaction.

8. I agree to have my eye movements data to be saved for further data analysis

9. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.

10. I understand that:

I may not directly benefit from taking part in this research.

It is free to withdraw from the project at any time, and I am free to decline to answer particular questions.

While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.

Whether I participate or not, or withdraw after participating, will have no effect on my job or any other effects.

I may ask that the eye tracking be stopped at any time and that I may withdraw at any time from the session or the research without disadvantage.

Participant's signature: Date:

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name: Othman Asiry

Researcher's signature Date

I, the participant whose signature appears below, have read a transcript of my participation and agree to its use by the researcher as explained.

Research Title: " Extending Attention Span for Children with ADHD Through a Webcam/Mouse Directed Attentive User Interface "

Participant's signature Date

B9: Consent Form(Arabic)

School of Computer Science, Engineering and Mathematics
Faculty of Science and Engineering
1284 South Road, Clovelly Park, SA 5042
GPO Box 2100
Adelaide SA 5001

خطاب الموافقة - معلمين

عنوان البحث:

"زيادة زمن الانتباه لدى الاطفال ذوي النشاط الحركي وضعف الانتباه من خلال إجراء تغييرات في واجهة المستخدم باستخدام أداتي الكاميرا / الفأرة"

انا .....

اوافق على المشاركة في البحث المعنون "زيادة زمن الانتباه لدى الاطفال ذوي فرط الحركة وتشتت الانتباه من خلال اجراء تغييرات على واجهة المستخدم باستخدام جهاز تتبع حركة العين" ، والموضحة تفاصيله في نموذج تعليمات البحث

وانني:

- قد قمت بقراءة المعلومات المرفقة
- قد تم توضيح تفاصيل واجراءات البحث بشكل كافي
- على علم بأنني يجب أن أحتفظ نسخة من ورقة الموافقة على المشاركة وورقة معلومات البحث كمرجع في المستقبل.

واننى على فهم تام لما يلي:

- يمكن ألا تكون هناك استفادة فورية من خلال مشاركته في البحث.
- لي مطلق الحرية بأن أنسحب من المشاركة في البحث في أي وقت وأن أرفض الإجابة على أي سؤال لا أرغب الإجابة عليه.
- سوف يتم نشر المعلومات المستخلصة من هذا البحث ولكن مع ذلك سوف تكون هويتي ومعلوماتي الشخصية سرية.

توقيع المشارك: ..... التاريخ: .....

أشهد بأنني قد قمت بشرح تفاصيل الدراسة للمتطوع وأعتبر أنه يفهم ماهية المشاركة ويوافق بحرية في المشاركة.

اسم الباحث: عثمان محمد عسيري

توقيع الباحث: ..... التاريخ: .....

أنا المشارك في البحث الموقع أدناه قد قرأت نسخة من مشاركتي في البحث والموافقة على استخدامها من قبل الباحث

توقيع المشارك: ..... التاريخ: .....

تمت الموافقة على إجراء هذا البحث من قبل لجنة اخلاقيات البحوث الاجتماعية والسلوكية بجامعة فلندرز- مشروع رقم 7199

لمزيد من المعلومات حول الموافقة يرجى الاتصال بمسؤول اللجنة على الرقم 82013116 او على الفاكس رقم 82012035

أو البريد الالكتروني:

human.researchethics@flinders.edu.au

B10: Information Sheet: Teacher (English)

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Date: 28 March 2016

INFORMATION SHEET

(Teachers)

Title: 'Extending Attention Span for Children with ADHD through a Webcam/Mouse Directed Attentive User Interface'

Investigators:

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Description of the study:

This study is part of the project entitled " Extending Attention Span for Children with ADHD through a Webcam/Mouse Directed Attentive User Interface." This project will investigate the effect of some factors (warm /cold colours, highlighting, Sharpening/ Blurring) on the attention and how these factors may extend the attention span for children with ADHD.

Purpose of the study:

This project aims to develop an application to help extending the attention span for children with Attention Deficit Hyperactivity Disorder (ADHD) by using an eye tracking device to monitor the attention of ADHD children and make changes in an attentive user interface based on the attention state of the child.

