Alexithymia and Emotional Face Detection: Testing the Anger Superiority Effect

By

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Abstract

Alexithymia is a dimensional personality trait primarily associated with difficulty identifying and describing emotions. While present in roughly 10% of the general population, its prevalence is significantly higher in clinical groups, including individuals with autism spectrum disorder, depression, social anxiety, schizophrenia, anorexia nervosa, and substance use disorders. Although prior research has examined how alexithymia affects emotional face processing, little is known about its role in the detection of social threats.

Visual search studies in the general population have demonstrated an *anger superiority effect*, whereby angry faces are detected more quickly and accurately than other emotional expressions. However, the findings have been inconsistent. This thesis investigates whether alexithymia modulates the anger superiority effect using variations of the face-in-the-crowd paradigm across six studies.

Studies 1A-1C used schematic facial stimuli to compare search performance across low, medium, and high alexithymia conditions. Study 1A (angry vs. happy faces) found that participants with higher alexithymia responded faster and with flatter search slopes, but with comparable accuracy. An anger superiority effect was observed overall. Study 1B (angry vs. sad faces) did not replicate these alexithymia-related differences but again supported the anger superiority effect. Study 1C included all three emotions and again supported the anger superiority effect, though no differences emerged across alexithymia levels.

Study 2 employed photographic stimuli to increase ecological validity. No anger superiority effect or alexithymia-related differences were found. Study 3 tested non-emotional visual search using numeric distractors (i.e., finding a “2” among “5”s) and found no differences across alexithymia conditions, suggesting similar general visual search performance across alexithymia severities.

Study 4 reintroduced schematic faces and included electroencephalography (EEG) to assess attentional allocation on a neural level using the N2pc component. Behavioural data again

supported the anger superiority effect, while EEG results showed faster N2pc onset for angry targets. No neural or behavioural differences were observed between the alexithymia conditions.

Across all studies, both frequentist and Bayesian analyses were used to evaluate effects and to explore the robustness of findings. Overall, the results suggest that higher levels of alexithymia do not impair emotional face detection or reduce the anger superiority effect. The anger superiority effect was reliably observed with schematic stimuli but not with photographic images, indicating the effect may vary based on the complexity of emotional stimuli. These findings suggest that the deficits in facial emotion processing associated with alexithymia either occur at a later stage of processing or are potentially overstated in the current alexithymia literature. In relation to the anger superiority effect, while evidence was found supporting its existence, the failure to replicate this effect using photographic stimuli indicates that it may be sensitive to stimulus type and complexity. Recommendations for future research are provided based on the findings.

Declaration

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

4. If generative artificial intelligence has been used in my thesis it has been duly acknowledged with details to identify the extent to which generative artificial intelligence formed the final thesis[1]

Signed Stephanie McGowan

Date 07/10/2025

[1] Microsoft Copilot with Enterprise Data Protection and Grammarly were used to assist with editing, grammar checking, and style improvements. These tools were also used to help clarify understanding of complex statistical and methodological concepts during the research process.

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Chapter 1: Literature Review

Project Overview

Despite the growing body of research investigating the effects of alexithymia on the processing of emotional facial expressions, very little research has been conducted on the impact of alexithymia on the detection of social threats (e.g. angry or scared faces). Research has displayed evidence of an anger superiority effect whereby angry faces are more salient than other emotional faces in the general population, resulting in more effective threat detection. It is unclear, however, whether this increased saliency of angry faces would still occur when an overall deficit in emotional facial expression processing is present, such as in alexithymia. Research by Luminet et al. (2018) suggests that individuals with higher alexithymia exhibit impairments in processing negative facial expressions, which could contribute to difficulties in identifying social threats. Further research is required to determine whether the emotional facial expression processing deficits observed in higher alexithymia extend to the identification of social threats, such as angry faces. The main aim of this thesis is therefore to investigate the impact of alexithymia on the detection of angry faces in a face-in-the-crowd threat detection task.

Emotional Visual Search and Social Threat Detection

Our ability to interpret a situation and its level of safety accurately has long been an important skill for survival (Blanchard et al., 2011). Imagine you are walking home alone at night, and you see a group of people gathered up ahead. How do you proceed, and what information would help guide this decision?

One element that helps us gather information on the perceived safety of a situation is facial expressions, in addition to other contextual cues. For example, if the group of people gathered up ahead were displaying angry expressions and shouting, you would be more likely to perceive the situation as potentially hostile and proceed by altering your route to avoid these individuals. In contrast, if the group of people gathered up ahead were laughing and displaying happy expressions, you may feel reassured and choose to continue on your planned path. Our ability to rapidly detect emotional faces, particularly threatening ones such as anger and fear, is an important skill for identifying potentially dangerous situations and determining the correct response to minimise risk. If we consider the example above, accurately detecting that the individuals appeared angry and using this information to alter our path may have helped avoid a potentially dangerous situation, such as an altercation or argument.

In an evolutionary context, the ability to rapidly and accurately detect threatening expressions in others would have been a significant survival advantage. Early humans adept at accurately reading signs of aggression or anger in others were more likely to avoid harmful encounters, increasing their odds of survival (Fischer & Manstead, 2008; Öhman & Mineka, 2001). In order to better navigate complex social environments where the intentions of others could significantly impact our safety and well-being, the development of an increased sensitivity to threat-related cues, particularly threatening facial expressions, would not be surprising (Öhman & Mineka, 2001; Reed et al., 2014).

The benefits of accurately interpreting emotional expressions extend beyond immediate threat recognition; it also plays an important role in the broader context of socialisation and group inclusion. Recognising emotions can help us to better read the responses of others and dictate our actions accordingly to maximise social inclusion. For example, being able to accurately read whether someone appears pleased or distressed by a behaviour you have displayed would provide guidance on how to proceed to ensure your actions were viewed as favourable within the group, reducing the likelihood of social exclusion (Fischer & Manstead, 2008; Soto & Levenson, 2009).

This argument for evolutionary development of emotion recognition is strengthened by Ekman et al.'s (1971) discovery of an interesting common link in research investigating the judgement of various emotional facial expressions, in that every study found evidence for the same six emotions: happiness, surprise, anger, fear, sadness, and disgust. This finding led to the development of the theory that there are basic emotions that are expressed and perceived in a universal manner. Evidence of accurate detection of these six emotions has been observed across numerous studies and cultures (Ekman, 1971; Ekman et al., 1969; Ekman & Friesen, 1971; Sorenson, 1975), leading some to posit that this universality developed due to evolution or some form of culturally common social learning. Essentially, each of the six basic emotions must be important for daily life across all cultures to warrant a universal capacity to identify them.

Stages of Emotional Perception and Processing

The process of identifying a specific emotional facial expression consists of several different stages and tasks. To explore these stages, this thesis will draw upon elements from the well-established *Differential Emotions Theory,* with a specific focus on the construct of *emotion knowledge* (Izard et al., 2009; Izard et al., 2011; Luminet & Zamariola, 2018). Emotion knowledge refers to an individual's capacity to understand emotion in facial expressions, behavioural cues and social contexts (Izard et al., 2009; Izard et al., 2011; Luminet & Zamariola, 2018). There are three central elements within emotional knowledge, each encompassing a different stage of emotion processing; (1) *detecting* and *identifying* emotions in ourselves and others, (2) *labelling* emotions within ourselves and others, and (3) *understanding the causes* and context that can elicit these emotional responses (Izard et al., 2009; Izard et al., 2011; Luminet & Zamariola, 2018). For example, if a sad individual was standing in front of us, in order to determine they were sad, we would first detect that there was an emotion present (i.e., a change/a non-neutral expression was detected), and we would then have to determine what emotion was being shown based on expression (e.g., they are crying, their eyebrows are furrowed, their mouth is downturned) (Izard et al., 2009; Izard et al., 2011; Luminet & Zamariola, 2018). Once these two processing steps have occurred, you may then be able to determine what the context that led to that emotion could have been (e.g., they had just walked out of a theatre showing a sad movie). Individuals with high emotional knowledge possess a greater understanding of their emotions and can more accurately detect/identify, label and understand their emotions (Luminet & Zamariola, 2018).

In order to understand and differentiate between an individual's skills in the three core components of emotion knowledge, different experimental paradigms must be employed (Grynberg et al., 2012). When exploring the *detection/identification* phase, experimental paradigms involving the perception of emotional faces on a more basic level, such as a detection task, are often used (e.g., visual search tasks). In contrast, when exploring the *labelling* phase, an experimental paradigm designed to assess an individual's capacity to accurately identify and label an emotional category would be used. These types of experimental paradigms, coupled with reaction times and accuracy, can provide us with further insight into an individual's performance across the different stages of emotional processing. When several studies are conducted with the aim of exploring different elements of emotional knowledge, we can then determine at which stage an individual's performance changes, providing us with a more nuanced understanding overall.

The "Face-in-the-Crowd" Paradigm

Within cognitive psychology research, one of the most commonly used methods of investigating detection/identification performance is the *visual search paradigm* (Müller & Krummenacher, 2006; Wolfe, 2021). The visual search paradigm consists of a task in which participants are presented with an array of visual stimuli and are then tasked with identifying a target within the presented stimuli (Wolfe, 2021). Participants' performance is typically measured by reaction time and accuracy across the experimental trials. Further insights into participant performance can also be gained by exploring changes in reaction time when manipulating the difficulty of the visual search task.

When conducting a visual search, there are a number of factors that can impact the ease with which a target is identified. For example, the *saliency* of a target has a significant impact on target detection performance (Treisman & Gelade, 1980). Attempting to identify a red circle amongst blue squares is a relatively easy task compared to identifying a blue circle amongst blue squares, given that colour is more salient than shape (Becker & Rheem, 2020). Another major contributor to target detection efficiency is the number of *distractors* that need to be searched. For example, attempting to identify a target hidden amongst 30 distractors will require significantly more time than identifying a target hidden amongst three distractors (Becker & Rheem, 2020; Fernández-dols & Crivelli, 2015; Langeslag et al., 2018; Öhman et al., 2012; Richards et al., 2016*)*. Each of these factors can affect the efficiency of the search processes used.

When a target is highly salient, individuals will typically demonstrate *highly efficient search*. Highly efficient search occurs when the identification of a target does not require extensive spatial attention, meaning the target effectively “pops out” (Becker & Rheem, 2020). Importantly, the efficiency of detecting highly salient targets is typically unaffected by the number of distractors in a visual search (Becker & Rheem, 2020). For example, a red circle will continue to pop out regardless of whether it is hidden amongst three blue squares or 100 blue squares.

When a target is less salient, such as a blue circle amongst blue squares or an ‘F’ amongst ‘E’s, *less efficient search processes* will typically be required to identify targets (Becker & Rheem, 2020; Öhman et al., 2012). This search process means that reaction times increase substantially with the number of distractors, as individuals must devote more attention to systematically examining the stimulus array to identify potential targets. When using less efficient search processes, two possible outcomes can occur. The first is a *self-terminating search* in which an individual searches each item until the target is identified (Becker & Rheem, 2020). The second is a *exhaustive search* in which an individual searches each item until they can determine that no target is present (Becker & Rheem, 2020). Between these efficiency extremes, *guided search* can occur, where top-down attention (i.e., goal-directed search based on target knowledge) and bottom-up saliency (i.e., automatic attention capture by visually distinctive stimuli) interact to produce intermediate levels of search efficiency (Wolfe, 2021). Thus, when trying to identify a target within distractors or a threat amongst non-threats, search efficiency can vary considerably depending on the specific stimulus characteristics and task demands.

The *face-in-the-crowd paradigm* is a specialised version of the visual search paradigm designed to assess an individual’s capacity to detect emotional facial expressions, particularly those associated with social threats such as anger, among a group of distractor faces. Initially created by Hansen and Hansen (1988), this paradigm involves displaying an array of faces (either schematic or photographic) typically displaying either a happy, angry or neutral expression with participants’ task being to determine whether the faces within the array belong to the same emotional category, or whether there is a unique emotional face within the array. Studies using this paradigm typically allocate 50% of experimental trials as target-absent, meaning that all faces within the array are distractors belonging to the same emotional category (e.g., all neutral, or all angry). The remaining 50% of trials would contain a target face within the array for participants to detect (e.g., five neutral faces and one angry face). As a derivative of the visual search paradigm, the face-in-the-crowd task allows us to draw conclusions on participants' search efficiency and the types of search processes used by assessing measures of performance, namely reaction time, across increasing task difficulty (i.e., more distractor faces). These measures allow us to gather additional information on the effectiveness of the search processes used across different emotions.

The Anger/Happiness Superiority Effect

Research has long suggested that emotional states, such as anger and happiness, impact an individual's efficiency in identifying targets in visual search tasks. In 1988, Hansen and Hansen first reported a phenomenon where angry faces were detected faster in a visual search task than happy faces. In this study, Hansen and Hansen asked participants to identify a discrepant photographed face (either angry, happy or neutral) among a crowd of distractor photographed faces (again, either angry, happy or neutral). Participants were found to be significantly faster and more accurate at detecting angry faces in neutral and happy crowds compared to happy and neutral faces in angry crowds. Not only that, the results of Hansen and Hansen's third study exploring the role of set size on search ability displayed a potential 'pop-out' effect for angry faces, suggesting angry faces were identified without the use extensive spatial attention. This pop-out was evidenced by minimal variation in response times across increasing set sizes (i.e., flatter search slopes). Importantly, this pop-out effect was not observed for happy or neutral faces. These findings led to the development of the "anger superiority effect" or the "face in the crowd effect", with researchers suggesting that individuals are more efficient at detecting angry or threatening facial expressions due to a processing advantage towards potential social threats (i.e., angry faces) as an evolutionary method of improved survival (Lundqvist et al., 1999; Öhman et al., 2001).

While the anger superiority effect is an interesting theory, some researchers were not convinced that the findings of Hansen and Hansen were due to the emotional content of the targets used but were instead due to differences in low-level perceptual factors. Purcell et al. (1996) investigated this possibility by replicating the methodology of Hansen and Hansen, while altering the photographic stimuli to reduce the likelihood of low-level visual confounds. Specifically, the original stimuli used by Hansen and Hansen were found to have inadvertently created a black splotch at the bottom of the angry face when converting the images from standard photographs to black and white pixelated images. Purcell et al. found that once the black splotch was removed from the stimulus image, Hansen and Hansen's findings of a pop-out effect for angry faces disappeared. In fact, Purcell et al. found that happy faces, rather than angry, were found fastest, suggesting a happiness superiority effect.

Further adding to the unclear narrative, Purcell et al.'s finding of a happiness superiority effect is not an isolated finding, with several similar studies also showing support for a happiness superiority effect. Craig et al. (2014) conducted several studies using a similar face-in-the-crowd design to explore whether methodological confounds had led to previous findings of an anger superiority effect in schematic face-in-the-crowd tasks. In their first study, participants identified an emotional target (i.e., an angry or a happy face) among a background of a mixture of sad (i.e., happy eyebrows with an angry mouth) and scheming (i.e., angry eyebrows with a happy mouth) distractor faces across four different set sizes (i.e., 1, 2, 4, and 6). Results demonstrated that RT was significantly faster, and accuracy significantly higher in happy target trials, compared to angry target trials. In study 2, the design was altered slightly so that a target was present within all trials, and the participants were now required to identify whether the target face was angry or happy, rather than whether a target was present or not. The results demonstrated that participants were able to identify happy targets significantly faster than angry targets. No significant differences in accuracy were observed. Study 3 replicated the design of Study 2, but altered the schematic facial stimuli to include a facial border (which was absent in both Study 1 and 2). Once again, happy targets were identified significantly faster than angry targets. It should be noted, however, that happy targets were also found to have higher error rates than angry targets, indicating a possible speed-accuracy trade-off. Finally, study 4 replicated the method of study 1, but altered the design slightly so that the distractor faces observed in the background always belonged to the same emotion category (i.e., all neutral, all scheming, or all sad). When using neutral distractor faces, no significant difference was found between angry and happy in both reaction times and accuracy. When using sad distractor faces, angry targets were identified significantly faster than happy targets. No significant difference in accuracy was observed. When using scheming distractor faces, faster reaction times were observed for angry targets compared to happy targets. No significant main effects of accuracy were observed. Craig et al. (2014) argued that the findings of study four suggest that the emotion of distractor faces and whether they are homogeneous are both key determinants of the anger superiority effect, suggesting methodological confounds may have played a role in previous findings supporting the anger superiority effect when using schematic faces.

Evidence of the happiness superiority effect has been found by researchers using both schematic (Craig et al., 2014) and photographed stimuli (Juth et al., 2005; Purcell et al., 1996); however, the general consensus as to whether there is an anger or happiness superiority effect remains mixed. Although Purcell et al. and similar studies displaying a happiness superiority effect do cast some doubt over the findings of Hansen and Hansen (1988) and the robustness of the anger superiority effect as a whole, subsequent research has continued to investigate and often support the existence of an anger superiority effect (Dickins & Lipp, 2014; Fox et al., 2000; Hansen & Hansen, 1988; LoBue et al., 2014; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Pinkham et al., 2010; Shasteen et al., 2014).

Öhman et al. (2001) conducted a series of studies using schematic friendly, threatening and neutral faces to explore the anger superiority effect further without the risk of perceptual confounds caused by photographic stimuli. In their first study, participants were asked to identify discrepant faces (either threatening/angry, friendly/happy or neutral) in a crowd of distractor faces (either threatening/angry, friendly/happy, or neutral), with exposure duration capped at either 1 second (short) or 2 seconds (long). It was found that participants detected angry targets faster than friendly targets for both the short and long exposure durations for neutral distractor trials, but angry targets were only detected faster for the long duration for the emotional distractor trials. During neutral distractor trials, accuracy remained equal between angry and happy targets. Greater accuracy was observed for angry targets among emotional distractors across both short and long durations. In their second and third studies, participants were once again asked to detect discrepant faces in a crowd of either neutral faces (study 2) or emotional faces (study 3 - e.g., a friendly/happy face among threatening/angry distractors). Differing from study 1, studies 2 and 3 varied the number of distractors across trials with a set size of 2x2 at the smallest, and 5x5 at the largest. In both studies 2 and 3, it was found once again that threatening targets had significantly faster RTs and accuracy than friendly targets, although this difference was relatively small. RT across set sizes was relatively stable for both emotional targets in study 2. Study 3 found a greater impact of set size on RT compared to Study 2, but this increase was not significantly different between threatening and friendly targets. Interestingly, studies 2 and 3 showed a significant drop in accuracy for friendly targets for the largest set size (5x5), which was not observed for threatening targets. Researchers suggested that participants may have developed a bias towards larger set size trials being absent of a target. While it would be expected that this bias towards a target absent response would result in lower accuracy across all target present trials, regardless of target emotion, this was not the case. A significant drop in accuracy during the 5x5 set size trials was only observed for happy target present trials, suggesting that the angry target present trials were less affected by this bias, potentially due to greater saliency for angry targets.

Study 4 by Öhman et al. investigated whether the effects observed in the previous three studies may have been due to specific features within the schematic face (e.g., the eyebrows or the mouth). To explore this potential confound, participants were still asked to identify if a discrepant face was present among the distractors. Half of the participants completed the standard task (as in study 1), while the other half were presented with inverted stimuli. The results demonstrated that the advantage for angry faces (i.e., faster RT and greater accuracy) was present for both the standard and inverted stimuli when compared to friendly faces. These findings indicate that the anger advantages displayed in previous studies were not due to isolated features acting as visual confounds (i.e., the downward angle of the brows, the downturned mouth), as these visual cues were tied to the happy targets for study 4 and did not result in any advantage. It should be noted, however, that it would typically be expected that performance in a visual search task using inverted faces would be significantly lower than a visual search task using non-inverted faces, as it is more challenging to determine emotional expression on an inverted target. The fact that Öhman et al.'s study displayed very minimal differences in accuracy for inverted stimuli compared to non-inverted stimuli is peculiar and may indicate the presence of a low-level perceptual confound for the angry faces.

Finally, study 5 explored the impact of emotional valence on task performance by expanding the emotional range of the stimuli to include friendly (i.e., smile and upward tilted eyebrows), threatening (i.e., frown and downward tilted eyebrows), scheming (i.e., smile and downward tilted eyebrows), and sad (i.e., frown and upward tilted eyebrows) faces. Once again, threatening faces were detected faster and more accurately than the other emotional faces.

Öhman et al.'s results were later challenged by researchers who believed the anger superiority effects that were observed may have once again been due to a perceptual confound – namely, a difference in position of the eyebrows in relation to the facial border for threatening faces. Purcell & Stewart (2010) used Öhman et al.'s stimuli to conduct a visual search task and found that, following removal of the stimuli's face outline, an angry superiority effect was no longer observed. It was claimed that the anger superiority effect observed was due to differences in distance between the eyebrow and face outline between the threatening and friendly stimuli, rather than due to the emotional content of the stimuli itself. These findings once again highlight the ongoing debate regarding the causes of the anger superiority effect and the potential confounding role of low-level perceptual differences.

It is important to note that Öhman et al.'s findings are not a once-off but instead contribute to a significant number of face-in-the-crowd studies that were able to replicate the anger superiority effect, providing support for the anger superiority effect being a genuine effect. Furthermore, evidence of an anger superiority effect has been observed in visual search task using both schematic (Dickins & Lipp, 2014; Eastwood et al., 2001; Fox et al., 2000; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Rued et al., 2019) and photographic stimuli (Diao et al., 2017; Feldmann-Wüstefeld et al., 2011; Hansen & Hansen, 1988; Lobue et al., 2014; Pinkham et al., 2010; Shasteen et al., 2014).

For example, Lipp, Price, and Tellegen (2009) explored the anger superiority effect by asking participants to detect emotional faces (angry, happy, or sad) among crowds of neutral faces, using both schematic (study 1) and photographic stimuli (study 2). Results from both studies indicated preferential processing of angry emotional faces compared to happy and sad emotional faces, falling in line with the expectations of the anger superiority effect. These findings suggest that this preferential processing of angry faces extends to both schematic and photographic stimuli. Pinkham et al. (2010) attempted to test the ecological validity of the anger superiority effect using the face-in-the-crowd paradigm and photographic stimuli. In this study, participants determined if a discrepant emotional face (i.e., angry, happy or neutral) was present within an array of emotional or neutral faces. Array size remained the same across all trials. Results provided additional support for the anger superiority effect, with angry targets being found significantly faster and with greater accuracy than happy targets. Additionally, while targets were observed to be found slower and less accurately among emotional distractors (as opposed to neutral), angry target trials were found to be less impacted by emotional distractors compared to happy targets. These findings provide distinct support for the existence of the anger superiority effect, which is particularly significant given the greater ecological validity by use of photographic stimuli.

Similarly, Williams and Mattingley (2006) also explored the anger superiority effect using photographic fearful and angry faces. Their results showed that angry faces were detected significantly faster than fearful faces, supporting the anger superiority effect overall. Their study aimed to explore the anger superiority effect and how it differed across gender. They found that the anger superiority effect was more pronounced for males compared to females. They also found that male participants’ detection speed for angry faces was unaffected by increased set size, suggesting the presence of a pop-out effect. While these results support the anger superiority effect, they also demonstrate that it may be modulated by gender.

Overall, it seems that there is significant evidence for the existence of an anger superiority effect, but the role of perceptual confounds and mixed findings continues to cast doubt on the legitimacy of this effect. While the use of schematic stimuli can help reduce the risk of perceptual confounds, this comes at the cost of lowered ecological validity.

Alexithymia

In 1967, Psychiatrists Dr John Nemiah and Dr Peter Sifneos noticed a trend among their patients with psychosomatic diseases, whereby they displayed greater difficulty finding the correct words to explain how they were feeling (Sifneos, 1967; Nemiah & Sifneos, 1970). This observation led to the development of the term 'Alexithymia', derived from the Greek words for lack (i.e., *a*), words (i.e., *lexis*), and mood or emotion (i.e., *thymos).* Since 1967, research has allowed us to gain a clearer understanding of alexithymia and its psychopathology. Alexithymia is now defined as a dimensional personality trait and has been shown to affect approximately 10% of the general population (Ricciardi et al., 2015).

While difficulty in identifying and describing emotions is considered a hallmark of alexithymia, alexithymia has also been linked to difficulty differentiating between emotions and bodily feelings (e.g., sadness vs. hunger), reduced imagination, and an externally oriented thinking style (Brewer et al., 2016). This impairment in identifying both emotions and bodily sensations reflects a fundamental deficit in interoceptive abilities (i.e., the ability to perceive and interpret internal physiological cues) (Critchley & Garfinkel, 2017). In typical emotional functioning, the brain uses interoceptive to assist in understanding emotional experiences (Barrett 2017). Impairments in the capacity to identify interoceptive states, as is seen in individuals with high alexithymia, therefore impact an individual's capacity to understand their emotions. For example, if an individual with higher alexithymia struggles to identify the internal physiological cues such as increased heart rate or increased breathing rate, this impairs their ability to identify when they are feeling anxious or fearful. Given the multi-faceted nature of emotion identification and processing deficits in alexithymia, it is vital that existing measures of alexithymia capture this complex presentation.

One of the most widely used measures designed to capture these deficits is the *Toronto Alexithymia Scale*, originally developed by Taylor et al. in 1985 and further revised in 1994 (Bagby et al., 1994). Within this measure, the common deficits associated with Alexithymia were categorised into three factors using a factor analysis: (1) difficulties identifying feelings, (2) difficulties describing feelings, and (3) externally oriented thinking. The first two factors, difficulty identifying feelings and difficulty describing feelings, refer to how emotions are interpreted and understood. For example, an individual with high levels of alexithymia may recognise that they are feeling ‘bad’ but struggle to pinpoint what specific emotion they are feeling (e.g. anger, sadness). The final subscale, externally oriented thinking, refers to a focus on external stimuli, rather than internal experiences. Essentially, individuals tend not to focus on and attend to their emotional state. While research since the development of the Toronto Alexithymia Scale has consistently displayed adequate psychometric properties as a full scaled score of alexithymia, some researchers have found that the externally oriented thinking subscale does not have sound content validity or internal consistency due to certain items poorly mapping on to the externally oriented thinking factor (Preece et al. 2017). Importantly, only three of the eight items assessing externally oriented thinking reference the individual’s level of attention to their emotions, despite many researchers viewing level of emotional attention as a core element of externally oriented thinking (Preece et al. 2017; Vorst & Bermond, 2001). These three items are also the only externally oriented thinking items that displayed satisfactory content validity with the externally oriented thinking factor (Preece et al., 2017). Of the remaining five externally oriented thinking items, two explore preferences around media consumption (i.e., favourite genres and typical level of analysis of shows), two explore the individual's likelihood to analyse everyday events, and one explores the individual's capacity to form close relationships.

More recently, the Perth Alexithymia Questionnaire (PAQ) was developed to rectify the internal consistency issues found within the Toronto Alexithymia Scale. While the PAQ uses the same core factors as the Toronto Alexithymia Scale (i.e., difficulty identifying feelings, difficulty describing feelings, and externally oriented thinking), two of these factors have been split to allow for differentiation between positively and negatively valenced emotions. Within the PAQ, deficits associated with alexithymia are categorised into five factors: (1) difficulties identifying negative feelings, (2) difficulties identifying positive feelings, (3) difficulties describing negative feelings, (4) difficulties describing positive feelings, and (5) general externally oriented thinking. The changes in assessing alexithymia made by the PAQ allow for a more detailed and accurate understanding of alexithymia, something that is particularly important when exploring the prevalence and impact of alexithymia across both the general population and various clinical populations.

Although alexithymia is less common in general populations, the prevalence of this trait increases significantly in several clinical populations (Porcelli & Taylor, 2018). Research has reported higher incidences of alexithymia amongst individuals with anorexia nervosa, schizophrenia, depression, social anxiety and substance abuse (Adenzato et al., 2012; Porcelli & Taylor, 2018; Thornberg et al., 2009; Van't Wout et al., 2007). Research has also consistently highlighted a particularly high co-morbidity between alexithymia and autism spectrum disorder, with some research indicating up to 50% of individuals with autism also have high levels of alexithymia (see Kinnaird et al., 2019 for review). Despite the significant overlap between autism and alexithymia, research suggests that the two conditions are distinct from one another (Bird et al., 2011; Shah et al., 2016; Trevisan et al., 2016). Supporting this distinction, a study conducted by Cook et al. (2013) found a significant positive correlation between alexithymia and attribution thresholds, indicating that higher alexithymia was associated with poorer precision in attribution of emotional expressions, while autism severity was found to be unrelated to expression attribution ability. In this study, Cook et al. had participants observe a series of emotional facial stimuli, which were created by morphing either anger and disgust, or surprise and fear across a continuum. Participants were then tasked with determining the emotion displayed using a fixed prompt (i.e. "Disgust or Anger?" or "Surprise or Fear?" respectively). As a positive correlation was observed between participants' precision of expression attribution and high alexithymia levels, but no positive correlation was found for autism severity, these findings support a distinction between autism and alexithymia. A number of studies have reported similar findings to those of Cook et al. (2013), further supporting this distinction (Ketelaars et al., 2016; Ola et al., 2020). Additionally, as discussed above, statistics on alexithymia prevalence highlight that, while higher alexithymia is common in the autistic population, it is not universal.

Behavioural Evidence of Impaired Face Processing in Alexithymia

A comprehensive empirical base supports the claim of a processing deficit for emotional facial expressions among individuals with alexithymia. Specifically, higher alexithymia has been associated with impairments in the matching, labelling and detection of emotional facial expressions (see Grynberg et al., 2012 for review). *Matching tasks* involve participants matching a previously seen emotional target face to the matching face within a group of distractors. *Detection tasks* involve detecting whether a target face is present within a group of distractors, while *labelling tasks* expand on this further by labelling the emotion being displayed by the target face (often from within a list of several emotional labels). If we consider these findings from an Emotion Knowledge perspective, Grynberg et al.'s findings suggest that Alexithymia may lead to deficits in at least two of the three key elements of emotion knowledge, namely *detection/identification* and *labelling*.

Supporting this emotional facial expression processing impairment, several studies consistently reported negative relationships between total alexithymia scores and performance in emotional labelling (Jessimer & Markham, 1997; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Ridout et al., 2010; Swart et al., 2009) and matching tasks (Lane et al., 2000; Prkachin et al., 2009). For example, Prkachin et al. (2009) asked participants to view a series of videos consisting of a face displaying an emotional expression, and verbally respond when they felt the stimulus expression matched a target emotion. Their results indicated that higher alexithymia levels were associated with poorer detection abilities for sadness, anger and fear.

Unfortunately, research investigating performance in emotional detection tasks is scarce, but the available research does support the theory of impairment in emotional detection ability in alexithymia (Grynberg et al., 2012). Parker et al. (2005) conducted an emotional detection task using a signal detection paradigm. In this task, participants viewed a series of facial expressions depicting neutral or negative emotions and stated whether they believed the face was depicting an emotion. Higher scores in the difficulty describing feelings component of alexithymia were found to be negatively correlated with detection ability for negative emotions. While these findings do support an impairment in emotional detection in alexithymia, further research is needed to better understand the extent of this deficit.

Findings on the impact of specific emotion types on detection, labelling and matching performance are rather mixed, with some evidence suggesting no difference between emotions and other evidence suggesting poorer performance for negatively valenced emotions in particular (Grynberg et al., 2012). While empirical evidence does display a clear link between higher levels of alexithymia and poorer identification of emotional facial expressions, the impact of emotion on this deficit requires further investigation. Furthermore, evidence has suggested that it may not be alexithymia as a whole that drives these deficits in detecting and labelling emotional facial expressions, but rather the difficulty identifying feelings and the difficulty describing feelings components within alexithymia. Ihme et al. (2014) conducted a series of studies investigating the effect of alexithymia on the automatic processing of information. Their second study looked specifically at the processing of emotional facial expressions. Participants were required to determine the emotion of a briefly displayed emotional facial expression. They found that higher difficulty describing feelings was related to poorer performance in labelling happy, angry, fearful and neutral faces. Difficulty identifying feelings was also associated with poorer labelling performance, but a significant correlation was found only for angry faces. Externally oriented thinking (i.e., a focus on external stimuli) was not found to be significantly correlated with labelling performance. These findings not only suggest that the difficulty describing feelings and difficulty identifying feelings components of alexithymia may drive emotional facial expression identification deficits, but that emotion type may further impact the presence and strength of these deficits.

Neural Evidence of Impaired Face Processing in Alexithymia

In addition to the behavioural research supporting an impairment in the processing of emotional facial expressions in alexithymia, neural studies provide further support of this impairment. Kugel et al. (2008) investigated amygdala activation during presentation of a series of emotional faces (i.e. sad, happy and neutral) masked by neutral faces in 21 healthy participants with varying levels of alexithymia. Difficulty identifying feelings negatively correlated with neural activation in the right amygdala, meaning higher scores on the difficulty identifying feelings facet of alexithymia were associated with lower brain activation of the right amygdala, for masked sad faces. The observed under-activation and low spontaneous reactivity of the right amygdala for sad faces suggests that the amygdala may be less engaged during the encoding of negative emotional stimuli in high alexithymia (Kugel et al., 2008).

Using a similar masking task to Kugel et al. (2008), Reker et al. (2010) examined whole-brain activity during the processing of emotional facial expressions in alexithymia. They found that, for sad faces, the level of alexithymia was negatively associated with activity in the left amygdala and the fusiform gyrus. In addition, alexithymia was also negatively associated with activation in a number of brain regions associated with the processes involved in understanding another's mental state (i.e. the insula, superior temporal gyrus, and inferior frontal gyrus; Reker et al., 2010). Reker et al. hypothesised that the reduced automatic reactivity observed in the amygdala and visual occipito-temporal areas could suggest less automated engagement in the encoding of emotional stimuli, and specifically sad faces, in alexithymia.

Behavioural Evidence of Impaired Threat Detection in Alexithymia

While research does appear to support the presence of an anger superiority effect in the general population, it is unclear whether this effect is also present in those with emotional facial expression processing deficits, such as those with higher alexithymia. A number of studies investigating the impact of emotional valence and specific emotions on emotional facial expression processing in alexithymia have displayed support for a greater deficit for negatively valenced emotional facial expressions, suggesting poorer threat detection abilities in individuals with higher alexithymia when compared to those with lower alexithymia (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). Prkachin et al. (2009) investigated the impact of alexithymia on participants' ability to identify a target emotional face using a detection task. Participants were asked to observe a single emotional face on a screen and determine whether the emotion displayed matched a specific target emotion. Results indicated that participants with higher alexithymia were worse at detecting negatively valenced emotional targets (i.e. anger, sadness, fear) compared to participants with lower alexithymia. These findings suggest that the deficits in facial emotion detection associated with alexithymia are stronger for negatively valenced faces.

In 2006, Vermeulen et al. conducted three studies investigating the influence of emotionally valenced words and faces in a priming task. Participants were presented with one of six potential primes (i.e. a positive, negative or neutral word or face) and were then asked to determine whether a target noun was positive, negative or neutral. Higher alexithymia scores were associated with reduced affective priming effects specifically for angry faces, suggesting that alexithymia may disrupt the automatic processing of affective information related to anger (Vermeulen et al. 2006). Furthermore, the second and third studies conducted by Vermeulen et al. displayed that the reduced affective priming effects were not observed for sad primes but remained for angry primes, supporting a deficit in anger specifically.

Finally, Luminet et al. (2011) investigated the ability of individuals with high levels of alexithymia to recognise complex emotional states. Participants completed a Reading the Mind in the Eyes test, which required them to look at a series of images of eyes displaying various complex emotions. Participants were then given a list of four mental states, and their task was to choose which mental state matched the emotion displayed by the eyes. An overall deficit in performance was found in those with higher alexithymia. This deficit was particularly pronounced for faces with more negative and intense emotions, suggesting that higher alexithymia scores particularly impact the processing of intense, negatively valenced emotional facial expressions. Not only do these findings provide further support for the presence of a stronger deficit in the processing of negatively valenced emotional facial expressions in alexithymia, but they also carry substantial implications for the impact of alexithymia on the detection of social threats.

Neural Evidence of Impaired Threat Detection in Alexithymia

Neuro-imaging studies provide further support for a potential impairment in the detection of threatening faces in higher alexithymia. FMRI research investigating brain activity during the processing of emotional facial expressions in alexithymia has highlighted potential reduced activation of the Amygdala and Anterior Cingulate Cortex (ACC) in those with higher alexithymia. The Amygdala is widely considered to play a key role in threat detection and is associated particularly with fear conditioning and the processing of negative emotions. These findings have important implications for threat detection abilities in alexithymia.

A number of fMRI studies have found that activation of the Amygdala was reduced during the processing of emotional facial expressions in individuals with higher alexithymia (Baxter et al., 2002; Jongen et al., 2014; Kugel et al., 2008; Reker et al., 2010). While these findings support the theory of impaired detection of threatening faces in alexithymia, it is important to note that the evidence for reduced Amygdala activation is somewhat mixed.

In addition to reduced Amygdala activation, fMRI studies have consistently found reduced activation of the ACC amongst individuals with higher alexithymia (Braem et al., 2017; Ihme et al., 2013; Jongen et al., 2014; Kano et al., 2003; Moriguchi et al., 2007; Vermeulen et al., 2008). Although there is some debate regarding the function of the ACC, research has suggested it may be associated with important roles including: emotion regulation, decision making, conflict monitoring, and the processing of anger (Stevens et al., 2011). Each of these processes likely impacts an individual’s assessment of, and response to, a threatening situation. Interestingly, in 2003, Kano et al. observed that individuals with higher alexithymia displayed a greater reduction in activation of the ACC when responding to angry faces, compared to neutral faces. In addition, Vermeulen et al. (2008) also observed under activation of the ACC when detecting angry faces in individuals with higher alexithymia. The findings of Kano et al. (2003), Vermeulen et al (2008) and the overall evidence of reduced activation of the ACC suggest that threat detection abilities, and the detection of angry faces specifically, may be impaired in individuals with higher alexithymia.

Summary

While there is evidence supporting an anger superiority effect, the underlying cause of this effect remains contentious. To determine the legitimacy of the anger superiority effect, future studies should include variation in the types of target stimuli used (i.e., schematic vs. photographic) to explore the role of potential perceptual confounds and provide greater ecological validity. More importantly, despite clear evidence of deficits in the processing of emotional facial expressions, minimal research has been conducted into whether this anger superiority effect persists among individuals who struggle with emotion identification and processing, such as those with higher levels of alexithymia. Behavioural evidence suggests that difficulty detecting and processing emotional facial expressions seen in higher alexithymia individuals can become more pronounced for negatively valenced faces specifically, such as anger (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). Neural research provides further support for poorer detection and processing of negatively valenced faces, with evidence showing diminished activation in brain regions associated with threat detection and emotion processing (i.e., the amygdala and ACC) in individuals with higher alexithymia.

Current Aims

This thesis aims to address this gap in the literature by exploring the impact of higher alexithymia levels on the presence of the anger superiority effect and the processing of threatening facial expressions overall using the face-in-the-crowd paradigm.

To explore this gap, the present thesis investigates four central questions regarding the processing of emotional facial expressions, focusing on threat detection and potential variability in performance associated with alexithymia. These questions were addressed through a series of six studies, each using variations in visual search tasks to explore various elements of emotional face processing and the theories that underlie it.

The first aim was to replicate and build upon the existing evidence supporting more efficient detection of angry faces compared to other emotional faces in the general population, namely the anger superiority effect (e.g., Diao et al., 2017; Dickins & Lipp, 2014; Hansen & Hansen, 1988; Öhman et al., 2001). This effect was initially examined in Study 1A, which replicated the schematic face-in-the-crowd design used by Öhman et al. (2001) using participants across three different alexithymia severity levels. Studies 1B and 1C expanded on this by manipulating emotional valence and facial expression type to further test the robustness of the anger superiority effect overall.

The second aim was to explore whether elevated alexithymia levels impact the anger superiority effect, if valid. As discussed above, prior research has linked alexithymia with deficits in identifying negatively valenced emotions such as anger (Luminet et al., 2011; Prkachin et al., 2009), suggesting that individuals with higher alexithymia might show a diminished or absent anger superiority effect. This possibility of a diminished anger superiority effect in higher alexithymia individuals was tested across Studies 1A - 1C. This aim was further explored under more ecologically valid conditions in Study 2, which replaced schematic stimuli with photographic emotional faces to assess whether the effect generalises to more realistic facial expressions. Study 4 then provided a more detailed exploration using electroencephalography to provide neural evidence of attentional deployment differences in response to angry and happy emotional faces in individuals with low and high alexithymia.

The third aim of the present research was to replicate consistent findings in the literature suggesting a general deficit in emotional face processing among individuals with higher alexithymia, regardless of the specific emotion or valence involved (Jessimer & Markham, 1997; Grynberg et al., 2012; Swart et al., 2009). This broader question was addressed not only across Studies 1A - 2, but also in Study 4 using electroencephalography to explore differences on a neural level. In addition, general visual search performance was explored across alexithymia severity levels in study 3, which involved detecting a target “2” among distractor “5”s.

The fourth and final aim was more methodological in nature and aimed to compare the interpretive value of Bayesian and frequentist approaches to statistical analysis. Given ongoing debates around the limitations of p-values and the benefits of Bayes Factors in quantifying evidence for both null and alternative hypotheses, all six studies were analysed using both methods as an additional learning exercise. For example, in 2016, the American Statistical Association released a statement discussing the common misinterpretations of p-values and emphasised the importance of considering other forms of evidence in addition to p-values

(Wasserstein & Lazar, 2016). Supporting the value of Bayesian statistics, Wagenmakers (2007) highlighted how Bayes Factors offer a more easily understandable and meaningful result by providing both a measure of significance and an estimation of evidence strength. This dual perspective allowed for more nuanced interpretations, particularly in the context of null findings or borderline effects. It also allowed for comparison between frequentist and Bayesian statistical performance for studies with small and unequal sample sizes, as was seen within the low and high alexithymia conditions across several studies within the present thesis. The six studies outlined in this thesis provide a comprehensive and multi-method investigation into how emotional faces are processed, how alexithymia impacts the efficiency of emotional processing, and how alternative statistical frameworks can enhance interpretation in psychological research.

