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LATERAL BIASES IN ATTENTION AND MEMORY IN NEUROLOGICALLY HEALTHY ADULTS

By

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Submitted in fulfilment of the requirements for the degree

PhD (Psychology)

in the Department of Psychology at the
University of Pretoria

Supervisor: Prof David JF Maree

March 2021

ACKNOWLEDGEMENTS

I would like to express my appreciation and thanks to the following individuals:

Academics and related:

- I would like to thank my supervisor, Professor David Maree for his incredible support, statistical analysis, feedback and time. You will always be my work dad and no amount of statistical significance can express my gratitude for everything you have done for me. *I could not have done this without you Prof!!*
- Thank you to all the participants: the students and staff members who offered their time to participate in my study.
- Romy de Jager, thank you for doing the language editing.
- Juanita Haug, a dear friend and colleague, thank you for improving the formatting and layout.
- Jacques Brosens and Rendani Kruger for your assistance with the eye-tracker setup and data extraction.
- Takalani Sigama for your great work in computerising the Line Bisection Task. Without you, my study would not have been possible.
- The late Professor Helene Gelderblom, thank you for your kind heart and willingness to provide your eye-tracker for data collection. I will always remember your kind gestures.

Other:

- My Lord and Savior Jesus Christ who gave me the talent, perseverance and opportunity to make this goal a personal achievement.
- Prof. Desiré Brits, my sister, you inspire me every day, thank you for your love and support. Thank you for motivating me to keep going and for holding me together when things seemed impossible.
- My parents, Francois and Nicolene Mostert, no number of words can accurately capture how much I love and appreciate you. Every opportunity and every accomplishment are because of you. I have always been a step ahead because you made it possible by taking the first step for me.
- Aliyah for your unconditional love and support. For keeping me company during the long hours and for never leaving my side.

DECLARATIONS

I, Sonja Nicolene Mostert, hereby declare that:

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I, Sonja Nicolene Mostert have obtained, for the research described in this work, the applicable research ethics approval. Reference number: GW20160825HS.

I declare that I have observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the Policy guidelines for responsible research.

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March 2021

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SUMMARY

LATERAL BIASES IN ATTENTION AND MEMORY IN NEUROLOGICALLY HEALTHY ADULTS

by

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Degree: Doctor of Philosophy

Keywords: Attention, Activation-Orientation hypothesis, Eye tracker, Fixations, Lateral bias, Pseudoneglect, Theory of Visual Attention, Visual Long-term Memory.

Attention enables us to experience the world around us and to prioritise relevant sensory information. Attentional capacity is, however, limited and the mechanisms underlying the ability to focus attention are not symmetrically presented in the brain. Healthy populations do not attend to their left and right sides equally when viewing the visual world. Some information may, therefore, be over attended while other stimuli are ignored. Pseudoneglect is the tendency to demonstrate a leftward bias in spatial attention. The strong link between attention and memory suggests that this leftward attentional bias may impact what is encoded to memory. This research study explored the impact of pseudoneglect on visual long-term memory and attention by using an eye tracker to record eye-movements. Pseudoneglect was measured using a computerised version of the line bisection task (LBT), consisting of different line lengths presented in different positions. Male and female LBT performance was also explored. Participants demonstrated a tendency to bisect lines, of different lengths more towards the left of the true midpoint. No significant gender differences with regard to LBT performance were found. The eye-tracking data produced significant differences between the number of left and right fixations according to the items viewed, $F(14, 28) = 2.74$ $p = .01$, $\eta 2 = .58$, indicating a large effect size. The findings also demonstrated that more items on the left were correctly recalled when compared to the right. On average, participants recalled more items on the left (M = 66.49, SE = 1.8) than on the right (M = 61.60, SE = 2.1), $t(34) = 2.86$, $p = .004$ (one-tailed). The eta squared (.483) indicated a small to medium effect size. Although a higher number of leftward fixations were observed and more items on the left were correctly recalled, the data revealed no significant correlations between leftward biases in attention and memory. There were no significant associations between the number of fixations and the number of items recalled. The study concludes that pseudoneglect impacts attention with a higher number of fixations recorded for the left-hemifield, but no significant differences were observed concerning memory encoding.

LIST OF ABBREVIATIONS

CBT	character line bisection task
CLT	cognitive load theory
CRUNCH	compensation-related utilization of neural circuits hypothesis
FBA	feature-based attention
HAROLD	hemispheric asymmetry reduction in older adults
IPS	the intraparietal cortex
LBT	line bisection task
LTM	long-term memory
OBA	object-based attention
PPC	posterior parietal cortices
RHAM	right hemi-aging model
SBT	solid line bisection task
STM	short-term memory
TVA	theory of visual attention
VLTM	visual long-term memory
VSTM	visual short-term memory
VWM	visual working memory
WM	working memory

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CHAPTER 1 INTRODUCTION

This introductory chapter provides a detailed discussion on the problem statement and purpose of the study. Particulars of the research question and the aim and objectives of the study are discussed. A brief outline of the dissertation chapters is also included.

1.1 PROBLEM STATEMENT

A detailed examination of the space around us is necessary for everyday life (Gigliotta, et al., 2017). People are constantly searching their surroundings and are exposed to a multitude of stimuli. Eckstein (2011) maintains that visual search is an essential part of our daily functioning and the ability to focus attention enables us to prioritise relevant sensory stimuli, a requirement for goal-directed behaviour. By accurately distributing our attentional resources we can experience the world around us (Thomas, Barone, Flew & Nicholls, 2017). Attention allows us to effectively manage the profusion of sensory input we are constantly faced with (Duecker & Sack, 2015; Forte, 2016), and the way we direct our attentional resources ultimately impact how we perceive the world around us. Our attentional capacity is, however, limited. Research suggests that people do not attend to their left and right sides equally when viewing the visual world (Gigliotta et al., 2017; Nuthmann & Matthias, 2014). Visuospatial attention, in a neurologically healthy population, appears to be asymmetrically distributed (Sosa, Teder-Sälejärivi, & McCourt, 2010).

The mechanisms underlying the ability to focus attention are not symmetrically presented in the brain (Nicholls, Loftus, Orr & Barre, 2008; Gigliotta et al., 2017). As a result, people do not attend equally to their left and right visual fields (Dickinson & Intraub, 2009; Helfer, Maltezos, Liddle, Kuntsi & Asherson, 2020; Nuthmann & Matthias, 2014). Some information may therefore be over attended while other stimuli are disregarded (Märker, Learmonth, Thut, Harvey, 2019; Thomas et al., 2017). This tendency is known as a special type of spatial asymmetry observed in both healthy and neurologically injured populations (Benwell, Thut, Learmonth, & Harvey, 2013; Brodie, 2010; Brooks, 2014; Forte, 2016; Foulsham, Gray, Nasiopoulos, & Kingstone, 2013; McGeorge, Beschin, Conaghi, Rusconi, & Della Sala, 2007; Schmitz, Deliens, Mary, Urbain & Peigneux, 2011; Szelest, 2014; Toba, Cavanagh & Bartolomeo, 2011).

Neurologically impaired patients often show a tendency to attend to objects found in the right side of space while ignoring objects located in the left visual field i.e., visuospatial neglect/unilateral neglect (Badok, Malhotra, Bernadi, Cocchini & Stewart, 2014; Bartolomeo & Chokron, 2002; Bultitude & Aimola Davies, 2006; Foulsham et al., 2013; Loftus & Nicholls, 2012; Toba et al., 2011).

Neurologically intact individuals, on the other hand, show an inclination towards the left visual field, a spatial bias known as pseudoneglect (Benwell et al., 2013; Brodie, 2010; Brooks, 2014; Failla, Sheppard, & Bradshaw, 2003; Bultitude & Aimola Davies, 2006; Hatin, Tottenham & Oriet, 2012; Loftus & Nicholls, 2012; Nuthmann & Matthias, 2014; Parra, Della Sala, Abrahams, Logie, Méndez & Lopera, 2011; Schmitz et al., 2011).

Pseudoneglect is described as "...a slight but consistent misplacement of attention toward the left visual field, commonly observed in young healthy subjects" (Schmitz et al., 2011, p.382). The concept of pseudoneglect was originally identified by Bowers and Heilman (1980). A prominent focus toward the left visual field means that the right side is largely ignored. The concept of pseudoneglect is, however, not yet fully understood and is regulated by various factors, including the nature of the task used to assess it (Friedrich, Hunter, & Elias, 2018; Jewell & McCourt, 2000), handedness, gender, age, and stimulus type, complicating the understanding of this phenomenon (Friedrich et al., 2018; Haussmann, Waldie, & Corballis, 2003; Jewell & McCourt, 2000; Szelest, 2014). Directing attention more toward the left visual field may have implications for subsequent cognitive functioning.

The strong correlation between attention and memory is well documented (Chun & Turk-Browne, 2007; Duchowski, 2007; Jarodzka, van Gog, Dorr, Scheiter, & Gerjets, 2013; Jarodzka, Holmqvist, & Gruber, 2017; Summerfield, Lepsien, Gitelman, Mesulam, & Nobre, 2006; Theeuwes, 2010; Theeuwes Belopolsky, & Olivers, 2009; Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009). Attention influences the encoding of information to memory and several memory systems interact when information is stored and retrieved. Working memory (WM), for example, plays a role in guiding the distribution of our attentional resources (Olivers, Peters, Houtkamp & Roelfsema, 2011; Theeuwes, 2010). Researchers argue that attention not only regulates memory encoding, but it is biased by what is presently on our minds. WM allows for the temporary manipulation of information, and Chai, Abd Hamid, and Abdullah (2018) argue that WM is connected to LTM as Cowan (2008) also outlined. Szelest (2014) explained that lateral biases can manifest as behavioural outcomes based on cognitive processing, specifically in relation to attention. The tendency to disregard the right side of space while leaning more towards the left consequently impacts what we pay attention to. As a result, stimuli on the left may become more salient when compared to the right (Brignani, Bagattini & Mazza, 2018; Friedrich, Hunter, & Elias, 2018; Hatin, Tottenham, & Oriet, 2012; Nicholls et al., 2008; Thomas et al., 2017).

1.2 RATIONALE

It is hypothesised that the leftward bias in attention i.e., pseudoneglect, may impact what information is encoded to memory but the exact nature of how is not yet well conceptualised (Lee et al., 2004; Szelest, 2014). Research has demonstrated that study participants generally recall more items in the left visual field compared to the right (Della Sala, Darling, & Logie, 2010; McGeorge et al., 2007). As a result, participants made significantly more errors in recalling items presented on the right. If attention is biased to the left, the inclination is that these items are better remembered: "...[suggesting] a spatial asymmetry in forming or retrieving...visual short-term memory" (Della Sala et al., 2010, p. 848). Lateral biases may therefore, depend on both our perceptual and attentional functioning (Olivers et al., 2011; Szelest, 2014).

Lateral biases are still misapprehended (Friedrich et al., 2018; Forte, 2016; Gigliotta et al., 2017; Haussmann, Waldie, & Corballis, 2003; Jewell & McCourt, 2000; Szelest, 2014), and differences about the demonstration of pseudoneglect are evident. The lack of agreement, regarding the demonstration of pseudoneglect in various population groups, provides support for more research. Limited research regarding the topic within a South African context is also apparent. Currently, to the knowledge of the researcher, no research on pseudoneglect has been conducted on a South African population. Internationally, the topic of pseudoneglect has been explored using different assessment techniques and diverse applications for the consequence of a leftward biase have been proposed. Inconclusive decisions regarding the impact of pseudoneglect on memory are, however, evident.

With the expansion of the digital world and technologies, Madore et al. (2020) argue that scholars, educators, and the general public have become more aware that attention is a rare asset, described as an 'attention economy' (p. 87). Increased use of digital media has also been linked to the enduring question regarding memory and why people sometimes recall content but other times forget. Similarly, why can some people remember better when compared to others who don't?

Internationally, online teaching is not a novel means of instruction. Locally, however, the availability of resources for online teaching is restricted. The context of the tertiary institution used in the current study is primarily a contact-based teaching facility and online course options are limited. The unplanned move to online teaching methods, amidst the Covid-19 lockdown regulations (Kupe, 2020), required the development of optimal online course material to ensure continual learning. The implications of a leftward bias in attention and/or memory may direct the planning of academic material to enhance future learning. Istrate (2009) highlights the importance of how educational content is presented to enable effective 'perceptual-visual learning' (p. 1). The design of educational content is an essential part of the educational message portrayed. Poorly designed courses can negatively impact the learning experience. The constant exposure to large amounts of sensory content requires the ability to direct attentional resources to the most important features (Yotsumoto & Watanabe, 2008). The design of online course material can thus play a determining role in student success, especially where a lot of content is presented (Rottmann & Rabidoux, 2017). If not properly designed and structured, online learning can easily become a ‘disinviting learning environment’. The position of content is significant in planning and creating e-learning courses, which Istrate (2009) notes as the left upper part of a page.

Online resources must be thoroughly planned and executed. As attention is described economically, as an asset that should be optimally managed, the current findings can be valuable in aiding the design of efficient teaching and learning platforms to ensure ideal learning. It can offer guidance to create online platforms that warrant sufficient navigation. A well-structured online platform should ensure that our limited attentional resources are optimally distributed. Significant and useful content should thus be located where attention is more likely to be directed. If attention is directed more towards the left visual field, this may instruct the layout of important content. Similarly, the design of textbooks and visual presentations may benefit from the study findings.

Linking to this, is the importance of memory. A core feature of academic learning and achievement is based on the memorisation of various content (El-Mir, 2019). The prominent role of various memory systems, including working memory and long-term memory is highlighted. Given the limited capacity of our attentional system, it is imperative that our attentional resources are optimally used to enable the memorisation of content. A leftward bias in attention may not only impact how content is perceived concerning visual processing, but can also predict changes in memory. The current study findings can thus contribute to a better understanding of our cognitive processing system, pertaining to both attention and memory.

The findings from the present study may also offer new ways of perceiving attentional and perceptual asymmetries in real-world scenarios (Klatt, Ford, & Smeeton, 2019). Accurately perceiving the visual space is vital in sports, for example (Noël, van der Kamp, Masters, & Memmert, 2016). If a leftward bias in attention is present, the implication may extend beyond the field of academics to inform several everyday functions, including sporting activities and driving habits. Klatt et al. (2019) explored lateral biases in attention and its impact on sport-specific decision-making. Similarly, Roberts and Turnbull (2010) studied the effects of pseudoneglect on putting ability. It was concluded that asymmetrical biases in attention significantly impact sports performance and affect ‘precision-based sports’ (p.369). Identifying the midpoint of the goal is critical for soccer players when attempting to score. Findings from a study conducted by Noël et al. (2016) demonstrated that scan direction impacts the way players perceive the position of the goalkeeper and their subsequent decision to kick. It is argued that the off-centre effect results from attentional biases present in the player's implicit perception of the goalkeeper's position.

Lateral biases in attention may also impact daily functions, like driving. Zheng, Yang, Easa, Lin, and Cherchi (2020), reported that research on traffic safety has demonstrated that accidents are generally the result of spatial attentional judgement. Friedrich, Elias, and Hunter (2017) observed that during crashes the impacted objects were mostly located on the left side of the vehicle. A leftward bias in crashes may be likely, but Friedrich et al. (2017) cautioned that more research is needed. Another study highlighted the extent of leftward biases on driving ability where identical road signs were presented together on both the right and left side of the road (Benedetto, Pedroti, Bremond & Baccino, 2013). The findings showed that attention was directed mostly to the signs located on the left side. The recent study by Zheng et al. (2020), also found that asymmetries in visual attention are present where preference is given to the left side of space. The researchers proposed that inexperienced drivers exhibit the leftward tendency whereas more experienced drivers appear to move their eyes more towards the center or right side of the road. Despite the leftward inclination observed, Zheng et al. (2020) noted that the leftward bias may, however, be mitigated by more driving experience. The results supported the notion of a leftward bias in visual attention where experienced and inexperienced drivers paid more attention to the left side compared to the right during a driving simulation.