What will I be asked to do?

Experiment:

You may be invited to volunteer to participate in an experiment; you will be asked to work on application aiming to assess and improve the attention while read a passage of variant length.

During the experiment, the session will be monitored by an eye-tracking device to track the eye position on the screen; this will help to make some changes on the interface layout according the attention state. The data extracted will be saved for further data analysis. The length of the experiment will be 30-40 minutes.

Questionnaire:

After that, you will be asked to answer some questions in a questionnaire; this questionnaire will assess the design of the application. The questionnaire time would be 20-30 minutes.

What benefit will I gain from being involved in this study?

Your participating in this study will help in investigating the factors that affect the attention, and the collected data will be used to develop an application to help ADHD children to pay attention for extended period of time. We are very keen to identify the interface elements that may attract or distract these children in order to minimize the distracting elements and enrich the attracting elements of the interface. The results of the study will help to tailor software helping ADHD children to be more focus.

Will I be identifiable by being involved in this study?

Any personal information that may potentially identify the participant will be removed, and all the data is stored on a password-protected computer that only the researched have access to it.

Are there any risks or discomforts if I am involved?

There will be no risks or discomfort in your involvement. However, if you have any concerns regarding anticipated or actual risks or discomforts, please raise them with the researcher. Participants can omit information by contacting the researcher within two weeks after the data has been collected. The researcher can be contacted by phone or by email.

How do I agree to participate?

Participation is voluntary. You may answer 'no comment' or refuse to answer any questions, and you are free to withdraw from the experiment or questionnaire session at any time without effect or consequences. A consent form accompanies this information sheet. If you agree to participate, please

read and sign the consent form.

How will I receive feedback?

Outcomes from the project will be summarized and given to you by the researcher if you would like to see them. Any concerns or questions regarding this research, please feel free to contact the researcher Mr. Othman by phone on +966 555620720 or by email to (asir0016@flinders.edu.au) or the supervisor Dr. Haifeng Shen on +61 8 82013969 or by email (haifeng.shen@flinders.edu.au).

Thank you for taking the time to read this information sheet, and we hope that you will accept our invitation to be involved.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number 7199). 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

B11: Student Questionnaire (English)

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Student Questionnaire

Please select the most appropriate answers that indicate the level of your agreement or disagreement with each statement (please circle one option only).

1 = Disagree

2 = Neutral

3 = Agree

Item number	Item	Disagree 	Neutral 	Agree 
1	The high colour contrast between the red text and green background colour helps me paying attention to that part of text	1	2	3
2	The high colour contrast between the orange text and blue background colour helps me paying attention to that part of text	1	2	3
3	The high colour contrast between the yellow text and violet background colour helps me paying attention to that part of text	1	2	3
4	Highlighting part of the text with red colour helps me paying attention to that part	1	2	3
5	Highlighting part of the text with orange colour helps me paying attention to that part	1	2	3
6	Highlighting part of the text with yellow colour helps me paying attention to that part	1	2	3
7	Sharpening part of the text with red colour helps me paying attention to that part	1	2	3
8	Sharpening part of the text with orange colour helps me paying attention on that part	1	2	3

Thanks for your co-operation.

B12: Student Questionnaire (Arabic)

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استبيان لقياس مدى امكانية استخدام البرنامج

الرجاء اختيار الاجابة الأنسب لك من خلال وضع دائرة حول الرقم الذي يبين
مدى اتفاقك أو اختلافك مع كل من العبارات التالية : (ضع دائرة حول اجابة واحدة فقط)