Chapter 2: Study 1A - 1C

Study 1A

Introduction

Despite the growing body of research investigating the effects of alexithymia on the processing of emotional facial expressions, very little research has been conducted on the impact of alexithymia on the detection of social threats (e.g., angry or scared faces). As discussed in Chapter 1, the theory of an anger superiority effect relies on the concept that angry faces are more salient than other emotional faces, thereby resulting in more effective threat detection. However, it is unclear whether this increased saliency of angry faces would still occur when an overall deficit in emotional facial expression processing is present, such as in alexithymia.

The first series of studies sought to investigate whether the emotional facial expression processing deficits observed in alexithymia extend to identifying social threats, such as angry and scared faces, resulting in the disappearance of the anger superiority effect. Rather than exploring deficits in processing or labelling of emotions, as is most common in the current alexithymia literature, this series of studies aimed to explore the detection of faces (i.e., how fast attention was allocated to identify that a target emotion is present) using a face-in-the-crowd task (Hansen & Hansen, 1988; Grynberg et al., 2012). The face-in-the-crowd task has several advantages, particularly its ability to provide a more realistic search task as it requires spatial shifts of attention while also allowing us to directly map how fast attention is allocated to an object (Schmidt-Daffy, 2011). Furthermore, the face-in-the-crowd task allows us to explore the potential impacts of higher alexithymia on different aspects of visual search (e.g., attention allocation, stimulus recognition, stimulus categorisation, ability to ignore distractor stimulus), an area which was largely unexplored at the time of experimentation.

These visual search processes can be understood through Wolfe's theory of visual selection, which proposes three components: (1) a parallel stage of perceptual description where visual information across the visual field creates a detailed mental picture, (2) a selection process where relevant information is identified by matching visual input with internal target templates, and (3) entry into visual short-term memory for coordinating responses (Wolfe, 2021). This framework provides the theoretical foundation for understanding how attention is allocated to emotional targets in the face-in-the-crowd paradigm and may help explain potential differences in performance between alexithymia groups.

Overall, we would expect to see evidence of the anger superiority effect in the general population, however this may not be the case for higher alexithymia individuals. Theoretically, the difficulties in emotional processing linked to higher alexithymia may affect the manifestation of the anger superiority effect, resulting in comparable performance across all emotional targets. Furthermore, due to the emotional processing difficulties associated with alexithymia, we anticipate observing lower overall detection performance in individuals with higher alexithymia.

Hypotheses

Hypothesis 1: A main effect of target type will be found whereby angry target faces will be detected significantly faster and more accurately than happy target faces, demonstrating the anger superiority effect (e.g., Hansen & Hansen, 1988; Öhman et al., 2001). This will be evidenced by shorter reaction times, shallower search slopes, and higher detection and labeling accuracy for angry compared to happy targets.

Hypothesis 2: A main effect of alexithymia condition will be found whereby higher alexithymia participants will show longer reaction times and lower accuracy when detecting emotional facial expressions compared to lower alexithymia participants, consistent with documented emotional processing deficits (e.g., Grynberg et al., 2012; Prkachin et al., 2009).

Hypothesis 3: The anger superiority effect will be diminished or absent in higher alexithymia participants, resulting in a significant interaction between alexithymia condition and target type on reaction times and accuracy measures.*Hypothesis 4:* A main effect of alexithymia condition on search slopes will be found whereby higher alexithymia participants will show steeper search slopes across all target types, indicating less efficient visual search processes and greater susceptibility to increases in set size.

Hypothesis 5: A main effect of alexithymia condition will be found for labeling accuracy whereby higher alexithymia participants will show significantly lower accuracy when labeling emotional facial expressions compared to lower alexithymia participants, reflecting deficits in the second stage of emotion knowledge (identification/labeling) consistent with documented difficulties in describing and identifying emotions (e.g., Jessimer & Markham, 1997; Mann et al., 1995; Swart et al., 2009).

Method

Participants

Prolific (https://www.prolific.com) was used to recruit 101 online participants. Of these, 10 were excluded due to low accuracy, resulting in a final sample of 91 participants (53 males, 35 females, and three non-binary). Of the 91 participants, 15 fell into the low alexithymia condition, 61 in the medium alexithymia condition, and 15 in the high alexithymia condition. Participants were between 18 and 73 years old ($M = 28.78$, $SD = 9.32$), fluent in English, and had normal or corrected-to-normal visual acuity. Participants received approximately $10 AUD for their completion of a single online experimental session consisting of an online threat detection task and completion of a questionnaire assessing alexithymia, the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018).

The chosen sample size was based on an a priori power analysis conducted using G*Power (Faul et al., 2009). According to G*Power, given an $\alpha = 0.05$, 20 participants (i.e. 10 per low and high alexithymia condition) are needed to detect an effect of this size with a power of $1 - ß= 0.80$. As the literature suggests that the prevalence of clinically relevant or high levels of alexithymia within the general population is approximately 1/10 (Ricciardi et al., 2015), an overall sample size of 100 participants was the goal for all studies. The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and informed consent was obtained from all participants.

Research Design

This study used a 3 (Condition: low alexithymia, medium alexithymia, high alexithymia) x 2 (target: angry, happy) x 2 (trial type: target-present, target-absent) x 3 (set size: 8, 15, 24) mixed between/within participants design and consisted of 240 trials total (30 practice and 210 experimental). Target and trial types were randomly selected across trials with approximately 50% probability. Due to limitations with the PsychoPy framework at the time of study creation, I was unable to set specific randomisation constraints (e.g., ensuring exactly 50% of experimental trials were target absent). Rather, I elected to use a randomisation feature in which a target was randomly selected from a pre-populated list of possible stimuli at the beginning of each trial. This pre-populated list contained 50% target absent stimuli, 25% target angry stimuli, and 25% target happy stimuli. Due to the high number of trials and participants in the present study, it was anticipated that this method would lead to a proportion of target-absent trials that was approximately 50% and a proportion of 25% for the angry/happy target-present trials. However, exact proportions may vary slightly between participants due to this randomisation process.

The dependent variables were reaction time (RT), search slope (i.e., the search time taken per item in an array), detection accuracy (i.e., the proportion of correct responses across target-present and target-absent trials), and labelling accuracy (i.e., the proportion of trials in which the target type, i.e., the emotion displayed by the target face, was correctly identified).

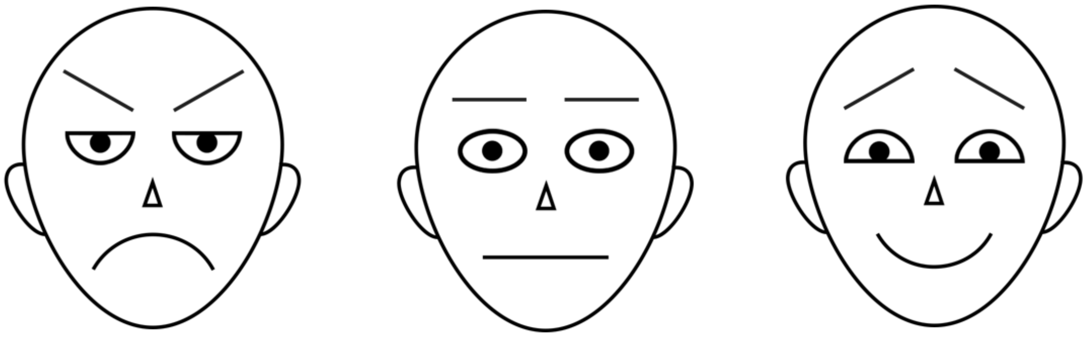
Stimuli and Apparatus

Stimuli consisted of 240 black and white images of various schematic faces, with the images being 1,920 x 1,080 pixels in size. These images were based on stimuli used by Öhman et al. (2001). The individual facial stimuli were created in Adobe Illustrator and combined in MATLAB to create the 2 x 4, 3 x 5 and 4 x 6 stimuli matrices.

The faces within the image were displayed in a matrix and portrayed either a neutral, angry or happy expression. The matrix size varied randomly between trials (i.e. 2 x 4, 3 x 5 or 4 x 6). The images were identical, with the only differences being (1) the varying matrix size and (2) the presence of an emotional face in half of the images (i.e. angry or happy face; target present), with the other half containing only neutral faces (target absent). The emotional face was randomly located in every target present image. Figure 1 shows sample stimuli.

Figure 1:

Sample Stimulus Images



Note: Sample angry (leftmost), neutral (centre) and happy (rightmost) stimulus images.

The study was programmed using the graphical builder interface of PsychoPy (Peirce, 2007) which generated and exported the study to a PsychoJS script. This script was then pushed to Pavlovia (https://pavlovia.org/) to be run online.

Materials

Perth Alexithymia Questionnaire (Preece et al., 2018). Participants' alexithymia levels were measured using the Perth Alexithymia Questionnaire (PAQ). The PAQ is a 24-item self-report measure consisting of a series of statements related to the processing of emotions (i.e. "*When I'm feeling bad, I can't find the right words to describe those feelings*"). Participants were asked to respond to each statement using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Scores range from 0 to 168, with higher scores indicating higher levels of alexithymia. Participants were then divided into a "low", "medium" and "high" alexithymia condition.

The low condition consisted of participants with scores ranging between 0 and 51, the medium condition consisted of participants with scores ranging between 52 and 112, and the high condition consisted of participants with scores ranging between 113 and 168. The low, medium and high alexithymia categorisations were based on recommendations within the PAQ interpretation guidelines and were calculated using normative data (Preece et al., 2018).

Procedure

Participants were recruited via Prolific, an online platform that facilitates the recruitment of individuals willing to participate in online studies for research purposes. Prior to beginning the task, participants were asked to read through an information sheet describing the study, what was expected of them, and their rights as participants. The information sheet asked participants to ensure they completed the study using a laptop or desktop computer. Finally, the information sheet also informed participants that, by choosing to sign up for the task on Prolific, they would be providing their consent to participate.

Once participants had signed up for the task, they were taken to Pavlovia, where a series of instructions were displayed on the screen. These instructions explained that participants would be viewing a series of images with drawn faces displaying different emotions and that their objective throughout the task was to determine whether all the faces on screen belonged to the same emotion category. Furthermore, participants were informed that approximately half of the trials would contain a target emotion that differs from other emotional faces displayed. Participants were asked to press the letter ‘P’ on the keyboard if they thought a target emotional face was present (i.e. a happy or sad face) and the letter ‘A’ on the keyboard if they thought the target emotion was absent and were asked to respond as quickly and accurately as possible. In addition, to differentiate between performance differences due to low-level perceptual factors (e.g., luminance, angles) versus the actual emotion of the target face, participants were required to label the emotion of the target face using a forced-choice method. Participants were asked to press the ‘1’ key if an angry target face was present, the ‘2’ key if a happy target face was present, and the ‘3’ key if no target face was present (i.e. all faces belonged to the same emotion category). A face displaying a target emotion (either anger or happiness) was present in 50% of the trials, with the remaining 50% consisting only of neutral distractor faces. Prior to beginning the experimental trials, participants completed 30 practice trials to help them get a feel for the task. Participants did not receive feedback on their performance on the task.

Measures

Measures of performance included reaction times (RTs), measures of detection accuracy, and search slope. Reaction time reflects the combined time for attention deployment, stimulus recognition, and response selection (Wolfe, 2021; Duncan & Humphreys, 1989). Search slope specifically isolates attention deployment efficiency, with flatter slopes indicating more parallel processing and steeper slopes indicating more serial search (Treisman & Gelade, 1980; Wolfe, 1998). Participants' RTs across the three set sizes were used to calculate participants' search slope across the study using the following formula:

$$m = \frac{\Delta y}{\Delta x} = \frac{\frac{y_3 - y_2}{x_3 - x_2} + \frac{y_2 - y_1}{x_2 - x_1}}{2}$$

Where m denotes the search slope, Δy denotes the change in Y coordinates (i.e., mean reaction times), and Δx denotes the change in X coordinates (i.e., set sizes) across the study. RTs from trials with incorrect responses were excluded from analysis. Any participants with an overall accuracy below chance (i.e., <50%) were also excluded from analysis. Ten participants were excluded based on accuracy requirements (four males and six females). Of the 10 excluded participants, two fell into the low alexithymia condition, five into the medium alexithymia condition, and three into the high alexithymia condition. Excluded participants were aged between 20 and 42 years (M = 30.8, SD = 7.955).

Time taken for participants to label the target emotion (i.e., labelling RT) and accuracy of target emotion labelling (i.e., labelling accuracy) was also calculated to provide further assessments of labelling performance. Detection accuracy reflects the first stage of emotion knowledge (detection/identification), while labelling accuracy taps the second stage (emotion labelling), allowing separation of these cognitive processes (Izard et al., 2011; Luminet & Zamariola, 2018).

Statistical Analyses

For the present study, in addition to traditional frequentist measures of statistical significance (i.e., p-values), Bayesian measures of evidence (i.e., Bayes factors) were also used. Bayes factors are defined as likelihood ratios that determine whether data favours one of two models, usually the null hypothesis versus the alternative hypothesis (Wetzels et al., 2011; Schmalz et al., 2023). Bayes factor values are labelled B_{10} (Rouder & Morey, 2012). While both approaches were employed, Bayesian results were only discussed in depth when they provided meaningful insights that differed from the conclusions drawn using frequentist methods.

There are a number of advantages to using Bayes factors that would not otherwise be present if using frequentist measures alone. Firstly, Bayes factors are largely unaffected by sample size due to their consideration of 'priors' (i.e., the probability distribution representing our assumptions and beliefs about a parameter prior to observing data) (Schmalz et al., 2023; Sullivan & Feinn, 2012; Wetzels et al., 2011). In contrast, p-values largely draw conclusions of significance based on the data you collect, making it more susceptible to potentially missing significant findings when a small sample size is used (Schmalz et al., 201l; Wetzels et al., 2011).

It should be acknowledged that, although Bayes factors can mitigate the impact of small sample sizes, this is not always guaranteed. McNeish (2016) found that the use of Bayesian statistics with small sample sizes and poorly chosen priors can, at times, lead to more biased conclusions than frequentist statistics. This finding highlights the importance of selecting appropriate priors for studies with small sample sizes. Importantly, McNeish (2016) identified that the use of weakly informed priors (i.e., priors that are not very constraining or influential in analysis) for Bayesian analysis can rectify this issue, leading to more trustworthy conclusions from smaller sample sizes compared to frequentist statistics. In line with this recommendation, all Bayes Factors within this thesis were calculated using Cauchy priors, a weakly informed prior. This use of an appropriate, weakly informed prior, was important given the current prevalence statistics for clinically relevant, high alexithymia in the general population sits at approximately 1 in 10 individuals (Ricciardi et al., 2015), and the fact that all studies within this thesis are unlikely to have an overall sample size larger than 100 due to financial limitations, the inclusion of Bayes analyses allows us to confirm the results found within this thesis are not impacted by sample size.

The second advantage is that Bayes factors are theoretically able to measure evidence in favour of the null hypothesis due to Bayes factors not assigning a special status to the null hypothesis (Wetzels et al., 2011). In frequentist statistics, the null hypothesis is considered the default, which means that any testing purely serves to prove that there is enough evidence to reject the null hypothesis. In contrast, Bayesian statistics treat the null hypothesis and the alternate hypothesis symmetrically, meaning neither is the default, which allows for evidence for and against both the alternative and null hypothesis to be collected, allowing conclusions to be drawn regarding the likelihood of the null hypothesis being true (Wetzels et al., 2012).

The third advantage of using Bayes factors is that it allows us to quantify the relative plausibility of the hypothesis being tested, therefore providing us with further information to draw meaningful conclusions (Wetzels et al., 2011). Specifically, the relative strength of evidence for or against the null or alternative hypothesis can be calculated depending on the size of the range of the reported Bayes factor, which is displayed in Table 1. Importantly, B_{10} values that fall within the 'Anecdotal' range (i.e., between 1/3 and 3) are considered to provide very little evidence for or against an effect and suggest further data collection may be needed.

Analyses and data visualisation were conducted in R (Version 4.4.2; R Core Team, 2024) using the BayesFactor (Version 0.9.12-4.7; Morey et al., 2024) and ez (Version 4.4-0; Lawrence, 2016) packages.

Table 1:

Evidence categories for Bayes Factors

Bayes Factor Range	Evidential Impact/Interpretation
$1/3 < B_{10} < 3$	Anecdotal
$(1/10 < B_{10} \leq 1/3)$ or $(3 \leq B_{10} < 10)$	Substantial
$(1/30 < B_{10} \leq 1/10)$ or $10 < B_{10} < 30$	Strong
$1/100 < B_{10} \leq 1/30$ or $(30 \leq B_{10} < 100)$	Very Strong
$(B_{10} < 1/100)$ or $(B_{10} > 100)$	Decisive

Note: Evidence categories for Bayes Factors adapted from Wetzels and colleagues (2011).

Results and Discussion

It should be noted that Greenhouse-Geisser corrections (Greenhouse & Geisser, 1959) were applied to adjust the degrees of freedom to reflect the results of the study more accurately where the assumption of sphericity was found to be violated, as indicated by Mauchly's Test of Sphericity (Mauchly, 1940).

Additionally, while there is a factor within the present study's design of trial type (i.e., target-present trial, target-absent trial), this factor was unable to be considered within the below analyses as there were no target-absent trials within the angry or happy target type conditions. To allow for comparison between target-present and target-absent findings, target-absent trials were instead categorised as a third target condition (i.e., neutral).

Reaction Time (RT). Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, happy, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and alexithymia condition was entered as a between-participants factor.

The ANOVA revealed a significant main effect of alexithymia condition, F (2,88) = 4.32, p = 0.016, n^2 = 0.05, B_{10} of 1.32E+09, providing extreme evidence in favour of a main effect of alexithymia condition. Post-hoc analyses showed significantly faster RTs for individuals in the high compared to the low alexithymia condition (p =.021) and for individuals in the high compared to the medium alexithymia condition (p = .027). There was no difference in RT for individuals in the low compared to medium alexithymia conditions (p =0.32) (See Figure 2). This finding on the effect of alexithymia on RT is contrary to current literature supporting deficits in the identification of emotional faces in alexithymia (see Grynberg et al., 2012 for review). For example, a recent study conducted by Suslow et al. (2021) also used the face-in-the-crowd task containing six target conditions consisting of happy, angry or neutral targets among happy, angry or neutral distractors. Their findings showed that high-alexithymia participants had significantly slower response times across all six target conditions compared to low-alexithymia participants. It should be noted that this study was conducted within a sample of individuals with depression, which may have influenced the results. However, ANCOVA analysis of covariates (i.e., level of education, reported depressive symptoms, anti-depressant use, and sex) found that the above covariates did not have a significant effect on response time, but the effect of alexithymia on response time remained significant (n^2= 0.14).

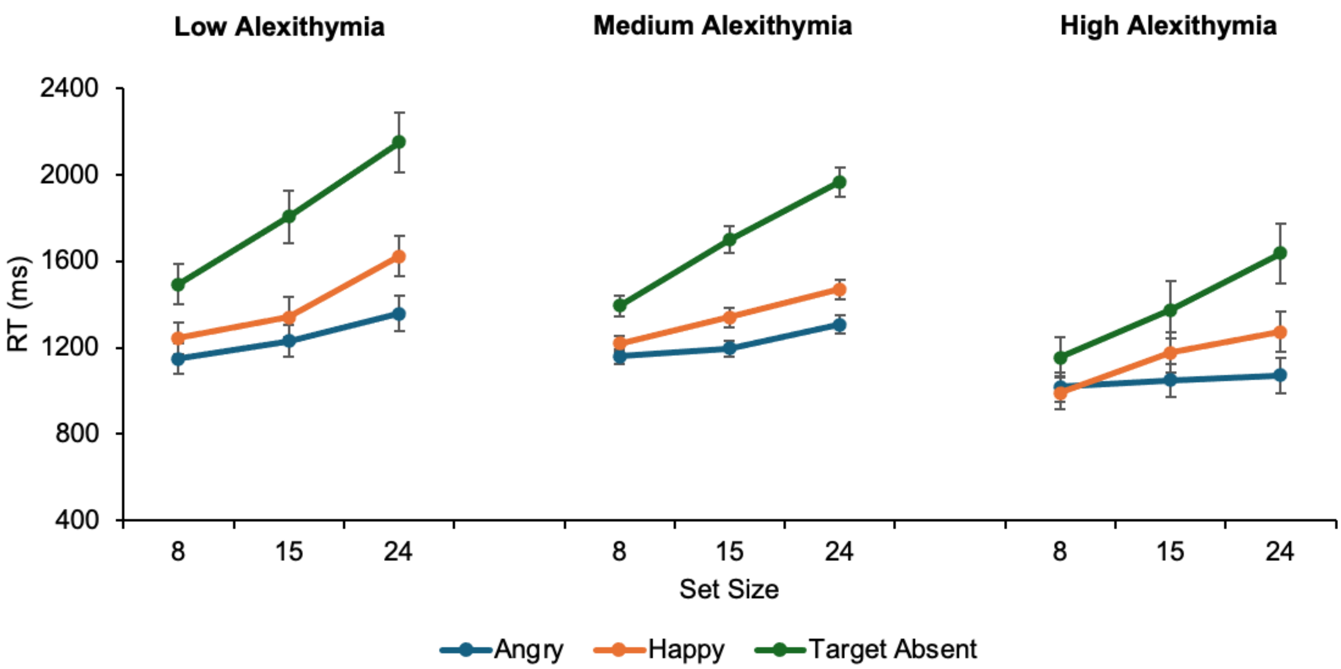
A significant main effect was also found for target type, $F(1,88) = 69.99$, $p<.001$, $n^2 = 0.13$, B_{10} = 6.73E+27, and set size, $F(1.77, 155.42) = 197.49$, $p<.001$, $n^2 = 0.07$, B_{10} = 9.21E+13. However, the significant main effects of target type and set size are moderated by a significant two-way interaction, $F(3.18, 274.32) = 35.11$, $p<.001$, $n^2 =0.02$, $B_{10} = 198.60$, providing extreme evidence in favour of a significant two-way interaction between set size and target type. This interaction between set size and target type indicates that the effect of set size on RT varied across the three target conditions (see Figure 2). To further explore this significant interaction, a series of post-hoc ANOVAs were completed, assessing RT across set sizes for each target type. A significant main effect of set size was found for angry [$F(1.78, 160.05) = 29.31$, $p<.001$, $n^2 = 0.25$], happy [$F(2, 180) = 89.12$, $p<.001$, $n^2 = 0.50$], and target-absent trials [$F(1.42, 127.69) = 232.53$, $p<.001$, $n^2 = 0.72$]. Notably, the f-values do differ between target conditions, with the lowest being angry target trials (29.31), followed by happy (89.12) and neutral target trials (232.53). These differences in f-values suggest that, despite all target types showing a significant effect of set size, the rate of increase in RT was higher for happy targets compared to sad, and for neutral targets compared to emotional targets. To confirm these findings, another series of post-hoc ANOVAs were completed, assessing RT across target type for each set size.

Analysis revealed significant main effects of target type across all set sizes. At set size 8, angry targets were detected the fastest (M = 1133ms, SD = 271.8), followed by happy targets (M = 1186ms, SD = 299.9) and target absent trials (M =1370, SD = 374.4), F (1.41, 127.14) = 47.42, $p<.001$, $n^2 = 0.35$. All three pairwise comparisons were significantly different, $p<.001$. At set size 15, the same pattern emerged with angry targets detected fastest (M = 1177ms, SD = 294.4), followed by happy targets (M = 1338ms, SD = 362.1) and target-absent trials (M = 1663ms, SD = 486.6), $F(1.37, 123.04) = 92.98$, p<.001, $n^2 = 0.51$. All three pairwise comparisons were significantly different, $p < .001$. At set size 24, this detection hierarchy was maintained with angry targets detected fastest (M = 1277ms, SD = 328.4), followed by happy targets (M = 1462ms, SD = 373.0) and target-absent trials (M = 1942ms, SD = 551.4), $F(1.44, 131.0) = 131.0$, $p<.001$, $n^2 = 0.59$. All pairwise comparisons were once again significant, $p<.001$.

As displayed in Figure 2, these findings demonstrate a clear detection hierarchy supporting the anger superiority effect, with angry faces showing the greatest detection efficiency, followed by happy faces, and target-absent conditions showing the slowest responses. These results align with Hansen and Hansen's (1988) finding that angry faces are detected more efficiently than happy and neutral faces in crowd searches, thereby supporting their proposed "anger superiority effect". Our findings similarly corroborate Öhman et al.'s (2001) research, which found that participants were significantly faster at identifying threatening (i.e., angry) faces compared to friendly (i.e., happy), scheming, and sad faces.

Figure 2:

RT for Each Target Type Across Set Size and Alexithymia Conditions.



Note: Mean RTs for angry (blue line), happy (orange line), and target absent trials (green line) across each set size and alexithymia conditions. Error bars indicate standard errors.

All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, $F(6.24, 274.32) = 0.78$, $p = .623$, $B_{10} = 0.01$. The Bayesian ANOVA gave extreme evidence in favour of the null hypothesis (i.e., a non-significant three-way interaction).

Search Slope. Figure 3 presents mean search slopes across the low, medium and high alexithymia categories. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, happy, neutral) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

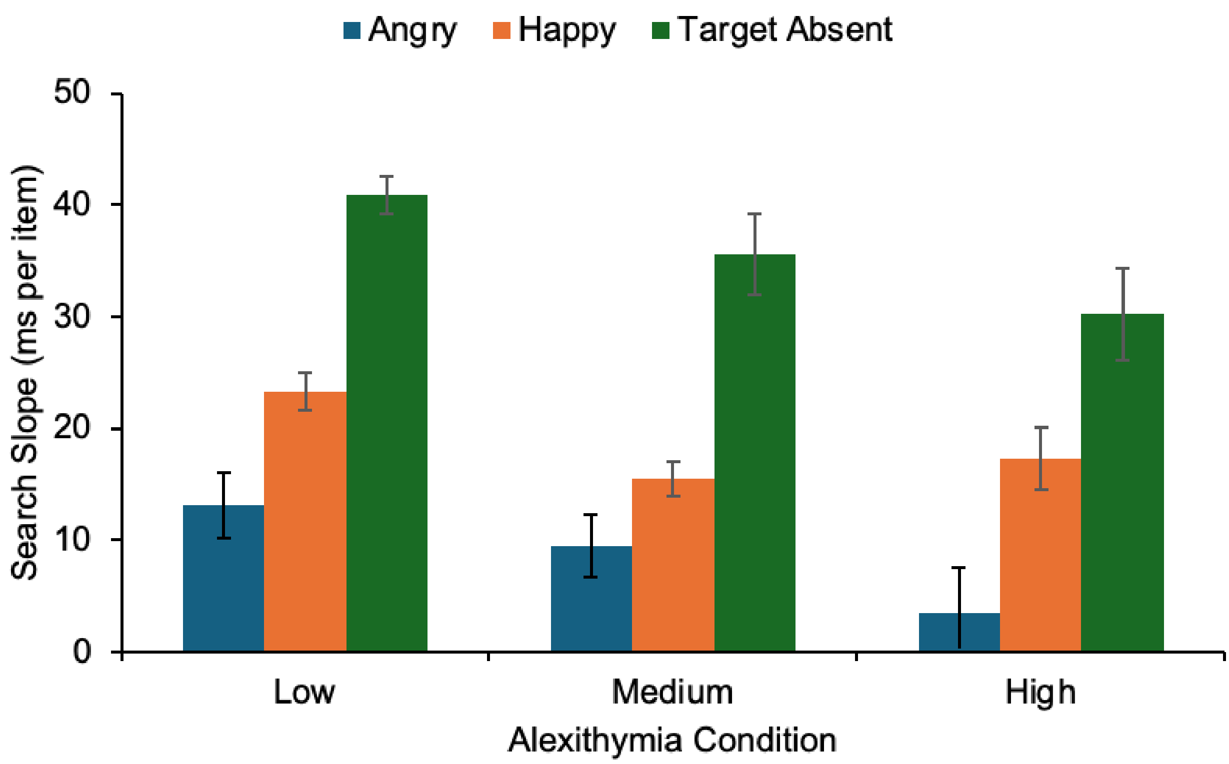
The ANOVA revealed significant main effects of alexithymia condition, $F(2, 88) = 3.33$, $p = .04$. $n^2 = 0.02$, $B_{10} = 1.45$, providing anecdotal evidence in favour of a main effect of alexithymia condition, and target type, $F(1.85, 162.41) = 51.70$, $p<.001$, $n^2 = 0.26$, $B_{10} = 3.88E+16$, providing extreme evidence in favour of a main effect of target type. The two-way interaction between alexithymia condition and target type was found to be non-significant, $F(3.69, 162.41) = 0.57$, $p = 0.672$, $n^2 = 0.01$. In support, the Bayesian mixed ANOVA yielded a B_{10} of 1/13.69, providing strong evidence in favour of the null hypothesis (i.e., a non-significant two-way interaction).

Further post-hoc exploration of the main effect of alexithymia condition showed that the high alexithymia condition had a significantly lower (i.e., flatter) search slope than the low alexithymia condition ($p = .041$), as is displayed in Figure 3. No difference in search slope was found between the low and medium ($p = .245$), and the medium ($p = .245$) and high alexithymia conditions ($p = .092$). This finding suggests that the reaction time was less impacted by increases in set size (i.e., the number of distractor items), indicating greater saliency of all targets, regardless of target emotion, within the high alexithymia condition compared to the low alexithymia condition (Becker & Rheem, 2020). However, Bayesian analysis gave only anecdotal evidence in favour of a main effect of alexithymia condition, suggesting further data is needed to draw meaningful conclusions.

Regarding the main effect of target type, Figure 3 displays a steady increase in search slope across the three target types. Post-hoc analysis shows that angry trials had a significantly lower search slope (*M* = 8.65, *SE* = 1.55) than both happy target trials (*p*<.001) and target-absent trials (*p*<.001). This finding further supports the theory of greater saliency for angry targets compared to happy targets, which is in line with current literature on the anger superiority effect (Öhman et al., 2001).

Figure 3:

Search Slopes Across Target Types and Alexithymia Conditions.



Note: Mean search slope for angry (blue bar), happy (orange bar), and target absent (green bar) across alexithymia conditions. Error bars indicate standard errors.

Detection Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, happy, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and alexithymia condition was entered as a between-participants factor.

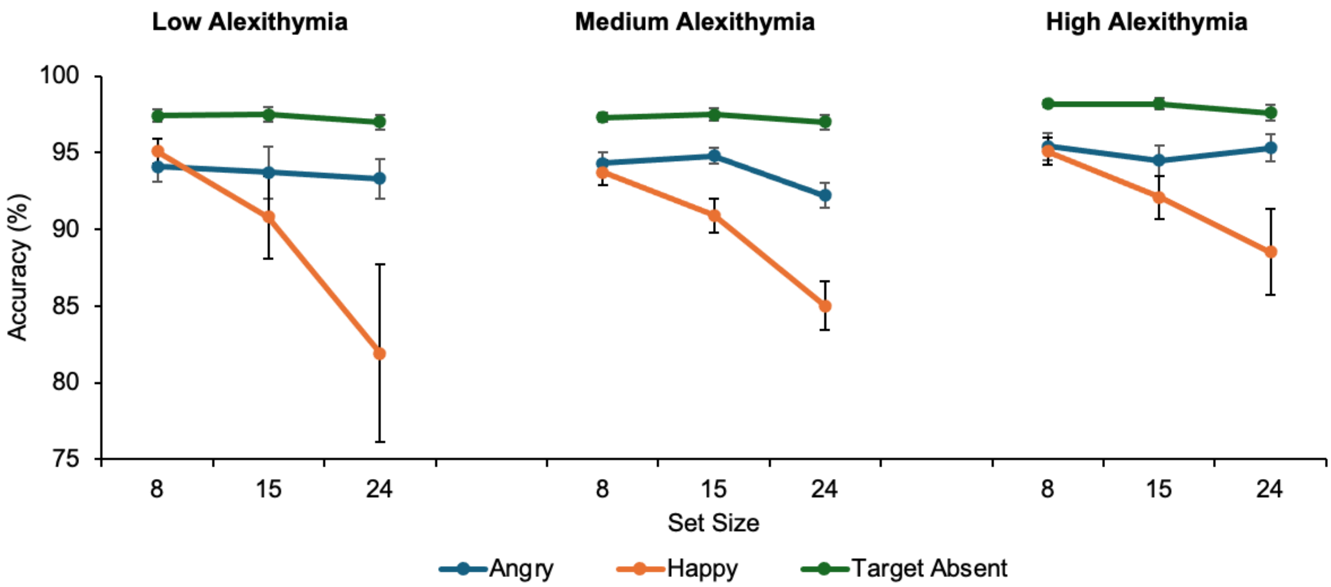
The ANOVA showed no significant main effect of alexithymia condition was found for accuracy, $F(2, 88) = 0.61$, $p = 0.544$, $n^2 = 0.004$, $B_{10} = 1/7.14$, providing substantial evidence in favour of the null hypothesis (i.e., no significant main effect of alexithymia on detection accuracy). This finding, contrary to previous literature (e.g., Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006), indicates evidence against a speed-accuracy trade-off among high-alexithymia participants compared to low-alexithymia participants.

A significant main effect of target type, $F(1.37,120.74) = 26.63$, $p<.001$, $n^2 = 0.07$, $B_{10} = 9.52E+11$, and set size, $F(1.45,127.88) = 12.21$, $p<.001$, $n^2=0.02$, $B_{10} =126.53$, was also found. However, these main effects were moderated by a significant interaction, $F(2.66, 233.68) = 19.60$, $p<.001$, $n^2 = 0.04$, $B_{10} = 1.12E+06$, providing extreme evidence in favour of an interaction between target type and set size. All other interactions were non-significant. As displayed in Figure 4, a steady decrease in accuracy across set size is clearly present for happy target trials, but not for angry target and target-absent trials. To further explore this significant interaction, a series of post-hoc ANOVAs were completed, assessing accuracy across set sizes for each target type. A significant main effect of set size was found only for happy trials [$F(1.59, 143.14) = 42.17$, $p<.001$, $n^2 = 0.15$]. No significant main effect of set size was found for angry [$F(2, 180) = 0.04$, $p = .965$] and target-absent trials [$F(1.57, 141.62) = 0.58$, $p =.563$].

These post-hoc findings were further explored through a series of ANOVAs assessing accuracy across target types for each set size. Analysis of detection accuracy revealed differential effects of target type across set sizes. At set size 8, no significant differences in accuracy emerged between angry target (M = 94.7%, SD = 4.1), happy target (M = 95.5%, SD = 3.6), and target absent trials (M = 96%, SD = 4.9), $F(2, 180) = 3.05$, $p = .05$, $n^2 = 0.033$. At set size 15, the highest accuracy was found for target absent trials (M = 96.3%, SD = 4.4), followed by angry target trials (M = 94.7%, SD = 4.2) and happy target trials (M = 91.6%, SD = 8.8), $F(1.36, 122.40) = 17.67$, $p<.001$, $n^2 = 0.16$. All three pairwise comparisons were significantly different, $p < .002$. A similar pattern was found for set size 24, with the highest accuracy observed for target absent trials (M = 96.3%, SD = 4.9), followed by angry target trials (M = 94.6%, SD = 4.8) and happy target trials (M = 96.3%, SD = 4.9), $F(1.30, 117.06) = 56$, $p<.001$, $n^2 = 0.38$. All pairwise comparisons were once again significant, $p<.002$. This pattern demonstrates that while angry targets maintain an accuracy advantage over happy targets with increasing search difficulty, both emotional target conditions show declining accuracy compared to target-absent trials, suggesting that detecting emotional targets becomes more challenging as set size increases. These findings support the results of Öhman et al. (2001), who similarly found that participants were most accurate in identifying threatening (i.e., angry) faces compared to friendly (i.e., happy), scheming and sad faces. All other interactions were found to be non-significant.

Figure 4:

Detection Accuracy for Each Target Type Across Set Size and Alexithymia Conditions



Note: Mean detection accuracy of angry (blue line), happy (orange line), and target absent (green line) trials across each set size and alexithymia condition. Error bars indicate standard errors.

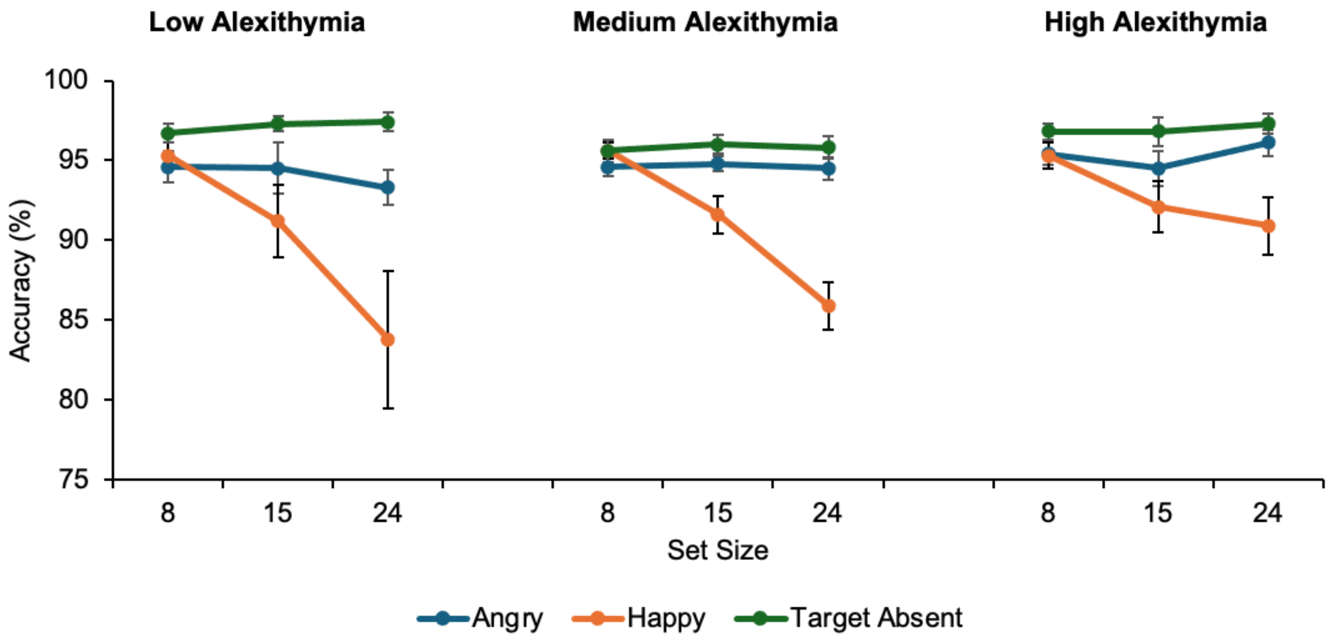
Labelling Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, happy, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and alexithymia condition was entered as a between-participants factor.

No significant main effect of alexithymia condition was found, $F(2, 88) = 0.81$, $p = .450$, $n^2 = .01$, $B_{10} = 1/4.86$, providing substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition on labelling accuracy). The absence of labelling accuracy differences between alexithymia conditions suggests there are no observable deficits in the labelling stage of emotion knowledge among those with higher alexithymia, which contrasts current literature findings (Jessimer & Markham, 1997; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Ridout et al., 2010; Swart et al., 2009). This finding also indicates that the faster RT observed in the higher alexithymia condition not only did not impact their ability to detect the emotion itself but also did not impact their ability to label the emotion being displayed. Essentially, despite their faster processing time, there were no observable deficits in the first (i.e., detection/identification) or second (i.e., labelling) stages of emotion knowledge.

A significant main effect was found for both target type, $F(1.28, 112.68) = 47.33$, $p<.001$, $n^2 = 0.11$, $B_{10} = 1.48E+20$, and set size, $F(1.54,135.15) = 18.17$, $p<.001$, $n^2 = 0.03$, $B_{10} = 2.54E+04$. However, a significant two-way interaction between set size and target type, $F(2.25, 198.34) = 16.27$, $p<.001$, $n^2 = .04$, $B_{10} = 9.56E+04$, indicates that the effects of set size on labelling accuracy vary across target types. This significant interaction was supported by the Bayesian ANOVA, which found extreme evidence in favour of a significant interaction between target type and set size. As displayed in Figure 5, a steady decrease in labelling accuracy across set sizes is clearly present for happy target trials, but not for angry target and target-absent trials. Post-hoc t-test confirmed labelling accuracy significantly reduced across set sizes for happy target trials (8-15: $p = .006$; 15-24: $p = <.001$), but found no differences in accuracy across the three set sizes for angry target trials (8-15: $p =1$; 15-24: $p =1$) or target-absent trials (8-15: $p =1$; 15-24: $p =0.391$). As was observed in the above findings in detection accuracy, these findings indicate that the influence of set size on accuracy was stronger for happy target trials compared to angry and target-absent trials. All other interactions were found to be non-significant.

Figure 5:

Labelling Accuracy for Each Target Type Across Set Size and Alexithymia Conditions



Note: Mean labelling accuracy for angry (blue line), happy (red line), and neutral (i.e., target absent) trials (green line) across each set size. Error bars indicate standard errors.

Study 1B

Introduction

As highlighted in Chapter 1, prior research has observed poorer processing of negatively valenced emotional faces amongst individuals with higher alexithymia compared to lower alexithymia participants (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). However, the impact of specific emotions on the observed deficits in the processing of negatively valenced emotions in alexithymia requires further investigation. Vermeulen et al. (2006) conducted three studies investigating the influence of emotionally valenced words and faces in a priming task. Their findings highlighted a difference in priming effects between sad and angry primes, suggesting a deficit in the processing of anger specifically.

In order to explore the impact of specific emotions outside of emotional valence and for the impacts of alexithymia on the anger superiority effect to be fully explored, a follow-up study was devised using only negatively valenced emotions as targets. For the anger superiority effect to be supported, it was expected that angry targets would continue to be detected significantly faster than sad targets. Additionally, based on the findings of study 1A, which displayed faster threat detection by higher alexithymia participants, it was expected that high alexithymia participants would continue to detect all targets at a faster rate than the low alexithymia condition.

Hypotheses

Hypothesis 1: A main effect of target type will be found whereby angry target faces will be detected significantly faster and more accurately than sad target faces, supporting the anger superiority effect within negatively valenced emotions (e.g., Vermeulen et al., 2006).

Hypothesis 2: Based on the unexpected findings from Study 1A showing enhanced performance in higher alexithymia participants, a main effect of alexithymia condition will be found whereby higher alexithymia participants will show faster reaction times when detecting negatively valenced emotions compared to lower alexithymia participants.