The findings from the present study may be more applicable to the field of teaching and learning where the aim is to determine how potential leftward biases in attention may impact memory. The demonstration of pseudoneglect in the current investigation may, however, also contribute useful information regarding the allocation of attention in other daily activities. Mitchell, Harris, Benstock, and Ales (2020) report that pseudoneglect research can also contribute to a general understanding of spatial attention in healthy individuals. This may offer valuable input in understanding attention disorders. Understanding the occurrence of pseudoneglect within a neurologically healthy population can thus advance the understanding of human cognition, specifically attention and the ability to perceive (Mitchell et al., 2020). Apart from the practical implications of the findings, methodological contributions can also be offered.

Chen, Kaur, Abbas, Wu, Luo, Osman, et al. (2019) highlighted the methodological concerns related to pseudoneglect research, specifically regarding the assessment measures used. Forte (2016) acknowledges the methodological limitations of pseudoneglect research and maintains that numerous studies focusing on pseudoneglect rely solely on the findings from the LBT as an indication of leftward biases. The present study, however, combined the LBT results with eye-tracking data to supplement the measure of lateral biases in attention. In conjunction with this, the present study computerised the traditional landmark task, i.e., the LBT, to minimise human error when calculating the deviations from the midpoint. An eye-tracker was used to capture the attentional fixations of participants to supplement the potential leftward tendency demonstrated by LBT performance.

The predisposition to favour the left visual field while allocating less attention to the right side of space can impact our memory but disagreement regarding the nature and extent of this is evident (Brignani, Bagattini & Mazza, 2018; Friedrich et al., 2018; Hatin, Tottenham, & Oriet, 2014; Nicholls et al., 2008; Thomas et al., 2017). Previous research used different means of assessment and varied samples. More importantly, the debate about whether the lateral bias is within the memory system itself or the way we allocate attention is also prominently highlighted. The findings from this study can offer a valuable contribution to elucidating the nature of pseudoneglect.

The deliberation regarding pseudoneglect is also extended to question its presence amongst different age groups and the possibility of gender differences. As noted, the impact of pseudoneglect is moderated by various factors including age and gender. Friedrich et al. (2018) emphasised that pseudoneglect is not yet well understood amongst older adults and research that examines the leftward bias in the context of ageing is limited. Märker et al. (2019) also note that with a larger senior population, the need to understand cognitive aging and to find potential identifiers of cognitive decline is vital. It has also been reported that gender differences exist in how pseudoneglect is demonstrated (Forte, 2016; Hausmann et al., 2002; Jewell & McCourt, 2000). Research showed that elderly people bisect lines left of the midpoint when stimuli are presented in right and central space, but tended to make rightward errors when lines were presented in left space (Friedrich et al., 2018; Harvey, Pool, Roberson, & Olk, 2000). The opposite was observed with younger participants. Brignani et al. (2018) argued that age-related changes in the underlying mechanisms of pseudoneglect are still debated hence the relevance of investigating pseudoneglect in relation to age.

Our ability to focus attention also changes as we get older specifically our ability to sustain attention and divided attention becomes compromised as well (Glisky, 2007; Rothbart, & Posner, 2015). Exploring possible differences in the demonstration of pseudoneglect amongst various age groups may thus be valuable to elucidate the impact of age on the asymmetrical bias in attention. Similarly, Hausmann et al. (2002) explored the relation between gender and pseudoneglect. Results showed that hand used and gender interact, where females tended to exhibit a leftward bias with both hands while males mainly demonstrated the leftward bias with the left hand. Findings also show that males tend to make larger leftward errors compared to females (Forte, 2016; Friedrich et al., 2018; Jewell & McCourt, 2000) but more research on gender is needed.

Based on the information provided, the purpose of the study was twofold: Firstly, to determine if pseudoneglect impacts memory, and secondly to explore possible differences in relation to male and female performance concerning the presentation of pseudoneglect. The findings may also guide future research to explore age differences.

1.3 THE AIM OF THE STUDY

The main aim of the present study was to investigate possible lateral biases in memory and attention for visually presented stimuli. The present investigation attempted to address the following research question: Does a leftward bias (pseudoneglect) impact visual long-term memory and attention for visually presented stimuli?

Additional exploratory questions were also included based on inconsistent results:

1. Does gender impact the demonstration of pseudoneglect?
2. Does age impact the demonstration of pseudoneglect?
3. How does hand use impact LBT performance?

The researcher endeavoured to answer the research questions by focusing on the following study objectives:

Study objectives included:

- To measure handedness in relation to LBT performance
- To measure eye movements using an eye-tracker to determine left-to-right scan patterns
- To measure overt attention using the eye tracker
- To measure pseudoneglect using the line bisection task
- To measure a component of long-term memory, i.e., visual long-term memory (VLTM) using a computerised memory test by asking participants to indicate whether they recall seeing a stimulus based on a simulation presented
- To explore pseudoneglect amongst males and females by comparing male and female LBT performance
- To explore pseudoneglect amongst younger and older participants by comparing LBT performance

Based on the research question, the following main hypotheses were formulated:

Hypothesis 1: A leftward bias/lateral bias impacts visual long-term memory and attention for visually presented stimuli.

Hypothesis 2: Pseudoneglect manifests differently for males and females.

2. LITERATURE REVIEW

The literature review is an important part of the research process and is discussed comprehensively in Chapter 2. The literature consulted included information and past research relevant to the current topic. The variables addressed in the present study are often conceptualised in different ways and a thorough examination of the literature enabled the researcher to apply the most widely used definitions and ensured that the concepts were appropriately operationalised. This chapter offers a conceptualisation of the variables pseudoneglect, attention, and memory.

3. THEORETICAL FRAMEWORK

The research study was rooted within a post-positivist paradigm. Post-positivists accept that absolute truths cannot be found but rather assumes that different methods can be used to explore the world and as Panhwar, Ansari, and Shah (2017) argue, all findings are important components in the creation of knowledge. Chapter 3 provides a detailed discussion on the ontological and epistemological viewpoints of the researcher. This chapter also offers a discussion on the theoretical framework that guided the present research process and interpretation of the findings.

4. METHODOLOGY

Chapter 4 includes a discussion on the research methodology. Details regarding the research design and data collection methods are presented. This chapter outlines information about how the sample was recruited, the measurement instruments used for data collection, and the data collection procedure. The statistical analysis process is also discussed in this chapter.

According to the ethical guidelines all individuals involved in the research project have the right to honesty and respect and the researcher has a responsibility to act ethically toward those who will be influenced by the research process and the results (Gravetter & Forzano, 2012; Willig, 2008). The study was approved by the Ethical Committee at the University of Pretoria, reference number: GW20160825HS. Refer to Appendix D for the ethical approval letter.

5. FINDINGS

The findings chapter provides extensive details on the results obtained from the statistical analysis. The findings are presented in relation to the study aim and objectives. To ensure a logical flow, the researcher presents the demographic findings first, followed by the line bisection data. The results from the eye tracker are provided to detail information regarding eye-movements, specifically the number of fixations and gaze patterns. The scores from the memory test are also summarised in this chapter.

6. DISCUSSION AND CONCLUSION

The final chapter provides a discussion on the research findings concerning the research questions outlined. This chapter also offers a section addressing the limitations of the present study as well as recommendations for future research.

CHAPTER 2 LITERATURE STUDY

This literature review offers a conceptualisation of the variables measured and enabled the researcher to discover the assumptions underlying the subject matter. The content of this chapter includes the most widely used definitions and other key concepts related to the topic (Opper, 2013).

In the present study, the main focus was on pseudoneglect and how this phenomenon impacts attention and a component of long-term memory. Neurological information pertaining to pseudoneglect was also regarded as significant given the secondary aims of including gender and age as variables. A very brief outline of relevant neurological information is thus included.

Various types of pseudoneglect are discussed in detail. Different forms of attention and memory have been identified, and to contextualise the current study, specific forms of attention relevant to this investigation are discussed. Important theories regarding attention are furthermore provided. Similarly, a review of central memory systems is included. The strong correlation between attention and memory and how this relates to the phenomenon of pseudoneglect is addressed as well. Reference is made to studies that explored pseudoneglect using different or similar assessment techniques and samples.

The first part of this chapter delineates the variables involved, followed by a brief outline of previous research on the subject matter. Findings of age, gender, and pseudoneglect are also discussed.

2.1 ATTENTION

In our daily lives, we continuously observe the world around us and use different types of visual information to guide our behaviour. We search for various objects and attend to multiple stimuli (Eckstein, 2011) while noticing different colours and objects in our surrounding environment. Every time we open our eyes, we have to deal with an overwhelming volume of information and not all aspects of our visual world can be processed equally (Chun & Johnson, 2011). Nevertheless, we are capable of understanding our visual world even with this overload of stimuli. This, however, requires selecting relevant information amongst irrelevant noise, which is partly determined by current behavioural goals (Carrasco, 2011; Eimer, 2014).

Searching our visual world is based on a decision-making process where we need to decide what objects or stimuli features are important for current behaviour. This is only applicable in situations where we are able to consciously control the distribution of attention. This search goal is then represented in memory by means of an attentional template. Attentional templates include memory representations of a present search objective, activated to guide our perceptual experience of the visual world (Eimer, 2014; Luck & Vogel, 2013).

Carrasco (2011) noted that the construct of attention has been widely used, but it has not always been clearly defined.

2.1.1 Conceptualisation of attention

Attention is defined as "sustained concentration on a specific stimulus, sensation, idea, thought, or activity, enabling one to use information processing systems with limited capacity to handle vast amounts of information available from the sense organs and memory stores" (Oxford Dictionary of Psychology, 2009, p.63). The initial processing of visual information depends on attention (Theeuwes, 2010). It is the tool that makes it possible to perceive what is important by focusing on specific locations of the visual world. Attention allows us to selectively process large amounts of information and prioritise certain features of the visual domain while disregarding others (Carrasco, 2011; Olivers et al., 2011). It is an essential cognitive process that makes it possible to use our capacity limited system, optimally. Carter, Aldridge, Page, and Parker (2014) explained that attention causes us to choose one aspect from the sensory input we are receiving, and to become more aware of that aspect, consciously directing our sense organs towards the stimulus and processing information from it.

When viewing our visual surroundings, our eyes move to different locations. As we experience the visual world, we sample visual information by means of a series of fixations including continuous eye-movements (Schneider, 2018). Nuthmann and Matthias (2014) reported that eye-movements move from one setting to the next about three times per second. We tend to move our eyes to bring a specific aspect of our visual world into conscious awareness, allowing us to focus our attention (Duchowski, 2007). The visual system is thus dependent on attention to coordinate selective information to yield effective processing (Serences & Yantis, 2006). Where individuals focus their gaze and what we pay attention to, impacts what is transferred to memory (Foulsham & Kingstone, 2013).

Theeuwes (2010) argues that when attention is directed towards the visual field, initial observations are mainly stimulus-driven. The ability to focus attention is, however, not symmetrically presented in the brain (Nicholls et al., 2008). Pseudoneglect is the tendency to ignore the right side of stimuli (Brooks, Logie, McIntosh, & Della Sala, 2011; Cocchini, Watling, Della Sala & Jansari, 2007; Hatin et al., 2012; Loftus & Nicholls, 2012; Nicholls & Lotus, 2007; Nicholls et al., 2008; Toba et al., 2011). This means that neurologically healthy individuals seem to display an attention bias where they fail to attend equally to the right and left side of space (Cocchini et al., 2007). Consequently, people do not attend equally to their left and right visual fields (Nuthmann &Matthias, 2014; Schmitz & Peigneux, 2011). This inclination to favour a specific side of the visual field is a spatial asymmetry observed in both healthy and neurologically damaged populations (Benwell et al., 2013; Brodie, 2010; Brooks, 2014; Foulsham, Gray, Nasiopoulos, & Kingstone, 2013; McGeorge, Beschin, Conaghi, Rusconi, & Della Sala, 2007; Schmitz, Deliens, Mary, Urbain, & Peigneux, 2011; Szelest, 2014; Toba, Cavanagh, & Bartolomeo, 2011; Zago et al., 2017). The asymmetrical nature of our attentional system is considered a product of hemispheric lateralisation, which holds certain cognitive benefits (Helfer et al., 2020).

Attentional resources are restricted; not only due to capacity limitations but also because the asymmetrical nature of attention distribution impacts our experience of the visual world (Siman-Tov et al., 2007). The processing of visuospatial information is thus subject to bias (Szelest, 2014). The limited processing capacity of our cognitive system prevents equal allocation of attention to all observed stimuli. During a search task, for example, attention is often directed towards stimuli and objects that we had no intention to look for. Certain stimuli features can thus attract more attention making these objects more noticeable (Chun & Johnson, 2011).

The visual world is organised hierarchically (Flevaris, Martinex, & Hilyard, 2014), including different objects, like a tree for example, which consists of local features like leaves. Visual attention in both neurologically healthy and brain-damaged individuals depends on processing local and global stimuli features (Gazzaley, 2011; Lee et al., 2004; Thomas et al., 2017). Cognitive resources are thus allocated to process local and global aspects of sensory input. Hemispheric lateralisation enables optimal cognitive processing as each hemisphere is specialised for specific functions (Helfter et al., 2020). It is generally accepted that the left hemisphere is predominantly responsible for processing language while the right hemisphere is superior for visuospatial processing (Asanowicz, Kruse, Śmigasiewicz, Verleger, 2017; Brederoo, Nieuwenstein, Lorist, Cornelissen, 2017). The hemispheric speciality is also extended to impact different features of visual content. The left hemisphere processes local aspects of visual input while the right hemisphere is prominently involved with processing global features (Brederoo et al., 2017; Flevaris et al., 2014). Stimuli presented in the left visual field, involve stronger global processing compared to stimuli presented in the right visual field, where local processing is more evident. In relation to attentional processing in contralateral space, irregularities concerning each hemisphere's influence on attention to global versus local feature processing exist (Lee et al., 2004; Siman-Tov et al., 2007; Sosa, Clark & McCourt 2009; Szelest, 2014; Varnava et al., 2013).

Due to the disproportionate nature of attention distribution, the neurologically healthy population shows an inclination to concentrate more on the left. The left visual field thus seems to elicit a stronger attentional focus, making it superior in the visuospatial attention network (Szelest, 2014). Stimuli on the left may then have accentuated features (Szelest, 2014; Thomas et al., 2017). The allocation of attention is biased in the direction opposite to the more active hemisphere. Depending on the task, increases in the activated hemisphere will result in more attention being directed to the opposite side (Bultitude & Aimola Davies, 2006; Loftus & Nicholls, 2012). As our scanning paths are influenced by the dispersal of attention, a leftward bias in attention could mean a dominant left-to-right scanning pattern, increasing the salience of the left side. Nicholls and Roberts (2002) agree that left-to-right scanning impacts the demonstration of pseudoneglect. A stronger attentional bias is then observed where stimuli cross from left to right (Nicholls & Roberts, 2002; Nicholls et al., 2004).

We can ultimately only process a small amount of information, which means that not all information reaches conscious awareness, and not all information can be stored in memory (Treue, 2003). The general tendency for people to exhibit a slight left-ward bias may therefore impact the visual stimuli that eventually reach conscious awareness and what is transferred to memory. Only after sensory input is processed does the information become something meaningful, i.e., the information is perceived. Perceptual and attentional processes then significantly impact various cognitive aspects, especially memory (Szelest, 2014). The strong connection between attention and memory means that lateral biases, i.e., pseudoneglect, can potentially skew our attentional resources (Chun & Turk-Browne, 2007; Jarodzka et al., 2013; Jarodzka et al., 2017; Summerfield et al., 2006; Theeuwes et al.., 2009). Schmitz, Dehan, and Peigneux (2013) highlight that it is not yet clear whether the bias is linked to recall issues related to memory or encoding issues attributed to attention. If attention is primarily directed towards the left hemispace, the processing of this information becomes particularly salient (Bultitude & Aimola Davis, 2006; Dobler et al., 2001; Gazzaley, 2011; Thomas et al., 2017).

Attention is generally classified in relation to covert and overt attention and two subdivisions of attention are identified as selective attention and divided attention (Forte, 2016). Different forms of attention impact the way attention guides our cognitive processing and subsequent memory systems. The main focus of the current study was overt attention. Eye-movements were equated with attention, specifically visuospatial attention (Duchowski, 2007; von Gog et al., 2009; Wedel & Pieters, 2000).

2.1.2 Overt and Covert attention

Covert attention is generally regarded as the distribution of attention without eye-movements whereas overt attention depends on the observer’s ability to move their eyes to locations of interest (Carrasco, 2011).