1= لا أوافق　　2= لا اعرف　　3= اوافق

م	العنصر	لا أوافق 	غير متأكد 	أوافق 
1	الفرق العالي بين لون النص الاحمر ولون الخلفية الخضراء يعمل على جذب انتباهي لذلك النص	١	٢	٣
2	الفرق العالي بين لون النص البرتقالي ولون الخلفية الزرقاء يعمل على جذب انتباهي لذلك النص	١	٢	٣
3	الفرق العالي بين لون النص الاصفر ولون الخلفية البنفسجي يعمل على جذب انتباهي لذلك النص	١	٢	٣
4	تظهير جزء من النص بلون احمر يعمل على جذب انتباهي لذلك النص	١	٢	٣
5	تظهير جزء من النص بلون برتقالي يعمل على جذب انتباهي لذلك النص	١	٢	٣
6	تظهير جزء من النص بلون أصفر يعمل على جذب انتباهي لذلك النص	١	٢	٣
7	زيادة حدة جزء من النص (جعله أكثر وضوحاً من غيره) بلون أحمر يساعد على جذب الانتباه لذلك الجزء	١	٢	٣
8	زيادة حدة جزء من النص (جعله أكثر وضوحاً من غيره) بلون برتقالي يساعد على جذب الانتباه لذلك الجزء	١	٢	٣

شكراً لتعاونك

Teacher Questionnaire

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Please select the most appropriate answers that indicate the level of your agreement or disagreement with each statement (please circle one option only).

1 = Strongly Disagree

2 = Disagree

3 = Neutral Agree

Item number	Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	I think that I would like to ask my students to use this system frequently.	1	2	3	4	5
2	I found the system unnecessarily complex.	1	2	3	4	5
3	I thought the system was easy to use.	1	2	3	4	5
4	I think that the students would need the support of a technical person to be able to use this system.	1	2	3	4	5
5	I found the various functions in this system were well integrated.	1	2	3	4	5
6	I thought there was too much inconsistency in this system.	1	2	3	4	5
7	I would imagine that most of my students would learn to use this system very quickly.	1	2	3	4	5
8	I found the system very cumbersome to use.	1	2	3	4	5
9	I think my students will feel very confident using the system.	1	2	3	4	5
10	I think the students needed to learn a lot of things before they could get going with this system.	1	2	3	4	5

4 = Agree

5 = Strongly Agree

Thank you for your co-operation.

APPENDIX C: EXTREME VALUES TABLE

Extreme Values

			Case Number	Value
t_NE_Cam	Highest	1	3	112.48
		2	2	108.59
		3	8	99.16
		4	11	99.16
		5	13	97.22
	Lowest	1	17	85.86
		2	6	86.46
		3	10	87.50
		4	20	89.60
		5	14	91.39
t_Cam_cont	Highest	1	8	137.15
		2	14	133.24
		3	13	132.09
		4	20	131.67
		5	16	131.41
	Lowest	1	10	105.19
		2	3	108.03
		3	5	109.32
		4	6	113.80
		5	7	115.99
t_Cam_high	Highest	1	18	139.86
		2	13	137.93
		3	12	135.70

		4	15	135.13
		5	20	134.98
	Lowest	1	6	110.84
		2	4	120.29
		3	5	122.74
		4	10	125.32
		5	9	125.62
t_cam_sharp	Highest	1	18	133.15
		2	7	130.99
		3	3	130.82
		4	9	130.71
		5	11	129.26
	Lowest	1	6	114.16
		2	15	116.70
		3	5	120.46
		4	17	121.43
		5	20	122.09
t_NE_Mouse	Highest	1	18	132.27
		2	21	132.27
		3	2	129.41
		4	8	128.90
		5	11	128.90
	Lowest	1	6	115.30
		2	5	117.65
		3	10	117.78
		4	20	119.47
		5	1	120.00

t_cont_Mouse	Highest	1	19	152.86
		2	15	152.82
		3	21	152.82
		4	17	152.08
		5	13	151.70
	Lowest	1	11	136.46
		2	5	139.95
		3	18	140.13
		4	9	140.66
		5	10	140.78
t_high_Mouse	Highest	1	18	154.00
		2	12	153.82
		3	19	153.41
		4	20	153.34
		5	13	153.07
	Lowest	1	8	141.65
		2	7	141.65
		3	9	145.42
		4	17	146.03
		5	6	147.25
t_sharp_Mouse	Highest	1	18	154.32
		2	16	154.26
		3	19	152.10
		4	9	152.05
		5	14	150.88
	Lowest	1	8	138.61
		2	20	139.34

3	6	139.60
4	11	140.77
5	12	140.86

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