Hypothesis 3: The anger superiority effect will persist within negative emotions regardless of alexithymia level, with no significant interaction between alexithymia condition and target type.

Hypothesis 4: Higher alexithymia participants will show shallower search slopes than lower alexithymia participants across both target types, replicating the enhanced visual search efficiency observed in Study 1A.

Hypothesis 5: Higher alexithymia participants will show comparable or enhanced labelling accuracy compared to lower alexithymia participants, consistent with Study 1A findings that contradict traditional alexithymia literature.

Method

Participants

Prolific (https://www.prolific.com) was used to recruit 100 online participants. Of these, 15 were excluded due to low accuracy, resulting in a final sample of 85 participants (49 males, 35 females, one non-binary; range 19 - 69 years; M = 30.91, SD = 10.64). Of the 85 participants, 13 fell into the low alexithymia condition, 62 in the medium alexithymia condition, and 10 in the high alexithymia condition. All participants were fluent in English and had normal or corrected-to-normal visual acuity. Participants received approximately $8 AUD for their completion of a single online experimental session consisting of an online threat detection task and completion of a questionnaire assessing alexithymia; the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018). The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and consent was obtained from all participants.

Design, Stimuli and Procedure

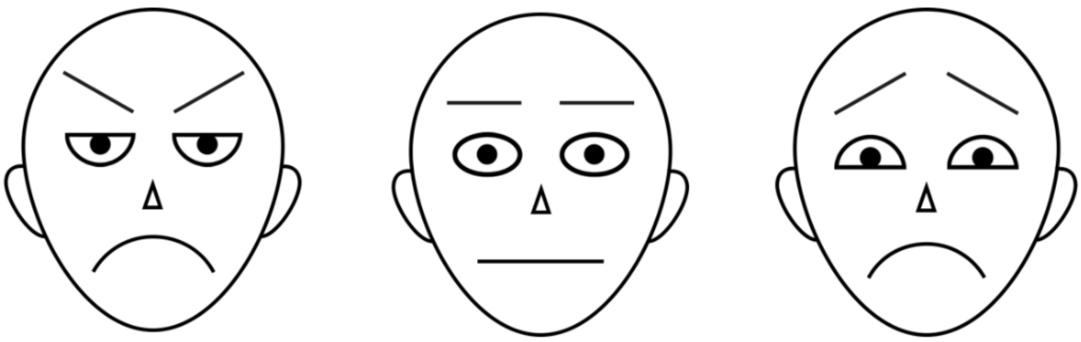
This study was an adaptation of study 1A, except for a change in the target emotions used within the task (i.e., angry and sad targets for the present study, compared to angry and happy targets in study 1A). Apart from these changes, all other aspects of the study were the same as those in Study 1A. Sample stimuli are depicted in Figure *6*.

Measures

RTs from trials with incorrect responses were excluded from analysis. Any participants with an overall accuracy below chance (i.e., <50%) were also excluded from analysis. Fifteen participants were excluded based on accuracy requirements (11 males and four females). Of the 15 excluded participants, six fell into the low alexithymia condition, seven in the medium alexithymia condition, and two in the high alexithymia condition. Excluded participants were aged between 19 and 67 years (M = 37, SD = 16).

Figure 6:

Sample Stimulus Images



Note: Sample angry (leftmost), neutral (centre) and sad (rightmost) stimulus images.

Results and Discussion

As with study 1A, several analyses violated Mauchly's test of sphericity. In these instances, the Greenhouse-Geisser correction was again applied to adjust the degrees of Freedom to more accurately reflect the study's results.

Additionally, target-absent trials were once again categorised as a third target condition (i.e., neutral) rather than a trial type due to the lack of target-absent trials within the angry or sad target-type conditions.

Reaction Time (RT). Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, sad, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and Alexithymia condition was entered as a between-participants factor.

Contrary to expectations, no significant differences in RT were observed between the three alexithymia conditions, $F(2, 82) = 0.35$, $p = .70$, $B_{10} = 1/4.63$. The Bayesian ANOVA also found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition on RT). Thus, the results from study 1A, which demonstrated that high alexithymia individuals were more efficient at detecting targets, could not be replicated.

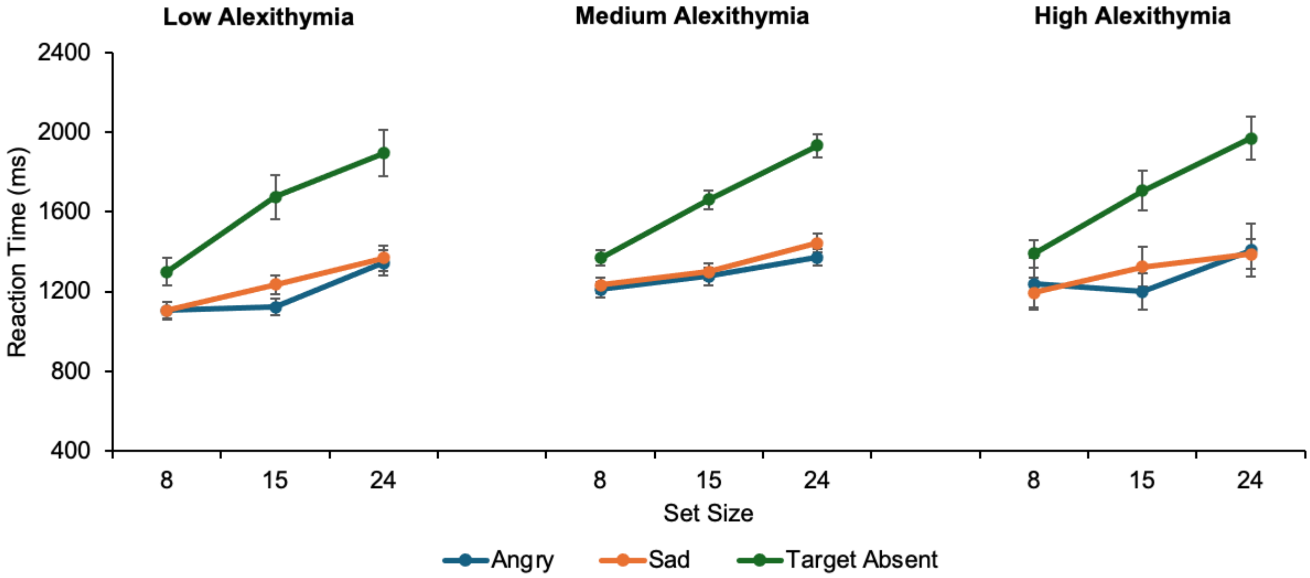
A significant main effect was also found for target type, $F(1.24, 101.44) = 97.82$, $p<.001$, $n^2 = 0.13$, $B_{10} = 2.33E+24$, and set size, $F(1.46, 116.85) = 152.82$, $p<.001$, $n^2 = 0.07$, $B_{10} = 1.70E+13$. However, these significant main effects are moderated by a significant two-way interaction, $F(3.51, 287.97) = 33.79$, $p<.001$, $n^2 = 0.02$, $B_{10} = 412.42$. As highlighted by the large Bayes factor, Bayesian analysis provided extreme evidence in favour of a significant interaction between target type and set size. A series of post-hoc ANOVAs exploring RT across set sizes for each target type were completed to further explore this significant interaction. A significant main effect of set size was found for angry [$F(2, 168) = 46.32$, $p<.001$, $n^2 = 0.36$], sad [$F(1.83, 154.06) = 52.36$, $p<.001$, $n^2 = 0.38$], and target-absent trials [$F(1.45, 121.76) = 265.42$, $p<.001$, $n^2 = 0.76$]. These RT findings demonstrate that RT consistently increased as set size increased, regardless of target type. Though, the rate of increase was larger for the neutral trials, as evidenced by the very large F value (265) compared to the other F values of 46.32 and 52.36.

To further explore the significant interaction, another series of post-hoc ANOVAs were completed, assessing RT across target type for each set size. Analysis revealed significant main effects of target type across all set sizes. At set size 8, angry targets (M = 1198ms, SD = 300.1) and sad targets (*M* = 1208ms, *SD* = 281.2) showed comparable detection speeds with no significant difference between them (p = .532), however both were detected significantly faster than target-absent trials (*M* = 1362ms, *SD* = 277.3), $F(1.65, 138.68) = 33.94$, $p < .001$, $n^2 = 0.29$. At set size 15, angry targets were detected fastest (*M* = 1244ms, *SD* = 328.2), followed by sad targets (*M* = 1293ms, *SD* = 304) and target-absent trials were the slowest of the three (*M* =1669ms, *SD* = 365), $F(1.36, 122.40) = 17.67$, $p<.001$, $n^2 = 0.61$. All three pairwise comparisons were significantly different, $p < .015$. At set size 24, the same pattern was observed with angry targets detected fastest (*M* = 1372ms, *SD* = 329.7), followed by happy targets (*M* = 1426ms, *SD* = 325.4) and target-absent trials (*M* = 1931ms, *SD* = 435.1), $F(1.47, 123.09) = 161.7$, $p<.001$, $n^2 = 0.66$. All pairwise comparisons were once again significant, $p<.016$.

As displayed in Figure 7, this pattern of results demonstrates that while both emotional targets show processing advantages over target-absent trials, angry faces develop a significant speed advantage over sad faces as search difficulty increases, supporting the anger superiority effect even within the broader category of emotional stimuli. All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, $F(7.02, 287.97) = 1.28$, p =.259.

Figure 7:

RT for Each Target Type Across Set Size and Alexithymia Conditions



Note: Mean target-present RTs for angry (blue line), sad (orange line),and target absent (green line) trials across each set size and alexithymia condition. Error bars indicate standard errors.

Search Slope. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, sad, neutral) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

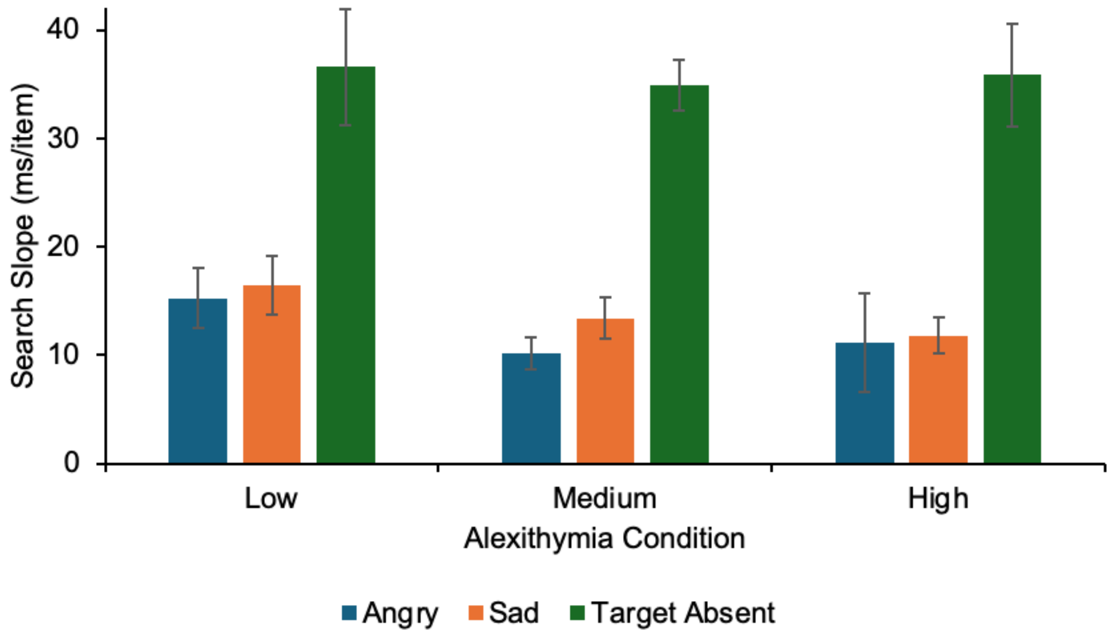
No significant difference in search slope was observed between alexithymia conditions, $F(2, 82) = 0.54$, $p = 0.58$, $B_{10} = 1/7.74$. This non-significant difference was supported by Bayesian analysis, which gave substantial evidence in favour of the null hypothesis. This lack of significant difference between alexithymia conditions once again suggests that, contrary to the RT and search slope findings in study 1A, alexithymia levels had no significant impact on target detection and visual search efficiency.

A significant main effect of target type was found and is presented in Figure 8, $F(2, 164) = 48.89$, $p<.001$, $n^2 = 0.23$. The Bayesian mixed ANOVA yielded a B_{10} of 4.23E+13, providing extreme evidence in favour of a main effect of target type. Post-hoc analysis demonstrated that participants' search slope was significantly lower (i.e., flatter) for angry targets compared to neutral targets ($p = <.001$) and for sad targets compared to neutral targets ($p = <.001$). No significant difference in search slope was found between angry and sad targets (p = .46). These slope findings suggest that participants' RT was less impacted by increases in set size when detecting whether an emotional target (i.e., both angry and sad) was present compared to detecting when an emotional target was not present (i.e., neutral trials), which aligns with the expectations of an exhaustive search approach in neutral trials. No notable difference was observed between the two target types, suggesting similar search processes were used regardless of the target emotion.

No significant interaction was observed between target type and alexithymia condition, $F(4, 164) = 0.15$, $p = 0.96$, $B_{10} = 1/18.29$. This non-significant interaction was supported by the Bayesian ANOVA, which found strong evidence in favour of the null hypothesis.

Figure 8:

Search Slopes Across Target Types and Alexithymia Conditions.



Note: Mean search slopes for angry (blue bar), sad (orange bar), and target absent (green bar) trials across alexithymia condition. Error bars indicate standard errors.

Detection Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, sad, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and Alexithymia condition was entered as a between-participants factor.

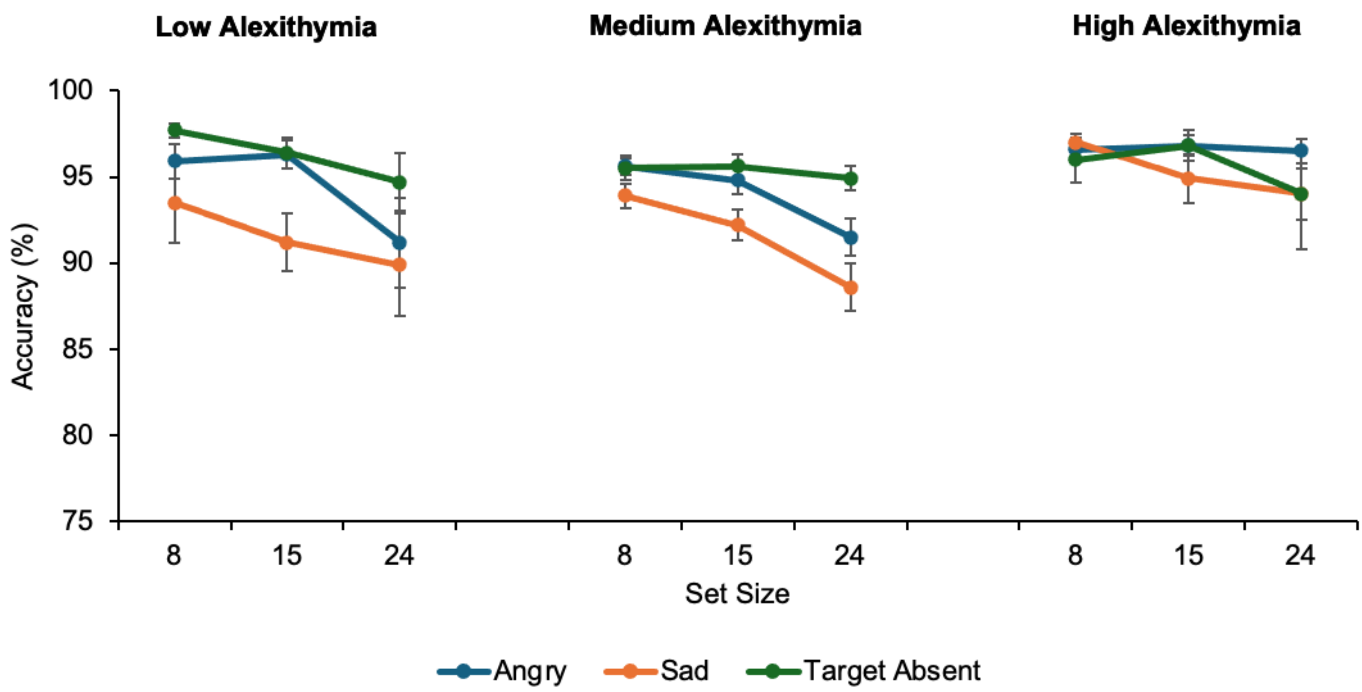
In line with the findings in study 1A, and in contrast with the current literature (i.e., Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006), no significant differences in accuracy were found between alexithymia conditions, $F(2, 82) = 1.10$, $p = 0.34$, $B_{10} = 2.08$. Interestingly, while the frequentist analysis did not reach significance, the Bayesian ANOVA found anecdotal evidence for the alternative hypothesis (i.e., a difference between alexithymia conditions), though this evidence is weak. The combination of non-significant frequentist results and weak Bayesian evidence in favour of a difference creates an ambiguous picture regarding the effect of alexithymia condition on target detection and should be interpreted with caution given the potential of data insensitivity based on the anecdotal Bayesian evidence. From an emotional knowledge perspective, the RT and accuracy findings in study 1B provide only anecdotal evidence for potential deficits in the detection stage across various levels of alexithymia severity, highlighting the need for further research with a larger sample size.

Figure 9 displays a significant main effect of target type, $F(1.53, 125.33) = 9.82$, $p<.001$, $n^2 = .02$, $B_{10} = 104.90$. This significant main effect was supported by the Bayesian ANOVA, which found extreme evidence in favour of a significant main effect of target type. Post-hoc analysis demonstrated that participants' accuracy was significantly higher for angry target trials compared to sad target trials ($p<.001$), and for neutral trials compared to sad target trials ($p = .002$). These accuracy results suggest that all participant were more accurate when identifying angry targets. Additionally, this highlights that the differences in accuracy across target types in study 1A were not due to emotional valence but were rather related to anger specifically. This finding that greater accuracy was specific to anger, as opposed to negatively valenced emotions, supports the findings of Vermeulen et al. (2006) who observed a greater reduction in affective priming effects for angry faces, as opposed to negatively valenced faces in general, such as sadness.

A significant main effect of set size was also found, $F(1.35, 110.69) = 12.46$, $p<.001$, $n^2 = .02$, $B_{10} = 83.27$. This significant main effect was supported by the Bayesian ANOVA, which found very strong evidence in favour of a significant main effect of set size. Figure 9 demonstrates a steady decrease in accuracy as the set size increased. Post-hoc t-tests confirmed that participants displayed significantly higher accuracy for trials with a set size of 8 compared to 15 (p = .034), and for trials with a set size of 15 compared to 24 (p<.001). All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, F(6.18, 253.16) = 0.98, p = .439.

Figure 9:

Detection Accuracy Across Target Types and Alexithymia Conditions



Note: Mean emotional accuracy for angry (blue line), sad (orange line), and target-absent trials (green line) across alexithymia conditions. Error bars indicate standard errors.

Labelling Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 3 (target type: angry, sad, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and Alexithymia condition was entered as a between-participants factor.

No significant main effect of alexithymia was found for labelling accuracy, $F(2, 82) = 0.34$, $p = 0.71$, $B_{10} = 1/4.86$. The Bayesian ANOVA also found substantial evidence in favour of the null hypothesis (i.e., a non-significant effect of alexithymia condition on labelling accuracy). These findings on emotional labelling performance across alexithymia conditions suggest there is no discernible difference in the identification/labelling stage of emotion knowledge between alexithymia conditions, contrary to research displaying labelling deficits in alexithymia (Jessimer & Markham, 1997; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Ridout et al., 2010; Swart et al., 2009) but in line with our findings in study 1A.

A significant main effect of target type was found and is demonstrated in Figure 10, $F(1.55, 126.77) = 7.86$, $p = .002$, $n^2 = .04$, $B_{10} = 1.48E+20$. As highlighted by the very large Bayes factor, Bayesian analysis gave extreme evidence in favour of a main effect of target type. Post-hoc t-tests confirmed labelling accuracy was significantly higher in target-absent trials compared to angry target trials ($p = .003$) and sad target trials ($p < .001$). No significant difference in labelling accuracy was found between angry and sad trials ($p = .978$), suggesting there is no evidence of an anger superiority effect when considering the identification/labelling portion of emotion knowledge.

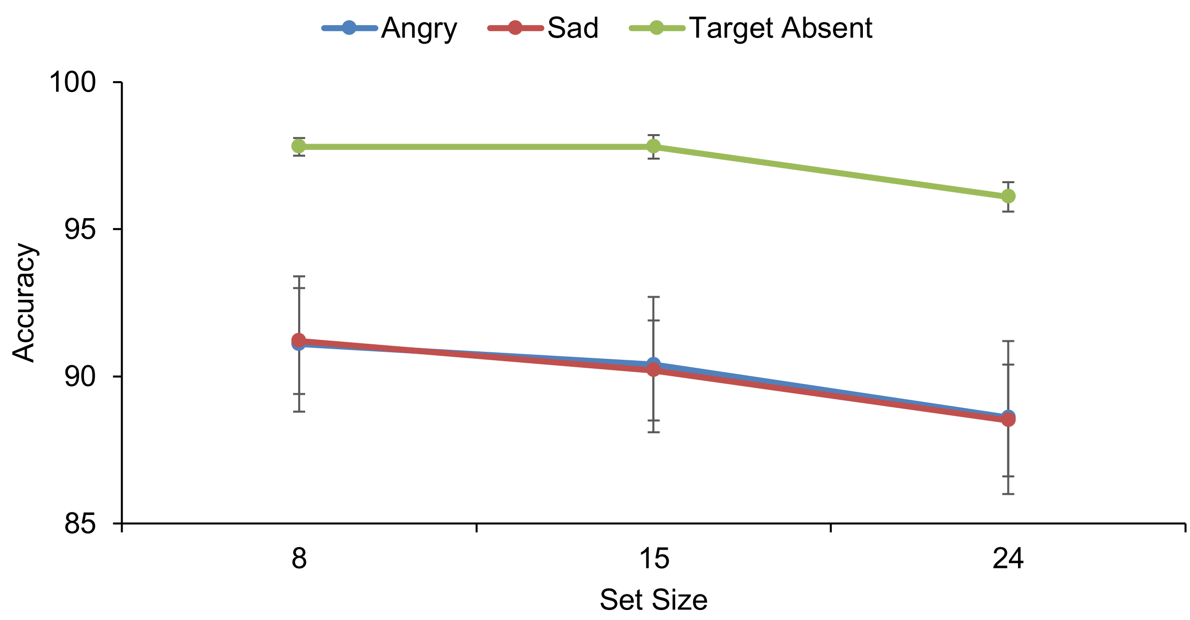
Figure 10 demonstrates a significant main effect of set size, $F(1.74, 142.46) = 5.97$, $p = .005$, $\eta^2 = 0.004$, $B_{10} = 25353.74$. This significant main effect was supported by the Bayesian ANOVA, which found extreme evidence in favour of a significant main effect of set size. Post-hoc t-tests confirmed labelling accuracy decreased steadily as set size increased, with a significant difference found between set sizes of 8 and 24 ($p = .015$), and 15 and 24 ($p = .032$). No significant difference was found between set sizes of 8 and 15 ($p = .32$). This finding on labelling accuracy largely aligns with the above findings in detection accuracy. The only notable difference was observed between set sizes of 8 and 15, with accuracy being higher for the lower set size for the detection of targets, but not for the labelling of the emotion which showed no difference between set sizes 8 and 15.

All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, $F(6.94, 284.32) = 0.91$, $p = 0.507$. The

Bayesian mixed ANOVA yielded a B_{10} of 1/72.36, providing extreme evidence in favour of the null hypothesis (i.e., a non-significant three-way interaction).

Figure 10:

Mean Labelling Accuracy for Each Target Type Across Set Size



Note: Mean labelling accuracy for angry (blue line), sad (red line), and target-absent trials (green line). Error bars indicate standard errors.

Study 1C

Introduction

Studies 1A and 1B investigated emotional target detection through basic visual search tasks, focusing on performance differences across various target types and levels of alexithymia severity. Despite both studies using a similar design, the results have been mixed. Current literature indicates that individuals with higher alexithymia often exhibit deficits in processing emotional facial expressions, characterised by longer reaction times and lower accuracy (Grynberg et al., 2012; Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). Based on this literature, it was anticipated that individuals with higher alexithymia would perform more poorly in emotional visual search tasks. When exploring performance across alexithymia, study 1A revealed that individuals with higher alexithymia were not only faster but also equally accurate at detecting emotional targets compared to those with lower alexithymia. In contrast, study 1B found no significant differences in target detection performance between alexithymia conditions. Both of these findings contradict the current alexithymia literature.

Building on the findings of studies 1A and 1B, study 1C was designed to take a more comprehensive look at search performance across a wider range of emotional target faces. As discussed in study 1B, prior evidence has displayed poorer detection of negatively valenced faces in general, as well as angry faces specifically (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). Studies 1A and 1B were therefore designed to compare performance across both emotional valence and specific target emotions. Study 1A explored negative valence (i.e., angry targets) versus positive valence (i.e., happy targets), while Study 1B explored specific emotions within negative valence (i.e., angry versus sad targets). Study 1C aims to provide a deeper understanding of how both emotional expressions and emotional valence impact performance in emotional visual search tasks across alexithymia severities by updating the design of studies 1A and 1B to include all three prior target types (i.e., angry, happy and sad). Additionally, study 1C also aims to replicate and further clarify the findings observed from studies 1A and 1B.

Hypotheses

Hypothesis 1: A main effect of target type will be found whereby a hierarchical detection pattern will emerge with angry faces detected fastest, followed by sad faces, then happy faces, and finally target-absent trials, supporting both anger superiority and negative valence advantages.

Hypothesis 2: A main effect of alexithymia condition will be found whereby higher alexithymia participants will show faster reaction times across all emotional target types compared to lower alexithymia participants, replicating the unexpected enhancement observed in Study 1A.

Hypothesis 3: The anger superiority effect will remain robust across alexithymia conditions, with significant interactions between alexithymia condition and target type.

Hypothesis 4: A main effect of alexithymia condition will be found for search slopes whereby higher alexithymia participants will show shallower search slopes across all target types, with angry targets showing the flattest slopes regardless of alexithymia condition.

Hypothesis 5: A main effect of target type will be found for detection accuracy whereby angry faces will be detected more accurately than sad and happy faces, with sad faces detected more accurately than happy faces, paralleling the reaction time hierarchy.

Method

Participants

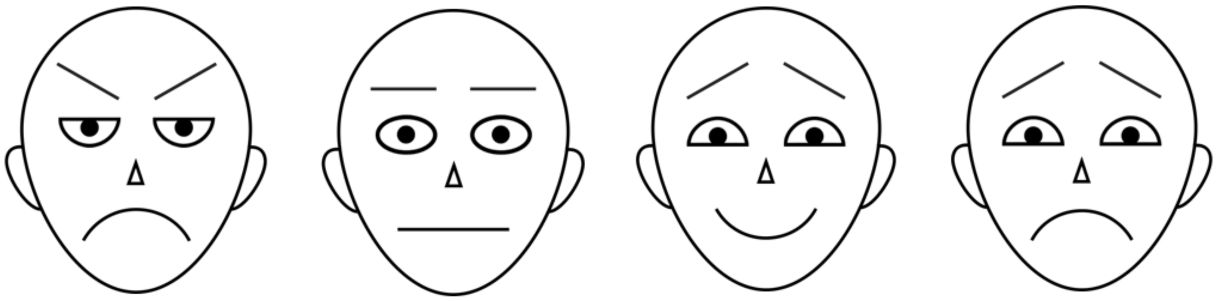
Prolific (https://www.prolific.co) was used to recruit 104 online participants (74 males, 29 females, one non-binary; range 19 - 69 years; M = 29.65, SD = 8.47). Of the 104 participants, 25 fell into the low alexithymia condition, 74 in the medium alexithymia condition, and 5 in the high alexithymia condition. All participants were fluent in English and had normal or corrected-to-normal visual acuity. Participants received approximately $5 AUD for their completion of a single online experimental session consisting of an online threat detection task and completion of a questionnaire assessing alexithymia; the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018). The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and consent was obtained from all participants.

Design, Stimuli and Procedure

This study was an adaptation of studies 1A and 1B, except for a change in the target emotions used within the task (i.e., angry, sad and happy targets for the present study compared to angry and happy targets in study 1A, and angry and sad targets in study 1B). To account for the additional target type, the study design was altered to a blocked design in which only one target type was presented per block, with the order of block presentation counterbalanced across participants. The number of trials within the study was also increased to 282, with 12 practice trials. Additionally, while the method of studies 1A and 1B required participants to identify the emotion of the target face following each trial to calculate participants labelling accuracy, this requirement was removed from the present study. Due to the blocked design of this study (i.e., one target presented per block), labelling accuracy could not be assessed in this study. Apart from these changes, all other aspects of the study were the same as those in Studies 1A and 1B. Sample stimuli are depicted in Figure 11.

Figure 11:

Sample Stimulus Images



Note: Sample angry (leftmost panel), neutral (centre-left panel), happy (centre-right panel) and sad (rightmost panel) stimulus images.

Measures

RTs from trials with incorrect responses were excluded from analysis. No participants had an overall accuracy below chance (i.e., $<50\%$), and therefore no participants were excluded.

Results and Discussion

As with studies 1A and 1B, several analyses violated Mauchly's test of sphericity. In these instances, the Greenhouse-Geisser correction was again applied to adjust the degrees of Freedom to more accurately reflect the results of the study. Additionally, target-absent trials were once again categorised as a fourth target condition (i.e., neutral) rather than a trial type due to the lack of target-absent trials within target-angry, target-sad or target-happy target-type conditions.

Reaction Time (RT). Data were submitted to a 3 (alexithymia condition: low, medium, high) x 4 (target type: angry, sad, happy, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participants factors, and the Alexithymia condition was entered as a between-participants factor.

While the frequentist ANOVA yielded a non-significant main effect of alexithymia condition on RT, $F(2, 101) = 1.85$, $p = .16$, the Bayesian analysis provided extreme evidence in favour of a main effect ($B_{10} = 16264.73$). This apparent discrepancy is a known statistical phenomenon often referred to as the "Jeffreys-Lindley paradox" (Jeffreys, 1961; Lindley, 1957; see also Robert, 2013). This paradox describes how, in some cases - particularly when the sample is large or when the data follow a clear pattern - a Bayesian analysis can strongly favour an effect, even though a frequentist test does not find it statistically significant. In the case of the present study, the alexithymia group means (low = 867.57 ms, medium = 962.31 ms, high = 927.16 ms) followed a relatively consistent pattern across participants, which may have been sufficient for the Bayesian model to detect evidence of an effect despite the small size of the differences. However, this interpretation is complicated by the very small and highly unequal group sizes, especially for the high-alexithymia group ($n = 5$), which makes the observed pattern unstable and the Bayesian result potentially inflated. Thus, while these findings may illustrate the Jeffreys-Lindley paradox, the results should be interpreted with caution, and no firm conclusions should be drawn regarding alexithymia effects on RT. This result should still be interpreted with caution, taking into account both statistical frameworks and the highly unequal group sizes, particularly the small sample size in the high alexithymia condition (i.e., n = 5).

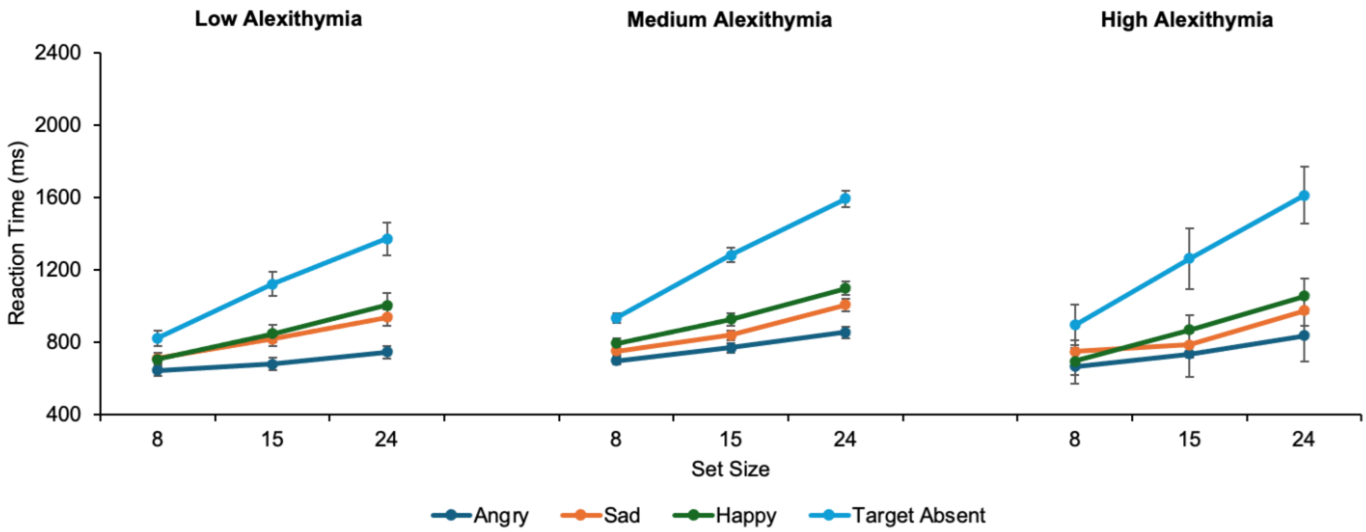
A significant main effect was also found for target type, $F(2.79, 281.50) = 60.21$, $p < .001$, $n^2 = 0.12$, $B_{10} = 1.23E+38$, and set size, $F(1.27, 127.86) = 171.91$, $p<.001$, $n^2 = 0.07$, $B_{10} = 7.14E+22$. However, the significant main effects of target type and set size are moderated by a significant two-way interaction, $F(4.88, 492.65) = 51.39$, $p<.001$, $n^2 = 0.02$, $B_{10} = 82$, providing very strong evidence in favour of a significant two-way interaction between target type and set size. This significant interaction suggests that the impact of set size on RT varied across the four target types, which is displayed in Figure 12. A series of post-hoc ANOVAs were conducted to further investigate this significant interaction by examining RT across set sizes for each target type. A significant main effect of set size was found for angry [$F(1.55, 159.95) = 76.20$, $p<.001$, $n^2 = 0.07$], sad [$F(1.65, 169.78) = 153.28$, $p<.001$, $n^2 = 0.16$], happy [$F(1.84, 189.71) = 200.76$, $p<.001$, $n^2 = 0.17$], and target-absent trials [$F(1.22, 125.96) = 570.05$, $p<.001$, $n^2 = 0.37$]. These reaction time findings show that RT consistently increased with larger set sizes, regardless of target type. However, the rate of increase was notably greater for neutral trials, as reflected by the exceptionally large F-value (570). Interestingly, the increase in RT across larger set sizes for angry target trials suggests that, despite lower RTs and more efficient search performance compared to other target types, a pop-out effect was not present for angry target trials. This lack of pop-out contradicts a number of findings within the anger superiority literature, including Öhman et al. (2001) (Dickins & Lipp, 2014; Eastwood et al., 2001; Fox et al., 2000; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Rued et al., 2019).

To further explore this significant interaction, another series of post-hoc ANOVAs were completed, assessing RT across target type for each set size. Analysis revealed significant main effects of target type across all set sizes. At set size 8, angry targets were detected the fastest *M* = 684.3ms, *SD* = 180.3), followed by sad targets (*M* = 741.7ms, *SD* = 179.3) and happy targets (*M* = 767.4ms, *SD* = 236.1), with no significant difference between sad and happy targets ($p = .255$). All emotional targets were detected significantly faster than target-absent trials (M = 906.3ms, SD = 227.2), F (2.28, 234.81) = 48.68, p <.001, n^2 = 0.32. At set size 15, angry targets continued to be detected the fastest (M = 746.6ms, SD = 214.2), followed by sad targets (M = 831.3ms, SD = 222), happy targets (M = 904.8ms, SD = 272), and target-absent trials (M = 1243.1ms, SD = 338.2), F (3, 309) = 163.5, p <.001, n^2 = 0.61. All pairwise comparisons were significantly different, p ≤ .001. At set size 24, the pattern continued with angry targets remaining fastest (M = 826.5ms, SD = 254.6), followed by sad targets (M = 988.5ms, SD = 272), happy targets (M = 1073.6ms, SD = 321.9), and target-absent trials (M = 1540ms, SD = 418), F (2.78, 286.27) = 233.5, p <.001, n^2 = 0.69. All pairwise comparisons were significantly different, p ≤ .001. Overall, these results show that angry faces were consistently detected significantly faster than other emotional targets across all set sizes, providing strong support for more efficient detection of angry targets, despite no pop-out effects being observed.

All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, F(9.76, 492.65)= 0.87, p = 0.559, B_{10} = 1/456.61, providing very strong evidence against a three-way interaction.

Figure 12:

Mean RTs for Each Target Type Across Set Size and Alexithymia Condition



Note: Mean target-present RTs for angry (dark blue line), sad (orange line), happy (green line) and neutral target trials (light blue line) across each set size and alexithymia condition. Error bars indicate standard errors.

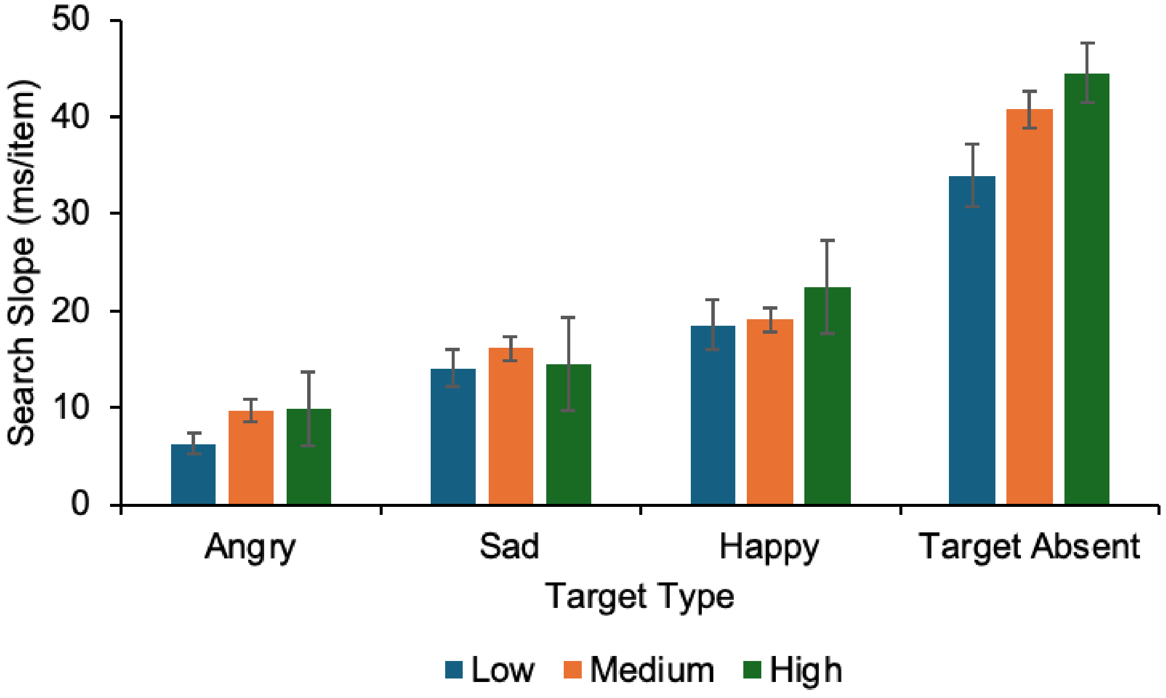
Search Slope. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 4 (target type: angry, sad, happy, neutral) mixed ANOVA. Target type was entered as within-participants' factors, and alexithymia condition was entered as a between-participants factor.

No significant difference in search slope was found between alexithymia conditions, $F(2, 101) = 1.37$, $p = .26$, $B_{10} = 1/1.25$. Interestingly, the Bayesian ANOVA found only anecdotal evidence for the null hypothesis (i.e., a non-significant effect of alexithymia condition), indicating further data is needed to draw stronger conclusions. This non-significant main effect of alexithymia supports the findings of study 1B, which found no significant differences in search slope across alexithymia conditions. However, this continues to contradict both the findings of study 1A (which observed flatter search slopes in the high alexithymia condition) and the current alexithymia literature, which displays poorer emotional visual search performance in individuals with higher alexithymia (Grynberg et al., 2012; Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006).

As presented in Figure 13, a significant main effect of target type was found, $F(2.70, 272.44) = 76.09$, $p<.001$, $n^2 = 0.25$, $B_{10} = 1.03E+26$. This significant main effect was supported by the Bayesian ANOVA, which found extreme evidence in favour of a significant main effect of target type. Post-hoc analysis demonstrated that participants search slope was significantly lower (i.e., flatter) for angry targets compared to sad targets ($p <.001$), happy targets ($p = .009$), and neutral targets (i.e., target absent; $p <.001$). Post hoc analysis also displayed a significant difference in search slope between neutral targets (i.e., target absent) and both sad targets ($p =<.001$) and happy targets ($p <.001$), and between sad and happy targets ($p = .019$). While RT findings suggest that there was no pop-out effect for angry targets, these slope findings do suggest that participants were quicker and more efficient at detecting angry targets specifically, as would be expected within the anger superiority effect. No significant interaction was observed between target type and alexithymia condition, $F(5.40, 272.44) = 1.03$, $p = 0.40$.

Figure 13:

Mean Search Slopes Across Target Types and Alexithymia Conditions



Note: Mean search slopes for angry, happy, sad and target absent trials across low (blue bar), medium (orange bar), and high (green bar) alexithymia conditions. Error bars indicate standard errors.

Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 4 (target type: angry, sad, happy, neutral) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and target type were entered as within-participant factors, and Alexithymia condition was entered as a between-participants factor.