Schneider (2013) reported that we sample visual information from our surroundings "…by means of successions of discrete sampling episodes [of]…fixations…" (p.1). Fixations are interrupted by saccades or eye-movements, which means that the extraction of valuable visual information is limited to periods of fixation. Disrupting eye-movements can then potentially attenuate memory details of observed objects (Johansson & Johansson, 2014; Laeng, Bloem, D'Ascenzo, & Tomassi, 2014). During a fixation, our visual processing capacity is restricted as not all information present is available for perception and encoding to memory (Schneider, 2013). Eye-movements create attentional pathways, described as gaze scan paths (Duchowski, 2007; Eimer, 2014; Theeuwes, Belopolsky, & Olivers, 2009; Van Gog et al., 2009; Wedel & Pieters, 2000). These gaze scan paths play a functional role in visuospatial memory (Bochynska, & Laeng, 2015). Research supports the claim that eye fixations impact memory encoding and the spatial location of eye fixations can prompt memory retrieval (Foulsham & Kingstone, 2012; Laeng et al., 2014). Where we focus our gaze, is related to what we pay attention to (Borji & Itti, 2013), and Duchowski (2007) explains that the number of fixations can be linked to what we extract from a scene and encode into memory. Hartmann (2015) reports that the eyes disclose the focus of spatial attention and eye-movements can therefore be a useful means of exploring spatial processing and associated higher cognitive functions (Eimer, 2014). It is further maintained that the duration of the fixation is not necessarily that important.

Attention essentially directs our mental ability to specific features of sensory input (Bochynaska, & Laeng, 2015; Carrasco, 2014; Chun & Turk-Browne, 2007; Duchowski, 2007; Treue, 2003) influencing what we focus on when presented with various stimuli. It has been proposed that guiding people's attention via eye-movements may enhance memorisation (Grant, & Spivery, 2003; Jarodzka et al., 2013).

When viewing our visual surroundings, our eyes move to different locations about three times per second (Itti & Koch, 2001; Nuthmann & Matthias, 2014). We move our eyes to bring a specific aspect of our visual world into conscious awareness, allowing us to focus (Duchowski, 2007). Attention is distributed directly by means of eye-movements, i.e., overt attention, but it also involves focusing on stimuli in the absence of eye-movements, described as covert attention (Carrasco, 2011).

This form of attention enables us to monitor our surroundings and can direct succeeding eye-movements. Overt attentional distribution is serial in that one location is favoured at a time, compared to covert attention, where multiple locations are attended to concurrently, referred to as parallel attentional distribution. Both attentional systems play a vital role in cognitive processing, but it is argued that covert attention occurs first, directing subsequent eye-movements (Carrasco, 2011, Chun & Johnson, 2011). Covert attention is therefore a necessary part of attentional distribution as it aids us in observing our surroundings and drives overt attention by guiding eye-movements to significant information.

Both overt and covert attentional distribution is essential in perceiving our visual world. Attentional processing is linked to areas of the visual cortex, the oculomotor system, responsible for eye-movements, i.e., overt attention, and controls our gaze in a visual scene based on the significance of stimuli, i.e., covert attention (Carrasco, 2011; Carrasco, 2014; Gazzaley, 2011; Treue, 2003). To enable us to effectively process the sensory information we experience, we rely on different memory systems as well. Tracking eye-movements relates to tracking the attentional pathways displayed by the observer (Duchowski, 200; (Foulsham & Kingstone, 2013; Johansson & Johansson, 2014). The significance of eye-movements in attention and memory extends beyond encoding to impact recall as well.

Concerning pseudoneglect, it was found that neurologically healthy individuals demonstrate a leftward bias with their first eye-movement when exploring the visual world (Cattaneo, Fantino, Tinti, Silvanto & Vecchi, 2010; Cattaneo, Fantino, Tinti, Pascual-Leone, Silvanto & Vecchi, 2011). Attention appears to be directed to the left almost instinctively (Niemeier et al., 2008). The ability to direct eye-movements to specific locations enables optimal processing of stimuli within that specific focus area, characteristic of visuospatial attention (Forte, 2016).

2.1.3 Visuospatial attention

Visual attention is defined as "...the conscious devotion of attention to visual information required to absorb it and transfer it to working memory" (Jarodzka et al., 2013, p. 63). Visual attention is related to where individuals are looking, and what they pay attention to, impacts what is encoded to memory (Gazzaley, 2011). It is often equated to a lens, and functions in various ways to place attended stimuli in the spotlight (Forte, 2016).

Carrasco (2011) distinguished between three types of visual attention: spatial attention i.e., visuospatial attention; feature-based attention (FBA) and object-based attention (OBA). *Visuospatial attention* can either be overt or covert and is based on the location of stimuli. Spatial attention relates to the importance of the location of stimuli and impacts what information is encoded for further processing (Treue, 2003), directing attention to specific locations. It is the ability to focus exclusively on specific locations in the visual field, enabling more efficient processing of stimuli in that specific location (Forte, 2016). This form of attention makes it possible to direct our attentional resources optimally and avoid focusing on irrelevant stimuli in our visual surroundings.

FBA is based on specific features of encountered stimuli and is stimulus-driven. Attention is then mainly focused on aspects like the colour, orientation, or motion of objects, irrespective of their location. *FBA* triggers attention based on the saliency of stimuli features. *OBA* is where attention is guided mainly by means of the structure of the object (Carrasaco, 2011).

Early visual processing is largely stimulus-driven as Theeuwes (2010) maintains that visual attentional processing is initially determined by stimulus features. The functioning of our visual system is optimised by the ability to direct attentional assets when we focus on various sources of information (Theeuwes, 2010).

Processing visual information is limited, consequently, attention is considered a process of selection (Carrasco, 2011). When confronted with multiple objects, these objects have to compete for attention (Eimer, 2014; Luck & Vogel, 2013; Serences & Yantis, 2006; Theeuwes, 2010). Despite the vast amount of information we encounter, we are able to orient our attentional resources, although our ability to control attention is not exempt from distractors. The ability to select important information from extraneous stimuli is essential to effectively process incoming sensations. Executing attentional control over several tasks simultaneously requires the ability to divide attentional resources by means of divided attention (Forte, 2016). Irrelevant stimuli can, nevertheless, still interfere with our ability to successfully perform activities (Thomas et al., 2017).

Ultimately, perception demands that some sensory information be ignored or disregarded. Meaningful perceptual experiences are a balance between selected sensory information and ignored information (Serences & Yantis, 2006). Attentional influences on competition can be initiated by either top-down processes that are task-dependent and based on volitional control or, bottom-up processes that are stimulus-driven and based on significant stimuli features (Serences & Yantis, 2006).[1] We are overwhelmed with sensory information and to enable the efficient use of our limited attentional resources selective attention and divided attention is critical. Selective attention enables the selection of significant stimulus information (Forte, 2016), guided by means of both top-down and bottom-up processing.

2.1.4 Selective attention: The importance of top-down and bottom-up processing

A vast amount of visual data enters our eyes every second and Driver (2001) maintains that our awareness of the world is partly determined by what we choose to allocate attentional resources to.

[1] Intentional distribution of attention to specific locations or stimulus features increases the sensory gain of that feature and concurrently weakens neural activation for distractor stimuli, thereby advantaging the attended stimulus (Serences & Yantis, 2006).

Processing such large amounts of data can be overwhelming without an effective system to reduce the amount of unnecessary data (Borji & Itti, 2013). Advanced cognitive processing, including the recognition of stimuli and scene interpretation, requires visual data to be transformed into something manageable. This is partly achieved by our ability to focus attention i.e., selective attention (Carrasco, 2011).

Our sensory experiences of the world are not only based on the stimulation of our sense organs but also depends on what we choose to focus on (Driver, 2001). If we were to perceive everything we encounter in our visual world, we would experience a type of perceptual blindness. Driver (2001) emphasises William James's account that our experiences are essentially based on what we decide to attend to. To do this, however, we need to distinguish what is important from that which is not, enabling us to make sense of the information despite the extraneous noise. Attention is the mechanism that changes looking into seeing (Carrasco, 2011).

Current behavioural objectives guide the distribution of attention and play a role in creating preparatory images - regarded as one of the critical components of selective attention (Theeuwes, 2010). Preparatory images are equated with an attentional template, defined as a working memory (WM) representation. WM allows information to be stored and manipulated for a limited time (Awh & Jonides, 2001). WM representations are based on behavioural objectives and are initiated with sensory experiences, guiding our attention and selection processes (Eimer, 2014; Gazzaley, 2011). Attention is in some instances directed by the activated memory template and guides what we look for i.e., pay attention to. Attention is thus selective, determined by the functionality of our attentional system; controlling, maintaining, and manipulating information that is significant for current or future behaviour (Chun & Johnson, 2011). Both overt and covert attentional distribution is thus evident. It empowers us to sufficiently encode applicable information in conjunction with WM that temporarily maintains and manipulates sensory input, continuously updating our attentional templates according to task-oriented objectives (Szelest, 2014).

Selective attention allows us to manage competition between various objects (Serences & Yantis, 2006), allowing us to effectively manage the profusion of sensory input we are constantly faced with (Duecker & Sack, 2015). The selection procedure acts as a gatekeeper to determine what information will enter our highly specialised visual system for additional processing (Treue, 2003). Bundesen, Vangkilde, and Petersen (2015) argue that all visual stimuli compete for encoding into WM before the system reaches capacity. Attentional weights are assigned to various stimuli based on their immediate relevance causing perceptual biases. This means that some stimuli will receive preference with regard to memory encoding as it is more relevant for current task performance (Vidal, Perrone-

Bertolotti, Kahane, & Lachaux, 2015). Visual input is selectively weighted in terms of relevance and task-defining features during visual processing (Eimer, 2014).

Attention is focused on a specific spatial area limiting attentional processing of information outside this area (Eimer, 2014). Theeuwes (2010) emphasises that the early stages of visual processing are important as it impacts subsequent selective attention, comprising a reciprocal relation between initial attentional processing and additional detailed processing (Szelest, 2014). Processing of initial visual input determines the elements that are selected for additional processing. From all the stimuli available in the visual field, each stimulus that is passed to the next stage of processing impacts decision-making and the resulting outcome (Theeuwes, 2010). Stimulus-driven selection is closely linked to the initial preparatory attention phase where feature-based attention impacts WM capacity as selective attention biases our attentional resources to focus on stimuli with the highest attentional weights and according to behavioural goals (Eimer, 2014).

Selective attention is central to all cognitive tasks and shortfalls in attentional processes can impede all cognitive functions (Serences & Yantis, 2006). As Thomas et al. (2017) explain we can control where we direct our attention to a certain degree, but distractors and irrelevant stimuli can interfere with our ability to perform tasks efficiently. Selection is, therefore, necessary to guide the process of allocating attention.

Heckler (2011) emphasises that competition occurs in how we allocate attention when multiple stimuli are present, some features may attract more attention compared to others. Bottom-up theories maintain that stimulus features can attract our attentional resources (Broji & Itti, 2013; Serences & Yantis, 2006), increasing the attentional weights assigned to these features. The salience of stimuli features along with the context in which they occur are determining factors for how attention will be distributed. Different levels of processing are needed to convert visual input to a lasting representation in memory (Awh, Vogel & Oh, 2006; Jarodzka et al., 2013). Finding task-relevant stimuli in the visual world is determined by discrete stages of visual attention and the complex interaction of multiple mechanisms (Eimer, 2014). Where our attentional resources are allocated is a process of bottom-up and top-down processing.

a. Top-down processing

As noted, stimuli need to compete for attention but researchers seem to disagree about how this competition is resolved. The dispute concerns the degree of volitional control. Volitional control over our attentional resources enables us to select input that is relevant to ongoing behaviour, described as goal-driven selection, i.e., top-down processing (Theeuwes, 2010). Behavioural objectives strongly influence the allocation of attention (Eimer, 2004; Jarodzka et al., 2013; Theeuwes, 2010). By means of top-down processing, we can orient our attentional capacity towards specific locations, allowing for the enhanced processing of spatial information (Awh & Jonides, 2001; Szelest, 2014).

Visual scenes can often be perceived in a "need-based manner…" (Broji & Itti, 2013, p. 188) and task demands govern how the visual environment is interpreted. Top-down processing is goal-driven and guided by cognitive processes including knowledge, expectations, and behavioural objectives (Broji & Itti, 2013). Stimuli saliency accounts for a substantial amount of our attentional distribution, but most eye-movements, i.e., overt attention, are task-driven, guided by top-down processing. Top-down activation guides attentional distribution when a particular target has to be found (Hwang, Higgins & Pomplun, 2009). In this regard, contextual information, as well as expectations, play a determining role in where we direct our gaze.

Top-down processing is slower and based on the intentional allocation of attention (Broji & Itti, 2013). The volitional control of attention increases the time it takes to process stimuli and to distribute attentional resources accordingly. Three main sources of top-down functioning are often identified based on how we decide where to look: 1) when searching for specific objects, attention is directed towards the features of the target object, 2) the context of the visual scene can also direct our attention, and 3) occasionally, the distribution of attention is less obvious when dealing with a complicated task. This implies that attention is controlled by the observer and selection is thus based on voluntary control and observers decide what they pay attention to (Theeuwes, 2010). Serences and Yantis (2006) emphasise that "activity in almost every level of the visual system is…shaped by top-down attentional modulations, which can enhance or attenuate the strength of incoming sensory signals depending on the goal of the perceiver" (p.38).

When a visual scene is experienced, the observer's account may be limited and encompass only a draft representation of the visual scene, lacking details about individual features. Top-down control is subject to difficulties when observing a multifaceted environment as attentional regulation can increase or decrease the strength of sensory input depending on the observer's goals (Gazzaley, 2011). The information is only sufficient for a basic scene description but limited with regard to semantic classification (Broji & Itti, 2013).

Researchers offer various opinions regarding the degree to which selective attention is voluntarily controlled by the observer, based on top-down influences, or specific stimuli features, i.e., bottom-up influences (Theeuwes, 2010). On the one hand, attention is based on volitional control and dependent on task-relevant information (Serences & Yantis, 2006). On the other hand, it has been noted that despite voluntary attentional control, salient stimuli features can attract attention even if unrelated to current behavioural goals. Theeuwes (2010) described this as 'attentional capture' where stimuli attract attention that can trigger external eye-movements to stimulus locations, referred to as 'oculomotor capture' (p. 77). This attentional capture is an automatic attentional shift and, stimuli located in the space where attention is directed will likely be included for additional processing (Theeuwes, 2010). Theeuwes (2010) argues that initial selection is, however, bottom-up in nature and stimulus-driven.

Despite top-down modulation in guiding attentional distribution stimuli features, irrelevant to the search goal, can bias attention. Serences and Yantis (2006) reasoned that attention is mainly guided by behavioural goals, but it is possible for salient, but irrelevant features, to engage attention. The nature of the encountered stimuli can also impact our attentional functioning. The more complex the information, the more strain is placed on our cognitive functioning (Mulder, 2017; Sweller, 2011). As a result, relevant information may be processed at a slower pace due to the presence of unrelated stimuli (Heckler, 2011).

Competing stimuli are always present and Hwang et al. (2009) emphasise that top-down processing may represent a way to regulate relevant bottom-up effects. This enables the observer to manage the focus of attention in relation to the amount of noise, i.e., irrelevant stimuli, present.

b. Bottom-up processing

Serences and Yantis (2006) describe visual processing as involving an 'attentional priority map' (p.39), where stimuli are firstly filtered to create a bottom-up, stimulus-driven, map that reflects the degree of significance, irrespective of the relevance or meaning of the stimuli. Bottom-up processing is defined by stimulus properties and occurs in an automatic way compared to voluntary control.

Itti and Koch (2001) describe bottom-up models as involving image-based control of attentional distribution. The perceptual saliency of stimuli is determined by the surrounding context. Accordingly, saliency maps are created that represent how noticeable and visible stimuli are in the context of the visual scene (Broji & Itti, 2013; Itti & Koch, 2001). Attention can then be biased towards specific targets based on the relative weights assigned to the targets in terms of different features. The integration of stimuli features for noticing a target is determined by the signal-to-noise ratio of the target relative to background noise (Navalpakkam & Itti, 2006). Specific locations from the visual scene that draw attention according to bottom-up assumptions, should be conspicuous enough compared to the rest of the context.