No significant differences in accuracy were found between alexithymia conditions, $F(2, 101) = 0.27$, $p = 0.763$, $B_{10} = 1/13.66$. The Bayesian analysis found strong evidence in favour of the null hypothesis (i.e., no significant main effect of alexithymia condition). This finding of equal accuracy across alexithymia conditions contradicts current findings within the alexithymia literature that higher levels of alexithymia result in poorer accuracy in emotional visual search tasks (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006).

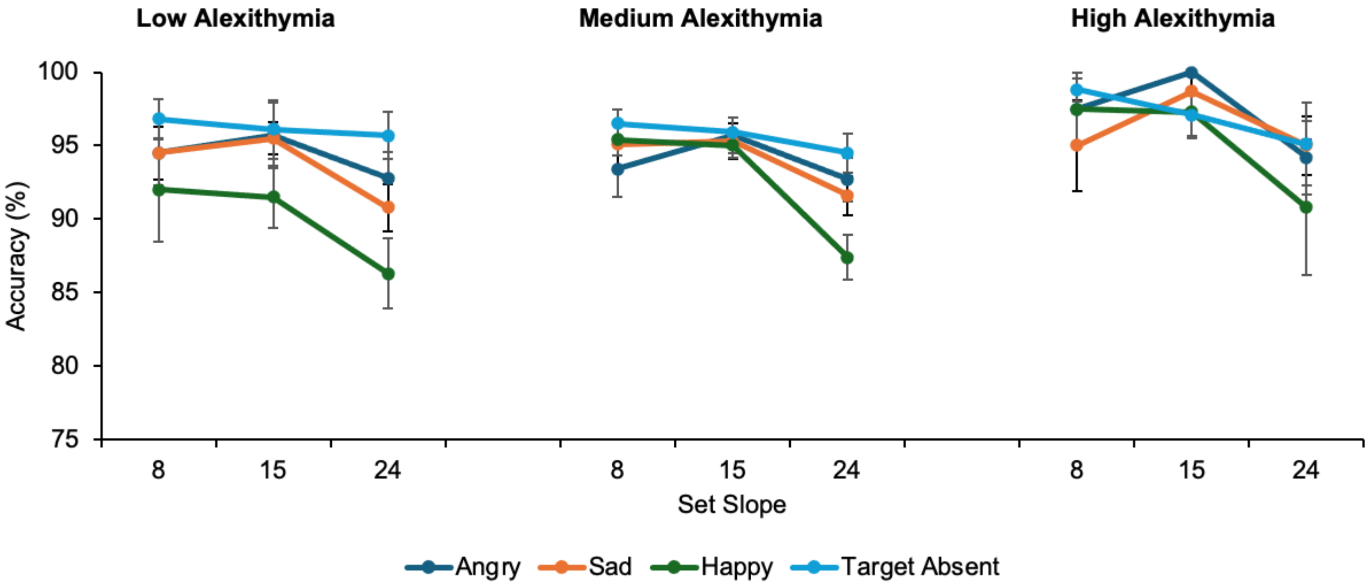
No significant differences in accuracy were found across the four target types, $F(2.24, 226.54) = 2.24$, $p = 0.102$, $B_{10} = 1/2.96$. The Bayesian ANOVA, however, found only anecdotal evidence for the null hypothesis (i.e., a non-significant effect of target type), again suggesting the need for further data to draw a clearer conclusion. Regarding the frequentist findings, this lack of significant difference in accuracy contradicts the findings of 1A and 1B, which reported significantly higher accuracy for angry target trials compared to happy and sad target trials, respectively. The introduction of a blocked design may have contributed to the equal accuracy observed across conditions in the present study, as 1A and 1B both presented all target types within the same block. However, further experimentation is needed to determine whether this lack of difference in accuracy is due to a design change or represents a genuine effect.

A significant main effect of set size was found and is displayed in Figure 14, $F(1.74, 175.22) = 11.47$, $p<.001$, $n^2 = .008$, $B_{10} = 1/8.53$. Bayesian analysis, however, gave substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of set size). Although the ANOVA revealed a significant main effect of set size, post-hoc t-tests revealed that no single comparison demonstrated a significant difference between conditions.

All other interactions were found to be non-significant, including the three-way interaction between set size, target type and alexithymia condition, $F(10.11, 510.65) = 0.36$, $p = 0.964$, $B_{10} = 1/143.95$.

Figure 14:

Mean Accuracy Across Set Size and Alexithymia Conditions



Note: Mean search slopes for angry (dark blue line), sad (orange line), happy (green line), and target absent (light blue line) trials across alexithymia conditions. Error bars indicate standard errors.

General Discussion

The three studies discussed in this chapter aimed to provide a comprehensive exploration of the impacts of alexithymia severity on emotion detection and labelling performance within a face-in-the-crowd task, framed from an emotional knowledge perspective. Across all three studies, we observed an anger superiority effect where angry faces were detected more rapidly than other emotional faces. These findings provide support for the existence of an anger superiority effect in the general population and support the findings of Öhman et al. and other researchers who found evidence of the anger superiority effect (Diao et al., 2017; Dickins & Lipp, 2014; Eastwood et al., 2001; Feldmann-Wüstefeld et al., 2011; Fox et al., 2000; Hansen & Hansen, 1988; Lobue et al., 2014; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Pinkham et al., 2010; Rued et al., 2019; Shasteen et al., 2014). Alexithymia severity was not found to interact with the presence of the anger superiority effect, providing further evidence of the robustness of the effect as a whole.

Anger Superiority Findings.

In study 1A, we aimed to identify whether an anger superiority effect was present in the general population. Results demonstrated that, for reaction time, angry targets were detected significantly faster than happy targets across all set sizes, with this anger advantage becoming more pronounced as set size increased. Search slope findings provided some support for this anger advantage, suggesting that angry target detection speed may have been less impacted by increases in set size compared to happy target trials, however Bayesian evidence suggests the need for further data collection to confirm. While a standard pop-out effect (i.e., search slopes below 10ms per item in an array; Wolfe, 1998) was not observed, the significantly flatter slopes observed for angry trials do suggest that angry target detection was less impacted by increases in task difficulty, suggesting the anger superiority effect is robust even under higher task difficulty. Beyond faster detection, angry targets were also detected more accurately than happy targets at larger set sizes (15 and 24 items), though this accuracy advantage disappeared at the smallest set size (8 items). This pattern suggests there was no speed-accuracy trade-off for angry target trials, particularly as visual search difficulty increased. Similarly, angry targets were labelled more accurately than happy targets. This advantage was most pronounced at larger set sizes, where labelling accuracy for happy targets declined significantly while labelling accuracy for angry targets remained relatively stable. This pattern further reinforced the notion of greater saliency of angry targets under increased task demands imposed by larger set sizes.

Study 1B aimed to determine whether the findings from 1A, which found more efficient detection of angry targets in the general population, were due to differences in the valence of emotional targets (i.e., negative vs positive) rather than due to anger specifically. The findings from 1B displayed a similar pattern of results as 1A: angry targets were detected faster and more accurately than sad targets, but only across larger set sizes. At the smallest set size (8 items), angry and sad targets showed comparable detection speeds with no significant difference between them, but both were detected significantly faster than target-absent trials. However, at larger set sizes (15 and 24 items), angry targets developed a clear speed advantage over sad targets, with all target types showing significantly different reaction times. This interaction pattern indicates that the anger superiority effect becomes more pronounced as visual search difficulty increases. This pattern also suggests that the advantage observed in 1A and 1B is specific to anger rather than negative valence generally. Additionally, angry targets were consistently detected more accurately than sad targets across all set sizes. In terms of labelling accuracy, no significant differences were observed between angry and sad targets, suggesting similar performance in the labelling stage of Emotion Knowledge. Taking these findings of equal labelling accuracy between angry and sad targets, but greater detection accuracy for angry targets, this suggests that the anger superiority effect is tied to the initial stage of processing, namely the detection stage.

Finally, study 1C aimed to further explore the impacts of specific emotions, as opposed to emotional valence, on the anger superiority effect by including several negatively valenced emotional targets (i.e., angry and sad). Including both angry and sad targets allows us to determine whether small deficits may have been associated with negatively valenced emotions alongside larger deficits for anger specifically. While there were significant main effects of target type on reaction time, these were moderated by a significant interaction with set size. At set size 8, angry targets were detected the fastest, followed by sad targets and happy targets, with no significant difference between sad and happy targets. All emotional targets were detected significantly faster than target-absent trials. At larger set sizes (15 and 24 items), a clear hierarchy emerged with angry targets remaining fastest, followed by sad targets, then happy targets, and finally target-absent trials, with all pairwise comparisons reaching significance. This pattern suggests that the faster RTs for angry targets were not due to emotional valence but were specific to the emotion of anger, with this advantage becoming more pronounced as task difficulty increased. Additionally, this also displays evidence of a negative valence superiority effect in addition to the anger superiority effect across larger set sizes, with sad targets detected significantly faster than happy targets for set sizes of 15 and 24. Search slope supported the anger superiority effect observed in the RT results, with angry targets found to have a significantly flatter search slope than both happy and sad targets. Furthermore, a significant difference in search slope was also found between happy and sad targets, supporting the presence of a more general negative valence advantage in addition to the anger superiority effect. Studies 1A and 1B both found evidence of enhanced accuracy for angry target detection, with Study 1A showing this advantage specifically under increased task difficulty and Study 1B showing consistent advantages across all set sizes. In contrast, no significant differences in detection accuracy were found between angry, happy and sad targets in study 1C. However, the Bayesian analysis provided only anecdotal evidence for this null effect (B_{10} = 1/2.96), suggesting further data is needed to draw firm conclusions. Importantly, the findings of 1C do still highlight that angry targets were able to be detected faster with no significant accuracy trade off, however this suggests the saliency of angry targets may not have been as significant as in the previous studies.

When taken together, the results of 1A, 1B and 1C provide evidence for an anger superiority effect that becomes particularly pronounced under conditions of increased cognitive demand (i.e., larger set sizes). Additionally, the results of study 1C suggest the presence of a broader negative valence advantage, with sad targets being detected significantly faster than happy targets at larger set sizes, suggesting that negative emotions in general may have processing advantages over positive emotions beyond the specific advantages conferred by anger.

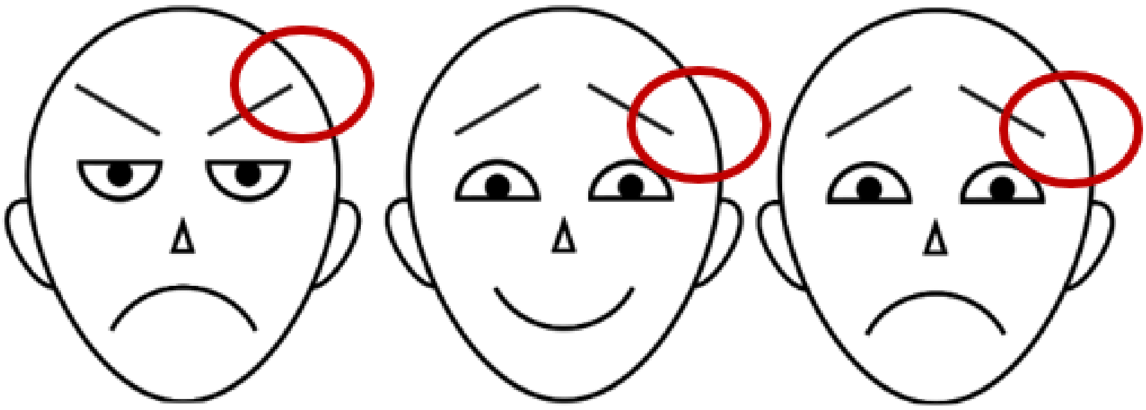
This pattern is consistent with the theoretical perspective that evolution has led to angry faces developing greater visual saliency as a form of increased survival (Lundqvist et al., 1999; Öhman et al., 2001). The three studies provide evidence that the detection stage of emotion knowledge may be more efficient for angry targets compared to other emotional targets, particularly in reaction time measures and under more challenging search conditions. Study 1A found that this anger superiority effect may even extend to the labelling phase of emotion knowledge under conditions of increased task difficulty, however these findings were unable to be replicated in study 1B, and were not explored in study 1C. Additionally, the hierarchical pattern observed in Study 1C's RT results (angry > sad > happy > neutral) suggests that emotion detection operates through multiple mechanisms: a specific anger superiority effect combined with a more general negative valence advantage. This supports the findings of Öhman et al (2001) and similar researchers who found more efficient processing of angry faces specifically, and is also consistent with broader research suggesting enhanced processing of negative emotional faces (Diao et al., 2017; Dickins & Lipp, 2014; Eastwood et al., 2001; Feldmann-Wüstefeld et al., 2011; Fox et al., 2000; Hansen & Hansen, 1988; Lobue et al., 2014; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Pinkham et al., 2010; Rued et al., 2019; Shasteen et al., 2014).

Given the inconsistent alexithymia findings across Studies 1A-1C, it is worth exploring the schematic stimuli used in further detail. The schematic faces in studies 1A-1C were deliberately simplistic, consisting of basic geometric elements: circular outlines, simple curved lines for mouths, and angled lines for eyebrows. The purpose of this was to minimise possible visual confounds that can arise with more complex stimuli (e.g., differences in luminance, variations in facial expression such as whether teeth are showing etc.).

Despite the intention of reducing possible visual confounds, the use of simplistic schematic stimuli may have inadvertently created new methodological issues. As discussed by Purcell and Stewart (2010), schematic faces can introduce their own perceptual confounds. In our stimuli, despite efforts to minimize such issues, the facial border used was oval shaped rather than perfectly circular, creating varying distances between eyebrows and the facial border across emotional expressions. Specifically, angry eyebrows were positioned closer to the facial border than happy or sad eyebrows due to their downward rotation (see Figure 15). This proximity difference may have acted as a visual cue that allowed for faster detection of angry faces compared to other emotional faces, regardless of the actual emotional content. These findings highlight the need for more ecologically valid stimuli that better capture real-world emotional face processing. Combined with design variations between studies (such as the shift from mixed to blocked presentation), these methodological factors may help explain the inconsistent alexithymia findings observed across Studies 1A-1C.

Figure 15:

Sample Stimulus with Border Highlighted



Note: Sample angry (leftmost panel), neutral (centre panel) and happy (rightmost panel) stimulus images, with eyebrow to facial border highlighted in the red circles.

Alexithymia Findings.

Previous research has consistently highlighted the presence of deficits in emotion processing in alexithymia through the use of emotion detection (i.e., the initial detection of a discrepant target face; Parker et al., 2005), matching (i.e., the identification of a previously presented target face among distractors; Lane et al., 2000; Prkachin et al., 2009) and labelling tasks (i.e., selecting the emotion from a provided list to best describe an expression; Jessimer & Markham, 1997; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Ridout et al., 2010; Swart et al., 2009). Based on this prior literature, it was anticipated that, when presented with a task that required quick identification and processing of a number of emotional faces such as in the face-in-the-crowd task, individuals higher in alexithymia would perform worse and require more time than individuals lower in alexithymia.

Study 1A unexpectedly found that individuals with higher alexithymia were more efficient at detecting all emotional faces, with faster RTs and equal accuracy compared to the low alexithymia conditions. These findings suggest that individuals who are higher in alexithymia are more efficient at detecting emotional faces, which conflicts with the significant evidence base supporting deficits in emotional processing in higher alexithymia individuals (see Grynberg et al., 2012 for review). Falling in line with these findings, a significant main effect of alexithymia on search slope was found, with the high alexithymia condition found to have significantly lower search slope than the low alexithymia condition, though the Bayesian analysis provided only anecdotal evidence for this effect (B_{10} = 1.45), suggesting these findings should be interpreted with caution. If this were a genuine effect, this lower search slope would suggest that search performance among higher alexithymia individuals was less impacted by increases in task difficulty (i.e., set size). Interestingly, no significant difference in labelling accuracy was observed between alexithymia conditions. These findings, if highlighting a true effect, would suggest that not only are there no deficits associated with higher alexithymia in the first stage of emotional knowledge (i.e., the detection stage), but there may actually be an advantage during this stage for those with higher alexithymia. Based on the lack of significant difference in labelling accuracy, this advantage does not seem to continue on to the second stage of emotional knowledge (i.e., identification/labelling), however there are also no signs of a deficit related to high alexithymia in this stage either. Alternately, these findings of greater performance in the high alexithymia condition across all emotional target types may be reflecting a general visual search advantage that is tied to identification of perceptual changes, rather than detection of emotion presentation. This explanation is certainly worth considering given that there is a reliable research base supporting a visual search advantage among autistic individuals (see Kaldy et al., 2016 for review), and a high comorbidity between ASD and high alexithymia severity (i.e., approximately 50%, see Kinnaird et al., 2019 for review).

This finding of greater search performance among higher alexithymia individuals was unable to be replicated in study 1B or 1C. Study 1B found no significant differences in RT, search slope, detection accuracy or labelling accuracy between the three alexithymia conditions, indicating equal performance among the three alexithymia conditions across all measures of performance. Study 1C presented a complex pattern for reaction time, where frequentist analysis found no significant effect of alexithymia condition (p = .16), but Bayesian analysis provided extreme evidence in favour of a main effect (B_{10} = 16264.73). Importantly, this result should be interpreted with extreme caution due to very small and highly unequal group sizes, particularly for the high alexithymia group (n = 5), making the observed pattern unstable and the Bayesian result potentially inflated. For search slope, no significant difference was found between alexithymia conditions, though the Bayesian analysis provided only anecdotal evidence for the null hypothesis (B_{10} = 1/1.25), indicating further data is needed to draw stronger conclusions. No significant differences were found for detection accuracy between the three alexithymia conditions. Labelling accuracy was not explored in study 1C. Overall, the results exploring the relationship between alexithymia severity and emotional face detection were mixed.

Prior to exploring potential explanations for the differing findings of 1A, 1B, and 1C, the potential impact of sample size must first be discussed. Although the overall sample size for study 1A, 1B and 1C were sufficiently large (91, 85, and 104 participants, respectively), the number of participants who fell into the low and high alexithymia categories (i.e., 15 low and 15 high; and 13 low and 10 high; and 25 low and five high, respectively) resulted in a smaller sample size for analyses investigating differences between alexithymia levels which may have impacted our findings. This reduced sample size is important to consider as low statistical power arising from small sample sizes increases the possibility that statistically significant results do not reflect true effects (Button et al., 2013). Additionally, low sample sizes can also mask potential effects due to difficulties in providing an accurate representation of a population (e.g., low or high alexithymia individuals). For example, the sample of high alexithymia participants who completed study 1A may have just been particularly good at visual search tasks resulting in a significant difference. Alternately, study 1A may have found a true effect that was unable to be replicated as the high alexithymia condition in studies 1B and 1C may have been particularly bad at visual search tasks. The prevalence of alexithymia in the general population, approximately 1 in 10 individuals, means that low sample sizes will likely be a limitation to consider across all studies within this thesis (Franz et al., 2008; Goerlich, 2018; Honkalampia et al., 2001).

One potential explanation for the differing results between 1A and 1B is that the differences in RT between the low and high alexithymia conditions may have been magnified by the use of both negatively and positively valenced targets (i.e., angry vs happy). While study 1A used target stimuli that were both differing emotions (i.e., happy vs angry) and differing emotional valence (i.e., positive vs negative valence), study 1B contained only differing emotions (i.e., sad vs angry) with both targets falling into the negatively valenced category. While there has been previous research conducted which highlighted more efficient detection abilities for anger specifically (e.g., Kano et al., 2003; Vermeulen et al., 2006; Vermeulen et al., 2008), it is possible that emotional valence may provide an additional factor that impacted the high alexithymia participants' emotion detection abilities. Study 1C was designed to test this potential explanation by using all three target types (i.e., angry, happy and sad) within the same study, and seemingly refutes this hypothesised explanation.

Another possible explanation may be that the variation in study designs between study 1A and 1C may have masked differences in Alexithymia conditions in study 1C or led to invalid differences between alexithymia conditions in study 1A. While study 1A used a mixed design for target presentation (i.e., angry and happy targets were presented within the same block), study 1C used a blocked design (i.e., only one target type was presented per experimental block). Importantly, this led to a change in the instructions participants were given. Within study 1A, participants were simply asked to identify if a 'different emotion' was present. In contrast, in study 1C participants were told what target type they would be searching for prior to each experimental block (i.e., "For the next block, the target face will be SAD. Your task is to determine whether there is a SAD emotional face within the faces on screen."). A theory of visual selection posited by Wolfe, which suggests that there are three components of visual selection: (1) a parallel stage of perceptual description (i.e., visual information across the visual field is used to create a detailed mental picture), (2) the selection process (i.e., relevant information is identified by matching the visual input with an internal/target template that reflects the individuals current needs), and (3) entry into visual short-term memory (i.e., selected information is entered into our memory to allow for coordinating actions or decisions to be made based on what is being seen) (Duncan & Humphreys, 1989; Wolfe, 2021), may provide further insight. If we consider these differing results between 1A and 1C from a visual selection lens, it may be that providing participants with information on the target emotion prior to beginning the study may have led to faster selection of a target template, thereby masking differences between 1A and 1C due to additional guidance (Frischen et al., 2008).

Alternately, even if this additional guidance had no impact on the selection of a target template, some researchers have suggested that the use of a mixed target design can lead to uncontrolled target templates impacting performance (Horstmann & Becker, 2020). When participants are only required to identify one target type within a block, it is assumed that participants would select a target template to produce the best performance, with these templates likely changing between target types (Becker, 2010; Horstmann & Becker, 2020). When targets differ across a single block, selecting the most appropriate target template becomes more challenging. Participants may choose to select a target template that is good for all target options, but perfectly matches none. However, this then introduces the possibility that the target template chosen may better fit one target than another, leading to performance differences across the various target types. Based on this theory of visual selection, it is possible that individuals with higher alexithymia can complete uncontrolled visual searches and choose a more effective target template than individuals with lower alexithymia.

Chapter 3: Study 2

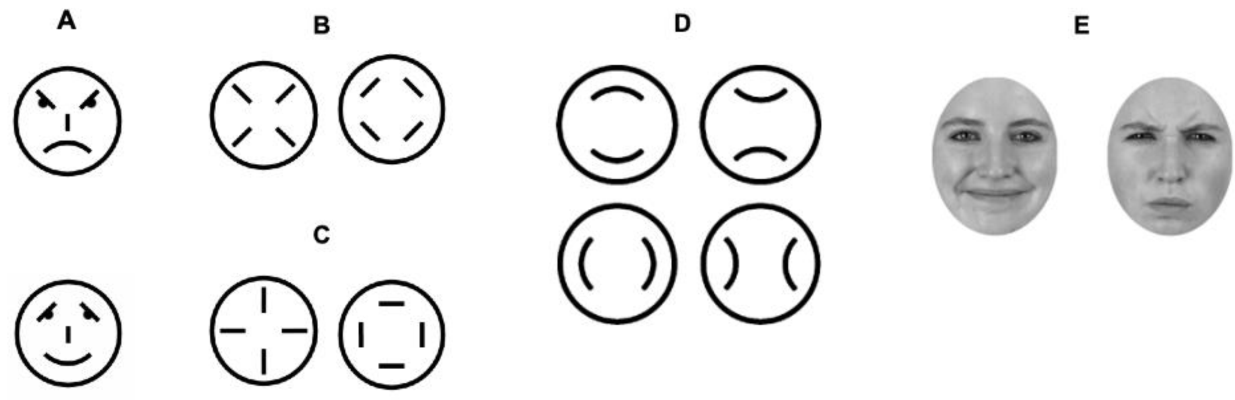
Introduction

Studies 1A, 1B and 1C each investigated the robustness of the anger superiority effect and its association with higher levels of alexithymia using basic schematic stimuli. Across these three studies, consistent evidence supported the presence of an anger superiority effect, with angry target faces being detected significantly faster than both happy and sad target faces. To address criticisms suggesting that the anger superiority effect may be driven by low-level visual confounds rather than emotional content, studies 1A, 1B and 1C each used simplistic, schematic stimuli to minimise the risk of perceptual confounds and to ensure any differences observed were reflective of the emotional content of the target faces. While the use of schematic stimuli does allow for greater control of perceptual confounds, they are not an accurate representation of how threats typically occur in real-world social interactions, resulting in reduced ecological validity.

In addition to greater ecological validity, the current study also aims to rule out potential impacts of perceptual confounds associated with schematic stimuli. Coelho et al. (2010) conducted series of studies exploring whether the anger superiority effect observed with schematic emotional faces might be driven by low level perceptual confounds, rather than genuine emotion processing. In their first study, Coelho et al. compared (1) an emotion condition using angry and happy schematic faces, and (2) an 'abstract' condition using diagonal lines positioned to mimic the eyebrows of angry and happy faces. Results showed faster reaction times for angry targets than happy targets in the emotional condition. In the abstract condition, the abstract stimuli matching the eyebrows of the angry target face were also detected significantly faster than the abstract stimuli matching the eyebrows of the happy target face. The second study by Coelho et al. (2010) explored the potential confounding role of mouths in emotional schematic faces. They created four sets of stimuli displaying a semi-circle shape at various locations on the circular outline of the stimuli: bottom placement mimicked angry frowns and happy smiles, while side placements served as contols. Once again, the abstract stimuli designed to match the angry frown were detected significantly faster than abstract stimuli matching the happy smile (see Figure 16 for Coelho et al.'s stimulus images).

Figure 16:

Schematic and Photographic Emotional Stimuli



Note: Comparison of schematic used in Coelho et al.'s (2010) experiment series and photographic emotional face stimuli. A) Coelho et al.'s (2010) schematic emotional faces used in visual search arrays, showing angry target among happy distractors. B) Abstract stimuli isolating eyebrow orientations that mimic happy (angled outward) and angry (angled inward) expressions. C) Control stimuli with identical line orientations positioned at non-facial locations to test for geometric bias effects. D) Abstract mouth stimuli examining smile/frown shapes in both facial (top/bottom) and control (side) positions. E) Photographic face stimuli used in the current study. Stimuli provided by and reproduced with permission from Professor Guy Wallis (Coelho et al., 2010).

These findings led Coelho et al. to conclude that the anger superiority effect observed with schematic faces may reflect low level perceptual biases towards specific geometric orientations rather than evolved threat detection capacity. This interpretation then raises questions as to whether the anger superiority effect observed with schematic stimuli generalize to real-world face processing.

To address this limitation of reduced ecological validity and the potential perceptual confounds associated with schematic emotional stimuli, study 2 investigated the robustness of the anger superiority effect using more ecologically valid, complex stimuli - photographed emotional faces. As photographic stimuli more closely resemble the complex and nuanced presentation of social threats in day-to-day life, their use in an experimental design allows for a more realistic test of the anger superiority effect. Supporting the importance of photographic stimuli use, Horstmann and Bauland (2006) argue that schematic stimuli do not offer the ecological validity needed to effectively test the anger superiority effect for several reasons. First, they recognised a trend within the research whereby evidence in favour of the anger superiority effect was weaker in studies using more complex stimuli (e.g., Nothdurft, 1993; Öhman et al., 2001), compared to studies using more simplistic stimuli. Although it should be noted that some more recent studies using complex stimuli, including photographic stimuli, have continued to find evidence supporting the anger superiority effect (Diao et al., 2017; Feldmann-Wüstefeld et al., 2011; Hansen & Hansen, 1988; Lobue et al., 2014; Pinkham et al., 2010; Shasteen et al., 2014).

The second reason is that studies using schematic angry stimuli typically use specific features to demonstrate anger; namely a downturned mouth and furrowed brows. Horstmann and Bauland argued that the frowning mouth was not actually a feature of a real-world angry facial expression, which they argued could be creating a significant effect that would not translate to more naturalistic stimuli. Their third study sought to explore this argument, with participants completing a visual search task using simplistic grey-scale images of either an angry or happy mouth (as opposed to a full emotional face). Interestingly, participants showed shallower search slopes for the angry mouth compared to the happy mouth. In fact, they found that stimuli using only one feature (i.e., the mouth) were actually searched more efficiently than full-face targets, indicating that specific features play an important role in the detection of angry threats overall.

Given that the prominent theory as to why an anger superiority effect would develop is that it evolved as an adaptive response to threats in the real world, ensuring that ecological validity is maintained is an important element to confirm accurate testing of the anger superiority effect. If the anger superiority effect is robust, it should still emerge despite the increased complexity, producing results consistent with Studies 1A- 1C. Study 2 aimed to examine whether using these more ecologically valid and complex emotional faces would reveal deficits in emotional face detection among individuals with varying levels of alexithymia, or whether the lack of significant condition differences observed in Studies 1B and 1C would persist.

It should be noted that some methodological changes were made for the present study to ensure an accurate assessment of the anger superiority effect could be completed. During piloting of the initial study design for study 2, which featured photographed stimuli displaying angry, happy, and neutral expressions, it became apparent that participants frequently confused neutral faces with angry ones. The experimental design was adapted to exclude neutral faces to ensure an accurate assessment of emotion detection performance. While studies 1A-1C presented target emotional faces among neutral distractor faces, study 2 instead embedded target emotional faces among emotional distractor faces (e.g., an angry target face among happy distractor faces). This approach ensured that the emotional faces used were easily discriminable, confirming that any benefits or deficits associated with specific emotional targets were an accurate reflection.

Hypotheses

Hypothesis 1: A main effect of target type will be found whereby the anger superiority effect observed with schematic stimuli will replicate with photographic stimuli, with angry faces detected faster and more accurately than happy faces, demonstrating ecological validity of the effect (e.g., Pinkham et al., 2010).

Hypothesis 2: No main effect of alexithymia condition will be found, with photographic stimuli replicating the lack of significant differences in reaction times and accuracy observed in Studies 1B and 1C.

Hypothesis 3: A main effect of target type will be found on search slopes whereby angry faces will demonstrate more efficient visual search processes than happy faces, evidenced by flatter search slopes for angry targets compared to happy targets, replicating the search efficiency advantages observed with schematic stimuli.

Hypothesis 4: A main effect of trial type will be found whereby target-present trials will show faster reaction times than target-absent trials, with this effect being consistent across both target types and alexithymia conditions.

Hypothesis 5: A significant interaction between set size and trial type will be found for accuracy, with target-present trials showing greater accuracy decline across larger set sizes compared to target-absent trials.

Hypothesis 6: Target-absent trials will show steeper search slopes than target-present trials, reflecting the use of exhaustive versus self-terminating search strategies.

Method

Participants

Prolific (https://www.prolific.co) was used to recruit 81 online participants (55 males, 25 females, and one non-binary). Of the 81 participants, 19 fell into the low alexithymia condition, 56 in the medium alexithymia condition, and 15 in the high alexithymia condition. Participants were aged between 18 and 66 years (M = 34.49, SD = 10.15), were fluent in English and had normal or corrected-to-normal visual acuity. Participants received approximately $9 AUD for their completion of a single online experimental session consisting of an online threat detection task and completion of a questionnaire assessing alexithymia, the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018).

The chosen sample size was based on studies 1A, 1B and 1C. The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and informed consent was obtained from all participants.

Research Design

This study used a 3 (alexithymia condition: low alexithymia, medium alexithymia, high alexithymia) x 2 (target type: angry, happy) x 2 (trial type: target-present, target-absent) x 3 (set size: 8, 15, 24) mixed between/within participants design and consisted of 298 trials total (10 practice and 288 experimental). Trial type was randomly selected across trials with approximately 50% probability. Due to limitations with the PsychoPy framework at the time of study creation, I was unable to set specific randomisation constraints (e.g., ensuring exactly 50% of experimental trials were target absent). Rather, I elected to use a randomisation feature in which a target was randomly selected from a pre-populated list of possible stimuli at the beginning of each trial. This pre-populated list contained 50% target-absent stimuli, 50% target-present stimuli (i.e., either angry or happy, depending on the target block). Due to the high number of trials and participants in the present study, it was anticipated that this method would lead to a proportion of target-absent trials that was approximately 50% and a proportion of 50% per block for the angry/happy target-present trials. However, exact proportions may vary slightly between participants due to this randomisation process. The dependent variables were reaction time (RT), detection accuracy (i.e., the proportion of correct responses within target-present trials) and search slope (i.e., the search time taken per item in an array). It should be noted that mean RTs were calculated by averaging RTs from accurate responses only.

Stimuli and Apparatus

Stimuli consisted of 48 black-and-white photographs of emotional faces sourced from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998). The images were 2444 x 1718 pixels in size, and 16 individuals displayed either angry or happy expressions in each image.

The emotional face photographs were cropped into oval shapes, using the GIMP GNU Image Manipulation Program, to exclude any non-essential features that could present as a visual confound (e.g., hair). Additionally, only expressions in which no teeth were showing were selected to minimise perceptual confounds again. The images were also matched for luminance and converted to greyscale to further minimise the risk of low-level visual confounds. Finally, the images were then combined in MATLAB to create the 2x4, 3x5 and 4x6 stimuli matrices.

The faces within the image were displayed in a matrix and portrayed either an angry or a happy expression. The size of the matrix varied randomly between trials (i.e. 2 x 4, 3 x 5 or 4 x 6).

Each array consisted of either 8, 15, or 24 emotional faces of the same individual. The identity of the emotional faces was randomly allocated for each trial. Across the experimental trials, a differing emotional face was present in half of the images (i.e. an angry face among happy or a happy face among angry; target present), with the other half of the trials containing only one type of emotional face (i.e., all angry or all happy; target absent). The target's emotional face was randomly located in every target present image. Figure 17 shows sample stimuli, and Figure 18 shows sample matrices.

Figure 17:

Sample Stimulus Images

Note: Sample happy target (leftmost panel) and angry target (right panel) stimulus images.

Figure 18:

Sample Stimulus Matrices

Note: Sample 2 x 4 happy target-present (left), 3 x 5 angry target-present (centre) and 4 x 6 target-absent (right) stimulus images.

The study was programmed using the graphical builder interface of PsychoPy (Peirce, 2007), which generated and exported the study to a PsychoJS script. This script was then pushed to Pavlovia (https://pavlovia.org/) to be run online.

Procedure

Participants were recruited via Prolific, an online platform that facilitates the recruitment of individuals willing to participate in online studies for research purposes. Before beginning the task, participants were asked to read through an information sheet describing the study, what was expected of them, and their rights as participants. The information sheet asked participants to ensure they completed the study using a laptop or desktop computer. Finally, the Information Sheet also informed participants that, by choosing to sign up for the task on Prolific, they would be providing their consent to participate.

Once participants had signed up for the task, they were taken to Pavlovia, where a series of instructions were displayed on the screen. These instructions explained that participants would be viewing a series of images with photographed faces displaying different emotions and that their objective throughout the task was to determine whether all the faces on the screen belonged to the same emotion category. The study design used a blocked design in which only one target type was presented per block, with the order of block presentation counterbalanced across participants. Before the beginning of each block, participants were informed of the specific target emotion to search for (e.g., “For the next block, the target face will be ANGRY. Your task is to determine whether there is an ANGRY emotional face within the faces on screen”). Furthermore, participants were informed that approximately half of the trials would contain a target emotion that differs from other emotional faces displayed. Participants were asked to press the letter ‘P’ on the keyboard if they thought a target emotional face was present (i.e. a happy or angry face) and the letter ‘A’ on the keyboard if they thought the target emotion was absent and were asked to respond as quickly and accurately as possible. A face displaying a target emotion (either anger or happiness) was present in 50% of the trials, with the remaining 50% consisting only of distractor faces (i.e., either all anger or all happiness, depending on the block).

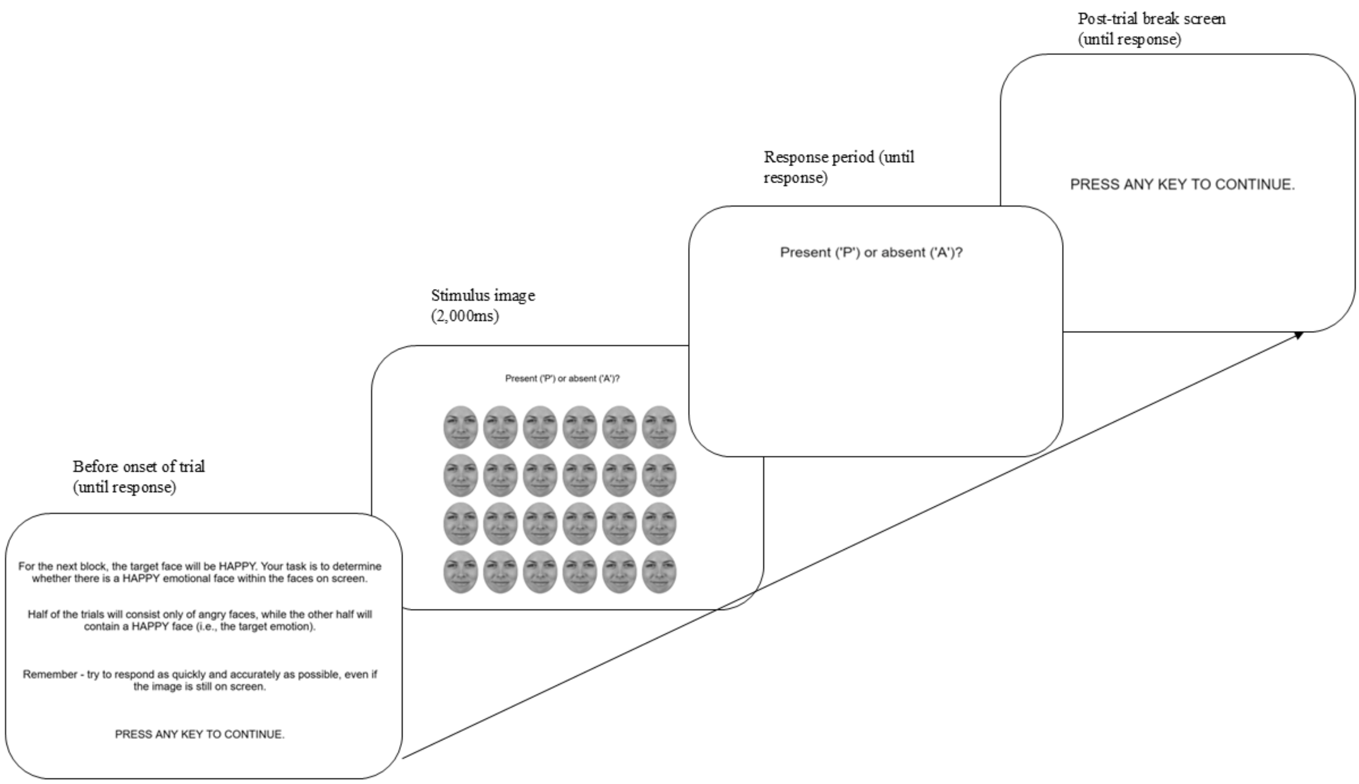
Before beginning the experimental trials, participants completed 10 practice trials to help them get a feel for the task. Participants did not receive feedback on their performance on the task. Figure 19 provides an example of the sequence of events for a target absent trial.

Figure 19:

Example Sequence of Events for a Target Absent Trial

Measures

RTs from trials with incorrect responses were excluded from analysis. Any participants with an overall accuracy below chance (i.e., <50%) were also excluded from analysis. Eight participants



were excluded based on accuracy requirements (six males and two females). Of the eight excluded participants, two fell into the low alexithymia condition, five in the medium alexithymia condition, and one in the high alexithymia condition. Excluded participants were aged between 18 and 47 years (M = 32.5, SD = 9.53).

Results and Discussion

As in prior studies, where the assumption of sphericity was found to be violated, as indicated by Mauchly's Test of Sphericity (Mauchly, 1940), Greenhouse-Geisser corrections (Greenhouse & Geisser, 1959) were applied to adjust the degrees of freedom to reflect the results of the study more accurately. Seven participants were excluded from analysis due to low accuracy (i.e., <50%).

Reaction Time (RT). Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (target type: angry, happy) x 2 (trial type: present, absent) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size, target type and trial type were entered as within-subject factors, and alexithymia condition was entered as a between-participants factor.

No significant differences in RT were found between the three alexithymia conditions, $F(2,78) = 0.13$, $p = 0.88$, $B_{10} = 1/18.44$. The Bayesian ANOVA also found strong evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition). These findings contradict those of study 1A, which found that higher alexithymia participants detected emotional target faces more effectively than lower alexithymia participants. These findings do, however, fall in line with the findings of studies 1B and 1C which both found no significant differences in RT between the low and high alexithymia conditions. Overall, these findings, coupled with the findings of 1B and 1C, suggest no identifiable differences in the processing of threatening faces and no significant differences in the processing of all emotional faces. These findings contradict a large body of prior research supporting impaired processing of emotional faces in higher alexithymia (see Grynberg et al., 2012 for review). One possible explanation may be that the emotion processing deficits observed in current alexithymia literature may occur at a later stage than detection. If we consider the emotional knowledge model, it may be that there are no observable deficits in the detection stage of emotional processing in higher alexithymia individuals, but rather, the impairment may occur in the later stages of labelling or understanding of the causes of emotions. The consistent pattern of null findings across studies 1B, 1C and the present study provides important theoretical insights into the nature of alexithymia. The emotional knowledge model (Preece et al., 2018) proposes that alexithymia involves difficulties across multiple stages of emotional processing: attention to emotions, appraisal of emotions, and conceptualization of emotions. The current results suggest that the attention stage may be relatively preserved in alexithymia, with deficits becoming apparent primarily in later stages involving emotion labelling, understanding emotional causes, or integrating emotional information with other cognitive processes. However, these conclusions must be interpreted cautiously given the small sample sizes for the extreme alexithymia groups (n = 19 for low, n = 15 for high), which limit the reliability of statistical comparisons and may have reduced power to detect genuine group differences.