Broji and Itti (2013) describe this type of attention as exogenous and automatic where the observer does not necessarily practice conscious control over where to allocate attention. Certain stimuli are naturally noticeable in a given context and automatically or unwillingly draw attention. Visual input that automatically draws attention becomes more significant and allocating attentional resources to other objects and locations thus requires more deliberate action. Information relevant to current behavioural goals is not always easily observable which means that they might not automatically occupy our attention, leaving room for distractors to interfere.

Bottom-up models of attention depict the processing of early visual features as an important first step in understanding how attentional resources is distributed. The initial stages of processing deconstruct incoming information by means of a ‘feature-selective filtering process’ (Itti & Koch, 2001, p. 198). Early visual processing does not necessarily require comprehensive attention but top-down functions can modulate attention during initial processing, impacting the resulting competition that arises between stimuli.

Selection is not always the result of bottom-up processing, since we can often select the stimuli relevant to our current goals. It remains unclear whether initially before sensory input is received by the retina, top-down objectives impact the way visual selection unfolds. Visual selection that is driven by WM content is considered to be bottom-up in nature as attentional distribution is mediated by the activated WM template (Theeuwes, 2010). Treue (2003) reasons that the representation is not necessarily based on the strength of the individual stimulus features, but by the significance of the stimulus in relation to surrounding visual information. Regarding pseudoneglect, the initial eye-movements to the left visual field are possibly based on bottom-up processing where left-sided stimuli elicit a stronger attentional capture. Top-down processing or voluntary attentional processing constitutes prior knowledge and seems to be initiated at a later stage.

Stimulus features together with top-down influences are eventually combined to create a ‘master attention map’ (Serences & Yantis, 2006). Selected sensory information together with attentional control then creates a saliency map of the visual world (Carrasco, 2011; Corbetta & Shulman, 2002; Gazzaley, 2011; Treue, 2003). The result is a representation of the visual world that indicates the visual system’s best guess of the most pertinent aspects of the visual world (Treue, 2003). Bottom-up sensory information and top-down attentional processes interact to produce a memory representation. This memory representation depicts the relative strength of stimuli and the behavioural importance of the sensory information (Eimer, 2014; Oliveira et al., 2013; Olivers et al., 2001; Treue, 2003). Chun and Johnson (2011) argue that if there were no interaction between top-down and bottom-up processing, we would not be able to accumulate knowledge across experiences.

Visual experiences, therefore, depend on the complexity of the interplay between bottom-up significance and top-down processing in accordance with behavioural objectives to create a unified saliency map that represents the visual scene. The allocation of our attentional resources thus comprises a balance between input from the external environment along with feedback, and input from memory templates. In some instances, the distribution of attention is controlled by the observer, while in other cases, attention is unwillingly attracted by the nature of a visual scene or stimuli features (Heckler, 2011; Navalpakkam & Itti, 2006; Serences & Yantis, 2006; Theeuwes, 2010).

Top-down influences include the constant feedback between different memory systems that impact attentional processing and direct the computation of bottom-up features. Attention has been the focus of research for the past few decades and many theories and models have been proposed to explain the functioning of our attentional system and the consequent impact it has on behaviour and other forms of cognition, including memory (Bundesen et al., 2015; Bundesen, 1990; Carrasco, 2011).

2.1.5 Theories of attention

Various theories have been proposed to conceptualise attention. Prominent theories include filter theories (Broadbent, 1990), ranging from early to late selection theories (Driver, 2001) as well as attenuation theory (Treisman, 1969).

Visual attention is vital to our daily functioning and both selection and relevance play a defining role in how we use this essential resource (Borji, & Itti, 2013).

Attentional filters are a means of prioritising certain features of stimuli while ignoring others. Selective attention thus dictates that attentional resources will be dominated by one thing over another (Driver, 2001).

Numerous theories have been dedicated to understanding how our selective attention system works. Popular theories include filter theory, proposing the use of a filter to enable selective attention.

a. Filter theories

Despite the magnitude of data experienced, we seem to make sense of the world around us (McLeod, 2018). Our ability to form coherent perceptions of the endless array of stimuli we encounter is grounded in the capacity to orient our attentional resources and to filter significant information from irrelevant input, consequently ignoring the unnecessary information, i.e., selective attention. The need to practice selective attention is essential due to the limit that exists in how much information we can process at a certain time. Being able to selectively focus our attention also enables us to focus on stimuli important for guiding behavioural goals. McLeod (2018) explains that various theories have equated this selective filtering to a bottleneck that can restrict the flow of information. The narrower the bottleneck, the lower the flow rate of information.

McLeod (2018) explains that Broadbent suggested that certain physical properties of stimuli are used to select one stimulus for additional processing while all other stimuli are lost from our sensory world. The initial stage of processing mainly involves the extraction of physical features for all incoming information in a parallel manner (Driver, 2001). An unlimited capacity sensory buffer manages all sensory input to enable only information with specific stimuli features to pass the filter for additional processing. The filter represents an information-processing system that maintains our limited capacity to process information and prevents the system from becoming burdened with too many irrelevant stimuli. The information not initially filtered for processing remains in a sensory buffer for a brief period and decays quickly if not processed (McLeod, 2018). Broadbent's conception of filter theory essentially suggests that information not allowed for processing is rejected at an early stage. The meaning of information is not taken into account during the early stages of processing but only becomes relevant after the filtering process (McLeod, 2018). The second stage of processing focuses on more complex details of stimuli (Driver, 2001). It is thus only after the sensory buffer has selected the information that requires attention that it is semantically processed. Input that is not permitted past the filter is therefore not understood. Subsequent levels of processing are subject to limitations and cannot manage all incoming sensory information at once. The selective filter thus acts as a protective factor, preserving the capacity of the second stage and preventing the system from becoming overloaded (Driver, 2001). Only stimuli that satisfy specific physical property features can therefore pass through the filter.

Filter theory assumes that unattended information, not permitted to pass the selective filter, would not be processed extensively in terms of meaning. Such processing only takes place in the second stage. Filter theory represents a model of early selection that assumes that the processing of attended vs. unattended stimuli is different. Unattended information was thought to be completely ignored once the filter was reached. Later research, however, suggests that this is not the case. Unattended stimuli appear to be processed in more detail than initially conceptualised. Attenuation theory was proposed as an expansion on early selection models (Driver, 2001).

Similar to Broadbent's conception Treisman also advocates for an early selection filter but according to the attenuation theory, unattended material is not lost but rather attenuated. Sensory input not passed through the filter is not completely blocked out. Both attended and unattended stimuli are then processed during the second stage although unattended stimuli are processed in less detail

(Driver, 2001). McLeod (2018) describes the process of attenuation as turning down the volume of incoming stimuli. Accordingly, we can reduce the load of certain stimuli to allocate more attentional resources to another. People are therefore still able to process the information semantically and unattended stimuli are not lost or rejected. Research conducted by Treisman showed that participants were able to recall contents from both attended and unattended information, suggesting that both are processed for meaning (Driver, 2001; McLeod, 2018). This contradicts Broadbent's conception that filtered information is ignored and not processed semantically.

Both theories fail to address certain shortcomings but made significant contributions to the field of attention.

b. Load theory of attention

Lavie, Hirst, de Fockert, and Viding (2004) explored the mechanisms of load theory of selective attention and cognitive control. Goal-driven behaviour involves focusing our attentional resources on information relevant to our current behavioural goals while ignoring distractors (Forte, 2016).

The skill to devote attention to a single source of information while disregarding others (Huang-Pollock, Carr, & Nigg, 2002) is essential for optimal cognitive and behavioural functioning. The visual world presents too much information to a system with processing capacity limitations. Selective attention thus enables us to minimise the sensory noise to make sensory input more manageable. Selection must give preference to some content and only permit this content for additional processing. Huang-Pollock et al. (2002) assert that selection is mainly a function of perceptual load in relation to the amount of significant information available in the visual scene. Cognitive load theory assumes that if the cognitive resources of the brain are overloaded, it will impact our WM system (Mulder, 2017).

Processing sensory information in WM is an essential part of our cognitive functioning. Cognitive load involves the amount of information that can be managed in WM (Sweller, 2011), which is limited to only a number of items at a time. The more the cognitive systems are strained, the more difficult it becomes to retain and process information. Two processes are involved with selective attention: a passive mechanism, i.e., perceptual selection, and an active attentional control mechanism. Perceptual selection relates to excluding unrelated stimuli during situations of high perceptual load. This means that insignificant information is simply not perceived when sufficient capacity for processing is not available (Lavie et al., 2004). The second process pertains to an active mechanism of attentional control during situations of low perceptual load. During such situations, irrelevant stimuli may be perceived but are not required to inform current behavioural goals, and as a result, a rejection process needs to be implemented. Once the unrelated stimuli are perceived, higher cognitive functions are executed to actively manage the attentional weighting of incoming information. Lavie et al. (2004) note that the active control of incoming stimuli is important to ensure that low-priority input does not impact behaviour, causing distraction.

Cognitive load essentially concerns how memory functions are applied during cognitive actions, such as learning (Mulder, 2017). When stimuli are encountered, part of the information is conveyed to WM. If not used, the information decays. When the information is actively applied and processed for task performance, it may be transferred to LTM (Awh & Jonides, 2001; Bundesen et al., 2015). Transferring information to LTM requires repetition and more importantly, the information must be connected to already existing content (Carlisle et al., 2011; Mulder, 2017; Szelest, 2014; Theeuwes, 2010). Sweller (2011) asserts that we combine new information with previously stored information. It is therefore easier to transfer information to LTM if the information can be linked with schemas of previously stored content.

Schemas enable effective processing of all content and improve memory retention (Mulder, 2017). When we encounter new stimuli, the input is reorganised and combined with information already retained in LTM (Sweller, 2011) where it is stored in knowledge structures, described as schemas. The more schemas are activated, the more it becomes an automated response (Richter, Bays, Jeyarathnarajah, & Simons, 2019), thereby exerting less strain on WM functioning. Drawing on existing knowledge expands WM capacity as less effort and resources are needed to manage incoming information. Consequently, cognitive load is minimised making the efficient allocation of attentional resources feasible (Mulder, 2017; Sweller, 2011).

To maximise the functioning of WM and attentional systems, we have to minimise cognitive load (Broadbent, 2011; Sweller, 2011). Relevant and irrelevant stimuli are always present and compete for attentional resources. Accordingly, it is reasoned that current behavioural objectives dictate the importance of certain stimuli over others, and the attentional resources allocated to available stimuli are governed by selective attention.

In summary, as Broji and Itti (2013) explicate, there is no unified model of agreement on how the attentional scale functions. Spatial attention, feature-based attention, or object-based attention is all determining factors in how we allocate our attentional resources. The theories are not viewed to be mutually exclusive and evidence supports all modes of attention allocation. The above-mentioned theories propose different ways by which attention can be distributed and how the resulting processing will influence memory encoding.

Pseudoneglect encompasses a general inclination to emphasise the left side of stimuli. Presenting stimuli in both visual fields would thus elicit competition for attentional resources. The theory of visual attention (TVA), discussed in chapter 3, reconciles components of both bottom-up and top-down models, assuming that particularly significant stimuli will receive preferential attentional processing. The TVA fundamentally explains how we attempt to resolve issues with competing visual input. If pseudoneglect does bias attention to the left, one would expect stimuli on the left to receive a higher attentional weight compared to stimuli on the right. Sensory input located on the left may then receive preference over stimuli available on the right.

Stimuli features, together with WM and LTM input, ultimately determine the allocation of attention and the resulting impact it has on our capacity to process additional information for encoding to memory.

2.2 Conceptualisation of memory

A core feature of cognition, closely related to attention, is memory. Encoding information about events and stimuli and recalling this information from memory is a necessary part of our daily functioning (Takeda, 2019; Theeuwes, Kramer & Irwin, 2011). Memory and attention enable goal-directed processing by directing our attentional resources (Awh, & Jonides, 2001; Szelest, 2014). As our visual context is constantly changing, memory records of detailed visual information are regarded as unnecessary. Items differing in colour, location, and shape along with other stimuli ultimately compete for attention (Eimer, 2014), and effective processing of multiple stimuli is based on our attentional capacity and different memory systems.

Memory consists of various subsystems defined by stages of processing, span, and stimuli content. There are three prominent stages of memory information processing: encoding; storage and; retrieval (Takeda, 2019; Wood, Baxter, & Belpaeme, 2011). Different memory systems are also classified based on duration and storage capacity and include sensory memory; short-term memory (STM); working memory (WM) and; long-term memory (LTM). STM is characterised by limited storage capacity and information is only maintained for a short period of time. LTM, however, has unlimited storage capacity and the duration of information is indefinite (Brady, Konkle, Alvarez, & Oliva, 2008; Chai, Abd Hamid, and Abdullah, 2018; Takeda, 2019). Information is passed from sensory memory to STM, manipulated and maintained in WM and, if rehearsal occurs, the content is eventually encoded to LTM (Brady et al., 2008). LTM and WM are defined by various subcomponents that contribute significantly to processing visual information based on the attentional capture.

2.2.1 Working memory (WM)

WM is described as a system that allows for provisional maintenance of certain information where this information is available for immediate access (Awh & Jonides, 2001). It is a memory system that enables us to maintain and manipulate conscious information based on attention.

Chai et al. (2018) emphasise the complexity of defining WM as different schools of thought have proposed different understandings for what WM entails. These varying definitions are mainly based on the cognitive dimensions that WM comprises. Wilhelm, Hildebrandt, and Oberauer (2013) proposed that WM is a cognitive system that allows access to information needed for subsequent cognitive processing. Generally, WM is defined as a key component in goal-directed behaviour where information must be maintained and manipulated to allow for the efficient implementation of tasks.

Baddeley (2000; 2003) conceptualised a multi-component model of WM based on the interaction of multiple cognitive components. Baddeley (2003) suggests that WM be subdivided into three systems: the phonological loop (verbal and acoustic information); visuospatial sketchpad (visual information) and; the central executive. The phonological loop is regarded as a temporary storage and maintenance system for vocal and sub-vocal rehearsal (Baddeley, 2012), described as verbal WM (Chai et al., 2018). The episodic buffer was only later suggested as a fourth subsystem (Baddeley, 2000). The episodic buffer is responsible for holding integrated sensory content and acting as a storage buffer (Baddeley, 2012). More importantly, the episodic buffer links WM components together but it also connects WM to perception and LTM mechanisms. It can therefore maintain multidimensional representations but with limited capacity (Baddeley, 2012; Chai et al., 2018). The interactive feedback relation between WM and LTM is able to bind information from the other subsystems and from LTM, to create WM representations (Baddeley, 2000) used to guide behaviour and the allocation of attention. The episodic buffer is equated with a bridge connecting WM and LTM thereby linking bottom-up and top-down functioning. The buffer thus represents a multidimensional medium that enables different parts, from various sources, to be grouped to allow us to perceive the focus of attention.

The visuospatial subsystem of WM integrates spatial and visual information into a representation that can be temporarily stored and manipulated (Haxby et al., 2000), described as visuospatial working memory (VWM). Harrison and Tong (2009) refer to VWM as an important link between perception and other cognitive functions, making the manipulation of information, that is no longer physically present, possible (Chun & Johnson, 2011; Schurgin, 2018). It thus enables us to use the information temporarily available in WM to direct attentional processing and decision-making in relation to our behavioural goals. Schurgin (2018) describes VWM as "…an interface between perception, short-term memory, and other mechanisms such as attention" (p.1036).

The central executive controls and coordinates information flow within WM (Erickson et al., 2015). Baddeley (2012) describes it as the most complex part of WM. The central executive part of WM is also implicated in dividing attention between multiple stimuli and connects WM with the LTM system (Chai et al., 2018; Eimer, 2014; Haxby et al., 2000; Luck & Vogel, 2013). Chai et al. (2018) describe the central executive as the "attentional control system" (p.2) and regard it as a regulator that manages the manipulation, retrieval, and processing of information to enable various outcomes.