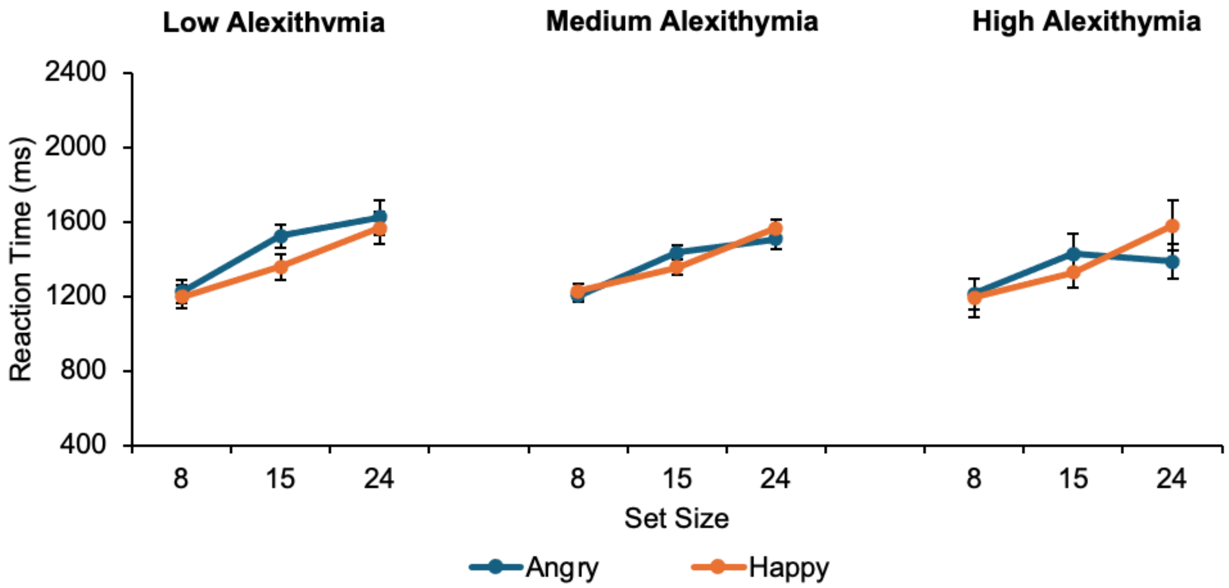
Surprisingly, no significant main effect was found for target type, $F(1, 78) = 0.03$, $p = 0.35$, $B_{10} = 1/8.79$. The Bayesian ANOVA supported this non-significant effect, which found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of target type). This means that no significant differences in RT were observed between the detection of angry and happy target faces. This absence of anger superiority contradicts both the theoretical predictions and the findings of studies 1A, 1B and 1C, which demonstrated that angry targets were detected faster than both sad and happy targets. The only significant difference between the present study and studies 1A-1C was the type of stimuli used, with the present study using photographed faces rather than schematic. While previous research has found evidence for the anger superiority effect in studies using both schematic (Dickins & Lipp, 2014; Eastwood et al., 2001; Fox et al., 2000; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Rued et al., 2019) and photographic stimuli (Diao et al., 2017; Feldmann-Wüstefeld et al., 2011; Hansen & Hansen, 1988; Lobue et al., 2014; Pinkham et al., 2010; Shasteen et al., 2014), this is not without some contention (Coelho et al., 2010). As discussed above, despite schematic stimuli often being used to reduce the risk of potential confounds associated with photographic stimuli, Coelho et al. have suggested that the features associated with schematic angry faces may be detected more efficiently due to the angle of specific features, namely the eyebrows and mouth. The inability to replicate the findings of studies 1A-1C with photographic stimuli does potentially fall in line with the possibility of perceptual confounds playing a role in the findings of studies 1A-1C. If anger superiority effects were driven by evolved threat detection mechanisms, as proposed by evolutionary accounts, they might be expected to emerge robustly with ecologically valid stimuli. The absence of the effect with more realistic stimuli raises questions about whether the advantages observed with schematic faces may partly reflect perceptual confounds rather than specialised threat detection advantages. However, further research exploring the impact of schematic angry features without an emotional component (e.g., an inverted face task) would be needed to explore this possibility further. Unfortunately, such an experiment was outside of the scope of the present thesis due to time and monetary constraints.

Alternately, the discrepancy between the current findings and previous research using photographic stimuli may reflect several methodological differences that highlight the sensitivity of anger superiority effects to specific task parameters, rather than being due to perceptual confounds with schematic stimuli. The use of emotional distractors (i.e., happy faces) rather than neutral distractors in the current study may have fundamentally impaired visual search performance through interference effects, masking any anger superiority effects. Some research has demonstrated that emotional faces presented as distractors throughout visual search tasks can impair performance due to the arousal level of the distractor faces, likely because cognitive resources must be devoted to actively inhibiting the emotional distractors while simultaneously focusing on the primary task (Burra et al., 2017; Melloni et al., 2012; Xu et al., 2023; Zsido et al., 2022; Zsido, Stecina, et al., 2021). This essentially would mean that when searching for an angry face among happy faces, participants must not only detect the target emotion but also actively suppress the processing of emotionally arousing happy distractors, creating additional cognitive demands that may have obscured subtle anger detection advantages. This increased cognitive load contrasts with Studies 1A-1C, where emotional targets were embedded among neutral distractors that would require minimal active inhibition. A significant main effect was found for both trial type, $F(1, 78) = 108.90$, $p<.001$, $n^2 = 0.11$, $B_{10} = 9.24E+26$, and set size, $F(1.56, 121.27) = 174.26$, $p<.001$, $n^2 = 0.10$, $B_{10} = 5.23E+23$. However, these main effects were moderated by a significant trial type × set size interaction, $F(2, 156) = 32.05$, $p<.001$, $n^2 = 0.008$, $B_{10} = 9.45$, providing substantial evidence in favour of the interaction, which was itself further qualified by a significant three-way interaction between trial type, set size, and target type, $F(2, 156) = 5.04$, $p = .008$, $n^2 = .001$, $B_{10} = 1/7.17$, though the Bayesian analysis provided anecdotal evidence against this three-way interaction, indicating potential data insensitivity. To further explore this significant interaction, a series of 2 (target type: angry, happy) x 3 (set size: 8, 15, 24) post-hoc ANOVA's assessing RT were conducted for each trial type (i.e., target present, and target absent). For target present trials, a significant two-way interaction between set size and target type was found, $F($1.55, 124.35) = 9.78*,* *p* < .001, n^2 = 002. Post-hoc pairwise contrasts comparing angry and happy target detection at each set size revealed that happy targets were detected significantly faster than angry targets, but only at set size 15 (*p* < .001). No significant differences between angry and happy targets were found at set size 8 (*p* = .692) or set size 24 (*p* = .599). For target-absent trials, no significant two-way interaction was found, *F(*2, 160) = 0.09, *p* = .911. Analysis did reveal a significant main effect of set size, *F(*1.69, 135.44) = 331.72, *p*<.001, n^2 = 0.63, with RT increasing as set size increased, as is shown in Figure 20 and Figure 21. No significant differences in target type were found, *F(*1, 80) = 1.78, *p* = .186. The interaction patterns observed here are consistent with standard visual search findings, where target-absent trials show greater search efficiency decline with increasing set size compared to target-present trials. The absence of consistent emotion-based differences across set sizes further supports the interpretation that photographic emotional faces do not engage the same efficient search mechanisms that appear to operate with schematic stimuli.

All other interactions were found to be non-significant, including the four-way interaction between set size, target type, trial type and alexithymia condition, *F(*4, 156) = 0.89, *p = .47,* B_{10} = *1/16.74.* This non-significant interaction was supported by the Bayesian ANOVA, which found strong evidence in favour of the null hypothesis (i.e., a non-significant four-way interaction).

Figure 20:

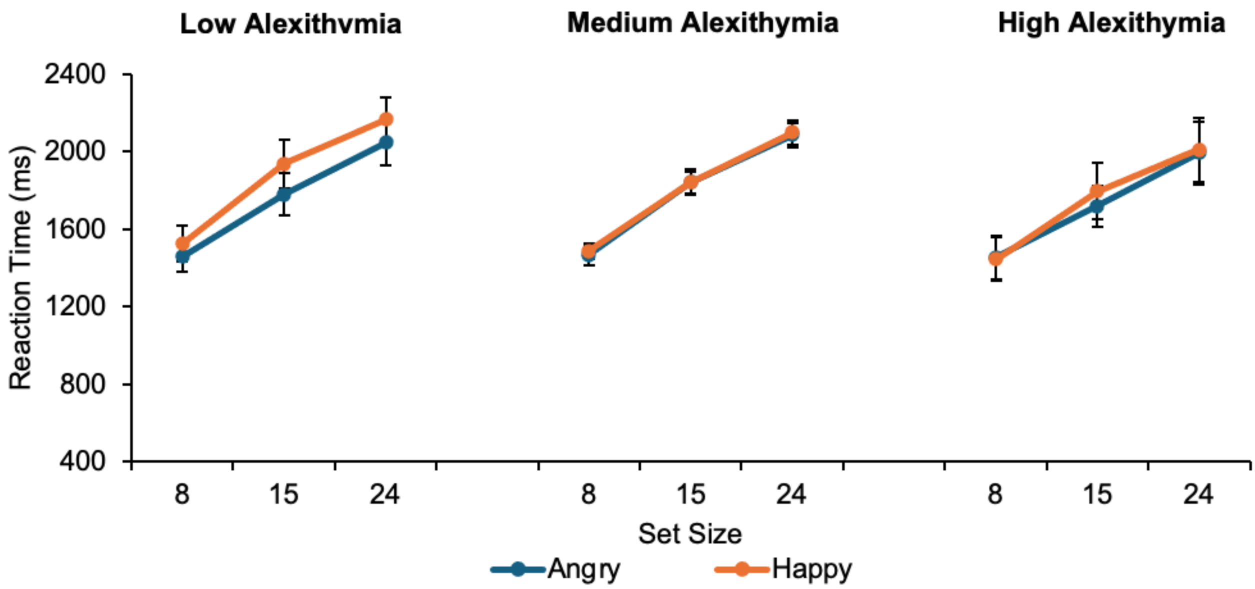
Mean Target Present RT for Each Target Type Across Set Size and Alexithymia Conditions



Note: Mean target-present RT for angry (blue line) and happy (orange line) target trials across each set size and alexithymia condition. Error bars indicate standard errors.

Figure 21:

Mean Target Absent RT for Each Target Type Across Set Size and Alexithymia Conditions



Note: Mean target-absent RT for angry (blue line) and happy (orange line) target trials across each set size and alexithymia condition. Error bars indicate standard errors.

Search Slope. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (target type: angry, happy) x 2 (trial type: present, absent) mixed ANOVA. Target type and trial type were entered as within-subjects factors, and alexithymia condition was entered as a between-participants factor.

As expected, based on target-present and target-absent RT results, no significant differences in search slope were found for alexithymia conditions, $F(2,85) = 0.09$, $p = .92$, $B_{10} = 1/7.27$. This non-significant effect was supported by the Bayesian ANOVA, which found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of the alexithymia condition). Figure 22 displays a significant and meaningful difference in search slopes between target-present and target-absent trials.

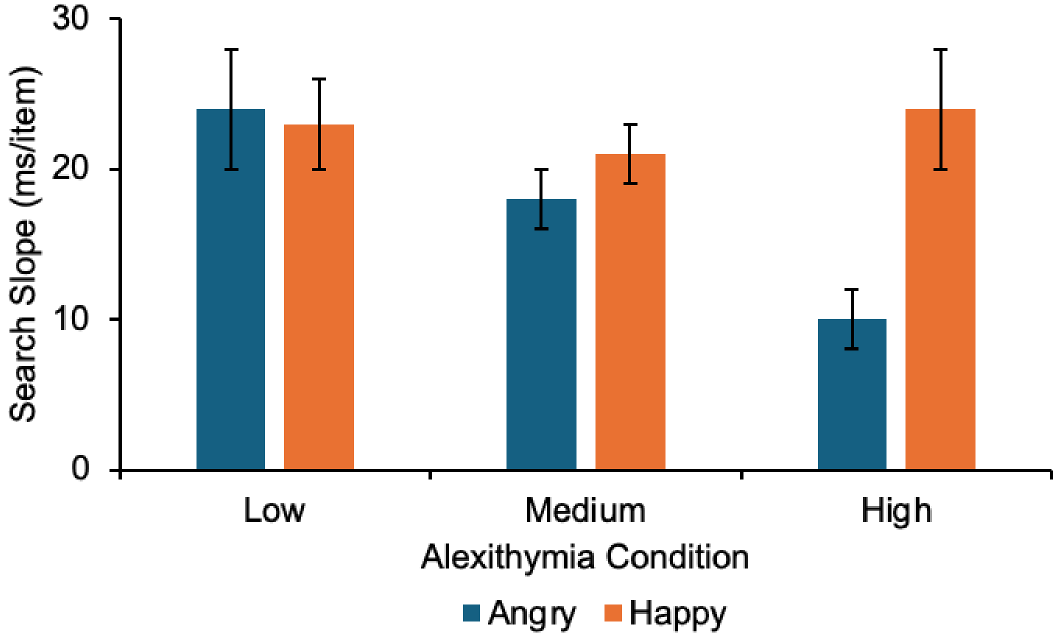
No significant differences in search slopes were found between happy and angry targets, $F(1,85) = 0.50$, $p = .48$, $B_{10} = 1/5.09$. The Bayesian ANOVA also found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of target type). The absence of search slope differences between angry and happy faces provides additional evidence against anger superiority effects with photographic stimuli. Search slopes are considered a particularly sensitive measure of visual search efficiency, as they directly reflect the additional time required to process each additional item in the display. The equivalent slopes for angry and happy faces suggest that neither emotion type benefits from more efficient search mechanisms when realistic facial stimuli are used. This differs considerably from the pattern of flatter angry target search slopes regularly found in studies 1A-1C when using schematic stimuli.

As displayed in Figure 22, a significant main effect of trial type was found, $F(1, 78) = 57.34$, $p<.001$, $n^2 = 0.10$, $B_{10} = 1/2.19$. The Bayesian ANOVA found only anecdotal evidence for the null hypothesis (i.e., a non-significant main effect of trial type condition), suggesting the need for further data to draw a clear conclusion.

All other interactions were non-significant, including the three-way interaction between target type, trial type, and alexithymia condition, with Bayes factor also giving substantial evidence in favour of the null hypothesis, $F(2, 78) = 0.93$, $p = .40$, $B_{10} = 1/5.30$.

Figure 22:

Mean Search Slope Across Target Type and Alexithymia Conditions



Note: Mean search slope for angry (blue bar) and happy (orange bar) trials across alexithymia conditions. Error bars indicate standard errors.

Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (target type: angry, happy) x 2 (trial type: present, absent) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size, target type and trial type were entered as within-subject factors, and alexithymia condition was entered as a between-participants factor.

No significant differences in accuracy were found between the three alexithymia conditions, $F(2, 78) = 0.12$, $p = 0.89$, $B_{10} = 1/30.48$, providing very strong evidence in favour of the null hypothesis (i.e., a non-significant effect of alexithymia condition). These findings, coupled with the RT results, suggest that alexithymia levels had no impact on performance within this task. Once again, this is contrary to current alexithymia literature (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006).

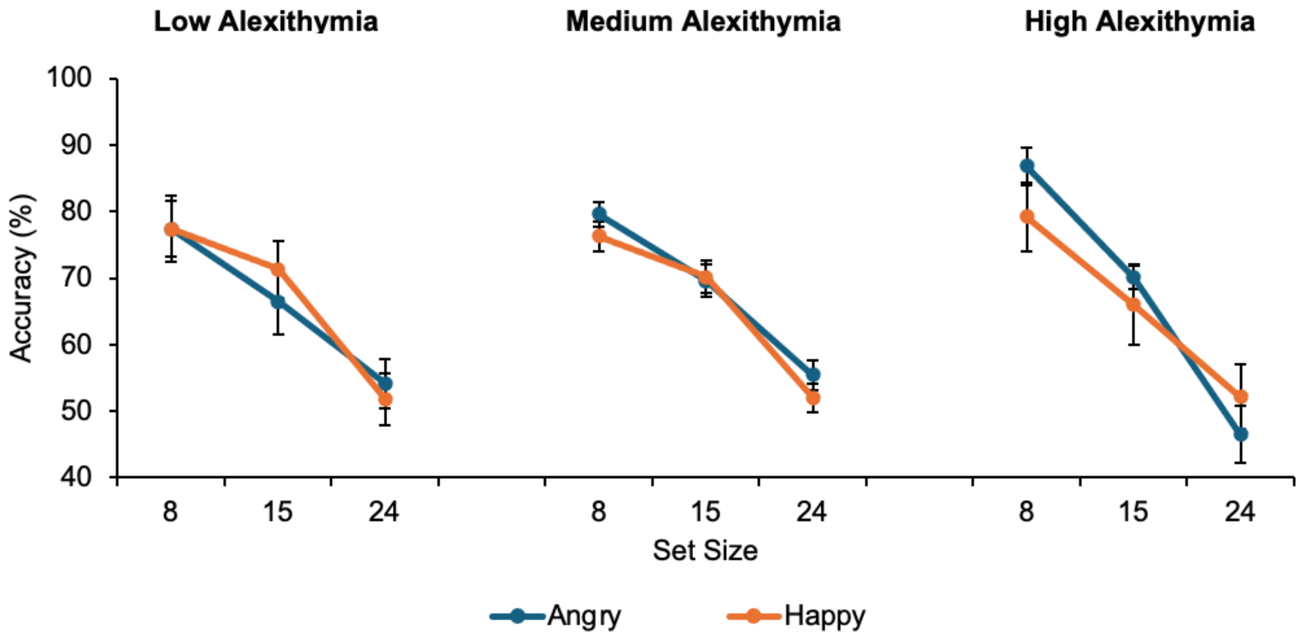
No significant main effect was found for target type, $F(1, 78) = 0.60$, $p = 0.44$, $B_{10} = 1/5.92$. This non-significant effect was supported by the Bayesian ANOVA, which found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of target type). These findings contradict not only the current anger superiority evidence using schematic stimuli (Dickins & Lipp, 2014; Eastwood et al., 2001; Fox et al.,2000; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Rued et al., 2019) but also evidence using photographic stimuli (Diao et al., 2017; Feldmann-Wüstefeld et al., 2011; Hansen &Hansen, 1988; Lobue et al., 2014; Pinkham et al., 2010; Shasteen et al., 2014). For example, Pinkham et al. (2010) conducted a similar face-in-the-crowd task using photographic stimuli in a neutral, angry or happy crowd. These researchers found that angry faces were detected faster and more accurately than happy faces, regardless of distractor emotion. Not only do these accuracy findings contradict current literature, but they also contradict the findings of studies 1A and 1B, both of which found significantly greater accuracy when detecting angry targets compared to happy and sad targets, respectively. Study 1C, in contrast, found no significant differences in accuracy between the three target types used (i.e., angry, happy and sad), which aligns with the present study's accuracy findings. It should be noted, however, that study 1C did find significantly faster RTs for angry targets, which was not the case in the present study.

A main effect was found for both trial type, $F(1, 78) = 145.20$, $p<.001$, $n^2 = 0.24$, $B_{10} =$ 5.05E+64, and set size, $F(1.75, 136.13) = 118.45$, $p<.001$, $n^2 = 0.05$, $B_{10} =$ 9.16E+12. However, these significant main effects are moderated by a significant two-way interaction, $F(1.73, 134.76) = 69.51$, $p<.001$, $n^2 = 0.03$, $B_{10} = 148758647$, providing extreme evidence in favour of a two-way interaction between trial type and set size. This interaction between set size and trial type indicates that the effect of set size on accuracy varied across the two trial types (see Figure 23). A series of post-hoc ANOVAs were conducted to further investigate this significant interaction by examining detection accuracy across set sizes for each trial type. A significant main effect of set size was found for target-present trials [$F(1.72, 137.62) = 194.24$, $p<.001$, $n^2 = 0.50$] and for target-absent trials [$F(1.77, 141.18) = 11.61$, $p<.001$, $n^2 = 0.01$]. These findings show that detection accuracy consistently decreased with larger set sizes, regardless of trial type. However, the rate of decrease appears to be greater for target-present trials, as reflected by the particularly large F-value (194.24).

All other interactions were found to be non-significant, including the four-way interaction between set size, target type, trial type and alexithymia condition, $F(4, 156) = 1.56$, $p = 0.19$, $B_{10} = 1/14.99$. Supporting this non-significant four-way interaction, Bayesian ANOVA gave strong evidence in favour of the null hypothesis.

Figure 23:

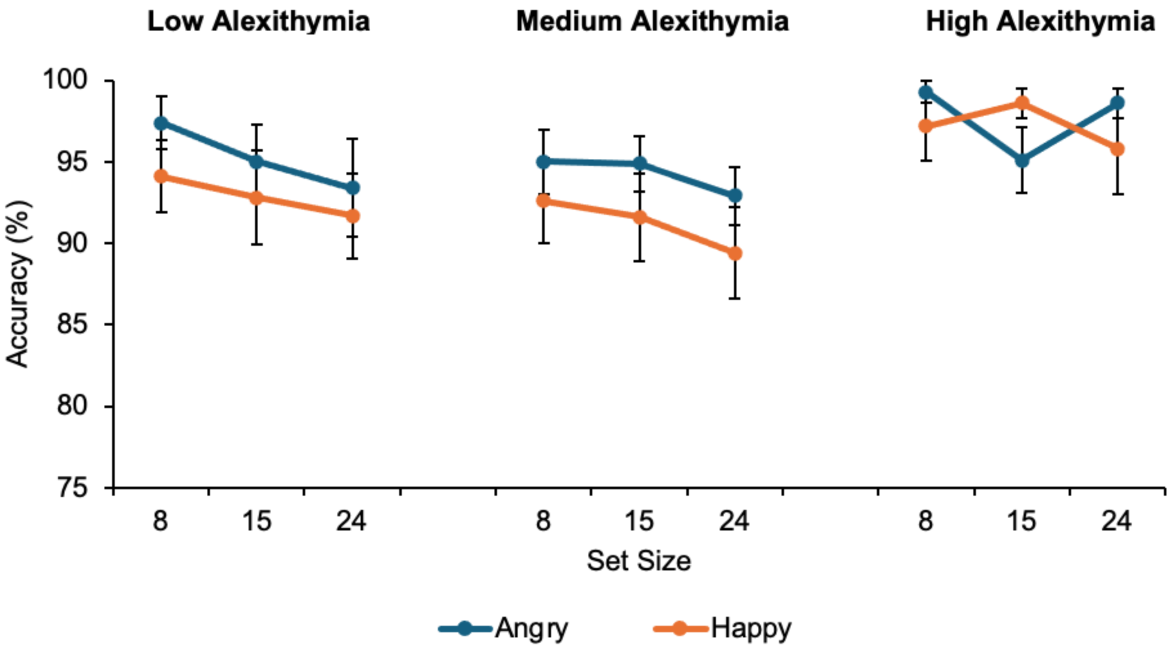
Mean Target Present Accuracy Across Set Size and Alexithymia Conditions



Note: Mean target present accuracy for angry (blue line) and happy (orange line) trials across each set size and alexithymia conditions. Error bars indicate standard errors.

Figure 24:

Mean Target Absent Accuracy Across Set Size and Alexithymia Conditions



Note: Mean target absent accuracy for angry (blue line) and happy (orange line) trials across each set size and alexithymia conditions. Error bars indicate standard errors.

Limitations and Future Directions

Importantly, there are several methodological limitations that may have influenced the pattern of results for the current study which should be considered when interpreting these findings.

Firstly, the use of online testing, while beneficial for participant recruitment during the COVID -19 pandemic, introduces a number of uncontrollable factors that may have impacted the results. Participants completed the study on personal computers with varying screen sizes, resolution settings, ambient lighting conditions, and potential environmental distractions. These factors could have reduced the validity of measurements and introduced confounds that obscured subtle emotion detection effects. However, recent research suggests that concerns about online data collection quality may be overstated. Comparative studies have found minimal differences in data quality between in-person and online testing methods, with online collection showing only small but acceptable decreases in data quality compared to laboratory-based approaches (Sauter et al., 2022; Uittenhove et al., 2022). Nevertheless, the potential for online testing to introduce additional variability remains a consideration when interpreting null findings, and laboratory-based replication with standardised equipment and controlled environmental conditions could provide additional confidence in these results.

Secondly, a significant limitation of study two is the difference in distractor type used in comparison to studies 1A-1C, specifically the use of emotional distractor faces as opposed to neutral distractor faces. This methodological change was necessitated due to pilot study findings, with participants indicating that neutral and angry faces were too challenging to differentiate when using photographic stimuli. However, this change also created challenges for direct comparison between schematic and photographic stimuli task findings. The use of emotional distractors may have introduced interference effects that masked anger superiority effects, making it impossible to determine whether the absence of anger superiority with photographic stimuli reflects genuine stimulus-dependent differences or methodological artifacts. Future research should use identical distractor types to allow for clearer interpretations, potentially by using more clearly distinguishable neutral photographic faces or developing alternative control conditions that maintain task equivalence.

Conclusion

The results of Study 2 demonstrates that anger superiority effects observed with schematic faces do not reliably extend to more realistic photographic stimuli. This absence of anger superiority effects with photographic stimuli suggests that the advantages observed with schematic stimuli may partly reflect perceptual confounds, though the potential interference effects of emotional distractors in the present study limit definitive conclusions about the underlying mechanisms.

Furthermore, the current study again found no differences in performance between lower and higher alexithymia participants, supporting the findings of study 1B and 1C, and contradicting the current alexithymia literature. These findings suggest that the emotional processing deficits observed among higher alexithymia individuals may potentially manifest at later stages of processing rather than at the level of basic emotion detection as measured in this task. However, methodological limitations including small sample sizes prevent definitive conclusions about the absence of such deficits, and future research with larger samples will be needed to fully characterise emotion processing differences in alexithymia.

Chapter 4: Study 3

Introduction

Plaisted et al. (1998) were the first researchers to observe an advantage in visual search tasks among individuals with Autism Spectrum Disorder (ASD; see Kaldy et al., 2016, for review). In their study, Plaisted et al. had two groups of children (eight autistic and eight neurotypical) complete two visual search tasks: a feature search task and a conjunctive search task. In the feature search tasks, the target item differed from the distractors in shape but shared colour with one kind of distractor (e.g., a red S among green X and red T distractors). In the conjunctive search task, the target item shared colour with one distractor type and shape with another (e.g., a red X among green X and red T distractors). The role of inclusion of both feature and conjunctive search tasks was to differentiate between basic visual discrimination (i.e., feature search) and more complex visual processing that requires discrimination of multiple features (i.e., conjunctive search). The results showed no significant difference in performance between the two groups on the feature search task; however, they did find that the autistic sample was significantly faster than the neurotypical sample in the conjunctive search task. Additionally, RT in the autistic sample remained stable as set size increased, whereas RT increased with larger set sizes in the neurotypical sample. These findings suggest that children with autism exhibit enhanced visual search abilities when tasks require integration of multiple features, potentially reflecting differences in visual processing or attention allocation.

This visual search advantage has been replicated numerous times since its initial identification (see Kaldy et al., 2016 for review). Remington et al. (2012) investigated this advantage further using a signal detection paradigm to explore their hypothesis that ASD individuals have a higher perceptual capacity, leading to more efficient visual search performance compared to non-ASD individuals. Their findings supported this theory, with visual detection performance decreasing as perceptual load increased in the non-ASD condition, but the ASD condition showed no changes. Collignon et al. (2013) had participants complete a visual search task during which they identified if there was a horizontal or vertical line among a series of diagonal lines at various angles. Their results demonstrated that the autistic participants were significantly faster at detecting the horizontal and vertical target lines compared to the typically developing group. Almeida et al. (2012) used the embedded figures task, a task in which participants are asked to detect a simple shape that is embedded in a more complex structure, to explore the role of differing processing types in the ASD advantage. They found that participants who scored 'high' on the Autism Quotient were significantly faster at detecting the target shape than participants who scored 'low' on the Autism Quotient.

However, not all studies have found consistent advantages in visual search performance among individuals with autism. For example, Iarocci et al. (2006) investigated global versus local visual processing in high-functioning children with autism using a visual search task. Across two studies, they found no differences in visual search performance between the autistic and neurotypical children at either the local or global level of processing. Exploring the emotional processing perspective, Ashwin et al. (2006) had participants complete a visual search task consisting of happy, threatening and neutral faces. Across their four studies, both participants with ASD and neurotypical controls were more efficient at detecting threatening faces compared to happy and neutral faces. Across all target conditions, however, participants with ASD were found to be significantly slower at detecting target emotional faces than their neurotypical peers. Overall, while there is considerable evidence supporting a visual search advantage in ASD, the effect is not universally observed.

Given that research suggests approximately 50% of autistic individuals also have high levels of alexithymia, this research base indicating a visual search advantage among autistic individuals raises the question - does this visual search advantage extend to non-autistic, higher alexithymia individuals? To my knowledge, there are currently no peer-reviewed papers exploring non-emotional visual search tasks in individuals with higher levels of alexithymia.

As discussed in Chapter 2, a general visual search advantage could explain the unexpected results observed in study 1A, where higher alexithymia participants showed faster reaction times when detecting emotional faces without any reduction in accuracy. Based on this possible explanation and the lack of research exploring non-emotional visual search capacities in higher alexithymia individuals, the present study aimed to explore visual search performance among various alexithymia severity levels using non-emotional target stimuli.

Hypotheses

Hypothesis 1: A main effect of alexithymia condition will be found whereby higher alexithymia participants will demonstrate enhanced visual search performance similar to that observed in autism spectrum disorder, evidenced by faster reaction times, shallower search slopes, and higher accuracy compared to lower alexithymia participants (e.g., Plaisted et al., 1998; Kaldy et al., 2016).

Hypothesis 2: A main effect of trial type will be found whereby target-present trials will show faster reaction times than target-absent trials, reflecting the use of self-terminating versus exhaustive search strategies.

Hypothesis 3: A significant interaction between trial type and set size will be found whereby target-absent trials will show steeper increases in reaction time across set sizes compared to target-present trials, reflecting exhaustive versus self-terminating search processes.

Hypothesis 4: A significant interaction between set size and trial type will be found for accuracy, with target-present trials showing greater accuracy decline across larger set sizes due to increased difficulty in locating targets among larger distractor arrays.

Method

Participants

Prolific (https://www.prolific.com) was used to recruit 76 online participants. Of these, one was excluded due to low accuracy, resulting in a final sample of 75 participants (57 males and 18 females). Of the 75 participants, 25 fell into the low alexithymia condition, 44 in the medium alexithymia condition, and 6 in the high alexithymia condition. Participants were aged between 20 and 62 years (M = 32.96, SD = 9.33), were fluent in English and had normal or corrected-to-normal visual acuity. Participants received approximately $9 AUD for their completion of a single online experimental session consisting of an online target detection task and completion of a questionnaire assessing alexithymia, the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018).

The chosen sample size was based on studies 1A, 1B and 1C. The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and informed consent was obtained from all participants.

Research Design

This study used a 3 (alexithymia condition: low alexithymia, medium alexithymia, high alexithymia) x 2 (trial type: target-present, target-absent) x 3 (set size: 8, 15, 24) mixed between/within participants design and consisted of 252 trials total (12 practice and 240 experimental). Target type and trial type were randomly selected across trials with approximately 50% probability. Due to limitations with the PsychoPy framework at the time of study creation, I was unable to set specific randomisation constraints (e.g., ensuring exactly 50% of experimental trials were target absent). Rather, I elected to use a randomisation feature in which a target was randomly selected from a pre-populated list of possible stimuli at the beginning of each trial. This pre-populated list contained 50% target-absent stimuli and 50% target-present stimuli. Due to the high number of trials and participants in the present study, it was anticipated that this method would lead to a proportion of target-absent trials that was approximately 50% and a proportion of approximately 50% target-present trials. However, exact proportions may vary slightly between participants due to this randomisation process.

The dependent variables were reaction time (RT), detection accuracy (i.e., the proportion of correct responses within target-present trials) and search slope (i.e., the search time taken per item in an array). Mean RTs were calculated by averaging RTs from accurate responses only.

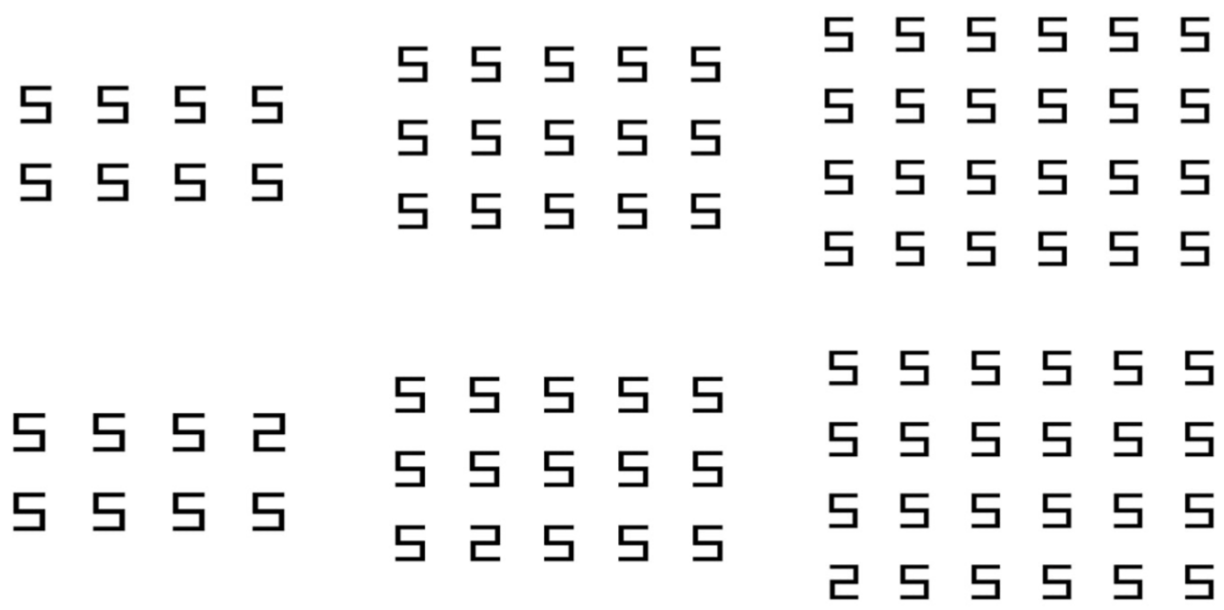
Stimuli and Apparatus

Stimuli consisted of 2 black and white images of a digital “2” and a digital “5” created using the GIMP GNU Image Manipulation Program, with the images being 156 x 191 pixels in size. Finally, the images were then combined in MATLAB to create the 2x4, 3x5 and 4x6 stimuli matrices.

Each array consisted of either 8, 15, or 24 black digital 2s and 5s presented on a white background. Across the experimental trials, a target 2 was present in half of the images (i.e. a two among distractor 5s), with the other half of the trials containing all distractor 5s. The target 2 was randomly located in every target present image. This visual search design was selected as it is typically associated with less efficient, serial search processes, allowing for clearer comparison between search ability compared to if the design used a ‘pop-out’ approach (e.g., a large black square among small black squares) (Wolfe, 1993). Figure 25 shows sample matrices.

Figure 25:

Sample Stimulus Matrices



Note: Sample target present (lower panel) and target-absent (upper panel) stimulus images across matrix sizes (2 x 4 in left panel; 3 x 5 in centre panel; 4 x 6 in right panel).

The study was programmed using the graphical builder interface of PsychoPy (Peirce, 2007), which generated and exported the study to a PsychoJS script. This script was then pushed to Pavlovia (https://pavlovia.org/) to be run online.

Procedure

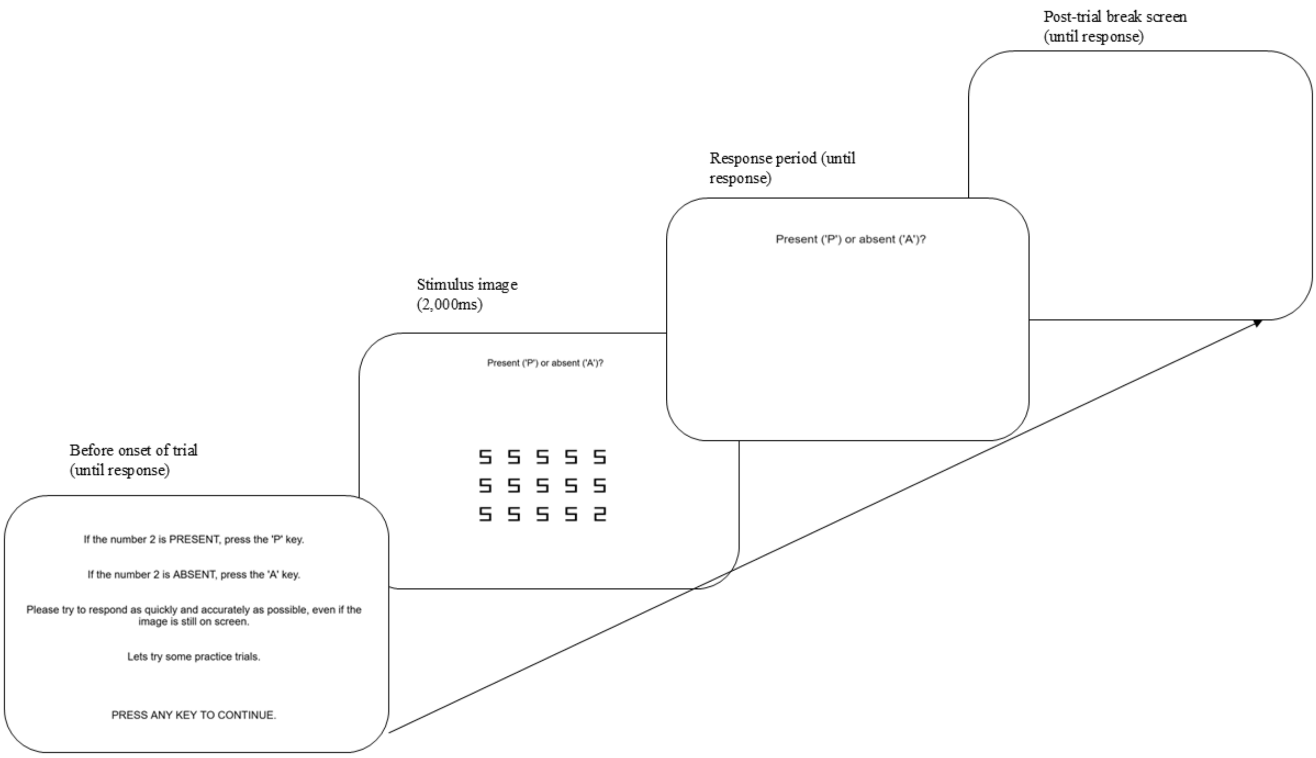
Participants were recruited via Prolific, an online platform that facilitates the recruitment of individuals willing to participate in online studies for research purposes. Before beginning the task, participants were asked to read through an information sheet describing the study, what was expected of them, and their rights as participants. The information sheet asked participants to ensure they completed the study using a laptop or desktop computer. Finally, the Information Sheet also informed participants that, by choosing to sign up for the task on Prolific, they would be providing their consent to participate.

Once participants had signed up for the task, they were taken to Pavlovia, where a series of instructions were displayed on the screen. These instructions explained that participants would be viewing a series of images displaying numbers, with 50% of the trials displaying only the number "5" while the other 50% of trials would contain a single number "2" embedded among "5"s. Participants were informed that their objective throughout the task was to determine whether the target number was present. Participants were asked to press the letter 'P' on the keyboard if they thought a target number was present (i.e. "2") and the letter 'A' on the keyboard if they thought the target number was absent and were asked to respond as quickly and accurately as possible.

Before beginning the experimental trials, participants completed 12 practice trials to help them get a feel for the task. Participants did not receive feedback on their performance on the task. Figure 26 provides an example of the sequence of events for a target-absent trial.

Figure 26:

Example Sequence of Events for a Target-Present Trial



Measures

RTs from trials with incorrect responses were excluded from analysis. Any participants with an overall accuracy below chance (i.e., <50%) were also excluded from analysis. One participant was excluded based on accuracy requirements. This excluded participant was male, aged 38 and fell into the low alexithymia condition.

Results and Discussion

As in prior studies, where the assumption of sphericity was found to be violated, as indicated by Mauchly's Test of Sphericity, Greenhouse-Geisser corrections were applied to adjust the degrees of freedom to more accurately reflect the study's results.

Reaction Time (RT). Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (trial type: target-present, target-absent) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and trial type were entered as within-subject factors, and alexithymia condition was entered as a between-participants factor.

Contrary to expectations, no significant differences in RT were found between the three alexithymia conditions, $F(2, 72) = 0.54$, $p = 0.587$, $n^2 = 7.37e-3$, $B_{10} = 1/3.06$. Supporting this non-significant effect, the Bayesian ANOVA found substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of condition). Research has consistently displayed evidence of an ASD advantage in visual search, including Collignon et al. (2012), who used a similar methodology of finding a horizontal or vertical line among diagonal lines and found that ASD participants were faster at detecting targets than the non-ASD participants. The present study's results do not provide evidence for visual search advantages in higher alexithymia individuals, despite the high co-morbidity between ASD and higher alexithymia levels. It is important to note, however, that one limitation of the present study is the inability to compare higher alexithymia participants directly with ASD participants. Future studies would benefit from including an ASD participant condition in addition to a higher alexithymia condition to allow for direct comparison. Unfortunately, this type of study was outside the scope of the current PhD. Alternatively, requiring participants in the high alexithymia condition to complete an assessment of ASD to ensure a clear sample would also be beneficial for future studies.

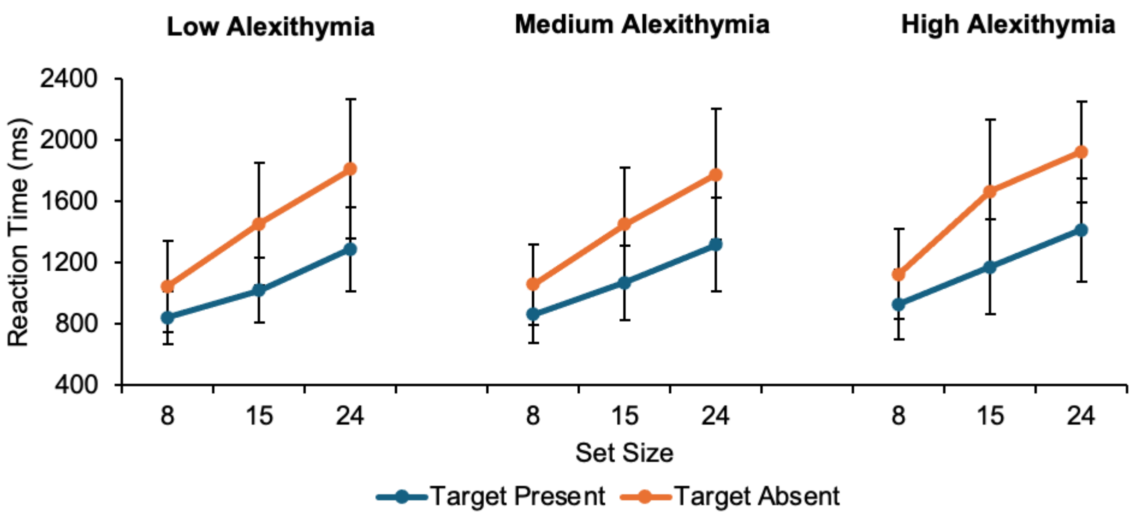
A significant main effect was found for both trial type, $F(1, 72) = 141.35$, $p<.001$, $n^2 = 0.12$, $B_{10} = 6.27E+16$, and set size, $F(1.37, 98.83) = 291.77$, $p<.001$, $n^2 = 0.22$, $B_{10} = 1.56E+28$. Importantly, these main effects were moderated by a significant two-way interaction, $F(1.82, 131.15) = 46.73$, $p<.001$, $n^2 = 0.01$, $B_{10} = 16.13$, providing strong evidence in favour of a significant interaction between trial type and set size. This interaction is displayed in Figure 27. To further explore this significant interaction, a series of post-hoc ANOVAs were completed, assessing RT across set sizes for each trial type. A significant main effect of set size was found for target-present [$F(1.52, 109.53) = 210.04$, $p<.001$, $n^2 = 0.24$] and target-absent trials [$F(1.50, 107.73) = 223.46$, $p<.001$, $n^2 = 0.28$]. These findings suggest that both trial types were susceptible to increases in RT across larger set sizes, indicating no pop-out effects were present. Interestingly, the effect size for target-absent trials was greater than target-present trials, suggesting a greater difference in RT across set sizes for target-absent trials, likely reflecting the use of an exhaustive search approach.

To further explore this significant interaction, another series of post-hoc ANOVAs were completed, assessing RT across trial type for each set size. Analysis revealed significant main effects of trial type across all set sizes. At set size 8, RT was significantly faster for target present trials (M = 861.50, SD = 185.18) compared to target absent trials (M = 1057.68, SD = 276.03), p <.001. Similar results were found for set size 15, with target present trials being significantly faster (M = 1060.73, SD = 238.71) than target absent trials (M = 1467.87, SD = 386.65), p <.001. At set size 24, the same pattern emerged with target present trials being significantly faster (M = 1315.63, SD = 293.75) than target absent trials (M = 1798.11, SD = 426.58), p <.001. This pattern aligns with the use of exhaustive search approaches for target-absent trials, while the faster RTs for target-present trials likely reflect self-terminating search approaches.

All other interactions were non-significant, including the three-way interaction between trial type, set size, and alexithymia condition, $F(3.64, 131.15) = 0.67$, p = .600, B_{10} = 1/13.06. Bayes factor gave strong evidence in favour of the null hypothesis.

Figure 27:

Mean Reaction Times Across Set Sizes, Trial Types and Alexithymia Conditions



Note: Mean RTs for target-present (blue line) and target-absent trials (orange line) across each set size and alexithymia conditions. Error bars indicate standard deviations.

Search Slope. Figure 28 presents mean search slopes across target-present and target-absent trials. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (trial type: target-present, target-absent) mixed ANOVA. Trial type was entered as a within subject factor, and alexithymia condition was entered as a between-participants factor.

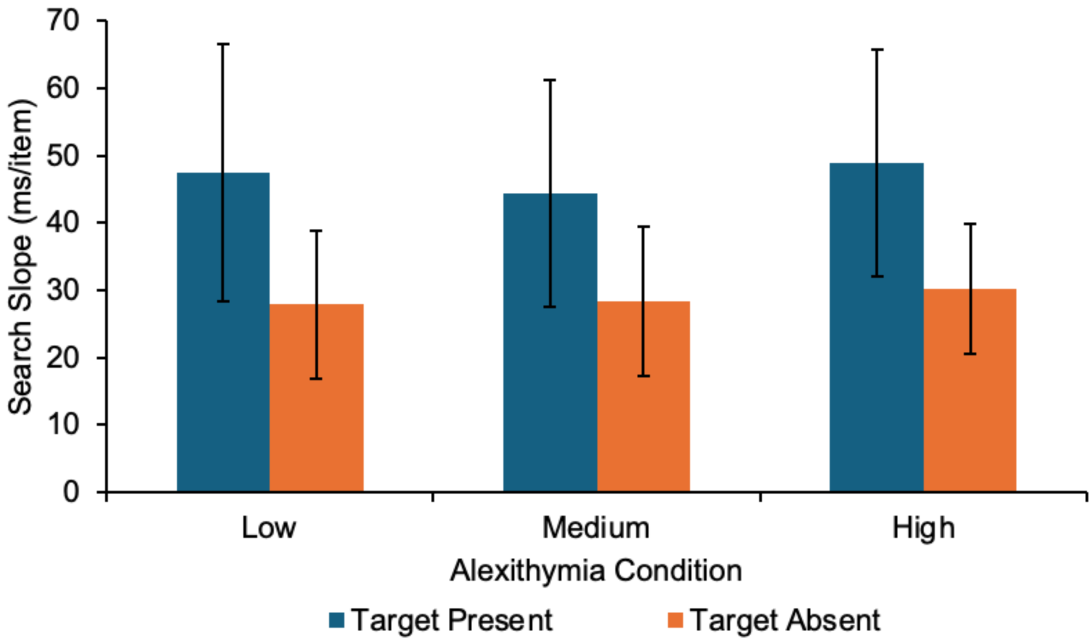
No significant differences in search slope were found between the three alexithymia conditions, $F(2, 72) = 0.21$, $p = 0.815$, $B_{10} = 1/8.93$. Bayesian analysis gave substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition). This finding indicates all three alexithymia conditions were equally impacted by set size, suggesting no pop-out effects were present across all alexithymia conditions.

A significant main effect of trial type was found, $F(1, 72) = 61.18$, $p<.001$, $n^2 = 0.17$, $B_{10} = 551829$. Bayes factor provides extreme evidence in favour of a significant main effect of trial type. As displayed in Figure 28 and confirmed by post-hoc t-tests, target-present trials had significantly lower (i.e., flatter) search slopes than target-absent trials ($p<.001$). The greater search slope observed for target-absent trials aligns with expectations for an exhaustive search approach. Although significantly faster than target absent, the target present search slopes (M = 28.045ms per item) were not low enough to indicate the use of highly efficient search processes or pop-out effects (i.e., 10 ms per item or below), suggesting less efficient search processes were used.

Finally, the two-way interaction between trial type and alexithymia condition was also found to be non-significant, $F(2, 72) = 0.50$, $p = 0.606$. The Bayesian mixed ANOVA yielded a B_{10} of 1/5.74, providing substantial evidence in favour of the null hypothesis (i.e., a non-significant interaction between trial type and alexithymia condition).

Figure 28:

Mean Search Slopes Across Trial Types and Alexithymia Conditions



Note: Mean search slopes across target present (blue bar) and target absent (orange bar) trials across alexithymia conditions. Error bars indicate standard deviations.

Accuracy. Data were submitted to a 3 (alexithymia condition: low, medium, high) x 2 (trial type: target-present, target-absent) x 3 (set size: 8, 15, 24) mixed ANOVA. Set size and trial type were entered as within-subject factors, and alexithymia condition was entered as a between-participants factor.

No significant differences in accuracy were found between the three alexithymia conditions, which was supported by Bayesian analysis, which gave substantial evidence against a main effect of alexithymia condition, $F(2, 72) = 0.42$, $p = 0.661$, $B_{10} = 1/8.06$. These findings do not fall in line with the expected results if alexithymia were associated with visual search advantages similar to those reported in autism spectrum disorder literature (Kaldy et al., 2016). However, as no direct assessment of ASD was conducted in the current study, these findings cannot definitively speak to the relationship between ASD-related visual search advantages and alexithymia levels.

A significant main effect was found for both trial type, $F(1, 72) = 30.77$, $p<.001$, $n^2 = 0.07$, $B_{10} = 62649577$, and set size, $F(1.49, 107.26) = 58.43$, $p<.001$, $n^2 = 0.09$, $B_{10} = 1304724431$. As displayed in Figure 29, these main effects were moderated by a significant two-way interaction, $F(1.51, 108.99) = 25.30$, $p<.001$, $n^2 = 0.03$, $B_{10} = 4213.65$, providing extreme evidence in favour of a significant interaction between trial type and set size. A series of post-hoc ANOVAs were completed to explore this interaction further, each assessing accuracy across set sizes for each trial type. A significant main effect of set size was found for target-present [$F(1.40, 99.99) = 49.35$, $p<.001$, $n^2 = 0.18$] and target-absent trials [$F(1.66, 119.74) = 11.31$, $p<.001$, $n^2 = 0.02$]. These main effects show that accuracy consistently decreased with larger set sizes, regardless of trial type. However, set size had a larger effect on target present trials, as evidenced by the larger F value for target present trials ($F = 49.35$) compared to target absent trials ($F = 11.31$). This is most likely because participants were more prone to missing the target in larger arrays, leading them to mistakenly respond ‘absent’.

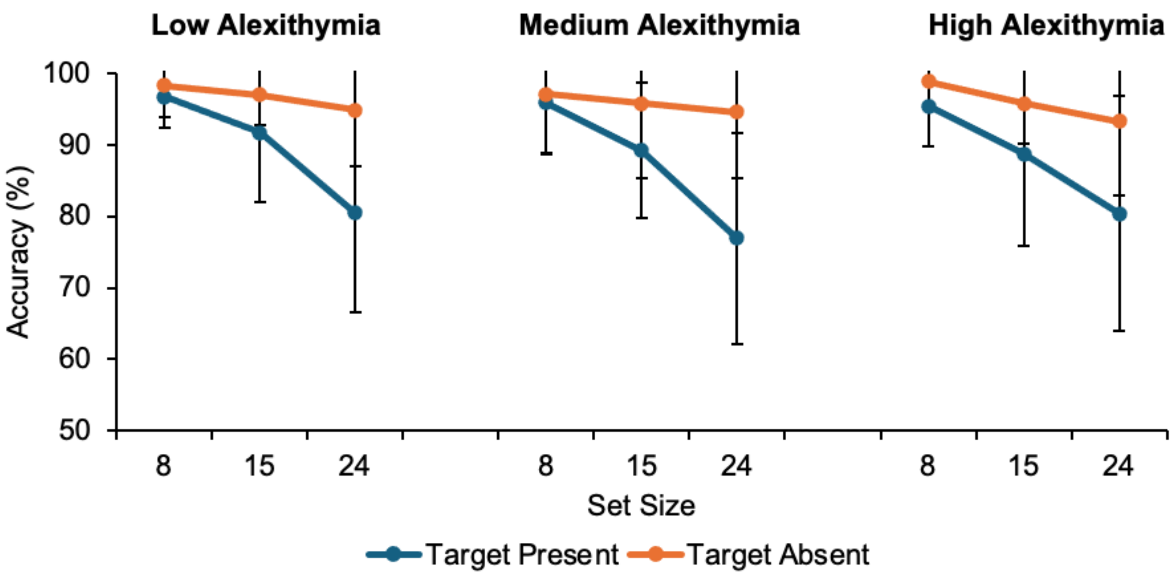
Furthermore, a series of post-hoc ANOVAs were also completed assessing accuracy across trial type for each set size. Analysis revealed significant main effects of target type across all set sizes. At set size 8, accuracy was significantly higher for target-absent trials ($M = 97.6\%$, $SD = 6.8$) compared to target-present trials ($M = 96.1\%$, $SD = 6.2$), $p = .004$. At set size 15, accuracy was once again significantly higher for target-absent trials ($M = 96.2\%$, $SD = 8.5$) compared to target-present trials ($M = 90\%$, $SD = 9.8$), $p < .001$. At set size 24, the same pattern emerged with target-absent trial accuracy significantly higher ($M = 94.5\%$, $SD = 8.8$) than target-present trial accuracy ($M = 78.4\%$, $SD = 8.8$), $p < .001$. As displayed in Figure 29, while these findings demonstrate accuracy declines for both trial types as set size increased, a steeper decline was observed for target detection compared to target-absent judgments (i.e., a decline of 17.7% compared to 3.1%). This likely reflects the greater difficulty of locating targets versus identifying the absence of a target in larger visual search arrays.

Finally, all other interactions were non-significant, including the three-way interaction between trial type, set size, and alexithymia condition, $F(3.03, 108.99) = 0.79$, $p = .506$, $B_{10} =$

1/13.06. Bayesian analysis gave strong evidence in favour of the null hypothesis (i.e., a non-significant three-way interaction).

Figure 29:

Mean Accuracy Across Set Size, Trial Type, and Alexithymia Conditions



Note: Mean accuracy for target-present (blue line) and target-absent (orange line) trials across each set size and alexithymia condition. Error bars indicate standard deviations.

Summary

The aim of the present study was to explore whether the general visual search advantage found among autistic individuals was also present for individuals with high alexithymia, given the high comorbidity between autism spectrum disorder and Alexithymia. To explore this, participants completed a visual search task of non-emotional stimuli (i.e., a 2 among 5's), and performance was then explored across the three alexithymia conditions. It is worth noting that the sample size for the high alexithymia conditions specifically was relatively small (i.e., 6 participants). Importantly, if a small sample size did not provide enough evidence to draw meaningful conclusions, we would typically see this reflected in the evidence provided by the Bayes factors. Specifically, evidence would fall in the 'Anecdotal' range. This was not the case with the present study, with all Bayesian ANOVA's providing substantial evidence in favour of the null hypothesis for RT, search slope, and accuracy, suggesting no significant impacts despite the small sample for low alexithymia.

Overall, no significant differences were observed between the alexithymia conditions across any performance measures (i.e., RT, search slope, and accuracy), suggesting no evidence for enhanced visual search performance in individuals with higher levels of alexithymia using this paradigm. These findings provide important context for interpreting the mixed results observed in Studies 1A-1C regarding alexithymia and emotional face detection. The unexpected advantage observed for high alexithymia participants in Study 1A, where they showed faster reaction times for emotional face detection, cannot be attributed to a general visual search advantage, as no such advantage emerged with non-emotional stimuli in the current study.

Additionally, the absence of visual search advantages in this study suggests that any relationship between alexithymia and non-emotional visual processing performance may differ from that observed in autism, though larger studies with direct autism assessment would be needed to draw firm conclusions about this relationship.

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Chapter 5: Study 4

Introduction

So far, the studies conducted within this thesis have painted a relatively clear picture of alexithymia and its general lack of impact on the anger superiority effect. Across studies 1A, 1B, and 1C using schematic stimuli, evidence of an anger superiority effect has been observed in both high and low alexithymia individuals. However, this effect was not replicated in Study 2 using photographic stimuli, which found no evidence supporting the anger superiority effect. This lack of evidence suggests that the anger superiority effect may not extend to environments with higher ecological validity or may even be driven by perceptual confounds within the schematic stimuli used. Additionally, no evidence of a general emotion detection or labelling deficit has been observed in higher alexithymia individuals across any of the studies. Study 1A actually found that higher alexithymia participants showed faster reaction times when detecting emotional faces, while Studies 1B, 1C, 2, and 3 found no performance differences between alexithymia groups. This finding conflicts with the current consensus within the alexithymia literature that higher alexithymia is tied to poorer emotional processing (Jessimer & Markham, 1997; Lane et al., 2000; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Prkachin et al., 2009; Ridout et al., 2010; Swart et al., 2009).

Additionally, the findings from Study 2 suggest that the type of distractor stimuli used may influence the detection of anger superiority effects. Study 2 indicated that when emotional distractors are used (happy faces among angry targets), the additional cognitive demands potentially required to process these emotionally arousing distractors could interfere with the detection of anger-specific advantages that appear with neutral distractors.

All studies within this thesis thus far have been designed to explore emotion knowledge specifically within the detection/identification phase (i.e., the face-in-the-crowd task), which is primarily tied to the deployment of attention (Wolfe, 2021). While reaction time is the most commonly used measure of attention deployment in visual search tasks, it is not the only measure available. Some researchers have argued that RT provides a secondary measure of attentional allocation due to its reliance on post-target selection motor responses (e.g., pressing a response key) rather than the immediate visual detection of a target. As such, RT may represent a delayed measure of attention deployment (Liu et al., 2020).

A common alternative to RT is the use of electroencephalography (EEG) to measure brain activation following exposure to specific target stimuli, also known as event-related potentials (ERPs). Reutter et al. (2017) conducted a study comparing different measures of attention, including reaction time and the N2pc ERP component, to determine the best measure of attentional engagement and deployment in a Dot Probe Task. To assess the internal consistency of each measure, Reutter et al. computed odd-even reliability by calculating the attentional bias scores for odd and even trials and correlating the results across all participants. Essentially, attentional measures that display a high correlation between odd and even trials are said to be a more reliable measure of attentional bias overall (Pourmehdi et al., 2021). Reutter et al. found no evidence of attentional biases for threatening faces based on reaction times; however, they also found that the odd-even reliability did not significantly differ from zero, suggesting poor internal reliability for reaction time as a measure. In contrast, the N2pc displayed clearer and more internally consistent and reliable results according to the odd-even reliability. The amplitude of the N2pc ERP component showed a significant attentional bias for angry targets overall. At the same time, peak latency of the N2pc displayed an attentional bias for angry targets only when presented in the left visual hemifield. Reutter et al. (2017) discuss possible impacts of differing methodology on internal reliability measures for attentional bias. As their study utilised a dot probe paradigm, which involves the presentation of distractor stimuli (i.e., the emotional faces) before the presentation of the response stimuli (i.e., : versus × ×), the N2pc may reflect participants' response to the distractor stimuli while the RT reflects their response to the response stimuli. As other visual search tasks, including the face-in-the-crowd task, typically involve responding to the facial stimuli itself, this difference in attentional bias between RT and the N2pc observed in Reutter et al.'s dot-probe task may not be present. Regardless, it raises the interesting possibility that attentional biases may be sensitive to the types of measurements used. Based on the findings of Reutter et al. (2017), it was determined that an additional measure of attentional bias, namely the N2pc ERP component, would be a beneficial addition to this thesis to ensure accurate investigation of attentional bias across target types and alexithymia conditions.

The N2pc has been proposed to reflect the process of "filtering out" distractors when identifying a target based on attentional focus (Luck, 2012; Weiser et al., 2018). The N2pc is derived from activity within the posterior regions of the left and right hemispheres of the brain, and typically occurs in the contralateral hemisphere to the attended visual target (Luck & Kappenman, 2012). For example, if the attended target is located in the left visual field, the resulting N2pc will occur in the brain's right hemisphere. The N2pc component is often presented as a difference wave comparing brain activation across the two hemispheres (i.e., contralateral activity minus ipsilateral activity).

Several ERP studies have found that facial expressions can modulate the N2pc, with Grimshaw et al. (2014) and Holmes et al. (2014) both finding larger N2pc amplitudes in response to fearful and angry faces compared to happy and neutral faces in a dot-probe task. Visual search tasks have also displayed similar findings, with larger N2pc amplitudes observed for fearful and angry faces in a study by Weymar et al. (2011). Evidence as to whether N2pc amplitude and latency differ for angry faces is mixed, much like evidence for the anger superiority effect as a whole. A meta-analysis by Liu et al. (2020) exploring the anger superiority effect in N2pc studies found that emotional faces (i.e., angry and happy) elicited significantly more pronounced N2pc amplitudes than neutral ones. Despite the N2pc amplitudes being more pronounced for angry than happy emotional faces, this difference was not statistically significant and therefore does not support the anger superiority effect. To the best of my knowledge, no studies have yet investigated differences in the N2pc ERP component between low and higher alexithymia individuals during the processing of emotional facial expressions.

In the context of visual search tasks, the N2pc therefore provides a neural measure of how much attentional effort is required to detect and select emotional targets from among distractors

(Luck 2012 This component can offer insights into an individual's capacity to effectively filter out distractors during target identification. Such information may help explain the differing results between studies 1A-1C (which used neutral distractors) and study 2 (which used emotional distractors), as the N2pc could reveal whether distractor type influences the neural mechanisms underlying attentional selection (Luck, 2012; Weiser et al., 2018).

Based on Weymar et al.'s findings and the evidence from studies 1A-1C supporting an anger superiority effect, it was expected that larger N2pc amplitudes and earlier N2pc latencies would be found for angry targets within a face-in-the-crowd task. Furthermore, drawing on the findings of Reutter et al. (2017) which demonstrated that the N2pc is a more sensitive indicator of attentional allocation than reaction time, it was predicted that individuals in the high alexithymia condition would show diminished and delayed attentional allocation with emotional targets, reflected by reduced N2pc amplitudes and delayed onset latencies. To further explore the significant anger superiority effect findings found in studies 1A-1C, and the non-significant visual search differences in alexithymia found in studies 1B, 1C and 3, the present study will mirror the methods of studies 1A-1C as closely as possible (e.g., same schematic stimuli). Any variation in methodology is discussed below, with relevant justifications.

Hypotheses

Hypothesis 1: A main effect of target type will be found for reaction times whereby angry target faces will be detected significantly faster than happy target faces, replicating the anger superiority effect observed with schematic stimuli in previous studies (e.g., Weymar et al., 2011).

Hypothesis 2: A main effect of target type will be found for detection accuracy whereby angry target faces will be detected significantly more accurately than happy target faces, providing behavioral evidence for the anger superiority effect consistent with prior findings.

Hypothesis 3: A main effect of target type will be found for N2pc onset and peak latency whereby angry target faces will elicit significantly earlier onset latencies compared to happy target faces, providing neural evidence for faster attentional deployment to threatening stimuli (e.g., Weymar et al., 2011).

Hypothesis 4: A main effect of target type will be found for N2pc mean and peak amplitude whereby angry target faces will elicit significantly larger peak amplitudes compared to happy target faces, reflecting enhanced attentional allocation to threatening facial expressions consistent with the anger superiority effect.

Hypothesis 5: No significant main effect of alexithymia condition will be found for behavioral measures (reaction times and accuracy), replicating the lack of performance differences observed in Studies 1B, 1C, and 2.

Hypothesis 6: A main effect of alexithymia condition will be found for neural measures whereby higher alexithymia participants will show significantly reduced N2pc amplitudes and delayed onset latencies compared to lower alexithymia participants, reflecting impaired attentional deployment to emotional faces consistent with documented emotional processing deficits (e.g., Grynberg et al., 2012; Prkachin et al., 2009) and the superior sensitivity of neural measures in detecting attentional biases (Reutter et al., 2017).

Method

Participants

The present study was divided into two parts. Participants for part 1 consisted of 79 first-year psychology students (62 females; range 18 - 54 years; M = 22.7, SD = 7.79). Participants for part 2 consisted of 50 first-year psychology students. All participants were recruited from Flinders University. All participants were fluent in English and had normal or corrected-to-normal visual acuity. The present study consisted of two parts. For part 1, participants received 30 minutes of course credit for their completion of an online questionnaire assessing Alexithymia; the Perth Alexithymia Questionnaire (PAQ; Preece et al., 2018). Based on their results on the PAQ, the 25 lowest and highest scoring participants were invited to proceed to part 2 of the present study and were allocated to a low or high Alexithymia condition. The participants who chose to complete part

2 received two hours of course credit for their participation in a single in-person experimental session that lasted approximately 90 minutes. Scores within the low alexithymia condition ranged from 30 - 58, and scores within the high alexithymia condition ranged from 92 - 135.

Of the 50 individuals who completed the in-person experimental session, 12 participants did not meet the inclusion criteria following artifact rejection (i.e., more than 50% of trials were rejected due to artifacts and/or less than 50% of target-left or target-right trials remained following artifact rejection). This inclusion criterion was based on the methodology of Couperus et al. (2021), who explored attention allocation via the N2pc component using a non-emotional visual search task. A further 13 participants were excluded due to technical or other issues occurring during one of the EEG measurements. After these exclusions, 25 participants were left for our final analysis (14 females; range 18 - 54 years; M = 26.54, SD = 9.72, 14 low alexithymia, 11 high alexithymia, 21 right-handed).

The initial chosen sample size of 50 participants was based on Wirth & Wentura (2023), who found significant evidence of an anger superiority effect using a dot probe task with a sample size of 48. The study received ethical approval from the Social and Behavioural Research Ethics Committee at Flinders University, and consent was obtained from all participants.

Research Design

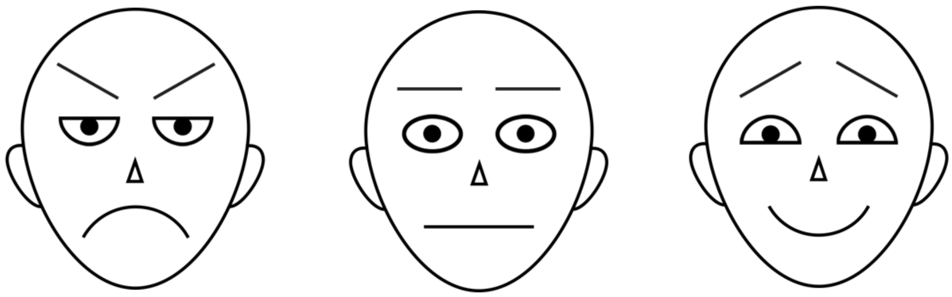
The present study used a 2 (alexithymia condition: Low Alexithymia, High Alexithymia) x 2 (target: angry, happy) x 2 (trial type: target-present, target-absent) mixed design. Participants completed four experimental blocks, each consisting of 240 trials, with target type and trial type being randomly selected across trials with exactly 50% probability. Electroencephalography (EEG) was used to measure the amplitude and latency of the N2pc component across the task. The dependent variables were target-present and target-absent reaction times, accuracy, and EEG amplitude.

Stimuli and Apparatus

Stimuli consisted of three schematic faces displaying an angry, happy, or neutral expression and were created based on stimuli used by Öhman et al. (2001). Schematic stimuli were used to replicate the design of Weymar et al.'s (2011) study, who found larger N2pc amplitudes for fearful and angry faces using similar stimuli. The images were 593 x 639 pixels in size and were created in Adobe Illustrator. The three emotional faces used as stimuli are displayed in Figure 30.

Figure 30:

Sample Stimulus Images



Note: Sample angry (leftmost), neutral (centre) and happy (rightmost) stimulus images.

The emotional faces discussed above were then presented in a circle around a central fixation cross, with a radius of 45mm. As the N2pc is obtained by comparing neural activity at posterior electrodes contralateral (i.e., opposite side) and ipsilateral (i.e., same side) to the target location, lateralised target presentation (i.e., target presentation in either the left or right visual field) is a crucial component to eliciting the N2pc component. A circular presentation of stimuli was chosen as it allowed for lateralised presentation while ensuring targets were close enough to the fixation cross to be observed using peripheral vision. Stimuli images were presented at an angle of 45° from the central point of the screen. The stimulus images were sized at a width of 2cm and a height of 2.5cm based on the method of Wieser et al. (2018).

Measures

Reaction time. Mean RTs were calculated by averaging RTs from accurate responses only. Inaccurate RTs were excluded from analysis.

Accuracy. Accuracy was calculated as the proportion of correct responses relative to the total number of trials.

Mean Amplitude of N2pc Wave. The mean amplitude of the N2pc difference wave was calculated by averaging the amplitude of the contralateral-minus-ipsilateral waveform within the time window of 180-300 ms. Electrode sites P7 and P8 were used, and time windows were selected based on prior research highlighting that the N2pc ERP is maximal at these sites and within this time window (Holmes et al., 2009; Reutter et al., 2017).

Peak Amplitude of N2pc Wave. Peak amplitude of the N2pc difference wave was defined as the most negative point within the time window of 180-300ms on the contralateral-minus-ipsilateral waveform. Electrode sites P7 and P8 were used.

Onset Latency of N2pc Wave. The Onset latency of the N2pc difference wave was measured using the 50% peak latency method, which identifies the time point when the contralateral-minus-ipsilateral waveform first reached half of its peak amplitude within the time window of 100-275ms at electrode sites P7 and P8.

Peak Latency of N2pc Wave. Peak latency of the N2pc difference wave was defined as the time point where the contralateral-minus-ipsilateral waveform reached its most negative value within the time window of 100-275ms at electrode sites P7 and P8.

Procedure

Participants were recruited via SONA. Part 1 of the present study consisted of a screening process. Participants were required to complete an online version of the Perth Alexithymia Questionnaire (PAQ) via Qualtrics, which was then used to determine eligibility to proceed to part 2 of the present study. Eligible participants were then invited to participate in part 2, an in-person visual search task.

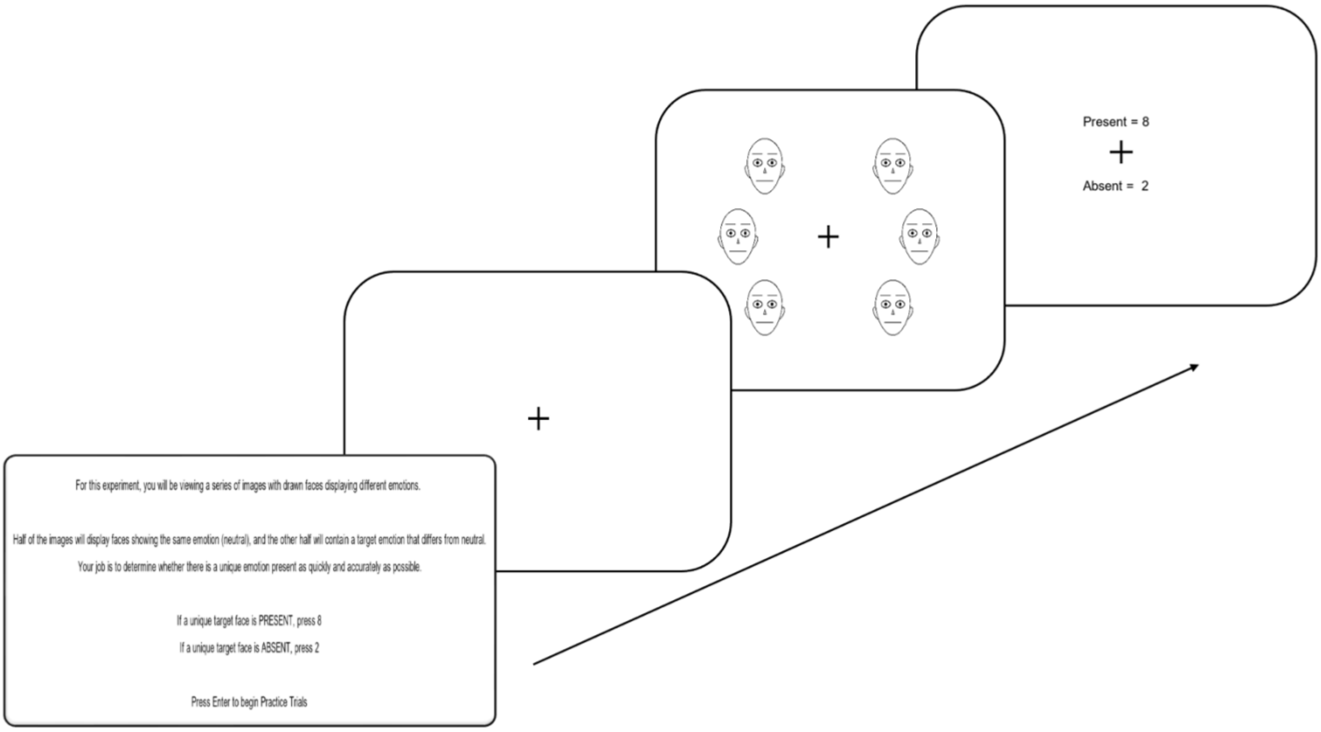
Prior to beginning the task, participants were asked to read through an information sheet describing the study, what was expected of them, and their rights as participants, and sign a consent form and a COVID-19 screening form. Part 2 of this study was conducted in person in the Brain and Cognition Laboratory. Participants were fitted with an EEG cap and asked to view a series of images with six drawn faces displaying different emotions. Following this, the participant's task was to determine whether the faces displayed on screen belonged to the same emotion category. Participants' viewing distance was constrained to 57cm using a chin rest. Trials began with the appearance of a central fixation cross, which appeared for 1000-ms ± 100 with uniform distribution (i.e. inter-trial interval is randomised from 900 - 1100 ms inclusive) and was then followed by the stimulus arrays. The stimulus arrays were presented in randomised order. As based on the methodology used in Kappenman et al. (2021), stimulus arrays were displayed for 500ms or until the participant made a response. Following a trial, an intertrial interval of 1000-ms ± 100 with uniform distribution occurred prior to the commencement of the next trial. Prior to beginning the task, subjects were instructed to avoid eye blinks and excessive body movements for the duration of the study, and particularly during the stimulus presentation period.

Participants were asked to make their response using the number pad on a keyboard, with participants pressing the number '2' or the number '8' depending on whether if they believed a target emotional face was present (i.e., a happy or angry face) or absent (i.e., all neutral faces). The keys used to make responses were randomly allocated between participants (i.e., '8' for target present and '2' for target absent and vice versa). Participants responded with one hand, and were not asked to respond with specific fingers. Participants were asked to respond as quickly and accurately as possible. A face displaying a target emotion (either anger or happiness) was present in 50% of the trials, with the remaining 50% consisting only of neutral distractor faces. For the duration of the study, participants were monitored to ensure their gaze remained in the centre of the screen.

Prior to beginning the experimental trials, participants completed 30 practice trials to aid in their understanding of the task. Participants did not receive feedback on their performance on the task. Figure 31 provides an example of the sequence of events for a target-absent trial.

Figure 31:

Example Sequence of Events for a Target-absent Trial



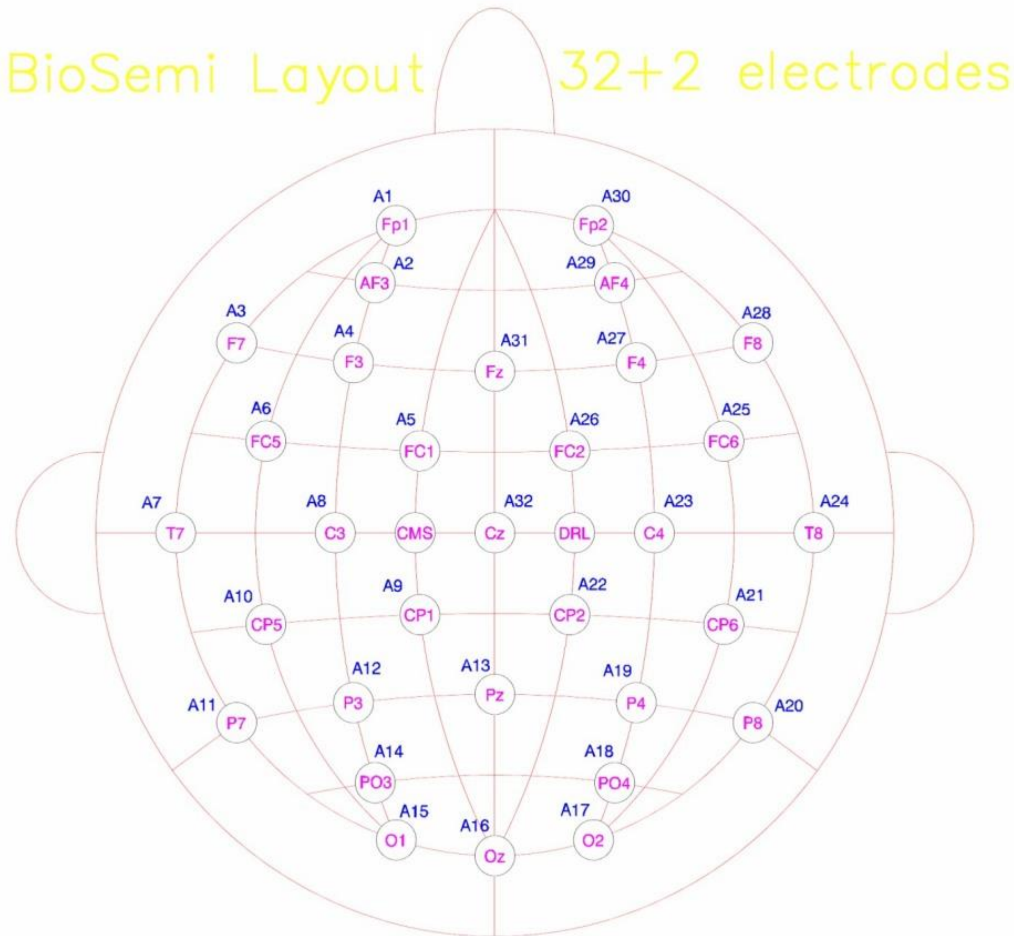
EEG Recording

The continuous EEG was recorded using a Biosemi ActiveTwo recording system with active electrodes (Biosemi B.V., Amsterdam, the Netherlands). We recorded from 32 scalp electrodes, mounted in an elastic cap and placed according to the International 10/20 System

(FP1, AF3, F3, F7, FC1, FC5, C3, T7, CP1, CP5, P3, P7, PO3, O1, Oz, Pz, Cz, Fz, FP2, AF4, F4, F8, FC2, FC6, C4, T8, CP2, CP6, P4, P8, PO4, O2; see Figure 32).

Figure 32:

BioSemi 32 Channel EEG Layout



The horizontal electrooculogram (HEOG) was recorded from electrodes placed on the outer corner of each eye. The vertical electrooculogram (VEOG) was recorded from an electrode placed below the left eye. All signals were low-pass filtered using a fifth-order sinc filter with a half-power cutoff at 204.8 Hz and then digitised at 1024 Hz with 24 bits of resolution.

Signal Processing and Averaging

Signal processing and analysis were performed in MATLAB using EEGLAB toolbox (version 13_4_4b; Delorme & Makeig, 2004) and ERPLAB toolbox (version 8.001; Lopez-Calderon and Luck, 2014).

To increase data processing speeds, the EEG and EOG signals were downsampled to 256 Hz. Electrodes placed on the mastoids were used as an offline reference for the EEG signals. A bipolar HEOG signal was computed as left HEOG minus right HEOG. A bipolar VEOG signal was computed as lower VEOG minus FP1.

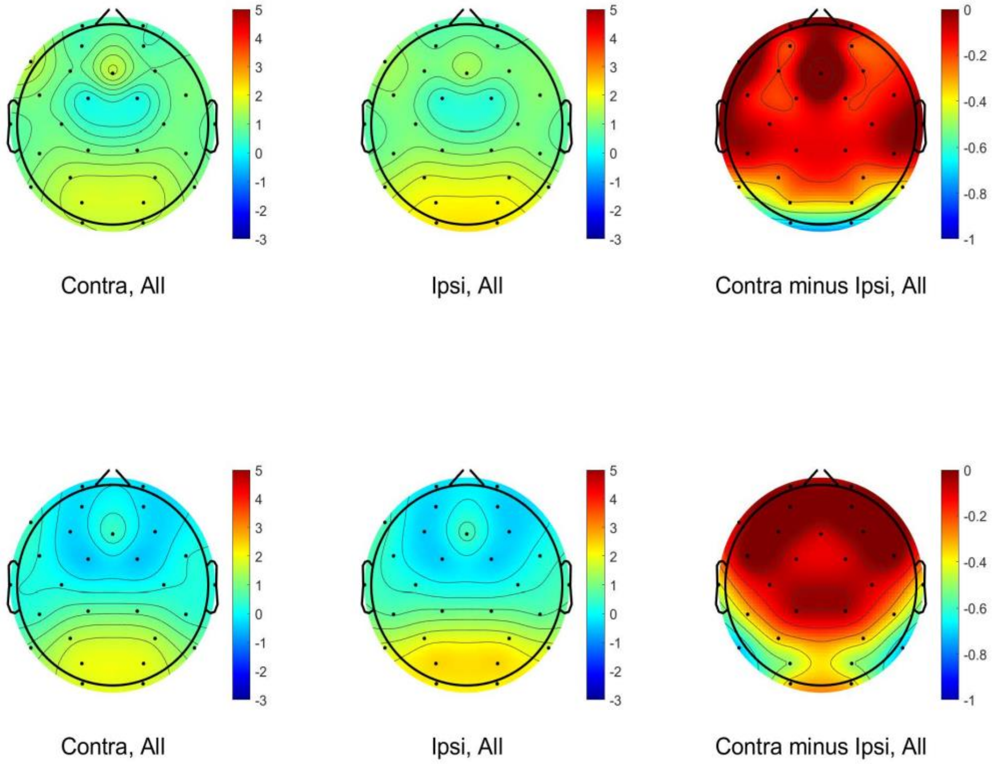
The EEG signals were high-pass filtered (non-causal Butterworth impulse response function, half-amplitude cut-off at 0.1 Hz, 12 dB/oct roll-off), and DC offsets were removed.

Portions of EEG containing extreme voltage offsets, large muscle artifacts, or break periods longer than two seconds were identified by the ERPLAB algorithm and removed in preparation for artifact correction. Following this, independent component analysis (ICA) was performed, and components that were clearly associated with eyeblinks or large muscle movements were removed. The components were analysed using the ICLabel EEGLAB plug-in (ICLabel v1.2.6; Pion-Tonachini et al., 2019), which classifies brain and non-brain components based on their waveforms and scalp topographies. Standard ICA rejection relies solely on visual inspection completed by researchers, a subjective process that, depending on the experience and training of the researcher completing it, can be prone to misclassifications (Pion-Tonachini et al., 2019). In contrast, automated processing using ICLabel has been found to encourage greater consistency in identifying eyeblinks and muscle movements (Pernet et al., 2021; Pion-Tonachini et al., 2019). For the present study, ICLabel was used to calculate the probability of each component being caused by eye movements or muscle artifacts. Components with a probability equal to or exceeding 80% were removed. This probability benchmark was selected based on the method used by Pernet et al. (2021), who employed a similar analysis method. Corrected bipolar HEOG and VEOG signals were computed from the ICA-corrected data. To provide a record of ocular and muscular artifacts present in the original data, the uncorrected bipolar HEOG and VEOG signals were also retained.

The data were segmented and baseline-corrected for each trial with an epoch window of -200 to 800 ms from stimulus onset (baseline period equal to -200 to stimulus onset). No channels were deemed to have excessive noise based on visual inspections, meaning none of the data was interpolated.