Cowan (2008) conceptualised an embedded-process model of WM that describes LTM and attention as important features of WM functioning. Based on this model, WM is viewed as a short-term memory system with limited capacity, strongly impacted by attention and LTM feedback (Chai et al., 2018, Cowan, 2008). It is noted that WM is not synonymous with STM, but Cowan (2008), argues that it is not completely distinct from STM. Chai et al. (2018) described the interconnected nature of various memory systems by highlighting Cowan's explanation that "…in the domain of long-term memory, there exists an intermediate subset of activated long-term memory (also the short-term storage component) and working memory belongs to the subset of activated long-term memory that is being attended to (p.2). A definition of WM should not be approached in terms of a single system, but rather that WM is a combination of several components functioning together (Cowan, 2008). Various models have been proposed to define WM and the mechanisms involved (Chai et al., 2018), but the important role of WM lies with the allocation of attention, specifically, controlling selective attention (de Fockert, Rees, Frith, & Lavie, 2001). In the allocation of attention, the essential issue relates to minimising interference from extraneous factors in the processing of stimuli. The more attention is consumed by the current task, the less capacity is available for processing unnecessary information.

WM is considered to be closely linked to LTM and is not simply a form of STM, although Cowan (2008) argues that it certainly includes STM. It is not simply a storage system but involves higher-order cognitive functions and executive processing (Chai et al., 2018). It is regarded as a system that involves multiple processing functions. The processing of sensory information is ultimately the result of multiple interacting systems, including both attentional networks and various memory systems.

The relation between attention and WM was initially assumed to be one-directional, where attention filters incoming content, permitting only relevant information for memory processing

(Downing, 2000). De Fockert et al. (2001) propose that to manage cognitive load sufficiently, WM maintenance is essential for indicating the level of relevance of each stimulus. WM ultimately plays different roles in different levels of attentional processes, specifically with WM capacity (Luck & Vogel, 2013). During the initial preparation phase of attention, WM initiates the attentional template required for task-related actions. Throughout the identification phase, WM is important for maintaining representation templates and comparing it with current search goals (Eimer, 2014; Luck & Vogel, 2013). Reviving representations not currently active relies on recovering information from previously stored content, making connections between active representations, and shifting between attentional templates and stimuli features guided by behavioural goals. WM representations are connected with LTM (Baddeley, 2012; D'Esposito & Postle, 2015; Erickson et al., 2015) and the content of WM is therefore determined by accessible LTM representations which are regulated by attention. It is important to note that memory templates that are not the current focus of attention can also impact WM content by means of top-down processing (Eimer, 2014; Erickson et al., 2015; Olivers et al., 2011; Serences & Yantis, 2006). Cowan (2008) and Erickson et al. (2015) emphasise that, generally, WM is reflective of the current state of focused attention. Only a few LTM templates are active, which are less accessible than the main attentional templates.

WM then plays a defining role in guiding selective attention (Downing, 2000), which minimises the load on the capacity-limited system by acting as a gate to control incoming information. The significant role of WM is thus notable as it plays a determining role in the distribution of attention to relevant information, and in so doing, limits the impact of extraneous factors (de Fockert et al., 2001).

WM is a temporary storage unit that manipulates sensory stimuli and transfers the content to LTM (Chai et al., 2018; Cowan, 2005). The content of WM appears to be mainly determined by active LTM representations. Downing (2000) emphasises that attention is then a product of both the initial filtering process and top-down mechanisms that bias attention distribution in favour of object representations held in LTM. An item is held in WM by means of top-down mechanisms that allow representations of the object to persist when it is no longer present (Theeuwes, 2010). This representation can then inform subsequent responses as the template initiates information from LTM to impact behaviour (Downing, 2000). As all stimuli present in the visual environment compete for attention, the activation of memory templates, related to target objects, provides a competitive advantage to these objects. This means that these objects will receive preferential attention and be encoded to WM while other stimuli are ignored. Wilhelm et al. (2013) maintained that WM capacity depends on the active maintenance of stimuli content as well as the retrieval of information from LTM. WM is not a separate memory system but constitutes an active part of LTM (Wood et al., 2011).

The reciprocal relation between attention, WM and, LTM in guiding behaviour and directing the allocation of attention is essential to enable effective processing of sensory input.

2.2.2 Long-term memory (LTM)

The difference between STM and LTM memory systems generally relates to issues regarding duration and capacity (Brady et al., 2008; Cowan, 2008). Content held in STM eventually decays over time and there is also a limit to the amount of content that can be held in STM compared to LTM.

Cowan (2008) argues that memory is a complex cognitive system and assessing one component of memory might not imply that another memory system was not used. Assessing STM performance, therefore, does not exclude the possibility that LTM components were also used during processing. This strengthens the reciprocal relation present between different memory systems and that memory should not be viewed as a single, isolated box. Rather memory should be described in the context of the cognitive processing path followed by stimulus input, received in one memory system and transferred to the next (Brady et al., 2008; Cowan, 2008). Different memory systems are interdependent and function correspondingly where content held in STM can draw on resources from LTM. Wood et al. (2011) concur that memory includes the interplay of several mechanisms and encompasses multiple subsystems.

STM is known as a temporary memory system that can hold only a limited amount of content (Cowan, 2008). The duration of content stored in STM deteriorates if not processed for long-term storage. The number of items held in STM is also restricted and the content is easily replaced by newly attended stimuli.

LTM is divided into declarative and non-declarative memory. Declarative memory is described as explicit memory and involves conscious awareness. This memory division includes semantic and episodic memories (Friedman, Johnson, & Williams; 2018; Gray, 2018; Takeda, 2019; Wood et al., 2011). General knowledge and fact-related content are described as sematic memory while episodic memory encompasses memories linked to a specific time and context. Non-declarative memory is not reliant on conscious recall and is described as implicit memory (Gray, 2018; Takeda, 2019). Memories of motor skills and swimming are examples of procedural memory which forms part of implicit/non-declarative memory (Wood et al., 2011). Evidence for the different subdivisions of LTM emphasises the notion that memory is not a single, isolated system but rather includes different cognitive domains and activates several neural circuits (Gray, 2018). Learning motor skills requires different cognitive processing and memory functions compared to learning factual content.

The connection between memory and the visual system is not yet well conceptualised, concerning other sensory functioning. The process of searching the visual world involves implicit memory as it relates to sensory information processing, not based on factual learning (Friedman et al., 2018).

Hwang et al. (2009) postulate that visual search forms a prominent part of our daily functioning. We are often faced with the task of finding a friend in a crowd or a specific item in a cluttered context. The complex nature of our daily environment along with the limited processing capacity of our visual system emphasises the need for efficient search processes that enable us to exclusively process content relevant to the task at hand.

Visual search is dependent on the integration of multiple cognitive systems including the oculomotor system, covert visual attention, the incorporation of visual input and memory. The importance of eye-movements and fixations are noted to be substantial in a visual search task as attention allows the observer to effectively process incoming sensory input (Awh et al., 2006; Jarodzka et al., 2013; Szelest, 2014). The cognitive system enables the ability to search and identify complex sensory content in the visual world and depends on the interaction of multiple levels of cognitive processing. To adequately identify incoming sensations, attention, perception and the oculomotor system need to function together. The interaction also includes various memory systems, but the magnitude of memory impact on visual search experiences is distinct, with some researchers downplaying the importance of memory (Friedman et al., 2018). Others maintain that memory is a crucial component in searching the visual world due to the interplay between attention and memory. Brady et al. (2008) argued in agreement that memory is a necessary part of our perceptual experience. Stimuli features must be maintained in memory to allow for efficient attentional processing but the nature of visual detail stored in various memory systems is questioned.

Friedman et al. (2018) emphasise the significance of LTM and propose a component specialised for storing visual information, known as visual long-term memory (VLTM). VLTM is the skill of learning several visual aspects at a given time and refers to a component of memory that allows significant sensory information to be maintained and stored as visual representations for an extended duration (Brady et al., 2008; Friedman et al., 2018). VWM actively maintains and manipulates content for short periods, which plays a significant role in behaviour (Cowan, 2008; Schurgin, Cunningham, Egeth & Brady, 2018). Schurgin et al. (2018) propose that during certain conditions people are able to disengage WM and instead activate LTM. LTM stores content and is able to activate memory traces without constant maintenance (Cowan, 2008). Research suggests that WM functioning is active when novel information is perceived or when the perceptual load is high, whereas VLTM is promptly accessible despite active WM templates (Schurgin et al., 2018). VLTM is conceptualised as a form of episodic memory (Schurgin, 2018), which specifically relates to identifying visual information. It is considered "…as the passive storage system of visual episodic memory" (p. 1037).

Visual input is acquired by means of a series of fixations based on eye-movements that momentarily disrupt visual processing (Luck & Vogel, 2013). It is argued that some type of memory component is required to account for the fleeting distraction caused by eye-movements. VWM, in conjunction with VLTM, plays an important role in maintaining attention despite the notion that saccades attenuate the focus of stimuli, highlighting the interplay between WM and LTM as a dynamic and fluid process (Schurgin et al., 2018). Luck and Vogel (2013) explain that VWM is the vital connection between "…the pre-saccade representation of an object at one retinal location with the post-saccade representation of that object in a different retinal location" (p.393). Research suggests that the objective of our next eye-movements is stored in VWM, and after changes occur in saccades, the VWM representation becomes associated with newly attended objects. Eye-movements can, however, be influenced to focus primarily on stimuli that correspond with current information maintained in VWM (Luck & Vogel, 2013), such that eye-movements are faster if the fixation target links to current VWM content. Stimulating an activated representation of an item that is no longer available, or a thought that becomes active enhances the attentional weighting of the encountered item making it the primary focus of attention (Chun & Johnson, 2011). This gives the attended stimuli an advantage which makes additional processing of this information more likely.

VLTM representations store more content than previously assumed (Schurgin et al., 2018). A prominent function of VLTM includes recognising objects (Schurgin, 2018). A study by Brady et al. (2008) included presenting participants with multiple images of real-world objects for a few seconds, similarly to the present investigation. Observers were instructed to memorise as much detail as possible. Memory was tested by asking participants to complete a forced-choice test where various objects were presented and they had to indicate whether they recall seeing the item. The findings supported the prominent role of VLTM by showing that memory representations seem to maintain detailed information of visual input (Brady et al., 2008).

The interactive relationship between different memory systems essentially promotes optimal use of our limited capacity system. Retaining information is dependent on the interaction between the basic functions of WM, selective attention, and LTM components (Erickson et al., 2015). Relying on the mechanisms of LTM, such as VLTM, reduces the cognitive load of WM and increases attentional resources available for processing incoming stimuli. The primary function of VLTM is to enable the recognition of previously encountered visual information based on past events (Schurgin, 2018). The dynamic interaction between different memory systems reduces cognitive load so that it's not limited to a single system. The burden on our limited cognitive system is, therefore, less constraint as multiple levels of processing and memory components function together to ensure prime use of our attentional resources.

The dynamic relationship between attention and multiple memory systems means that the focus of attention activates certain memory representations, and also impacts what is captured to memory from visual experiences. Pseudoneglect demonstrates a prominent focus to stimuli present in the left visual field (Brooks et al., 2011; Çiçek et al., 2009; Cocchini et al., 2007; Hatin et al., 2012; Lee et al., 2004; Loftus et al., 2009; Nicholls & Loftus, 2007; Nicholls et al., 2008; Nicholls, Bradshaw, & Mattingley, 1999; Sosa et al., 2010; Toba et al., 2011) which may bias the content encoded to memory. Manning, Halligan, and Marshall (1990) propose asymmetrical scanning of stimuli to account for the leftward bias, linking it to the general tendency of reading text from left to right. It is, however, noted that scanning asymmetries might be due to asymmetries influenced by the dispersal of attention.

2.3 The conceptualisation of pseudoneglect

The tendency to overestimate the size, colour, number, or spatial occurrence of stimuli located on the left side is described as pseudoneglect (Bowers & Heilman, 1980; Friedrich, 2018). The demonstration of pseudoneglect is well documented (Brignani et al., 2018; Jewell and McCourt, 2000), but the degree and direction of the deviation are mediated by several factors, including handedness, scanning direction, the assessment used and the spatial position of lines (Brignani et al., 2018; Bultitude & Aimola Davies, 2006; Failla et al., 2003; Hausmann et al., 2002). Various explanations of the mechanisms underlying pseudoneglect have been suggested.

The most common method used to assess spatial neglect and pseudoneglect involves using the line bisection task (LBT) (Brodie, 2010; Brooks, 2014; Brooks et al., 2014; Bultitude & Aimola Davies, 2006; Cocchini et al., 2007; Crollen & Noël, 2015 Dobler, Manly, Atkinson, Wilson, Ioannou, & Robertson, 2001; Failla et al., 2003; Fink, Marshall, Weiss, Toni & Zilles, 2002; Foulsham et al., 2013; Harvey et al., 2000; Hatin et al., 2012; Jewell & McCourt, 2000; Nuthmann & Matthias, 2014; Nicholls & Lotus, 2007; Nicholls et al., 2008; Porac et al., 2006). Participants are expected to indicate the centre of standard-length lines by drawing a line through the midpoint. Neurologically normal participants tend to bisect the line more towards the left of the midpoint, thereby demonstrating a leftward bias i.e., pseudoneglect (Brignani et al., 2018; Brodie, 2010; Dobler et al., 2001; Foulsham et al., 2013; Harey et al., 2000; Hatin et al., 2012; Hausmann et al., 2003; Hausmann et al., 2002; Nichols & Lotus, 2007; Nicholls et al., 2008; Toba et al., 2011).

2.3.1 Theories of Pseudoneglect

a. Hemispheric lateralisation: Right hemisphere dominance

The brain consists of lateralisation of cognitive functions between homologous regions of the two hemispheres (Ribolsi, Lisi, Di Lorenzo, Koch, Oliveri, Magni et al., 2013; Ribolsi, Di Lorenzo, Lisi, Niolu & Siracusano, 2015). Hemispheric specialization is important for functional organisation purposes (Hausmann, Güntürkün, & Corballis, 2003; Zago et al., 2017) and contributes cognitive advantages (Helfer et al., 2020). Hemispheric activation plays an important role in the demonstration of pseudoneglect.

The cognitive and neural mechanisms that impact attention are not symmetrically represented in the brain as illustrated by unilateral neglect (Hatin et al., 2012; Nicholls & Loftus, 2007; Nicholls et al., 2008; Siman-Tov et al., 2007; Varnava, Dervinis & Chambers, 2013). Vogel, Bowers, and Vogel (2003) and Schmitz et al., (2011) agree that visuospatial information is not symmetrically represented in the brain. Apart from differences in attentional processing in the activated hemisphere, hemispheric asymmetries also exist in how each hemisphere processes attention with regard to global vs. local stimuli features (Chun & Johnson, 2011; Lee et al., 2004; Siman-Tov et al., 2007; Theeuwes, 2010). One of the most common arguments for explaining pseudoneglect involves hemispheric specialization (Brignani et al., 2018; Bultitude & Aimola Davies, 2006; Niemeier, Stojanoski, Singh & Chu, 2008; Szelest, 2014; Çiçek et al., 2009).

Normal participants' inclination to demonstrate pseudoneglect is reasoned to be mainly due to the right hemisphere's superiority for spatial attention (Szelest, 2014; Siman-Tov et al., 2007; Varnava et al., 2013). Differential processing between the two hemispheres with regard to global-local stimuli features (Lee et al., 2004) can also account for the leftward tendency. Accordingly, pseudoneglect and hemineglect are described as twin manifestations of the same attentional mechanism (Jewell & McCourt, 2000; Szelest, 2014).