Figure 33:

Grand Average Topographic Maps



Note: Grand average topographic maps of the contralateral and ipsilateral waveforms (left and centre panel, respectively) and difference waveform (right panel) during the N2pc window period (i.e., 180 - 300 ms) for low alexithymia participants (see upper image) and high alexithymia participants (see lower image).

Any remaining data containing artifacts were then flagged and excluded from analysis using automated ERPLAB procedures with set thresholds being used across all participants, which varied slightly based on the artifacts being examined. For identifying commonly recorded artifactual potentials (CRAP), the simple voltage threshold algorithm (threshold of -200 to 200) and the moving window peak-to-peak algorithm (threshold of 100) were used.

To identify eyeblinks and horizontal eye movements within the stimulus presentation period for the non-ICA corrected VEOG signal, the moving peak-to-peak algorithm (threshold of 150) and the step-like algorithm (threshold of 32) were used, respectively. Finally, to identify any uncorrected horizontal eye movements within the ICA corrected signal, the step-like algorithm was used (threshold of 64). Additionally, any trials containing large voltage excursions in any channel were excluded. Threshold values across all algorithms used were chosen based on the pre-selected values within ERPLAB's pre-processing script (Lopez-Calderon & Luck, 2014).

As ICA does not always correct eye movements perfectly, any trials with evidence of large eye movements (greater than 4° of visual angle) were discarded from the corrected HEOG. Furthermore, trials that contained horizontal eye movements greater than 0.2° of visual angle that occurred between -50 and 350ms relative to stimulus onset were removed to ensure the N2pc remained unimpacted. Finally, any trials in which an eyeblink or horizontal eye movement was present in the uncorrected HEOG or VEOG signal were also excluded. Trials with incorrect behavioural responses were excluded from all analyses.

Reaction times (RTs) that were observed to be excessively fast or slow (i.e., faster than 200ms and slower than 4000ms) were also excluded from all analyses. Finally, the proportion of correct trials within the accepted RT period prior to artifact rejection was used to calculate accuracy.

Component Isolation with Difference waves

Separate stimulus-locked averages were created for left-side and right-side targets. The data was then collapsed across visual fields into contralateral waveforms (i.e., right hemisphere electrodes for targets presented on the left and vice versa) and ipsilateral waveforms (i.e., right hemisphere electrodes for targets presented on the right and vice versa). A contralateral-minus-ipsilateral difference waveform was then computed to isolate the N2pc component. The measurement procedures described below were used for the calculation of all amplitude and latency measurements on the difference waves.

Amplitude and Latency Measures

Prior to beginning analyses, the decision was made for the N2pc to be measured at electrode sites P7 and P8 between the time window of 180-300ms. This decision was based on prior research highlighting that the N2pc ERP is maximal at these sites and within this time window (Holmes et al., 2009; Reutter et al., 2017).

Using the electrode sites of P7 and P8, and the time window of 180 - 300ms, we measured the mean amplitude, peak amplitude, and peak latency from the N2pc difference waves. We also calculated the peak onset latency (i.e., the time at which the voltage reaches 50% of the peak amplitude; see Kiesel et al., 2008; Kappenman et al., 2021), however measurement windows were shifted 100 ms earlier for these peak onset measurements.

Results and Discussion

Behavioural Data

The purpose of the present study was to explore differences in the deployment of attention between different target types and alexithymia severities. Therefore, the decision was made to only report target-present reaction times, consistent with the methodology used for N2pc calculations.

Target-Present Reaction Time (RT). Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

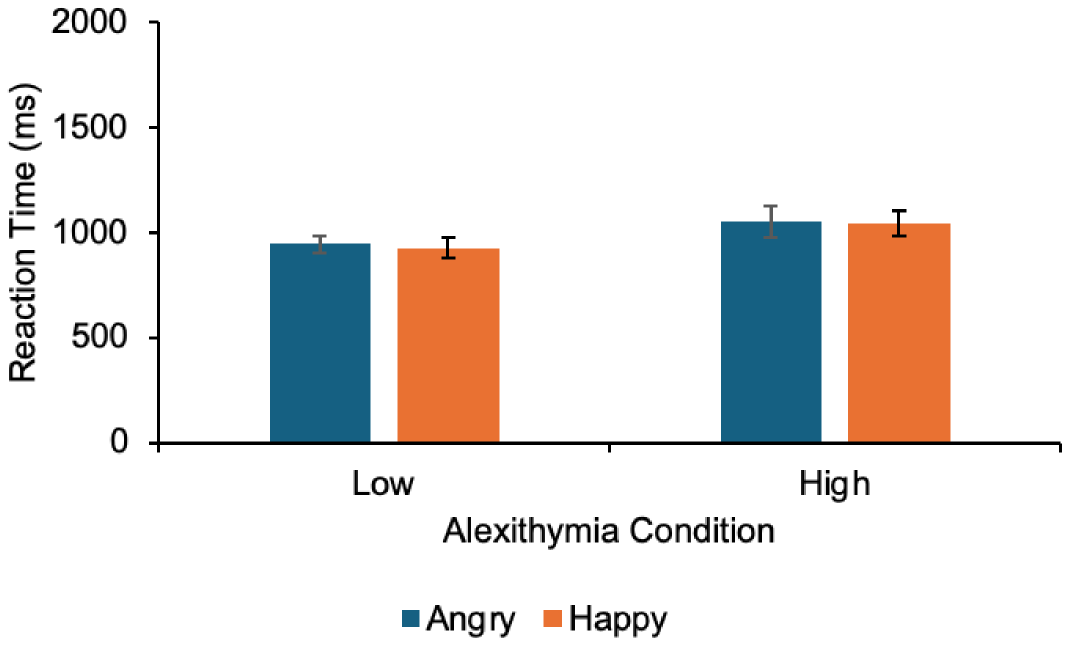
No significant differences in RT were observed between the two alexithymia conditions, $F(1, 23) = 2.19$, $p = 0.152$, $B_{10} = 2.04$. This finding suggests that individuals with higher alexithymia detect target faces at the same speed as those with lower alexithymia, which aligns with the previous results from studies 1B, 1C, and 2. Bayes factors analysis gave anecdotal evidence in favour of a main effect; however, this evidence is not strong enough to draw concrete conclusions from (Wetzels et al., 2011). Further data would be required to form stronger conclusions from a Bayesian perspective.

A significant main effect of target type was found and is shown in Figure 34, $F(1, 23) = 5.49$, $p = 0.028$, $n^2 = 0.09$, $B_{10} = 1/1.97$. As shown in Figure 34, participants were significantly faster at detecting angry faces than happy ones. Bayes factor analysis gave anecdotal evidence against a main effect, contradicting the significant main effect found using the frequentist approach.

Finally, the two-way interaction between target type and alexithymia condition was also non-significant, $F(1, 23) = 2.80$, $p = 0.108$, $B_{10} = 1/2.62$. Bayesian analysis gave anecdotal evidence in favour of the null hypothesis (i.e., a non-significant interaction), again suggesting the need for further data to draw stronger conclusions.

Figure 34:

Mean RT Across Target Types and Alexithymia Conditions



Note: Mean target-present RTs for angry (blue bar) and happy target trials (orange bar) across alexithymia condition. Error bars indicate standard errors.

Accuracy. Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

No significant differences in accuracy were observed between the two alexithymia conditions, $F(1, 23) = 0.42$, $p = 0.526$, $B_{10} = 1/2.53$. This finding suggests no differences in accuracy between high and low alexithymia, which aligns with previous findings from studies within this thesis. Once again, Bayesian analysis gave only anecdotal evidence in favour of the null hypothesis (i.e., a non-significant main effect), indicating the need for further data to draw more concrete conclusions.

No significant differences in accuracy were observed between happy and angry target trials, $F(1, 23) = 0.10$, $p = 0.751$, $B_{10} = 1/3.40$. In support of this non-significant main effect of target type, Bayesian analysis gave substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect). These findings contradict the accuracy results found in studies 1A and 1B, however they fall in line with the results found in studies 1C and 3. Furthermore, these findings contradict those of Öhman et al. (2001), who found greater accuracy when identifying angry faces compared to friendly (i.e., happy), scheming and sad faces.

Finally, the two-way interaction between target type and alexithymia condition was also non-significant, $F(1, 23) = 0.64$, $p = 0.430$, $B_{10} = 1/2.61$. Bayesian analysis gave anecdotal evidence in favour of the null hypothesis (i.e., a non-significant interaction), again suggesting the need for further data to draw stronger conclusions.

Electrophysiological Data

Mean Amplitude of N2pc Wave. Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

No significant difference in N2pc mean amplitude was observed between the high and low alexithymia conditions, $F(1,23) = 0.07$, $p = .789$, $B_{10} = 1/3.42$. This non-significant effect is supported by Bayesian analysis, which gave substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition). As greater amplitude of the N2pc typically suggests greater allocation of attention, this non-significant finding suggests that attention allocation was equal among low and high alexithymia individuals (Eimer, 1996; Weymar, 2011).

Additionally, no significant differences in N2pc mean amplitude were observed between angry and happy target trials, $F(1,23) = 0.04$, $p = .852$, $B_{10} = 1/3.77$. Bayesian ANOVA also gave substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of target type). These non-significant results again suggest that attention allocation performance was the same regardless of target type, contradicting the significant findings of Weymar et al. (2011) and supporting the non-significant findings of Liu et al.'s (2020) meta-analysis. Overall, these results do not fall in line with the expectations of the anger superiority effect.

The two-way interaction between target type and alexithymia condition was non-significant, $F(1, 23) = 0.26$, $p = 0.616$, $B_{10} = 1/2.66$. Bayesian analysis, however, gave only anecdotal evidence in favour of the null hypothesis (i.e., a non-significant interaction), meaning further data is needed to confirm there was no interaction between target type and alexithymia condition for mean amplitude.

Peak Amplitude of N2pc Waves. Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

No significant difference in N2pc peak amplitude was found between the two alexithymia conditions, $F(1,23) = 0.02$, $p = .901$, $B_{10} = 1/3.35$. The calculated Bayes factor supports this non-significance, giving substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition). This non-significant main effect suggests, as discussed above, that there was no difference in the allocation of spatial attention between the high and low alexithymia conditions. This finding supports the consistent lack of difference in visual search performance across alexithymia severity observed in studies 1B, 1C and 2.

Additionally, no significant difference in N2pc peak amplitude was found across happy and angry targets, $F(1,23) = 0.94$, $p = .343$, $B_{10} = 1/2.64$. The Bayesian ANOVA gave anecdotal evidence in favour of the null hypothesis (i.e., a non-significant main effect of target type). This non-significant effect suggests a difference in attention allocation between angry and happy target faces, contrary to expectations based on the anger superiority effect and the findings of Weymar et al. (2011).

The two-way interaction was also found to be non-significant, $F(1, 23) = 0.04$, $p = 0.343$, $B_{10} = 1/2.54$. Bayesian analysis, however, gave only anecdotal evidence in favour of the null hypothesis (i.e., a non-significant two-way interaction).

Onset Latency of the N2pc Wave. Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

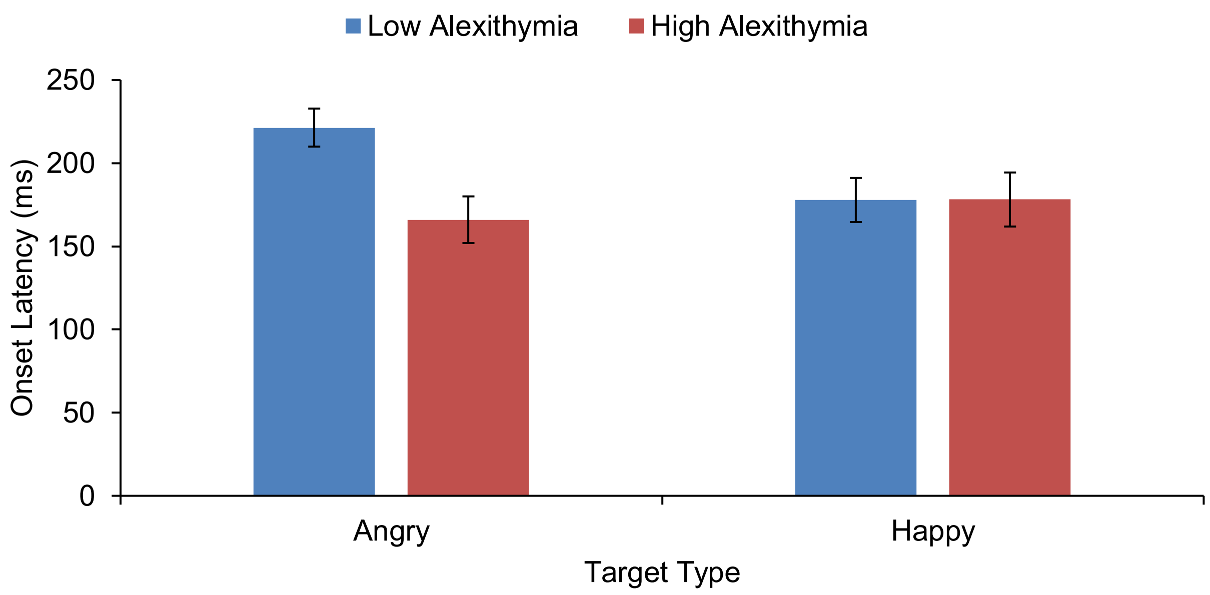
No significant differences in onset latency were observed between high and low alexithymia participants, $F(1,23) = 3.84$, $p = .062$, $B_{10} = 1.44$. Bayesian analysis gave anecdotal evidence in favour of a significant main effect of alexithymia condition, suggesting the need for further data. This finding indicates there were no significant differences in the onset of the N2pc, and therefore the onset of attention allocation, between high and low alexithymia participants. This non-significant finding supports the evidence from studies 1B, 1C, and two, which suggest that alexithymia severity appears to have no impact on performance in the face-in-the-crowd task, suggesting deficits may instead occur at a later stage of processing.

In contrast with the findings of studies 1A, 1B, 1C, and 2, no significant difference in onset latency was found between angry and happy targets, $F(1,23) = 1.33$, $p = .262$, $B_{10} = 1/2.64$. Bayesian analysis gave anecdotal evidence in favour of the null hypothesis. This non-significant effect of onset latency between target types suggests there was no difference in the timing of initial attention allocation between the two target types, meaning there was no evidence of faster detection of angry targets. Importantly, this finding contradicts the findings of RT, with a significant main effect of target type being found. Not only does this finding not support the existence of the anger superiority effect, but it also contradicts the findings of Weymar et al. (2011), who found faster RTs and greater N2pc amplitude for angry target faces. It is worth noting that the schematic stimuli used by Weymar et al. (2011) were the same schematic faces used in Öhman et al.'s 2001 face-in-the-crowd study. As the stimuli in the present study were developed based on the stimuli used in Öhman et al. (2001) and Weymar et al. (2011), it would be expected that similar results supporting the anger superiority effect would be observed in the present study.

No significant two-way interaction was found between alexithymia condition and target type, $F(1,23) = 4.16$, $p = .053$, $B_{10} = 1.80$. Bayesian analysis, in contrast, gave anecdotal evidence in favour of a significant interaction. It is important to note that, despite this non-significant two-way interaction, post-hoc analysis does show a significant difference in the onset latency of the N2pc waves between the high alexithymia (M = 166.02, SE = 14.004) and low alexithymia (M = 221.35, SE = 11.43) conditions for angry target trials, $p = .033$, $d = -1.154$. This difference between onset latency for the high and low alexithymia conditions was not significant for happy target trials (p = 1). Figure 35 displays the onset latency of the N2pc difference waves across alexithymia conditions and target types.

Figure 35:

Onset Latency Across Target Types and Alexithymia Conditions



Note: Onset Latency of the N2pc difference wave for angry and happy target trials across low (blue bars) and high (red bars) alexithymia participants. Error bars indicate standard errors.

Latency of Peak N2pc Waves. Data were submitted to a 2 (alexithymia condition: low, high) x 2 (target type: angry, happy) mixed ANOVA. Target type was entered as a within-participants factor, and alexithymia condition was entered as a between-participants factor.

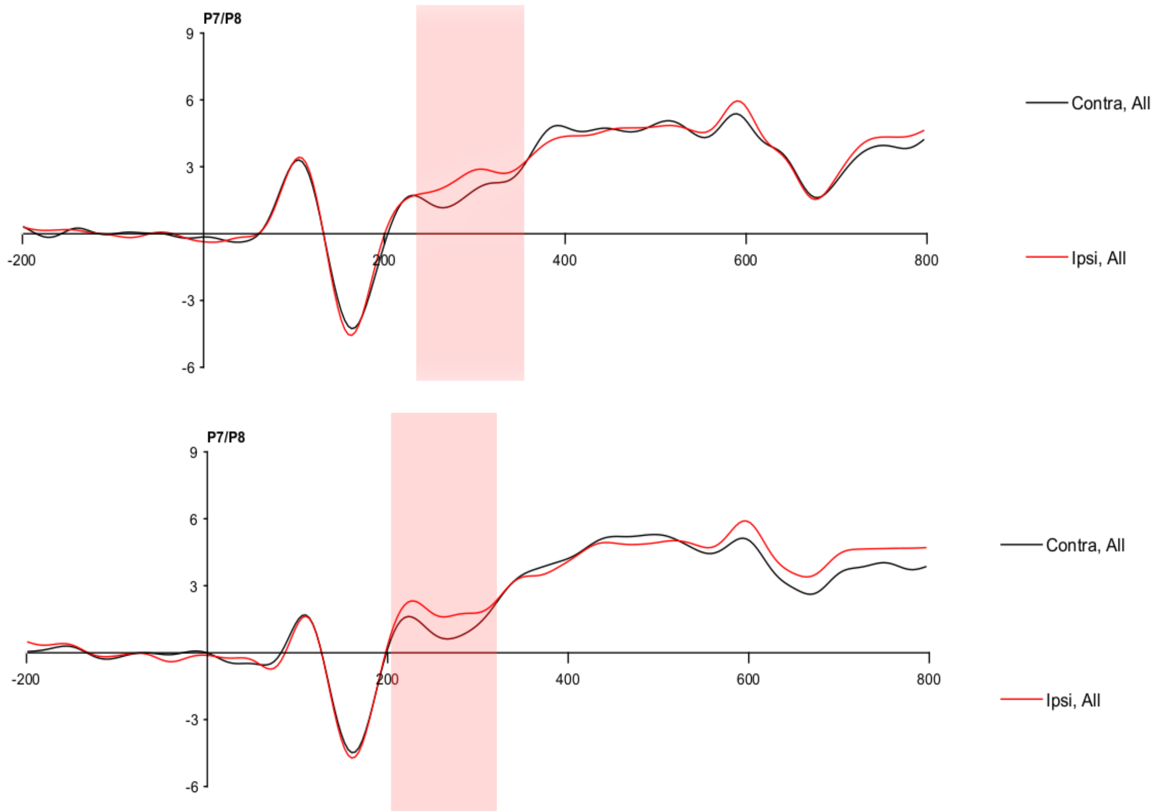
No significant differences in peak latency were found between the two alexithymia conditions, $F(1,23) = 0.06$, $p = .804$, $B_{10} = 1/3.35$. The Bayesian ANOVA supported this non-significant effect, with Bayes factors giving substantial evidence in favour of the null hypothesis (i.e., a non-significant main effect of alexithymia condition). This finding indicates there was no significant difference in the timing of full attention allocation deployment (i.e., when the N2pc amplitude peaked) between high and low alexithymia participants. This finding supports the evidence from studies 1B, 1C, and two, which found that alexithymia severity appears to have no impact on performance in the face-in-the-crowd task, suggesting deficits may instead occur at a later stage of processing.

No significant differences in the latency of the N2pc peak amplitude were found between angry and happy target trials, $F(1,23) = 2.51$, $p = .127$, $B_{10} = 1/2.56$. Bayesian analysis gave anecdotal evidence in favour of the null hypothesis (i.e., a non-significant effect of target type). In addition to the onset latency findings, these findings refute the presence of an anger superiority effect. Furthermore, they contradict the findings of Weymar et al. (2011), who found evidence of an anger superiority effect in the form of faster RTs and greater N2pc amplitude for angry targets.

No significant two-way interaction was found between alexithymia condition and target type, $F(1,23) = 0.17$, $p = .687$, $B_{10} = 1/2.57$. Bayesian analysis gave anecdotal evidence in favour of the null hypothesis (i.e., a non-significant two-way interaction).

Figure 36:

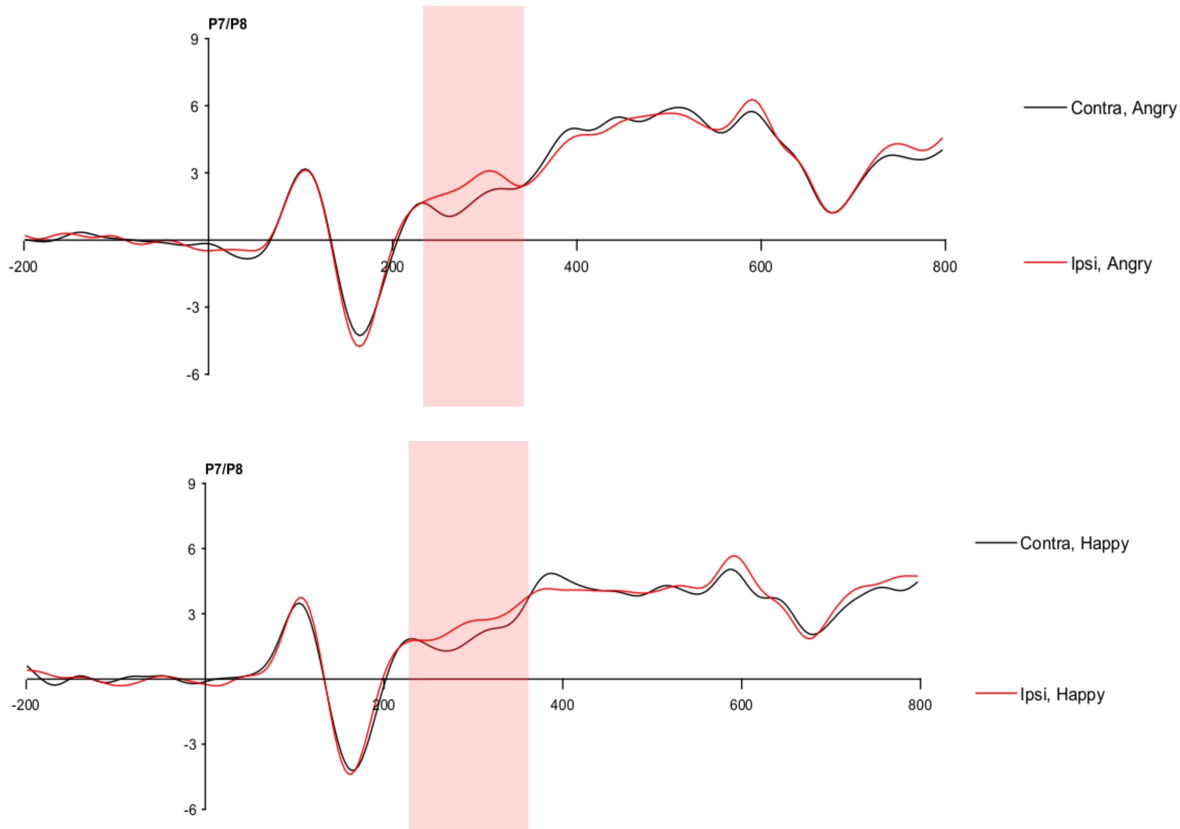
Contralateral and Ipsilateral N2pc Waves Across Alexithymia Conditions



Note: Contralateral and Ipsilateral waves for low (upper panel) and high (lower panel) alexithymia participants, collapsed across target type. The area highlighted in red displays the N2pc.

Figure 37:

Parent N2pc Waves Across Target Types



Note: Parent waves for angry (upper panel) and happy (lower panel) target trials, collapsed across alexithymia conditions. The area highlighted in red displays the N2pc.

Summary

The present study aimed to explore visual search performance using an alternate measure of attention allocation, namely the N2pc ERP component. This decision was based on the findings of Reutter et al. (2017), who found that the N2pc ERP component was a more internally consistent and reliable measure of attentional bias compared to RT in a dot-probe design. Participants completed a face-in-the-crowd task of happy, angry, and neutral schematic faces displayed in a circle to explore potential differences in visual search performance. Performance was then explored across the two alexithymia and target conditions to further explore the anger superiority effect and the impacts of alexithymia severity on visual search performance.

Overall, the present findings gave little support for the anger superiority effect, despite the evidence in favour of the anger superiority effect observed in studies 1A, 1B, and 1C. Frequentist analysis found a significant effect of target type for RT, with angry faces being detected significantly faster than happy faces. This aligns with previous research demonstrating that angry expressions are detected more rapidly, consistent with the anger superiority effect (Diao et al., 2017; Dickins & Lipp, 2014; Eastwood et al., 2001; Feldmann-Wüstefeld et al., 2011; Fox et al., 2000; Hansen & Hansen, 1988; Lobue et al., 2014; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Pinkham et al., 2010; Rued et al., 2019; Shasteen et al., 2014). Bayesian analysis, however, provided only anecdotal evidence in favour of this effect, suggesting the result should be interpreted with caution. These findings suggest that while there may be a behavioural advantage for angry faces in visual search tasks, this does not appear to extend to a neural level. Additionally, Bayesian analyses suggest that further data is needed to draw stronger conclusions.

Regarding search performance across the low and high alexithymia conditions, no consistent evidence supports the hypothesis that higher alexithymia levels lead to an impairment in the detection of emotional faces. Frequentist analysis exploring all measures of visual search performance (i.e., RT, accuracy, mean amplitude of the N2pc, peak amplitude of the N2pc, onset latency of the N2pc, and peak latency of the N2pc) found no significant differences in performance between the low and high alexithymia conditions. Bayesian analyses did provide evidence in favour of a significant main effect of alexithymia condition for RT and onset latency, however the strength of this evidence was anecdotal suggesting the need for further data before drawing conclusions. This lack of evidence is apparent and consistent across studies 1B, 1C, and two within this PhD. Study 1A displayed a significant difference in the detection of emotional faces with higher alexithymia individuals detecting emotional targets faster. However, this finding could not be replicated. The results of the present study suggest that individuals with high levels of alexithymia do not have impairments in emotion detection across reaction times, accuracy, or neural markers of attentional engagement for this experimental paradigm.

One limitation within the current study that should be considered when interpreting the findings is the small sample size following artifact rejection and the exclusion of participants who did not meet the necessary inclusion criteria. There have been studies with small sample sizes that have detected significant differences in the N2pc for angry targets (e.g., Yao et al., 2014), however these researchers were exploring the anger superiority effect in the general population rather than in sub-populations like higher alexithymia individuals. Additionally, given the number of Bayes factors yielding only anecdotal evidence, the small sample size may have impacted our ability to find significant effects in the present study. Future research with larger sample sizes would help to provide further clarity on differences in behavioural and neural components of attention allocation between target types and alexithymia severities.

General Discussion

Research Aims

The current thesis aimed to explore four main research questions relating to the processing of emotional faces. The first aim was to replicate and extend the current literature supporting faster and more accurate detection of angry faces compared to other emotions, also known as the anger superiority effect (Diao et al., 2017; Dickins & Lipp, 2014; Eastwood et al., 2001; Feldmann-Wüstefeld et al., 2011; Fox et al., 2000; Hansen & Hansen, 1988; Lobue et al., 2014; Lundqvist & Öhman, 2005; Lyyra et al., 2014; Öhman et al., 2001; Pinkham et al., 2010; Rued et al., 2019; Shasteen et al., 2014). The use of both schematic and photographic stimuli allowed for an exploration of the presence of the anger superiority effect, and sought to explore claims that many pivotal anger superiority effect studies (i.e., Hansen & Hansen, 1988; Öhman et al., 2001) are due to perceptual confounds in the schematic stimuli used, rather than a true effect (Purcell et al., 1996; Purcell & Stewart, 2010). Schematic stimuli were found to elicit an anger superiority effect in the general population; however, this effect did not extend to photographic stimuli.

The second aim was to explore whether the presence of higher levels of alexithymia impacted the effects of the anger superiority effect, if valid. Despite alexithymia being associated with an overall deficit in emotional processing, support for particularly strong impairments in the processing of negatively valenced faces has been found in several studies (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006). Given this stronger deficit for processing negatively valenced faces, it was predicted that the anger superiority effect may not occur for individuals with higher alexithymia levels. In contrast with this research (Luminet et al., 2011; Prkachin et al., 2009; Vermeulen et al., 2006), no significant differences in the processing of negative emotions were observed in higher alexithymia participants compared to lower alexithymia participants.

The third aim was to replicate the current and consistent alexithymia literature supporting deficits in processing emotional facial expressions, regardless of emotion or valence, in individuals with higher alexithymia levels (Jessimer & Markham, 1997; Lane et al., 2000; Mann et al., 1995;

Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Prkachin et al., 2009; Ridout et al., 2010; Swart et al., 2009; see Grynberg et al., 2012 for review). Interestingly, no consistent evidence supported significant differences in the processing of emotional faces between lower and higher alexithymia individuals.

The fourth and final aim took a methodological focus by comparing frequentist and Bayesian statistical approaches across all six studies. This was completed primarily to explore differences in frequentist and Bayesian conclusions, but this exploration also allowed us to address limitations associated with small and uneven sample sizes, particularly in the alexithymia conditions. While frequentist and Bayesian conclusions were often consistent, Bayesian evidence did allow for more detailed and nuanced interpretations of the findings. This added nuance was particularly valuable for non-significant effects and instances where further data was required.

Summary

Study 1A explored the relationship between alexithymia severity and the anger superiority effect using schematic angry and happy faces in a face-in-the-crowd task. Faster RT and flatter search slopes were observed for angry targets compared to happy targets. Additionally, higher detection and labelling accuracy were found for angry compared to happy targets. Finally, higher alexithymia was associated with faster RTs and flatter search slopes than in participants with lower alexithymia, though the search slope effect had only anecdotal Bayesian evidence (B_{10} = 1.45), requiring cautious interpretation. Detection and labelling accuracy did not differ based on alexithymia severity.

Study 1B used schematic angry and sad targets to investigate the impact of emotional valence on the anger superiority effect in individuals with varying levels of alexithymia. This study found that angry targets showed faster RTs than sad targets at larger set sizes, with no differences at the smallest set size. Additionally, results found greater detection accuracy for angry targets compared to sad targets. No significant differences between angry and sad targets for search slope and labelling accuracy were found. No significant differences in RT, search slope, detection accuracy, and labelling accuracy were found between the alexithymia conditions.

Study 1C combined the methodology of studies 1A and 1B by using angry, happy and sad schematic faces to explore the anger superiority effect across both emotional valence and specific emotions. Faster RTs and flatter search slopes were found for angry targets, with the RT advantage becoming more pronounced as set size increased, creating a clear hierarchy (angry > sad > happy > neutral) at larger set sizes. Detection accuracy across the three target types was not significantly different. No significant differences in RT, search slope, or detection accuracy were found between alexithymia conditions.

Study 2 investigated the anger superiority effect and alexithymia in a more ecologically valid method by using photographic angry and happy targets. No significant main effects of target type were found for RT, search slopes, or detection accuracy, though happy targets were detected faster than angry targets at one set size. Additionally, no significant differences in RT, search slope, or detection accuracy were found between the alexithymia conditions.

Study 3 investigated visual search performance using non-emotional targets, namely a two hidden among 5's, across alexithymia conditions. This study aimed to explore the possibility of a general visual search advantage, similar to what has been observed amongst autistic individuals (see Kaldy et al., 2016 for review). This was an important area to explore given the high comorbidity between autism and higher alexithymia levels. No significant differences in RT, search slope, or accuracy were found between the alexithymia conditions.

Study 4 used electroencephalography (EEG) to provide a more detailed measure of attention deployment in a face-in-the-crowd task among low and high alexithymia conditions using schematic stimuli. Participants were faster at detecting angry targets than happy targets, though the Bayesian analysis provided only anecdotal evidence against this effect (B_{10} = 1/1.97), contradicting the frequentist finding and requiring cautious interpretation. Participants were equally accurate at detecting angry targets and happy targets. No significant differences in RT or accuracy were found between the low and high alexithymia conditions. EEG results revealed a significant overall N2pc effect, however no significant differences in N2pc amplitude were found between angry and happy target trials or between the low and high alexithymia conditions. Additionally, no significant differences in the latency of the N2pc were found between angry and happy target trials. Additionally, while no significant main effects of latency were found for alexithymia condition, the high alexithymia condition was found to have a significantly faster N2pc onset latency for angry trials compared to the low alexithymia condition.

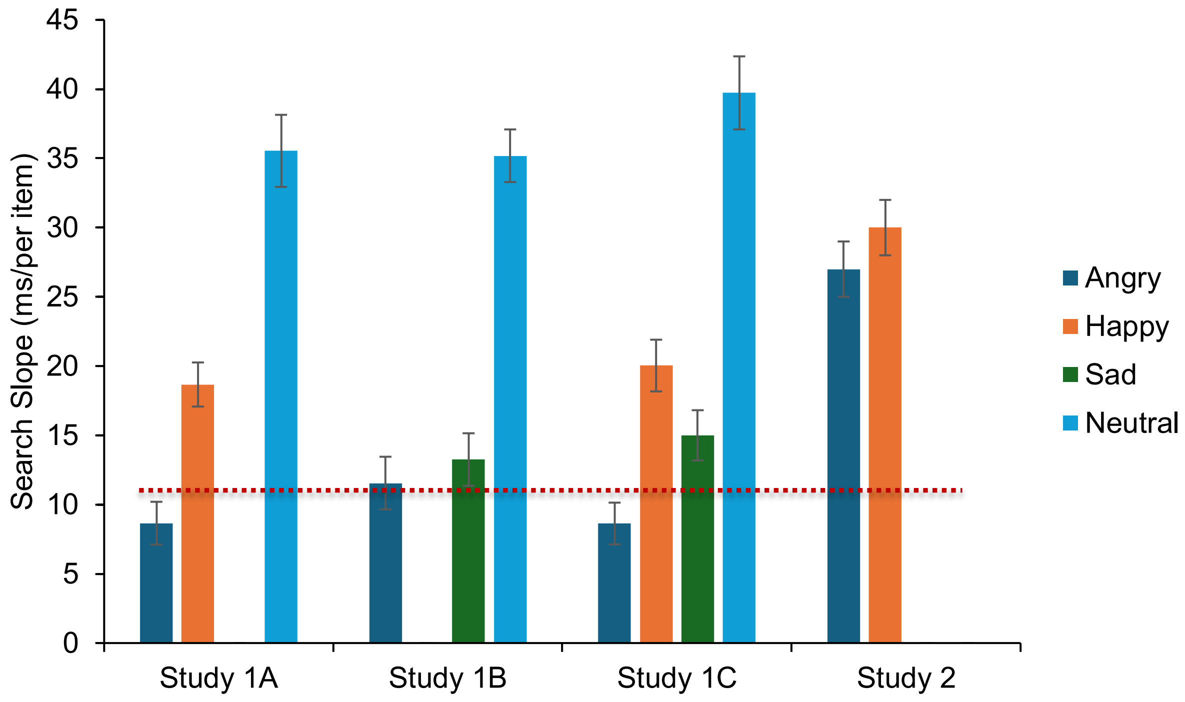
The Anger Superiority Effect in the General Population

The findings discussed above paint an interesting picture of the anger superiority effect in the general population, particularly regarding the role of stimulus type. As discussed in Chapter 1, Hansen and Hansen (1988) were the first to identify a “pop-out effect” for angry faces in visual search tasks, whereby the time taken to detect an angry target was largely unaffected by increases in the number of distractors, suggesting the use of a highly efficient search process. Purcell et al. (1996) later demonstrated that the pop-out effect observed by Hansen and Hansen was instead due to a perceptual confound within the target stimuli. Despite this, the association between the anger superiority effect and the pop-out effect persists.

According to Wolfe (1998), a pop-out effect is defined by a search slope of 10ms per item in an array or less, with less efficient search processes typically producing search slopes above 10ms per item. Figure 38 presents the mean search slopes for each target type across studies 1A, 1B, 1C, and 2. Notably, only the angry target trials in Studies 1A and 1C produced search slopes below the 10 ms per item threshold, indicating the use of highly efficient search processes. No other emotional targets elicited evidence of a pop-out effect occurring, further supporting the existence of an anger superiority effect overall.

Figure 38:

Mean Search Slopes Across Target Types for Each Study



Note: Mean search slopes for each target type across studies 1A, 1B, 1C, and 2. The red dotted line denotes the 10ms/item cut-off typically associated with highly efficient "pop-out" searches. Target types not included in a given study are not represented. Study 3 was excluded due to the use of non-emotional targets, and Study 4 was excluded as the set size was not manipulated. Error bars indicate standard errors.

Overall, evidence supporting an anger superiority effect was found when using schematic stimuli, as evidenced by faster RTs, lower search slopes and equal or greater accuracy for angry targets compared to other emotional stimuli. Importantly, however, these RT, search slopes and accuracy findings could not be replicated when using photographic stimuli, as displayed by the results of Study 2. Possible explanations for this pattern of results are discussed further below.

The first possible explanation for these results is that the schematic stimuli findings do reflect a genuine anger superiority effect, but this was unable to be replicated with photographic stimuli due to methodological differences in study design. As study 2 was the only study to use photographic stimuli, it is important to note that there were some changes made that led to significant methodological differences between study 2 and the other schematic stimuli studies (i.e., 1A, 1B, 1C, 4). Due to the visual similarities between photographic neutral and angry faces and the significant difficulty observed with differentiating the two during study development and piloting, it was decided that study 2 would use emotional distractor faces rather than neutral, as was used in previous studies. For example, instead of presenting angry faces among neutral distractors, study 2 presented angry faces among happy distractors and vice versa. Based on these methodological differences, one possible explanation for the lack of anger superiority effect observed in study 2 is that using emotional distractors, as opposed to neutral ones, introduced a confound that impacted the effects of targets and distractors. Essentially, the use of emotional distractors may introduce additional confounds, as research has demonstrated that emotional faces with higher arousal ratings are more distracting during visual search tasks, potentially requiring greater inhibitory control to dismiss compared to neutral distractors (Becker & Rheem, 2020). In the context of a lack of significant difference as seen in study 2, we have no way of confirming whether this lack of difference is due to the angry and happy targets being equally salient (i.e., no anger superiority effect) or whether happy distractors were more time consuming to search, thereby masking a possible anger superiority effect.

Contrary to this explanation, Shasteen et al. (2014) found no evidence of the distractor emotion's role in modulating the anger superiority effect. They further explored this question using eye-tracking during a visual search task involving angry and happy faces embedded among neutral or emotional distractor crowds. Shasteen et al. also found significant evidence supporting the anger superiority effect, with participants fixating on angry targets more rapidly than happy targets. Additionally, no difference in the duration of fixation time was observed between angry and happy distractor faces, suggesting that the emotional content of distractor faces does not influence the anger superiority effect.

Fox et al. (2000) also investigated whether angry facial expressions were found more efficiently than happy or neutral faces in a face-in-the-crowd task. Supporting the anger superiority effect, they found that angry faces were detected more rapidly and accurately than happy faces when presented in a crowd of neutral distractors. Importantly, they also found that search times were slower for trials using angry faces as distractors than happy and neutral distractors, which they theorised reflected a greater capacity for angry faces to hold visual attention. Contrasting the above findings of Shasteen et al., these findings by Fox et al. suggest that the emotional content of distractor faces can significantly alter search patterns and performance. Additionally, the use of identical facial identities across each array may have inadvertently reduced task difficulty, potentially masking subtle emotion detection advantages. When all faces in an array belong to the same individual, participants need only focus on emotional variations within that specific face, eliminating the additional cognitive load of processing different facial structures, ages, and features that would be present with mixed-identity arrays. This simplified task design may have created a ceiling effect where both angry and happy faces were detected with relatively high efficiency, obscuring the subtle attentional advantages that angry faces typically demonstrate under more challenging search conditions. Future research should employ arrays with different identities to increase task difficulty and better isolate emotion-specific processing effects.

Alternately, it is possible that the anger superiority effect could not be replicated with photographic stimuli as it was not a genuine effect but was rather due to perceptual confounds within the schematic stimuli. As discussed in Chapter 1, some researchers have long questioned the legitimacy of the anger superiority effect and the role of perceptual confounds (Purcell et al., 1996; Purcell & Stewart, 2010). For example, Purcell & Stewart (2010) attempted to replicate the anger superiority effect observed in a series of studies conducted by Öhman et al. (2001) with one noticeable perceptual difference - the removal of the facial border. Purcell & Stewart argued that the anger superiority effect observed was not due to greater saliency of the angry emotional face itself, but was instead due to a difference in the distance between the eyebrows and the facial border between the different emotional faces, with the gap being the smallest for angry faces. Notably, the anger superiority effect observed by Öhman et al. was no longer present once the facial border was removed, suggesting the difference in distance between the eyebrows and facial border may have confounded the results.

Due to arguments regarding the possible impacts of perceptual confounds, considerable effort was made to minimise perceptual differences between emotional faces to reduce the possible impacts of visual confounds. For example, it was ensured that key facial features (e.g., eyebrows, mouth) were kept in a fixed position across each of the three emotional expressions to ensure differences in feature location did not act as a visual confound. The eyebrows, a critical feature for expressing anger, remained in a fixed position but were rotated based on the emotion being expressed. Additionally, the eyebrows used for happy and sad faces were created by mirroring the brows of the angry faces, ensuring the angle of rotation remained consistent across the three target emotions.

As discussed in chapter 1, despite these efforts to minimise perceptual confounds, a limitation may have remained in the schematic face design. Namely, as the facial border used for schematic stimuli was not a true circle but was rather an oval shape with a widened centre, the distance between the eyebrows and the facial border was not uniform across emotional faces. Specifically, the angry eyebrows were positioned closer to the facial border than the sad and happy eyebrows due to the direction of rotation of the brows. Based on the findings of Purcell & Stewart, it is possible that this discrepancy in distance may have contributed to the observed advantage for detecting angry faces; however, further experimentation eliminating this perceptual difference would be needed to confirm.