The spatial asymmetry observed in a leftward bias is the result of the right hemisphere's specialisation for visuospatial attention (Benwell et al., 2013; Benedetto et al., 2013; Bultitude & Aimola Davies, 2006; Harvey et al., 2000; Hatin et al., 2012; Hausmann, Waldie, & Corballis, 2003; Hausmann, Ergun, Yazgan, & Güntürkün, 2002; Jewell & McCourt, 2000; Nicholls et al., 1999; Nicholls et al., 2008; Rilea, Roskosewoldsen, & Boles, 2004; Thiebaut de Schotten et al.,2005; Toba et al., 2011). The understanding of the functional network underlying the right hemisphere's superiority for spatial attention is still somewhat limited. The right hemisphere, specifically the posterior parietal cortex, mainly underlies the presentation of visuospatial attention (Bultitude & Aimola Davies, 2006; Çiçek et al., 2009; Eardley et al., 2017; Gigliotta et al., 2017; Posner & Rothbart, 2007; Ribolsi et al., 2013; Schmitz et al., 2013; Varnava et al., 2013). Damage to this area results in patients neglecting to acknowledge or attend to stimuli present in the opposite side of space, presenting with unilateral neglect (Badok et al., 2014; Bartolomeo & Chokron, 2002; Chun & Johnson, 2011; Loftus et al., 2009; McGeorge et al., 2007; Ribolsi et al., 2013; Serences & Yantis, 2006). It constitutes a failure to attend to, or react to stimuli found in the opposite side of the damaged hemisphere, known as visuospatial neglect (Badok et al., 2014; Bartolomeo & Chokron, 2002; Bultitude & Aimola Davies, 2006; Loftus et al., 2009; McGeorge et al., 2007; Nicholls & Roberts, 2002; Nuthmann & Matthias, 2014; Toba et al., 2011). Following unilateral neglect, patients disregard the contralesional side of the body. They may for example fail to dress or groom the contra-lateral side and bump into things located in the neglected hemispace (Bartolomeo & Chokron, 2002; Nicholls & Loftus, 2007; Nicholls et al., 2008). As a result, patients consequently tend to disregard the left side of stimuli. This is not limited to visual information only but impacts all aspects of the sensory system.

Anatomically, the three white matter regions of the superior longitudinal fasciculus (SLF) that constitute the fronto-parietal network show a dorsal to ventral gradient of lateralisation. The ventral branch appears to be larger and more lateralised in the right hemisphere (Brignani et al., 2018; Thiebaut de Schotten et al., 2011). Accordingly, it was also claimed that larger leftward tendencies were linked to a larger volume of the white matter regions in the right hemisphere. The right parietal cortex shows increased activation with visuospatial and line bisection tasks as evidenced by brain imaging results (Eardley et al., 2017).

Varnava et al. (2013) support the role of the right hemisphere in the leftward bias, but also note that neglect is often diagnosed in patients following left hemisphere damage. This suggests that visuospatial processing may be bilateral in nature with most individuals presenting with right hemisphere dominance, but not all.

Pre-motor activation of the right hemisphere consequently results in the emphasis of the left hemispace, altering perception (Nicholls & Roberts, 2002; Porac et al., 2006; Szelest, 2014). Kinsbourne (1970) showed that unilateral activation of a hemisphere resulted in attentional biases to the opposite side of space, meaning that due to right hemisphere dominance, a leftward tendency is observed (Çiçek et al., 2009). Pseudoneglect can be moderated by different variables (Szelest, 2014;

Varnava et al., 2013) so the nature of the task may impact the extent to which subjects demonstrate left or right biases (Lee et al., 2004). By changing the activation of the hemispheres, it can influence the extent to which a leftward bias is observed. Presenting stimuli in the left hemispace, for example, activates the right hemisphere resulting in a stronger leftward error. Reuter-Lorenz et al. (1990) also found similar results with left-hemiretinal presentation and left-hand use. It was contended that the magnitude of pseudoneglect seems to be reduced by factors that lessen or invert the activation of the right hemisphere, including using the right hand to complete tasks, right hemispace or hemiretinal presentation, or rightward gaze direction (Bultitude & Aimola Davies, 2006). In some cases, a rightward bias is found, possibly a consequence of processing direction and the position of stimuli during initial processing (Reuter-Lorenz et al., 1990; Szelest, 2014).

Kinsbourne (1993) specified that the interaction between the two hemispheres plays a determining role in controlling attention and general higher-order mental abilities. It is well known that the right and the left hemispheres are responsible for different cognitive functions with each hemisphere having its primary connection to the opposite side. Unilateral neglect generally results from right hemisphere damage (Badok et al., 2014; Bartolomeo & Chokron, 2002; Bultitude & Aimola Davies, 2006; Çiçek et al., 2009; Foulsham et al., 2013; Loftus & Nicholls, 2012). As a result, Kinsbourne (1993) maintains that the undamaged left hemisphere assumes control, biasing attention towards specific stimuli. Both hemispheres are involved in orienting attentional and other cognitive resources in the direction it has been biologically programmed. This biological tendency was conceptualised as an attentional gradient (Kinsbourne, 1993), with organisms systematically orienting to the most right-sided or left-sided space of horizontally aligned stimuli. The attentional gradient concerns the degree to which one stimulus compared to another captures attention and through this controls subsequent actions and decisions.

Kinsbourne (1993) explains that attention is not intact within only one hemispace in hemineglect. It is argued that a lateral gradient of attention moves right across both hemispaces in such a way that attention is inclined more towards the right, irrespective of stimuli location. This applies to both overt and covert forms of attention. Some authors maintain that separate and independent mechanisms control attention within the left and right hemispheres (Kinsbourne, 1993), while others maintain that the right hemisphere is primarily involved in controlling attention (Brignani et al., 2018; Thiebaut de Schotten et al., 2011). It is disputed that the right hemisphere may be responsible for the placement of attention in both the left and right hemispace (Bultitude & Aimola Davies, 2006; Nicholls et al., 2004; Niemeier et al., 2008). Helfer et al. (2020) explained that in visual processing, sensory input is sent to both hemispheres from both eyes, but the connection to the opposite side is stronger. More importantly, it is argued that the allocation of attention is based on the functioning of the right hemisphere. The right hemisphere attends to both the left and right visual fields, while the left hemisphere distributes attention mainly to the right visual field. Siman-Tov et al. (2007) stress the indication that the right hemisphere may in fact control attention in both the left and the right hemifields, with the left hemisphere primarily linked to the right hemifield. The neural mechanisms underlying attentional control in an intact brain, however, remain uncertain with some researchers highlighting the importance of the right hemisphere only (Brignani et al., 2018), while others argue the possibility of interhemispheric competition (Siman-Tov et al., 2007; Szelest, 2014). Gray (2018) reports that the right hemisphere could compensate for attentional processing if the left hemisphere's attentional regions are damaged, but vice versa do not apply. Although right hemisphere supremacy is also acknowledged by Siman-Tov et al. (2007), the authors advocated for bihemispheric left-hemifield superiority in visuospatial attention.

There is support for the hemispheric activation theory (Brignani et al., 2018; Lee et al., 2004; Nicholls et al., 2004; Szcepanski & Kastner, 2013; Szelest, 2014 Thiebaut de Schotten, 2011), maintaining that the functional differences of the left and right hemispheres are responsible for the leftward bias. Nicholls and Roberts (2002), however, suggest that pseudoneglect may be due to asymmetries present in the neural mechanisms that control attention and not the nature of task-related hemisphere activation. Szcepanski and Kastner (2013) state that both frontal and posterior parietal cortex areas are important for controlling spatial attention across the visual field (Chun & Johnson, 2011). Varnava et al. (2013) also maintain that in some cases the left hemisphere can be implicated in visuospatial functioning.

Spatial attention tasks induce a stronger activation of the right hemisphere resulting in the overestimation of the left side, producing pseudoneglect (Szelest, 2014). The left side of the line in the LBT receives more attention and is viewed to be longer. This is in accordance with the activation-orientation theory (Bultitude & Aimola Davies, 2006).

b. Activation-orientation hypothesis

Unilateral neglect is the consequence of right hemisphere damage during which patients exhibit an inability to attend to stimuli on the left side of space (Badok et al., 2014; Bartolomeo & Chokron, 2002; Bultitude & Aimola Davies 2006; Foulsham et al., 2013; Loftus & Nicholls, 2012). The inability to notice stimuli on the contralesional side has also been described in terms of an attentional deficit. Driver (2001) reports on studies that found that neglect patients may attend to stimuli in the 'blind' visual field when their attention is drawn to it, improving on their shortcoming. Some studies have also reported that neglect patients can often detect a single stimulus on the left side. However, when more than one stimulus is present at the same time, patients fail to notice those presented on the neglected left side. Similar to normal functioning subjects, stimuli often go unnoticed, especially when multiple stimuli have to be processed simultaneously. When multiple stimuli are present, stimuli compete for attentional resources, as TVA assumes (Driver, 2001; Theeuwes, 2010). In unilateral neglect, patients' attention may be biased due to brain damage, and as a result, they favour the right side. Driver (2001) therefore maintains that neglect patients may suffer from an attentional limitation where their selective attention ability is inclined towards the right following brain damage.

In relation to the focus of attention in neglect patients, Kinsbourne (1993) maintains that arguing for an extreme right side attentional display is correct but somewhat insufficient as these patients demonstrate rightward inconsistencies as well.

Loftus and Nicholls (2012) support the argument that the leftward bias observed in pseudoneglect is mainly due to the stronger activation of the right parietal areas. This is similar to Kinsbourne's (1993) observations that the right hemisphere seems to be more implicated in the demonstration of pseudoneglect.

Orr and Nicholls (2005) describe the activation-orientation theory as a model that conceptualises a system where each hemisphere is responsible for a vector of attention, increasing in strength from same-sided to contralateral space (Kinsbourne, 1993). Accordingly, neurologically healthy participants show a distribution of attention based on the interaction between the vectors, which function as opponent processors. The relative strength of each vector is influenced by the selective activation of each hemisphere. The nature of the task at hand will then ultimately impact the dissemination of attention (Orr & Nicholls, 2005). The activation-orientation model proposes that spatial attention is directed more to the opposite side of the more active hemisphere (Kinsbourne, 1993; Reuter-Lorenz, et al., 1990). The activation-orientation model asserts that activating the right posterior parietal cortices (PPC) in the execution of visuospatial activities will result in a leftward attentional bias, thereby making leftward stimuli more noticeable. It can therefore be reasoned that the inclination to overemphasize the left side of the line, as observed with the LBT, may be due to the saliency of stimuli presented in the left hemispace.

Friedrich et al. (2018) argue that pseudoneglect may be a multi-component phenomenon and vulnerable to deviations as defined by task demands. Stimuli properties, as well as differences in neurological functioning, may impact how sensory input is perceived in relation to the representation of space (Szelest, 2014). Divergent results on leftward biases may thus stem from the different tasks used as well as the nature of the tasks itself (Brignani et al., 2018). Pseudoneglect is ultimately a product of both perceptual and attentional factors (Porac et al., 2006).

2.3.2 Subtypes of pseudoneglect

Szelest (2014) explains that the attentional bias is related to different variations of pseudoneglect including both attentional and perceptual functioning mechanisms. The differences observed in pseudoneglect presentation, suggest that subtypes of pseudoneglect may exist (Varnava et al., 2013).

The cognitive mechanisms that underlie different forms of pseudoneglect may then be distinct as Eardly et al. (2017) report that findings support the possibility of different neural mechanisms for visual/perceptual pseudoneglect and representational forms of neglect.

a. Perceptual pseudoneglect

Healthy individuals exhibit a leftward spatial bias, failing to equally attend to the right side of space (Cocchini et al., 2007; Forte, 2016; Gray, 2018; Nicholls et al., 2004; Schmitz & Peigneux, 2011; Zago et al., 2017). Siman–Tov et al. (2007) describe this phenomenon as right pseudoneglect defined by a leftward inclination in the observation of length, size, brightness, and numerosity. Attention is instinctively directed to the left due to the activation of posterior parietal areas in the right hemisphere (Bultitude & Aimola Davies, 2006; Çiçek et al., 2009; Lee et al., 2004; Szelest, 2014; Ribolsi et al., 2013), altering our perception.

Perceptual pseudoneglect is defined as the leftward bias in visuospatial attention observed in neurologically healthy individuals (Ribolsi et al., 2015) resulting in an overestimation of the properties on the left side of stimuli causing right-sided inattention (Brignani et al., 2018; Loftus et al., 2009; Siman-Tov et al., 2007). This form of pseudoneglect is observed for stimuli that are physically present and can be assessed using various techniques, most commonly the LBT.

The nature of the task impacts the degree of pseudoneglect (Lee et al., 2004) as the ‘what’ and ‘where’ pathways can account for some of the observed differences with regard to left or right errors.

Lee et al. (2004), for example, used both a solid line task and two-character line tasks. The midpoint judgement task involves the “where” system while length determination depends on the “what” pathway. “Where” judgements are reliant on observer-centred distribution of attention and are directed by the right hemisphere’s dorsal stream (Brignani et al., 2018; Lee et al., 2004; Thiebaut de Schotten, 2011). Length judgements in contrast, involve the “what” ventral stream in the left hemisphere. Differences with left and rightward biases are thus observed as LBT judgements activate the “where” system in the right hemisphere, producing a leftward bias, while the character line task invokes the “what” system in the left hemisphere, generating a rightward bias. The dorsal- and ventral frontoparietal systems in the attention network are emphasised as constituting important neural pathways with regard to pseudoneglect (Gigliotta, Malkinson, Miglinio, & Bartolomeo, 2017; Schmitz et al., 2013; Siman-Tov et al., 2007; Szelest, 2014). Based on their findings, Lee et al. (2004) argue that the direction of the errors seems to rely on the task used to assess pseudoneglect.

Apart from the general LBT for assessing perceptual asymmetries, other methods include presenting pre-transected horizontal lines to participants where they are requested to make judgements about the location of the transection mark relative to the left and right side of the line (Bultitude & Aimola Davies, 2006). Participants had to determine if the transector was located more to the left or right side of the line. Despite the line being pre-transected, participants continued to show asymmetries in performance, consistent with the usual LBT (Milner, Harvey, Roberts & Forster, 1993). It is emphasised that the LBT is not entirely a visuospatial task, but it necessitates the need to transform spatial information into applicable motor action (Hausmann et al., 2002). Bultitude and Aimola Davies (2006), however, report that “…line-bisection biases of neglect and pseudoneglect cannot be attributed solely to motor effects, and are at least in part due to the perceptual overestimation of the length of the one half of the line in comparison to the other” (p.1850).

Other popular measures used to assess perceptual pseudoneglect include brightness tasks. Szelest (2014) used a brightness judgement task using individual disks displayed in a circular arrangement. The disks differed in shade from left to right and vice versa. Subjects were instructed to judge the brightness of the display by identifying the darker side. Response times and the left and right responses were measured and used to determine the overall bias. A strong directionality bias with the position of presentations and the direction of the stimulus array was found (Szelest, 2014). It was concluded that screen position, as well as the orientation of the greyscale, produced the most noticeable impact on the direction and extent of the bias (Szelest, 2014).

Apart from the task used to assess perceptual pseudoneglect, another important factor that impacts attentional bias is handedness (Szelest, 2014). The hand used to complete the task can impact LBT performance. Right-handed participants show a higher degree of pseudoneglect compared to left-handed participants, especially when using the left hand to perform the task (Brookes et al., 2014; Szelest, 2014). Hand use, therefore, appears to sway perceptual asymmetry (Brignani et al. (2018; Jewell & McCourt, 2000; Nicholls et al., 2004). Findings from Failla et al. (2003), for example, produced observable differences amongst young and old participants only when the left hand was used.

The lack of agreement regarding the presentation of pseudoneglect is based on various factors, including the task used to assess it as well as factors related to hand use and position of demonstration. A leftward inclination is, nonetheless evident, regardless of different means of assessment or reading/scanning direction (Nicholls & Roberts, 2002). Helfter et al. (2020) also demonstrated pseudoneglect within an adult population diagnosed with attention-deficit/hyperactivity disorder (ADHD). A comparable pattern of lateralisation in attention is thus observed for neurologically healthy adults across different assessment means and varying population groups.

Perceptual pseudoneglect manifests in various age groups, but the magnitude of the leftward bias may differ depending on the task used for assessment. It is also mediated by other factors linked to the activation of the left and right hemispheres. Generally, when neurologically healthy participants try to find the midpoint of horizontal lines, errors to the left are commonly reported (Jewell & McCourt, 2000; Darling et al., 2012), i.e. pseudoneglect, specifically perceptual pseudoneglect. McGeorge et al. (2007) and Darling et al. (2012) emphasise a comparable lateral bias detected for visuospatial representations held in LTM. The term *representational pseudoneglect* is used to describe this variation of the leftward bias.

b. Representational pseudoneglect

An interesting aspect of the leftward bias is that it is also demonstrated in the absence of vision. Accordingly, pseudoneglect is not only observed for physically present stimuli, but a representational form appears to be applicable as well. Asymmetries of visuospatial representations in memory are described as representational pseudoneglect (Darling et al., 2012; Forte, 2016; Gray, 2018) and relate to a bias towards the left side of space when visual information is recalled from memory even though people are not physically exposed to the visual information.

Ribolsi et al. (2013) agree that there is support for the presence of representational pseudoneglect as evidenced by the mental number line bisection test where participants are expected to indicate the midpoint of a mental number line, oriented left to right. Brookes et al. (2014) publicised the notion that the leftward bias is also observed when participants are asked to mentally represent a stimulus or to explore stimuli without physically seeing the visual stimulus. Participants are for example requested to mentally recall a stimulus they previously experienced (Brookes et al., 2014). Darling et al. (2012) defined representational pseudoneglect as "...a bias toward the left side of space that occurs when visual information is remembered" (p.879). Representational pseudoneglect thus involves failing to recall normal representation of the contralesional side of mental images (Gray, 2018; Rode et al., 2007).

McGeorge et al., (2007) conducted a study where they asked participants from varying age groups to envision a scene of the Piazza del Duomo in Milan, Italy, and to detail the landmarks on each side of the Cathedral Square from two different viewpoints. The findings revealed that more landmarks were stated from the left side compared to the right, regardless of the perspective from which it was mentally recalled (Brookes et al., 2014; McGeorge et al., 2007). Similar results were found in a study conducted by Bourlon et al. (2011). Canadian participants tended to locate different North American cities too far to the west (left) side, suggesting a similar form of pseudoneglect (Friedman, Mohr, & Brugger, 2012). Research using postgraduate students revealed that the students were able to remember more content from the left side of photographs compared to the right side (Dickinson & Intraub, 2009). Salla et al. (2010) also highlight the role of pseudoneglect in memory when participants were able to recall more items represented on the left, making significantly more errors recalling stimuli from the right.

Darling et al. (2012) used the LBT to study representational pseudoneglect by asking participants to bisect the lines from memory. Researchers asked participants to bisect horizontal lines presented in distant extra-personal space, since viewing distance has an impact on line bisection, specifically, more distant spaces eliminate or minimise the leftward bias (Darling et al., 2012). Longo and Lourenco (2010) confirm that as viewing distance increased, the leftward bias observed in their number line task decreased. Results showed that when participants bisected remembered lines, there was a definite leftward bias. Participants reported the midpoint predominantly to the left. It was however stated that the observed findings were only applicable to long and medium-length lines. These findings seem to suggest that VWM is also exposed to a lateral bias (Darling et al., 2012; Olivers, Peters, Houtkamp & Roelfsema, 2011).

Cocchini, Watling, Della Sala, and Jansari (2007) conducted a study using virtual reality tasks to measure the representation of space behind participants, i.e., backspace. The researchers discovered that the left backspace area was judged to be bigger compared to the right side. Leftward biases have also been reported with mental number lines (Darling et al., 2012). Loftus et al. (2009) conducted a study where participants were asked to bisect mental number lines presented in a left-to-right ascending sequence. Participants had to determine whether the numerical distance was larger on the left or right side of the middle number. It was noted that although the spatial configuration of the stimulus was changed, results demonstrated that participants consistently overestimated the numerical length on the left. Accordingly, the authors reasoned that the bias was not influenced by alterations to the actual stimulus, and is thus based on mental representations. Participants were also given a two-number spanning interval after which they were probed to identify the midpoint, overtly calculating it. According to results, they tended to show a leftward bias (Darling et al., 2012; Göbel, Calabria, Farnè, & Rossetti, 2006; Loftus, Nicholls, Mattingley, Chapman, & Bradshaw, 2009; Longo, & Lourenco, 2007; Longo, & Lourenco, 2010).

Longo and Lourenco (2007) conducted a similar study, asking participants to complete both the normal LBT followed by two number LBTs. The first number LBT requested participants to view 80 different number pairs and instructed them to guess the midpoint number of each pair. The smaller number was displayed to the left and the larger number to the right. The second trial involved presenting half of the small numbers on the left and half on the right side. Results showed a leftward bias for both the physical LBT and the number LBT (Longo & Lourenco, 2007).

Brookes et al. (2014) furthermore reported the presence of pseudoneglect with a tactile rod bisection task, with no direct visuospatial processing. In this case, the representation is determined through touch and not vision. The task involved asking participants to bisect a wooden rod with their index finger without seeing the object. It was found that participants bisected the rods significantly towards the left of the actual midpoint (Brookes et al., 2014).

Research on pseudoneglect appears to suggest that the leftward bias is a result of a perceptual irregularity in space (Loftus et al., 2009), arguably due to the left-to-right eye movements. Evidence however suggests that the bias is present with mental representations as well and does not merely originate due to asymmetries in space. Biases in mental representations have also been observed with neglect patients who suffered right hemisphere damage (Eimer, 2014; Loftus et al., 2009; Bartlomeo et al., 2002; Rode, Revol, Rossetti, Boisson, & Bartolomeo, 2007).

Research also includes verbal presentations to demonstrate leftward biases. Göbel et al. (2006) used auditory presentations to assess pseudoneglect. The researchers presented participants with number pairs (e.g., 117_166) and participants were expected to guess the middle number without using any calculations. A leftward bias was detected, with participants misbisecting number pairs to the left of the true midpoint. It was argued that this tendency resulted from the inclination to overemphasize the left side of the mental number line (Göbel et al. (2006). Similarly, Brookes et al. (2011) had participants listen to verbal descriptions of matrix patterns. Participants had to construct mental representations of the patterns and estimate which side of the matrix, left or right, had the most filled cells. Results showed that more participants reported the left side as fuller compared to the right.

These findings support the notion that a predisposition to the left is not exclusive to physically present stimuli, but visual mental representations as well (Brookes et al., 2011). It was, however, noted that the strong leftward bias in mental representation did not necessarily elicit an impact on memory. There was thus no difference in the content remembered from the left, or right side of the representation. Similar results were reported in a study requesting participants to mentally represent streets with landmarks. Descriptions of the mental representations revealed that the left side of the represented street contained more landmarks compared to the right, but no differences were found with regard to lateralised memory recall (Brookes et al., 2011; Brookes et al., 2014). Accordingly, it was reasoned that "...the left side of a mentally represented stimulus may...be more perceptually salient than the right side, but there may not be the capacity for retrieving greater detail from the more salient half (Brookes et al., 2014, p.50).

Based on past findings, pseudoneglect can thus be observed for both visual and imagined stimuli (Bourlon et al., 2011; Brookes et al., 2011; Brookes et al., 2014; Darling et al., 2012; Helfer et al., 2020; Loftus et al., 2009). Generally, it is reasoned that perceptual pseudoneglect results from the fact that the two hemispheres orient attention differently to contralateral space and, as a result, activation of the right hemisphere directs attention leftwards (Brookes et al., 2011; Jewell & McCourt, 2000; Lee et al., 2004). Imagining the layout of verbally described stimuli may also activate the visuospatial pathways in the right hemisphere, resulting in a leftward bias in attention and memory (McGeorge et al., 2007). Consequently, attention is focused towards the left, making the left side more prominent thereby increasing the likely recall of information on the left side (Brookes et al., 2011). Brookes et al. (2011) failed to find any clear lateralised bias in recall suggesting that visual mental representations might be similar in detail for both left and right stimulus. The bias is mainly present with attention associated with the left of the mental representation in WM and not due to a lack of representation of detail for stimuli on the right side. The stronger attentional connection to stimuli on the left side thus makes it easier to maintain in WM and recall from LTM.

2.3.3 Pseudoneglect and memory

Nuthmann and Matthias (2014) refer to the biased competition model of attention which states that "...the rightward spatial bias in neglect patients reflect lower attentional weighting for information presented in the left hemispace, which leads to a processing advantage for stimuli presented in the over-attended right hemispace" (p. 113). Accordingly, it is argued that people preferentially attend to the left (Brookes et al., 2014). This is in agreement with Budesen et al's. (2015) TVA, which assumes that stimuli with a higher attentional weight, are more likely to be encoded to STM and eventually, LTM.

It is clear from the above discussion that attention is not distributed equally and our first eye-movements are usually to the left when we attempt to explore our visual world (Nuthmann & Matthias, 2014). The allocation of attention is important for subsequent behaviour and the leftward tendency may therefore mediate our attentional resources (Porac et al., 2006). Visuospatial attention involves directing eye-movements to specific locations, and what individuals are observing and where attention is allocated, impacts what is transferred to memory (Luck & Vogel, 2013); neither cognitive process can function without the other (Chun and Turk-Browne, 2007).

Eardley et al., (2017) explained that neglect manifests as a lateralised disturbance of spatial attention where there is a discrepancy in attention to the side opposite of the damaged hemisphere. Neurologically damaged patients then attend to objects found in the right side of space (i.e. visuospatial neglect) while ignoring objects located in the left visual field (Badok, Malhotra, Bernadi, Cocchini & Stewart, 2014; Bartolomeo & Chokron, 2002; Çiçek, Deouell, & Knight, 2009; Foulsham et al., 2013; Loftus & Nicholls, 2012; Ribolsi et al., 2013; Thomas, Castine, Loetscher, & Nicholls, 2015; Toba et al., 2011). Neurologically intact individuals show a preference for the left side of space (Benwell et al., 2014; Benwell et al., 2013; Brodie, 2010; Brooks, 2014; Bultitude & Aimola Davies, 2006; Eardley et al., 2017; Failla et al., 2003; Hatin et al., 2012; Loftus & Nicholls, 2012; Loftus et al., 2009; Nuthmann & Matthias, 2014; Parra et al., 201; Schmitz, Deliens, Mary, Urbain & Peigneux, 2011; Szelest, 2014). The leftward tendency subsequently results in favouring the processing of visual input in the left visual field (Brignani et al., 2018) while disregarding the right side of space. Stimuli on the left may then appear more salient when compared to the right (Hatin et al., 2012; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004; Varnava, Dervinis & Chambers, 2013; Zago et al., 2017), drawing more attention thereby increasing the prospect of encoding to memory.

We generally show a tendency to direct our attention to the left but visual attention can be influenced by other factors as well. Sosa et al. (2010) conducted research using visual cues before the presentation of line stimuli on either the left or right side. Participants were expected to dissect the lines indicating the midpoint. The results supported the premise that visual attention would be directed to the cued field. LBT performance was therefore mediated by spatial location cues (Szelest, 2014). Comparable results have been found by other studies as well (Bultitude & Aimola-Davis, 2006; Reuter-Lorenz et al., 1990) although there is still a lack of agreement concerning the impact of spatial cues. It is argued that the use of visuospatial cues may activate different neural mechanisms in addition to those active during perception and attention, consequently modulating observed biases (Szelest, 2014).

Memory and attention are ‘intricately interwoven’ resulting in a relation that is bidirectional and multifaceted (Gazzaley, 2011). Research proposes that the link between memory and attention is so strong that attention is biased by what is currently on our minds (Olivers et al., 2011; Szelest, 2014).

Activated memory templates can thus act as a navigating system to direct subsequent eye-movements and bias the distribution of attention.

An important issue on pseudoneglect involves determining if the distortion is within memory and not a consequence of distortions in perception (Darling et al., 2012). Szelest (2014) also argues that perceptual asymmetries are different from representational asymmetries. It is necessary to show that the leftward bias in perception, i.e., attention, results in a distortion in memory and not a distortion of memory itself. Nicholls and Roberts (2002) support the argument that the leftward perceptual bias is linked to an attentional bias and not a bias due to scanning pathways.

Della Sala et al. (2010) demonstrated that participants recalled more bindings between colour, location, and identity of objects from the left side. Similarly, Dickinson and Intraub (2009) showed that more objects were remembered from the left compared to the right in a natural visual scene. A leftward bias in memory was also observed with representational pseudoneglect when stimuli involved using wooden rods for tactile stimulation (Brookes et al., 2011), with no visual input (Darling et al., 2012). Szelest (2014) also demonstrated that attentional asymmetries influenced WM and argued that such biases become more apparent with WM processing and can potentially result in representational biases in memory itself. It was concluded that the content held in WM seem to change the direction and magnitude of lateral biases during visual attention. The rightward tendency cannot be attributed to attentional factors alone, but additional neural processes including WM might also be implicated (Szelest, 2014).

Barnett-Cowan, Jenkin, Dyde, Jenkin, and Harris (2013) found that participants demonstrated a form of pseudoneglect when they were asked to judge the orientation of unusual stimuli. Participants appeared to recognise more stimuli when their bodies were oriented toward the left (Brookes et al., 2014). Although a leftward bias was demonstrated with the mental representation task, the researchers found no significant results with regard to pseudoneglect impacting memory recall.

When we focus on objects in one hemifield, objects in the less significant, i.e., less attended hemifield, provoke enhanced visual responses only if stimuli match aspects relevant to current task performance (Eimer, 2014). This will also be mediated by memory representations currently activated in memory. Different levels of processing are involved when visual input is converted to a lasting representation in memory (Broji & Itti, 2013; Jarodzka et al., 2017) as emphasised with top-down and bottom-up attentional processing. Evidence supports the idea that attention moderates the processing of visual stimuli at both early and later stages of sensory processing (Gazzaley, 2011). Attention thus targets both the early perceptual phases of sensory processing as well as later stages, which means that the leftward tendency may be strongly implicated with attentional distribution and memory itself. The prominent focus to the left side thus impacts the allocation of attention and subsequent memory formation.

The debate about the impact of pseudoneglect centres on whether attentional resources are biased, or whether the bias is based on information recalled from memory. Schmitz et al. (2013) argued for a ‘memory pseudoneglect phenomenon’ (p.1314) where it is reasoned that when people attempt to recall familiar stimuli, the temporary activation of such information stored in LTM appears to be subjected to a leftward bias (Brookes et al., 2011). Only later in the visual processing stage, and after memory feedback, is the observer able to bias visual selection in a top-down manner and able to direct attention as regulated by existing behavioural goals. Leftward biases may therefore not be limited to perception and attention only, but impact WM as well (Szelest, 2014).

Despite the lack of consensus, the impact of lateral biases on both attentional processes and memory is evident in that the memorisation of stimuli is mitigated by attention and since attention is directed mainly towards the left, neglecting the right, we may recall more items from the biased visual field (Della Sala et al., 2010; Darling et al., 2012; McGeorge et al., 2007). Exploring the mechanisms that underlie attentional asymmetry can thus offer important insights to enhance our understanding of functional brain lateralization (Siman-Tov et al., 2007).

The next section is about the neurological mechanisms that underlie pseudoneglect. This section serves as an introduction to contextualise the importance of the variables gender and age and provides support for including the variables in the present investigation.

2.4 Neurological mechanisms underlying pseudoneglect

Eimer (2014) postulates that visual attentional processes are based on four provisional stages: preparation, guidance, selection, and identification. Each stage is responsible for a specific function and is linked to differential neural activity. The selection process at the retina is based on bottom-up stimulus features, where most processing is reliant on feature detector neurons that pick up information about motion, orientation, and direction of stimuli (Serences & Yantis, 2006; Treue, 2003). The attentional system becomes more specialised as sensory information progress to higher-order functional areas. Eimer (2014) argued that each attentional processing stage activates a particular neural network. Attention is therefore not a single functionally and anatomically separate regulator system, but is based on the synchronised function of various neurocognitive processes (Gray, 2018). The executive control function of attention impacts how visual information is processed and ultimately how the input is represented for the purpose of selection (Carrasco, 2011).

Attentional processing creates a neural representation of the visual world that is based on the significance of visual input and in line with current behavioural goals. Treue (2003) emphasise the importance of understanding what is selected through our attentional filter when multiple stimuli compete for attention (Eimer, 2014). The processing of visual information is facilitated by knowledge and expectations about the world, current behaviour, and the presence of unexpected but potentially useful input in the environment (Carassco, 2011).

Neuroimaging studies have allowed researchers to identify the cortical and subcortical brain regions implicated in attentional processing. Carrasco (2011) reports that three networks have been identified each linked to a certain aspect of attention. The three networks are: alerting; orienting and executive control. Alerting is the capacity to sustain a heightened state of sensitivity to receiving input and is linked to activity in the frontal and parietal areas of the right hemisphere. Orienting involves selecting information from visual input with the parietal lobe, the temporal-parietal junction, and the frontal eyelids that are active during this process. Executive control is described as the feature that resolves conflict within attentional processing and is linked to the anterior cingulate and the lateral prefrontal cortex (Carrasco, 2011). Cook and Maunsell (2002) suggest that the strength of attentional influences increases as information moves through the cortical processing hierarchy.