Alexithymia and the Anger Superiority Effect

While Alexithymia is characterised by deficits in the ability to identify and process one's own emotions, many studies have investigated and verified that this deficit appears to extend to the processing of emotional facial expressions in others (Jessimer & Markham, 1997; Lane et al., 2000; Mann et al., 1995; Montebarocci et al., 2011; Pedrosa Gil et al., 2009; Prkachin et al., 2009; Ridout et al., 2010; Swart et al., 2009).

Contrary to the current alexithymia literature, the findings within this thesis did not support this deficit in the processing of emotional facial expressions in higher alexithymia individuals. Study 1A was the only study to show a significant difference in RT and search slope between the high and low alexithymia conditions, and this difference actually showed that higher alexithymia participants were more efficient at visual search of emotional faces compared to the low alexithymia participants.

This more efficient visual search performance was highlighted by the significant difference in search slopes between high alexithymia (16.946ms/per item) and low alexithymia participants (25.743ms/per item) in study 1A, though this effect had only anecdotal Bayesian evidence (B_{10} = 1.45), requiring cautious interpretation. However, this difference in performance between alexithymia conditions was unable to be replicated in any of the following studies in this thesis.

While it is possible that study 1A's findings indicating faster detection of emotional targets represent a genuine finding, the inability to replicate these findings despite the use of identical stimuli and similar methodology is suspicious. One possible explanation for the inability to replicate the target detection advantage in high-alexithymia participants observed in Study 1A may lie in individual differences within that sample that were not present in the other five studies. Alexithymia is frequently comorbid with various psychological disorders, such as Autism Spectrum Disorder, Major Depressive Disorder, and Anxiety Disorder, however these disorders are primarily associated with impairments in emotional processing (Dalbudak et al., 2013; Honkalampi et al., 2001; Kinnaird et al., 2019). Notably, individuals with Borderline Personality Disorder (BPD) have been found to exhibit significantly higher levels of alexithymia compared to those without BPD (Chaim et al., 2024; Kılıç et al., 2020). Although some studies have reported deficits in facial emotion perception among individuals with BPD (e.g., Kılıç et al., 2020), a literature review by Domes et al. (2009) also highlighted a tendency for heightened sensitivity to negative emotional expressions in this population. It is possible that the high-alexithymia condition in Study 1A included a disproportionate number of individuals with BPD, potentially contributing to enhanced detection of emotional targets. However, this explanation falls short, as the observed advantage in detection performance in Study 1A extended across all target types, not just negative emotion.

Given that sample characteristics alone do not adequately account for the difficulty in replicating the results of Study 1A, the possibility of a Type 1 error should be considered. Type 1 errors are an inherent risk in statistical testing, particularly when multiple comparisons are made or when sample sizes are relatively small. In psychological research, the expected false positive rate under conventional significance thresholds (e.g., $p < .05$) is approximately 5% (Simmons et al., 2011). Therefore, it may be that the significant differences observed in Study 1A represent a statistical anomaly rather than a true effect, underscoring the importance of replication and cautious interpretation of isolated findings.

Regarding the findings of the remaining 5 studies within this thesis, and the consistent evidence rejecting a significant difference in emotional target detection between alexithymia conditions, this raises the question: if many studies have supported a deficit in processing emotional facial expressions, why was there no evidence of this within the present thesis?

One possible reason for the lack of significant differences observed between the alexithymia conditions is that deficits in emotional face processing may occur at a later stage of processing rather than during the initial detection phase. The face-in-the-crowd task is designed to test an individual's capacity to detect a target emotional face, aligning with the first stage of emotion knowledge, the identification/detection stage. A question asking participants to label the target emotion observed was included in studies 1A and 1B to explore the second emotion knowledge stage, the labelling stage. Importantly, no significant differences in labelling accuracy and detection accuracy were found in studies 1A and 1B overall, suggesting similar performance in detection and labelling regardless of alexithymia condition. Additionally, labelling accuracy for study 1A and 1B sat at around 94% and 92.43% overall, indicating good performance. Although these are not detailed measures of labelling performance, these initial findings do not indicate any deficits in the labelling stage either. No tasks investigating the third stage of emotion knowledge, understanding the causes and context that elicit emotional responses, were included as this was outside the scope of this thesis. Future research would benefit from employing multiple visual search tasks, each focused on a different stage of processing, to gather further information on where the deficits observed in the alexithymia literature begin.

Providing an alternate reason for this lack of significant difference, Baxter and Hobson (2024) recently suggested that deficits in emotion recognition in higher alexithymia may be overstated in the literature due to possible publication bias. In their recent study, Baxter and Hobson investigated emotion recognition abilities in individuals with Autism, high alexithymia, and mood disorders (i.e., depression and anxiety). In their study, 80 autistic individuals and 98 non-autistic individuals completed an online face processing task, which required them to identify the emotion and identity of the face displayed on the screen. Stimuli consisted of 14 images of two morphed faces displaying two emotions (i.e., anger or disgust) and two identities (i.e., 'Harold' or 'Felix') at varying intensities. Baxter and Hobson then conducted a series of hierarchical regressions were conducted to analyse the results across the different variables. Age, gender and ethnicity were entered in step 1, their alexithymia measure was then entered in step 2, their anxiety and depression measure was entered in step 3, and finally their measure of autism traits was entered in step 4. Supporting the lack of significant difference between alexithymia conditions found in this thesis, alexithymia traits did not explain a significant amount of variance in face processing abilities after controlling for demographic variables. In fact, gender was the only variable found to be a significant predictor of emotion processing abilities.

Based on the difference in the current findings within the alexithymia literature and the results of their study, Baxter and Hobson hypothesised that there may be further studies that failed to find effects of alexithymia on emotion processing that have remained unpublished. Meta-analyses investigating related areas were identified, specifically one analysis exploring alexithymia and facial emotion recognition in individuals with craniofacial pain (La Touche et al., 2021) and one analysis exploring the neural correlates of emotion recognition impairments in alexithymia (Van der Velde et al., 2013). To our knowledge, however, no meta-analyses investigating behavioural evidence of emotion recognition deficits in alexithymia have been completed with a healthy sample, nor has there been any exploration of whether a publication bias may be present in this literature. This highlights a significant gap in the literature and an important step for future research.

Given the high co-morbidity between higher alexithymia and clinical disorders associated with impaired emotional processing (including autism spectrum disorder, major depressive disorder, and social anxiety disorder), discussion of the potential influence of co-morbid conditions on the results of the studies within this thesis is necessary (Dalbudak et al., 2013; Honkalampi et al., 2001; Kinnaird et al., 2019). Literature exploring deficits in the processing of emotional faces among autistic individuals has displayed mixed evidence, as discussed in Chapter 1. Despite these mixed findings, evidence of deficits in emotion processing continues to be found among autistic samples (see Kaldy et al., 2016 for review). Similar trends have also been observed in mood disorders, including depression and anxiety, with research finding evidence of impaired recognition of emotional facial expressions among individuals with these disorders. A meta-analysis conducted by Krause et al. (2021) found that depressed individuals displayed poorer accuracy of facial emotion recognition compared to euthymic individuals, with accuracy reducing further as depression severity increased. As discussed above, this deficit in emotion detection among individuals with depression was found to be stronger for happy facial expressions. Regarding the impacts of anxiety, a systematic review and meta-analysis conducted by Baez et al. (2023) found that patients diagnosed with social anxiety disorder and generalised anxiety disorder both showed worse emotion recognition performance than healthy individuals.

It is important to note that the possible impacts of these disorders on the results would be an important factor to consider if a significant effect of alexithymia on emotional face detection was found. However, given that no evidence has been found of improved emotional facial detection in autism, depression or anxiety, the impacts of these disorders are irrelevant to the findings within this thesis. It is interesting to note, however, that despite the high comorbidity levels and the known impairments associated with each of these disorders, the studies within this thesis still consistently found no impairments in face detection in higher alexithymia individuals, highlighting the robustness of these non-significant findings.

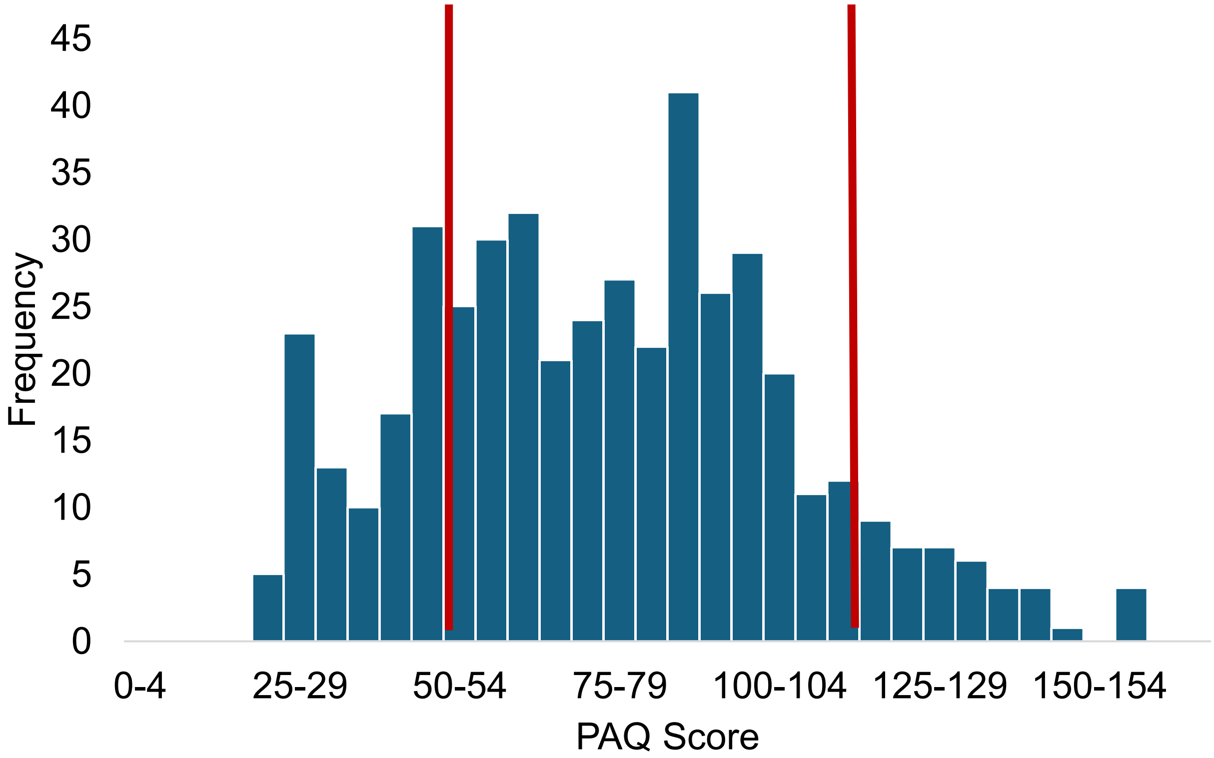
Methodological Limitations

While the studies conducted and discussed within this thesis provide valuable insight into the relationship between alexithymia, emotional expression processing, and the anger superiority effect, it is important to acknowledge certain methodological limitations and their potential influence on the findings of this thesis, as well as the steps taken to address these limitations.

The first limitation worth discussing is the potential impact of sample size on the findings of this thesis. While the overall sample size for each study was generally quite large, with most samples sitting around 100 participants. The issue with sample size instead revolves around difficulty finding a significant and equal number of participants within the overall sample who fell into the high and low alexithymia conditions. Across several studies, the number of participants in the low-alexithymia condition is larger than the number of participants in the high-alexithymia condition. The distribution of alexithymia scores on the Perth Alexithymia Questionnaire across all studies is displayed in Figure 39.

Figure 39:

Alexithymia Distribution Across All Six Studies



Note: Distribution of Perth Alexithymia Questionnaire scores across all six studies within this thesis. The red lines denote the cutoff scores for the low (left) and high (right) alexithymia conditions, which were developed based on recommendations within the PAQ interpretation guidelines and calculated using normative data (Preece et al., 2018).

While this is an important limitation to consider when interpreting differences in results between the low and high alexithymia conditions, several steps were taken to try to address this limitation.

The first step to address this limitation occurred prior to beginning data collection. An a priori power analysis was conducted using G*Power (Faul et al., 2009) to determine the number of participants required in the high and low alexithymia conditions to find a significant effect with a small effect size in a repeated measures ANOVA. The power analysis indicated that a minimum of 20 participants total (i.e. 10 per low and high alexithymia condition) was required. As the literature suggests that the prevalence of clinically relevant or high levels of alexithymia within the general population is approximately 1/10, an overall sample size of 100 participants was the goal for each study. While a greater sample size would have been ideal to maximise the number of participants in each alexithymia condition, this was outside of the scope of the current thesis due to budgetary issues.

The second and most significant step was the decision to use Bayesian statistics to assess significant effects within the results. As frequentist statistics largely draw conclusions of significance based on the data you have collected, it is more prone to being influenced by, or potentially missing significant findings, when the sample size used to collect data is small (Button et al., 2013; Maxwell, 2004). In contrast, Bayesian statistics does not simply rely on the data collected; it also considers the information already known about a problem before looking at the data. This is typically referred to as “priors”. When studies have smaller sample sizes and more limited data, including Bayesian statistics and considering the known “priors” can provide clearer and more trustworthy conclusions even with smaller sample sizes (McNeish, 2016). Some research has suggested that the use of Bayesian statistics with small sample sizes and poorly chosen priors can sometimes lead to more biased conclusions than frequentist statistics (McNeish, 2016). Importantly, however, these biased conclusions can be rectified by using weakly informed priors (i.e., priors that are not very constraining or influential in analysis), leading to more trustworthy conclusions from smaller sample sizes compared to frequentist statistics (McNeish, 2016). As the Bayesian calculations within this thesis were calculated using Cauchy priors, which is a weakly informed prior, the inclusion of Bayes factors provides a more trustworthy interpretation of the data, given the small sample sizes, particularly for the low-alexithymia condition.

To assess the robustness of conclusions to prior specification, sensitivity analysis was conducted on Study 1A using Bayesian priors at half (r = 0.354), default (r = 0.707), and double (r = 1.414) scale parameters. This analysis revealed that while core anger superiority effects (target type and set size main effects) remained stable across all prior specifications, the alexithymia condition effects showed notable sensitivity to prior choice. Most importantly, the search slope advantage for high alexithymia participants shifted from anecdotal evidence in favour under the half prior to anecdotal evidence against under both default and double priors. This sensitivity may help explain why the Study 1A alexithymia advantages could not be replicated in subsequent studies, and reinforces the importance of cautious interpretation of weak Bayesian evidence. The robustness of core anger superiority effects across different prior specifications, however, strengthens confidence in these fundamental findings. Overall, this robustness analysis demonstrates that while default Cauchy priors provide a reasonable balance for interpretation, weak effects (such as the alexithymia condition differences) are particularly sensitive to prior specification, whereas more robust effects (such as the anger superiority pattern) remain stable across different prior assumptions, reinforcing the importance of replication for effects with only anecdotal Bayesian support.

One consideration is the fact that the majority of the studies within this thesis, with the exception of study 4, were conducted online due to difficulties with in-person data collection during the COVID-19 pandemic. While the move to online studies was a necessary step to gather the amount of data and the sample sizes required, this is a significant difference in study methodology compared to most studies within the anger superiority effect and alexithymia literature. However, recent research has highlighted that there are little to no differences in the quality of data collected in-person compared to online (Sauter et al., 2022; Uittenhove et al., 2022). Uittenhove et al. conducted a comparison of both testing methods (i.e., in-person vs. online) and participant pools (i.e., web-based students vs. participants from Prolific vs. participants from MTurk). They found a small but acceptable loss of quality for online data collection methods compared to in-person methods.

More importantly, however, Uittenhove et al. found participants recruited from MTurk performed significantly worse than participants recruited via Prolific or web-based students, with only 34.7% of MTurk response patterns passing all quality criteria. No significant difference in performance or attention was observed between participants from Prolific compared to web-based students, with 72.6% (web-based students) and 71.3% (Prolific participants) of response patterns passing quality checks. These findings were supported by Douglas et al. (2023), who found participants on Prolific were significantly more likely to pass attention checks, provide meaningful answers, and have a unique IP address and geolocation, among other benefits, compared to participants collected via MTurk (Douglas et al., 2023). These findings highlight the importance of recruiting participants from quality participant pools. Given the findings discussed above and the fact that all online participants were recruited via Prolific, it is unlikely that using an online design would have significantly reduced the quality of the studies within this thesis or led to significant differences in results compared to in-person studies.

Finally, it is important to consider potential limitations of the measure used to assess alexithymia levels. While the Perth Alexithymia Questionnaire demonstrates strong psychometric properties including excellent internal consistency (Cronbach's $\alpha = 0.95$; Preece et al., 2020) and was specifically designed to address limitations of earlier alexithymia measures (Preece et al., 2018), the categorical approach to group assignment used across all studies may present some challenges. The division into low/medium/high groups based on cut-off scores, while following established guidelines, may not fully capture the continuous nature of alexithymia traits. Additionally, the small sample sizes in extreme groups (particularly high alexithymia: $n = 5$-15 across studies) may have limited power to detect genuine group differences, potentially contributing to the inconsistent alexithymia effects observed across studies.

Bayesian vs. Frequentist Statistics

As discussed above, the goal of using both frequentist and Bayesian statistics was to counteract possible issues caused by small sample sizes, particularly within the low and high alexithymia conditions (see Appendix A for a full comparison table of frequentist and Bayesian significance measures). Significant main effects-particularly for Target Type and Set Size-were consistently supported by both frequentist and Bayesian analysis (i.e., p<.001 and B_{10} = extreme evidence of a main effect), except for the main effect of Target Type in Study 4, where support was only anecdotal. This near-universal support across both statistical methods reinforces the strength and reliability of these main effects of target type and set size, which further strengthens the evidence collected in support of the anger superiority effect.

With the exception of findings from study 1A, Bayesian evidence frequently supported the non-significant findings for alexithymia condition across different performance measures. This support by Bayesian analysis is particularly present for main effects of alexithymia condition for reaction time, all of which, aside from studies 1A and 4, were non-significant and provided substantial or higher Bayesian evidence for the null hypothesis. Evidence of non-significance was even more pronounced for interactions, especially higher-order interactions involving alexithymia (e.g., set size × target type × alexithymia). Frequentist p-values for these effects were almost always non-significant, implying a lack of effect. Bayesian evidence further supported this non-significance, consistently providing very strong to extreme support for the null hypothesis. For example, Study 1C found a non-significant three-way interaction (i.e., set size x target type x alexithymia condition) as evidenced by the p-value of 0.559. Bayesian evidence expanded on this, finding extreme evidence favouring the null hypothesis as evidenced by its very large Bayes Factor of 1/456.610. These findings not only suggest that the interactions were non-significant, but the Bayesian data actively rejected them. This pattern repeated across studies (e.g., Studies 1B, 1C, and 2), suggesting a robust lack of interaction effects involving alexithymia.

There were several instances worth noting in which a non-significant p-value was found, which appeared to be contradicted by Bayesian analysis providing anecdotal evidence supporting a significant effect (see Study 4 Onset Latency for examples). In these instances, this anecdotal Bayesian evidence indicates insensitivity in the data rather than the absence of a significant effect (Dienes, 2014). Essentially, the Bayesian evidence displays early signs of a possible weak effect. However, more data is required to increase the sensitivity of the data before we can draw a clear and meaningful conclusion. Instances where a non-significant p-value was supported by only anecdotal evidence in favour of the null hypothesis (e.g., the two-way interaction for RT in study 4) indicate a similar need for further data collection to increase data sensitivity and allow for a clearer conclusion on the effects found.

While frequentist and Bayesian statistics often agreed on strong main effects, Bayesian statistics added valuable nuance when interpreting non-significant frequentist findings, particularly given the small sample sizes for studies within this thesis.

Conclusion

This thesis investigated not only whether the anger superiority effect is genuine but also explored whether the effect is robust enough to persist in individuals with greater difficulty processing emotions, as is seen in higher alexithymia individuals. Evidence of an anger superiority effect was observed, regardless of alexithymia condition, when using schematic facial stimuli, however this effect disappeared when using photographic stimuli. While the findings within this thesis support the existence of a genuine anger superiority effect, it is important to note, as discussed above, that the possible impact of a perceptual confound in the schematic facial stimuli could not be ruled out.

Contrary to the Alexithymia literature, no significant difference in emotional face detection was observed across the three alexithymia severity conditions, regardless of emotion. This lack of significant difference suggests that either the deficits in detecting emotional facial expressions associated with higher alexithymia occur at a later stage of processing than the study within this thesis explored, or these deficits are potentially overstated in the alexithymia literature. Further research, particularly a meta-analysis exploring possible publication bias in the literature, is needed before concrete conclusions can be drawn.

Taken together, the results of this thesis show no evidence of an impact of alexithymia on the robustness of the anger superiority effect. Additionally, the results of this thesis suggest that higher alexithymia levels have no negative impacts on facial emotion processing at the detection stage, however the very small sample sizes in extreme alexithymia groups (n = 5-15) mean these findings should be interpreted with caution.

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Appendices

Appendix A

P-values and Bayes Factors across all variables and interactions for each study within this thesis.

Study	DV	IV / Interaction	P-value	Frequentist Interpretation	Bayesian Statistic	Bayesian Interpretation
1A	Reaction Time	Alexithymia	0.016	Significant	1.32E+09	Extreme evidence in favour of an effect
1A	Reaction Time	Target Type	<.001	Significant	6.73E+27	Extreme evidence in favour of an effect
1A	Reaction Time	Set Size	<.001	Significant	9.21E+13	Extreme evidence in favour of an effect
1A	Reaction Time	alexithymia x target type	0.3	Non-significant	1/23.7697716961	Strong evidence in favour of the null hypothesis

1A	Reaction Time	set size x target type	<.001	Significant interaction	198.6	Extreme evidence in favour of an interaction
1A	Reaction Time	Alexithymia x set size	0.064	Non-significant	1/74.5256442742	Very strong evidence in favour of the null hypothesis
1A	Reaction Time	set size x target type x alexithymia condition	0.623	Non-significant	1/151.00651125	Extreme evidence in favour of the null hypothesis
1A	Search Slope	Alexithymia	0.04	Significant	1.449	Anecdotal evidence in favour of an effect
1A	Search Slope	Target Type	<.001	Significant	3.88E+16	Extreme evidence in favour of an effect
1A	Search Slope	alexithymia x target type	0.672	Non-significant	1/13.691	Strong evidence in favour of the null hypothesis
1A	Detection Accuracy	Alexithymia	0.544	Non-significant	1/7.14236227918	Substantial evidence in favour of the null hypothesis

1A	Detection Accuracy	Target Type	<.001	Significant	9.52E+11	Extreme evidence in favour of an effect
1A	Detection Accuracy	Set Size	<.001	Significant	126.529	Extreme evidence in favour of an effect
1A	Detection Accuracy	alexithymia x target type	0.557	Non-significant	1/37.5485737737	Very strong evidence in favour of the null hypothesis
1A	Detection Accuracy	set size x target type	<.001	Significant interaction	1E+06	Extreme evidence in favour of an interaction
1A	Detection Accuracy	Alexithymia x set size	0.248	Non-significant	1/27.2056727092	Strong evidence in favour of the null hypothesis
1A	Detection Accuracy	set size x target type x alexithymia condition	0.47	Non-significant	1/69.8954154898	Very strong evidence in favour of the null hypothesis
1A	Labelling Accuracy	Alexithymia	0.45	Non-significant	1/4.86190961224	Substantial evidence in favour of the null hypothesis

1A	Labelling Accuracy	Target Type	<.001	Significant	1.48E+20	Extreme evidence in favour of an effect
1A	Labelling Accuracy	Set Size	<.001	Significant	2.54E+04	Extreme evidence in favour of an effect
1A	Labelling Accuracy	alexithymia x target type	0.841	Non-significant	1/94.0895751573	Very strong evidence in favour of the null hypothesis
1A	Labelling Accuracy	Alexithymia x set size	0.523	Non-significant	1/55.8436467242	Very strong evidence in favour of the null hypothesis
1A	Labelling Accuracy	set size x target type	<.001	Significant interaction	1E+05	Extreme evidence in favour of an interaction
1A	Labelling Accuracy	set size x target type x alexithymia condition	0.441	Non-significant	1/72.3558111484	Very strong evidence in favour of the null hypothesis
1B	Reaction Time	Alexithymia	0.7	Non-significant	1/4.62500890314	Substantial evidence in favour of the null hypothesis

1B	Reaction Time	Target Type	<.001	Significant	2E+24	Extreme evidence in favour of an effect
1B	Reaction Time	Set Size	<.001	Significant	1.70E+13	Extreme evidence in favour of an effect
1B	Reaction Time	alexithymia x target type	0.727	Non-significant	1/74.2937082887	Very strong evidence in favour of the null hypothesis
1B	Reaction Time	Set Size x Target Type	<.001	Significant	412.4177	Extreme evidence in favour of an interaction
1B	Reaction Time	Alexithymia x set size	0.694	Non-significant	1/88.7108363835	Very strong evidence in favour of the null hypothesis
1B	Reaction Time	set size x target type x alexithymia condition	0.259	Non-significant	1/80.8890679234	Very strong evidence in favour of the null hypothesis
1B	Search Slope	Alexithymia	0.584	Non-significant	1/7.74325833213	Substantial evidence in favour of the null hypothesis

1B	Search Slope	Target Type	<.001	Significant	4E+13	Extreme evidence in favour of an effect
1B	Search Slope	Target x Alexithymia	0.961	Non-significant	1/18.2862660085	Strong evidence in favour of the null hypothesis
1B	Accuracy	Alexithymia	0.337	Non-significant	2.079345	Anecdotal evidence in favour of an effect
1B	Accuracy	Target Type	<.001	Significant	104.9007	Extreme evidence in favour of an effect
1B	Accuracy	Set Size	<.001	Significant	83.27454	Very strong evidence in favour of an effect
1B	Accuracy	alexithymia x target type	0.232	Non-significant	1/15.7172924323	Strong evidence in favour of the null hypothesis
1B	Accuracy	set size x target type	0.399	Non-significant	1/31.017937363	Very strong evidence in favour of the null hypothesis

1B	Accuracy	Alexithymia x set size	0.714	Non-significant	1/64.7738453576	Very strong evidence in favour of the null hypothesis
1B	Accuracy	set size x target type x alexithymia condition	0.439	Non-significant	1/39.0767569105	Very strong evidence in favour of the null hypothesis
1B	Labelling Accuracy	Alexithymia	0.711	Non-significant	1/4.86190961224	Anecdotal evidence in favour of the null hypothesis
1B	Labelling Accuracy	Target Type	0.002	Significant	1E+20	Extreme evidence in favour of an effect
1B	Labelling Accuracy	Set Size	0.005	Significant	25353.74	Extreme evidence in favour of an effect
1B	Labelling Accuracy	alexithymia x target type	0.319	Non-significant	1/94.0895751573	Very strong evidence in favour of the null hypothesis
1B	Labelling Accuracy	set size x target type	0.942	Non-significant	95644.26	Extreme evidence in favour of an effect

1B	Labelling Accuracy	Alexithymia x set size	0.633	Non-significant	1/55.8436467242	Very strong evidence in favour of the null hypothesis
1B	Labelling Accuracy	set size x target type x alexithymia condition	0.498	Non-significant	1/72.3558111484	Very strong evidence in favour of the null hypothesis
1C	Reaction Time	Alexithymia	0.162	Non-significant	16264.73	Extreme evidence in favour of an effect
1C	Reaction Time	Target Type	<.001	Significant	1E+38	Extreme evidence in favour of an effect
1C	Reaction Time	Set Size	<.001	Significant	7E+22	Extreme evidence in favour of an effect
1C	Reaction Time	alexithymia x target type	0.395	Non-significant	1/31.8209675993	Very strong evidence in favour of the null hypothesis
1C	Reaction Time	Set Size x Target Type	<.001	Significant	8157967	Extreme evidence in favour of an effect

1C	Reaction Time	Alexithymia x set size	0.292	Non-significant	1/81.1157635508	Very strong evidence in favour of the null hypothesis
1C	Reaction Time	set size x target type x alexithymia condition	0.559	Non-significant	1/456.610371174	Extreme evidence in favour of the null hypothesis
1C	Search Slope	Alexithymia	0.259	Non-significant	1/1.24578038611	Anecdotal evidence in favour of the null hypothesis
1C	Search Slope	Target Type	<.001	Significant	1E+26	Extreme evidence in favour of an effect
1C	Search Slope	Target x Alexithymia	0.4	Non-significant	1/19.5578938104	Strong evidence in favour of the null hypothesis
1C	Accuracy	Alexithymia	0.763	Non-significant	1/13.9658777296	Strong evidence in favour of the null hypothesis
1C	Accuracy	Target Type	0.102	Non-significant	1/2.93703956398	Anecdotal evidence in favour of the null hypothesis

1C	Accuracy	Set Size	<.001	Significant	1/8.27898867186	Substantial evidence in favour of the null hypothesis
1C	Accuracy	alexithymia x target type	0.675	Non-significant	1/114.412588039	Extreme evidence in favour of an effect
1C	Accuracy	set size x target type	0.07	Non-significant	1/8.48841670656	Substantial evidence in favour of the null hypothesis
1C	Accuracy	Alexithymia x set size	0.966	Non-significant	1/140.110025601	Extreme evidence in favour of an effect
1C	Accuracy	set size x target type x alexithymia condition	0.964	Non-significant	1/140.35999813	Extreme evidence in favour of an effect
2	Reaction Time	Alexithymia	0.882	Non-significant	1/18.4410592397	Strong evidence in favour of the null hypothesis
2	Reaction Time	Target Type	0.351	Non-significant	1/8.79373674894	Substantial evidence in favour of the null hypothesis

2	Reaction Time	Trial Type	<.001	Significant	9E+26	Extreme evidence in favour of an effect
2	Reaction Time	Set Size	<.001	Significant	5E+23	Extreme evidence in favour of an effect
2	Reaction Time	alexithymia x target type	0.874	Non-significant	1/24.1068357102	Strong evidence in favour of the null hypothesis
2	Reaction Time	Alexithymia x trial type	0.895	Non-significant	1/27.2128466406	Strong evidence in favour of the null hypothesis
2	Reaction Time	Alexithymia x set size	0.771	Non-significant	1/96.8812003968	Very strong evidence in favour of the null hypothesis
2	Reaction Time	Target type x trial type	0.304	Non-significant	1/4.24895114641	Substantial evidence in favour of the null hypothesis
2	Reaction Time	Target type x set size	0.071	Non-significant	1/18.4075448845	Strong evidence in favour of the null hypothesis

2	Reaction Time	Trial Type x Set Size	<.001	Significant	9.448921	Substantial Bayesian support for interaction
2	Reaction Time	alexithymia x target type x trial type	0.233	Non-significant	1/4.25536622958	Substantial evidence in favour of the null hypothesis
2	Reaction Time	Trial x Set size x Target	0.008	Significant	1/7.16750311428	Substantial evidence in favour of the null hypothesis
2	Reaction Time	Trial x set size x alexithymia	0.797	Non-significant	1/38.5932751218	Very strong evidence in favour of the null hypothesis
2	Reaction Time	Alexithymia x target type x set size	0.669	Non-significant	1/42.8153856232	Very strong evidence in favour of the null hypothesis
2	Reaction Time	alexithymia x target type x trial type x set size	0.467	Non-significant	1/16.7406912131	Strong evidence in favour of the null hypothesis
2	Search Slope	Alexithymia	0.625	Non-significant	1/7.27400220693	Substantial evidence in favour of the null hypothesis

2	Search Slope	Target Type	0.162	Non-significant	1/5.08951955953	Substantial evidence in favour of the null hypothesis
2	Search Slope	Trial Type	<.001	Significant	1/2.19366075914	Anecdotal evidence in favour of the null hypothesis
2	Search Slope	Alexithymia x trial type	0.516	Non-significant	1/9.57718637588	Substantial evidence in favour of the null hypothesis
2	Search Slope	Target x Trial	0.398	Non-significant	1/4.63724673677	Substantial evidence in favour of the null hypothesis
		alexithymia x target type	0.532	Non-significant	1/11.0719434959	Strong evidence in favour of the null hypothesis
2	Search Slope	Target x Trial x Alexithymia	0.398	Non-significant	1/5.30214821837	Substantial evidence in favour of the null hypothesis
2	Accuracy	Alexithymia	0.889	Non-significant	1/30.4785776745	Very strong evidence in favour of the null hypothesis

2	Accuracy	Target Type	0.44	Non-significant	1/5.91733133091	Substantial evidence in favour of the null hypothesis
2	Accuracy	Trial Type	<.001	Significant	5E+64	Extreme evidence in favour of an effect
2	Accuracy	Set Size	<.001	Significant	9E+12	Extreme evidence in favour of an effect
2	Accuracy	alexithymia x target type	0.855	Non-significant	1/19.25036388	Strong evidence in favour of the null hypothesis
2	Accuracy	Alexithymia x trial type	0.642	Non-significant	1/10.448620944	Strong evidence in favour of the null hypothesis
2	Accuracy	Alexithymia x set size	0.518	Non-significant	1/142.980943929	Very strong evidence in favour of the null hypothesis
2	Accuracy	Target type x trial type	0.745	Non-significant	1/6.70852338021	Substantial evidence in favour of the null hypothesis

2	Accuracy	Target type x set size	0.29	Non-significant	1/24.5760327156	Strong evidence in favour of the null hypothesis
2	Accuracy	Trial Type x Set Size	<.001	Significant	1487586477	Extreme evidence in favour of an interaction
2	Accuracy	alexithymia x target type x trial type	0.799	Non-significant	1/12.3463130946	Strong evidence in favour of the null hypothesis
2	Accuracy	Trial x Set size x Target	0.573	Non-significant	1/13.5370716769	Strong evidence in favour of the null hypothesis
2	Accuracy	Trial x set size x alexithymia	0.407	Non-significant	1/37.2625999756	Very strong evidence in favour of the null hypothesis
2	Accuracy	Alexithymia x target type x set size	0.698	Non-significant	1/47.619047619	Very strong evidence in favour of the null hypothesis
2	Accuracy	alexithymia x target type x trial type x set size	0.187	Non-significant	1/14.9856826788	Strong evidence in favour of the null hypothesis

3	Reaction Time	Alexithymia	0.587	Non-significant	1/3.05878027466	Substantial evidence in favour of the null hypothesis
3	Reaction Time	Trial Type	<.001	Significant	6E+16	Extreme evidence in favour of an effect
3	Reaction Time	Set Size	<.001	Significant	2E+28	Extreme evidence in favour of an effect
3	Reaction Time	Alexithymia x trial type	0.604	Non-significant	1/11.1556830229	Strong evidence in favour of the null hypothesis
3	Reaction Time	Alexithymia x set size	0.591	Non-significant	1/46.0398585471	Very strong evidence in favour of the null hypothesis
3	Reaction Time	Trial x Set Size	<.001	Significant	16.13396	Strong evidence in favour of an interaction
3	Reaction Time	Alexithymia x trial type x set size	0.6	Non-significant	1/20.2871236612	Strong evidence in favour of the null hypothesis

3	Search Slope	Alexithymia	0.815	Non-significant	1/8.9261486168	Substantial evidence in favour of the null hypothesis
3	Search Slope	Trial Type	<.001	Significant	551829	Extreme evidence in favour of an effect
3	Search Slope	Trial x Alexithymia	0.606	Non-significant	1/5.73975052748	Substantial evidence in favour of the null hypothesis
3	Accuracy	Alexithymia	0.661	Non-significant	1/8.0575112926	Substantial evidence in favour of the null hypothesis
3	Accuracy	Trial Type	<.001	Significant	62649577	Extreme evidence in favour of an effect
3	Accuracy	Set Size	<.001	Significant	1304724431	Extreme evidence in favour of an effect
3	Accuracy	Alexithymia x trial type	0.81	Non-significant	1/12.2876871968	Strong evidence in favour of the null hypothesis

3	Accuracy	Alexithymia x set size	0.897	Non-significant	1/47.2025636656	Very strong evidence in favour of the null hypothesis
3	Accuracy	Trial x Set Size	<.001	Significant	4213.653	Extreme evidence in favour of an interaction
3	Accuracy	Alexithymia x trial type x set size	0.506	Non-significant	1/13.0600645428	Strong evidence in favour of the null hypothesis
4	Reaction Time	Alexithymia	0.108	Non-significant	2.03865	Anecdotal evidence in favour of an effect
4	Reaction Time	Target Type	0.028	Significant	1/1.96593042572	Anecdotal evidence in favour of the null hypothesis
4	Reaction Time	Alexithymia x Target Type	0.63	Non-significant	1/2.6224851351	Anecdotal evidence in favour of the null hypothesis
4	Accuracy	Alexithymia	0.526	Non-significant	1/2.53344784518	Anecdotal evidence in favour of the null hypothesis

4	Accuracy	Target Type	0.751	Non-significant	1/3.39480879418	Substantial evidence in favour of the null hypothesis
4	Accuracy	Alexithymia x Target Type	0.43	Non-significant	1/2.60703712317	Anecdotal evidence in favour of the null hypothesis
4	N2pc Mean Amplitude	Alexithymia	0.789	Non-significant	1/3.41920203347	Substantial evidence in favour of the null hypothesis
4	N2pc Mean Amplitude	Target Type	0.852	Non-significant	1/3.76742197198	Substantial evidence in favour of the null hypothesis
4	N2pc Mean Amplitude	Alexithymia x Target Type	0.616	Non-significant	1/2.66112797231	Anecdotal evidence in favour of the null hypothesis
4	N2pc Peak Amplitude	Alexithymia	0.901	Non-significant	1/3.3475066766	Substantial evidence in favour of the null hypothesis

4	N2pc Peak Amplitude	Target Type	0.343	Non-significant	1/2.63613251944	Anecdotal evidence in favour of the null hypothesis
4	N2pc Peak Amplitude	Alexithymia x Target Type	0.842	Non-significant	1/2.53551752955	Anecdotal evidence in favour of the null hypothesis
4	N2pc Onset Latency	Alexithymia	0.062	Non-significant	1.438	Anecdotal evidence in favour of an effect
4	N2pc Onset Latency	Target Type	0.262	Non-significant	1/1.88699859853	Anecdotal evidence in favour of the null hypothesis
4	N2pc Onset Latency	Alexithymia x Target Type	0.053	Non-significant	1.8	Anecdotal evidence in favour of an effect

4	N2pc Peak Latency	Alexithymia	0.804	Non-significant	1/3.34719966582	Substantial evidence in favour of the null hypothesis
4	N2pc Peak Latency	Target Type	0.127	Non-significant	1/2.56080110053	Anecdotal evidence in favour of the null hypothesis
4	N2pc Peak Latency	Alexithymia x Target Type	0.687	Non-significant	1/2.56459772874	Anecdotal evidence in favour of the null hypothesis

Appendix B

Bayes Factors for Study 1A calculated using Bayesian priors with half (r = 0.354), default (r = 0.707), and double (r = 1.414) scale parameters across all main effects and interactions.

DV	IV / Interaction	Half Prior	Default Prior	Double Prior
Reaction Time	Alexithymia	B_{10} = 2.774508	B_{10} = 2.763796	B_{10} = 1.645184
Reaction Time	Target Type	B_{10} = 9.22E+68	B_{10} = 1.19E+69	B_{10} = 1.23E+69
Reaction Time	Set Size	B_{10} = 3.34E+38	B_{10} = 2.14E+38	B_{10} = 1.31E+38
Reaction Time	Alexithymia x Target Type	B_{10} = 0.3507344	B_{10} = 0.4474537	B_{10} = 0.0948763
Reaction Time	Alexithymia x Set Size	B_{10} = 0.1075416	B_{10} = 0.01947988	B_{10} = 0.001902971
Reaction Time	Target Type x Set Size	B_{10} = 3.85E+10	B_{10} = 8.82E+09	B_{10} = 1.02E+09
Reaction Time	Alexithymia x Target Type x Set Size	B_{10} = 0.03528205	B_{10} = 0.002851449	B_{10} = 5.21E-05
Detection Accuracy	Alexithymia	B_{10} = 0.2092363	B_{10} = 0.06932378	B_{10} = 0.02191199
Detection Accuracy	Target Type	B_{10} = 1.17E+17	B_{10} = 6.28128E+16	B_{10} = 3.27486E+16

Detection Accuracy	Set Size	B_{10} = 5644.291	B_{10} = 1771.311	B_{10} = 487.851
Detection Accuracy	Alexithymia x Target Type	B_{10} = 0.09790388	B_{10} = 0.0160365	B_{10} = 0.001500829
Detection Accuracy	Alexithymia x Set Size	B_{10} = 0.148979	B_{10} = 0.02543098	B_{10} = 0.002240979
Detection Accuracy	Target Type x Set Size	B_{10} = 2651912233	B_{10} = 529607945	B_{10} = 58573498
Detection Accuracy	Alexithymia x Target Type x Set Size	B_{10} = 0.05584395	B_{10} = 0.00535515	B_{10} = 1.33E-04
Labelling Accuracy	Alexithymia	B_{10} = 0.2131081	B_{10} = 0.08059079	B_{10} = 0.02545125
Labelling Accuracy	Target Type	B_{10} = 1.41E+27	B_{10} = 6.10765E+26	B_{10} = 3.67121E+26

Labelling Accuracy	Set Size	B_{10} = 5104722	B_{10} = 1796787	B_{10} = 633105.3
Labelling Accuracy	Alexithymia x Target Type	B_{10} = 0.03294433	B_{10} = 0.004280641	B_{10} = 0.00035632
Labelling Accuracy	Alexithymia x Set Size	B_{10} = 0.06200707	B_{10} = 0.009291405	B_{10} = 0.000858475
Labelling Accuracy	Target Type x Set Size	B_{10} = 46294465	B_{10} = 15487593	B_{10} = 3571865
Labelling Accuracy	Alexithymia x Target Type x Set Size	B_{10} = 0.05664231	B_{10} = 0.003756909	B_{10} = 1.64E-04
Search Slope	Alexithymia	B_{10} = 1.244601	B_{10} = 0.564273	B_{10} = 0.1715628
Search Slope	Target Type	B_{10} = 6.59253E+17	B_{10} = 1.24942E+18	B_{10} = 3.98895E+18

Search Slope	Alexithymia x Target Type	B_{10} = 0.1510629	B_{10} = 0.03460359	B_{10} = 0.004309865