Physiological research illustrates that attentional control, in terms of neural activity in the visual cortex, demonstrates that activity in cells that prefer attended stimulus features increases, while the activity of cells that prefer non-attended features are concurrently suppressed. Neurons thus selectively fire in relation to significant stimuli features and neural activity induced by attended stimuli takes preference over activity of unattended information at each level of the visual processing system.

Only during later stages of visual processing does top-down influences moderate and improve neural representations (Serences & Yantis, 2006). It is argued that neurons have spatial receptive fields (RFs) and different neurons code different features of visual stimuli (Serences & Yantis, 2006). Neurons in the initial phase of visual processing have small spatial RFs to code basic aspects of images whereas neurons located in later processing streams have larger RFs to code more detailed features of stimuli and determine its relevance to the task at hand. Multiple stimuli can activate the RFs of a single neuron and objects have to compete to gain neural representation. Serences and Yantis (2006) suggest that this hierarchical system complicates perception as stimuli compete for attention if a single RF is activated. Selective attention is therefore essential as it manages the activity of different neurons to solve the competition and align the visual representations (Theeuwes, 2010).

Anatomically, fMRI results suggest the involvement of several brain areas in visual attention (Gray, 2018; Haxby et al., 2000). Neuroimaging studies, as well as results from lesion studies, support the importance of the right hemisphere with the visuospatial sketchpad (Baddeley, 2003). Chun and Johnson (2011) highlight the importance of frontal and parietal regions as both areas are active during attention. Gigliotta, Malkinson, Miglino, and Bartolomeo (2017) also emphasise the prominent role of the fronto-parietal networks. Attention is maintained by two orienting systems: a dorsal stream that includes the frontal eye fields and the intraparietal cortex (IPS) that is associated with behavioural objectives, specifically top-down attentional processing (Chun & Johnson, 2011). The ventral stream involves the inferior frontal cortex and is responsible for bottom-up processing. The ventral system demonstrates a right hemisphere bias and controls the ability to direct attention to significant actions that may impact the observer. Reflective attention also relies on activity in the frontal and parietal areas, specifically the left dorsolateral prefrontal cortex and the left parietal regions.

Directing attention away from primary focus areas is described as 'reorienting' (Chun & Johnson, 2011, p. 8), and this involves resetting the activity of the dorsal stream. The dorsal network is generally responsible for inhibiting ventral stream activity during times of focused attention (Gigliotta et al., 2017). Johansson and Johansson (2014) also emphasise the important implications of the ventral and dorsal streams in visual processing as this impacts memory. Similarly, Schmitz et al. (2013) refer to the dorsal and ventral posterior parietal cortices (PPC) in attentional processing.

There is also neurophysiological support for a distinction between the different WM components. The visuospatial storage system and the phonological loop are separate memory stores although WM content overlaps with other cortical areas related to perception and LTM (Awh & Jonides, 2001; Eriksson et al., 2015).

Individual differences observed in WM capacity are linked to differential attentional processing in how significant input is filtered (Luck & Vogel, 2013). Differences in filtering proficiency are also observed between younger and older adults, emphasising the important impact of age.

2.5 The significance of age and gender in relation to pseudoneglect

The prominent role of hemispheric specialisation has been emphasised, especially the dominance of the right hemisphere in the allocation of attention and pseudoneglect. Hemispheric lateralisation has functional significance, but these asymmetries are however unstable and change across the lifespan. Both the left and the right hemispheres differ structurally and are lateralised for special functions (Peters, 2006). The right hemisphere appears to show more rapid age-related decay compared to the left. The significance of the right hemisphere in the demonstration of pseudoneglect is known and this may partly explain observed age-related differences. Consequently, it is argued that age influences each hemisphere differently. Changes in age can exert an impact on a variety of cognitive functions (Forte, 2016). Research suggests that performance on tasks involving the right hemisphere appears to show more age-related declines compared to left hemisphere activities (Hausmann et al., 2003; Lee et al., 2004). In accordance, Schmitz and Peigneux (2011) agree that normal aging appears to be linked to a more pronounced decay of the right hemisphere.

Varnava and Halligan (2007) emphasise that age and gender are biological factors that can impact cognitive processing of basic tasks like the LBT, either distinctively or collectively. These variables are also linked to the asymmetric changes observed across the left and right hemispheres (Failla et al., 2003; Hausmann et al., 2002; Roig & Cicero, 1994). The potential modulating impact of age and gender have been explored but findings are largely unreliable and are still debated (Forte, 2016).

Within the current study, the term gender was used to refer to women and men following from biological sex (female vs. male) as explained by Morgenroth and Ryan (2020). The following two subsections offer an overview of the significance of age and gender concerning asymmetrical biases.

2.5.1 Age and pseudoneglect

Our ability to focus attention, changes as we get older, specifically our ability to sustain attention (Glisky, 2007). Normal aging appears to undermine global attentional processing more rapidly than the processing of local features (Lee et al., 2004). Kinugawa et al. (2013) also note that both our long-term– and episodic memory capacity declines with age, along with our ability to multitask and shift our focus between different tasks. Different tasks also necessitate different degrees of attention and Lee et al. (2004) report that older subjects may be more susceptible to attentional changes as tasks exert greater demands on their attentional capacity. Divided attention thus becomes compromised as people get older (Baddeley, 2003; Glisky, 2007). What we focus on ultimately influences what is encoded to memory (Eimer, 2014; Theeuwes, 2010), and age-related changes to attention can subsequently impact memorisation as well. Exploring possible differences in the demonstration of pseudoneglect may be valuable to elucidate the impact of age on the asymmetrical bias in attention.

Friedrich (2018) maintained that age-related changes and pseudoneglect have received considerable attention (Friedrich et al., 2016; Harvey et al., 2000; Jewel & McCourt, 2000; Schmitz & Peigneux, 2011, Varnava & Halligan, 2007), but the findings are inconclusive. Some studies argue for a reversal in pseudoneglect while others maintain that the leftward bias persists. More research is thus needed to elucidate the impact of age on pseudoneglect.

Several models have been suggested to explain the changes, or lack thereof, in pseudoneglect due to aging.

a. The hemispheric asymmetry reduction in older adults (HAROLD)

Brignani et al. (2018) and Friedrich (2018) describe two prominent models related to cognitive aging that has primarily been applied in investigating changes in spatial asymmetry due to age: the hemispheric asymmetry reduction in older adults (HAROLD) and the right hemi-aging model (RHAM).

Hausmann et al. (2003) describe the HAROLD as an important theory as well as the differential-aging hypothesis. The differential-aging hypothesis is proposed to explain the decline in performance IQ observed among older adults, specifically on the Wechsler Adult Intelligence Scale (WAIS). In accordance with the differential model, age differences may involve a general decline of processing and not necessarily specific neurological changes. The same decline in performance IQ is observed in patients with damage to the right hemisphere, the hemisphere commonly responsible for nonverbal visuospatial functioning (Hausmann et al., 2003). Consequently, it is postulated that the right hemisphere seems to be more vulnerable to age-related deterioration compared to the left, or that the right hemisphere may age more rapidly (Brignani et al., 2018; Brooks et al., 2011; Brooks, 2014; Wilzeck and Kelly, 2012).

Assumptions from the HAROLD model is based on neuroimaging results that show brain activation during cognitive performance between young and old adults. The HAROLD model assumes that cognitive processing is lateralised in one hemisphere in young adults, but the cognitive specialisation becomes less pronounced as age increases (Hausmann et al., 2003; Learmonth, Benwell, Thut & Harvey, 2017). Activation of the prefrontal cortex becomes less specialised with age, impacting cognitive functioning (Brooks, Darling, Malvaso & Della Della Sala, 2016; Friedrich, 2018). Schmitz et al. (2013) argue that the HAROLD model highlights age-related deterioration in the right hemisphere. If the right hemisphere is more vulnerable to age-related changes, this should be evident in the performance of tasks that primarily activate the right hemisphere (Milano, Douyon, Falchook & Heilman, 2014). A study conducted by Schmitz and Peigneux (2011) showed an age-related suppression of the leftward bias using the perceptual landmark task. Based on the HAROLD model, older people tend to exhibit more bilateral activation of the prefrontal cortex when memory tasks are involved, compared to younger populations where the right prefrontal cortex is more prominently activated (Cabeza et al., 2002; Friedrich, 2018). Neuroimaging research shows right prefrontal cortex activity during memory retrieval in young adults compared to older adults where both the left and right hemispheres are active. Friedrich (2018) reports support for the HAROLD model's hypothesis. The reduction of pseudoneglect, observed in some studies, is generally supported by the HAROLD model (Learmonth et al., 2017; Milano et al., 2014).

Changes observed in hemispheric lateralisation may predict more input from the left hemisphere and less superiority of the right hemisphere with regards to spatial attention (Schmitz &, Peigneux, 2011). Aging suggests more prominent changes within the right hemisphere (Brignani et al., 2018; Brooks et al., 2011; Brooks, 2014; Learmonth et al., 2017; Wilzeck and Kelly, 2012) as assumed by the RHAM model.

b. The right hemi-aging model (RHAM)

According to the RHAM model, the right hemisphere, along with the cognitive skills maintained by this hemisphere, is more susceptible to age-related changes, consequently resulting in more significant decline. Cognitive functions prominently linked to greater right hemisphere activation, thus exhibit more pronounced decline (Friedrich, 2018; Learmonth et al., 2017). As a result, the left hemisphere may become more active to compensate for the decline observed in the right hemisphere. Support for the RHAM model is based on observing lateralised functions in young and old populations. Findings reveal that older adults show more pronounced changes in spatial tasks, based on WAIS testing, compared to younger age groups, indicating right hemisphere decline (Hausmann et al., 2003). Similarly, changes in emotional processing, a core feature of the right hemisphere, are also observed amongst older people. The nature of the right hemisphere decline foresees a stronger influence of the left hemisphere (Friedrich, 2018), such, that the left hemisphere becomes more superior. The RHAM model then supports the changes observed in pseudoneglect, where evidence suggests an elimination of the leftward bias to produce more rightward errors.

c. The compensation-related utilization of neural circuits hypothesis (CRUNCH)

The leftward bias may then be preserved in older adults and the compensation-related utilization of neural circuits hypothesis (CRUNCH) is used to explain this continued attentional bias despite aging (Brignani et al., 2018; Friedrich et al., 2018). Accordingly, it is proposed that older adults rely on extra brain regions compared to younger adults to meet task demands. Based on the CRUNCH hypothesis, older adults continue to display a leftward bias that is comparable to younger adults (Friedrich, 2018). The activation of different brain regions for task performance is described as a compensatory mechanism where the aging brain compensates for areas no longer functioning effectively (Brooks et al., 2016; Varnava & Halligan, 2007). This means that additional cortical areas can be activated to compensate for functional deterioration. Hausmann et al. (2003) agree that depending on the complexity of the task, it is possible that older participants recruit more brain regions thereby, enhancing the brain's processing ability. The activation of additional neural circuits thus compensates for the neural decline caused by ageing (Reuter-Lorenz et al., 1990). When the supplementary activated regions are found in the right hemisphere, the hemispheric imbalances are conserved producing the usual leftward bias (Brignani et al., 2018). Additional neural activation enables older adults to counter the age-related decline. Accordingly, it is reasoned that restructuring of the neural circuits due to aging is not limited to the opposite hemisphere and more neural activity does not predict more pronounced hemisphere asymmetry as maintained by the HAROLD model. The activation of more brain regions can occur in any area of the cortex and may be limited to a single hemisphere (Brooks et al., 2014; Friedrich, 2018; Hatin et al., 2012). Varnava and Halligan (2007) propose that a functional re-organisation of the brain can also occur due to neurotransmitter imbalances and a decline of synaptic connections and dendrite deterioration. Activities used to assess pseudoneglect generally activate attentional systems in the right hemisphere, and as this hemisphere is particularly susceptible to age-related decline, more brain regions in the right hemisphere are used resulting in the usual leftward bias (Friedrich, 2018).

Brignani et al. (2018) claim that both the HAROLD and RHAM models attribute the decline in leftward biases, observed in older populations, to a decrease in hemispheric imbalances. Based on these findings, it is reasoned that age can impact pseudoneglect and it seems to be linked to reduced cerebral laterality caused by age-related cognitive and neural changes (Forte, 2016; Friedrich, 2018). Varnava and Halligan (2007) explain that age-related decline can impact perceptual and cognitive abilities differently. Older adults may also use different areas of the brain compared to younger adults (D'Esposito, Postle, Ballard, & Lease, 1999). Each model proposes different mechanisms and reasons for the continued leftward bias or rightward bias in older populations. Hemispheric changes based on the RHAM model provide evidence for a rightward bias due to hemispheric asymmetry. The HAROLD model maintains that older adults display hemispheric functions that are less lateralised. The CRUNCH model, however, holds that increased neural activity of several brain regions preserves the leftward bias in older adults (Brooks et al., 2016; Friedrich, 2018; Learmonth et al., 2017). Pseudoneglect literature suggests that the effects of aging on lateral biases remain inconsistent (Forte, 2016, Learmonth et al., 2017; Friedrich, 2018), more research is thus needed. Friedrich (2018) explained that more research is necessary to enhance the construct validity of pseudoneglect and to inform models of cognitive aging that may explain the contradictory findings with regards to visuospatial attention. Similarly, the predictive validity and real-world implications of age-related decline in lateral biases need to be explored, especially with regard to driving ability.

2.5.2 The impact of aging on pseudoneglect

Most studies have limited their focus to the age group 18 to 25 years. As a result, not much is known about age-related changes. Ageing is linked to the abandonment of certain skills and abilities, increased prevalence of medical disorders, and neurobiological changes that account for cognitive decline (Hausmann et al., 2003). It is yet to be determined how functional cerebral asymmetries change over time and the debate concerns the nature of the change and whether these changes are systematic or not (Forte, 2016; Friedrich, 2018; Learmonth et al., 2017).

Lateral biases amongst older adults are not yet well understood and research exploring pseudoneglect in the context of aging is limited. Brignani et al. (2018) argue that research exploring age-related changes in pseudoneglect produce contradictory results likely due to variations in methodology and comparison groups. The complex neurological changes that underlie the decline in motor, perceptual and cognitive functioning associated with ageing were reiterated by Varnava and Halligan (2007). It is argued that the developmental differences observed in LBT performance imply that cognitive functioning in older participants is different from that observed for those younger than 30. More research is needed to elucidate the impact of age on biases in attention. To identify and delay the negative effects of ageing on cognitive functioning, it is important to improve understanding of the mechanisms underlying cognition and how it is influenced by ageing (Wilzeck & Kelly, 2012). Research concerning normal and pathological aging is necessary to enhance our comprehension of age-related cognitive changes (Brignani et al., 2018; Friedrich, 2018).

Neuroimaging research supports the belief that the brain changes anatomically and physiologically with ageing, thereby adjusting its functioning (Cabeza, Anderson, Locantore, & Mcintosh, 2002; Glisky, 2007; Gray, 2018) and this may affect the manifestation of pseudoneglect (Hatin et al., 2012). Both the left and the right hemispheres are lateralised for specific functions which means that age may impact each differently (Brooks, 2014; Cabeza et al., 2002; Friedrich et al., 2018; Friedrich, 2018; Lee et al., 2004). Research shows that there appears to be a reduction of hemispheric specialization and an increase in individual variability as age increases (Wilzeck & Kelly, 2012). Aging can therefore impact how the two hemispheres are used to complete tasks like those that require visuospatial attention (Lee et al., 2004). The maturation and ageing process can alter individual hemispheric input in spatial attention, which can subsequently result in gender differences as well. Age can impact task performance differently, depending on which hemisphere is affected (Peters, 2006). Other factors, including the nature of the task and handedness, can also impact the observation of perceptual biases.

Some report that age has a significant impact on pseudoneglect with the leftward bias becoming less obvious. Studies show that older adults lean towards a rightward attentional bias in line bisection in contrast to the normal leftward inclination. However, LBT research shows that elderly people bisect lines left of the midpoint when stimuli are presented in right and central space, but tend to make rightward errors when lines are presented in the left space (Harvey et al., 2000). The opposite is observed with younger participants. Jewell and McCourt (2000) and Faila et al. (2003), for example, report that the tendency to bisect to the left of the midpoint disappears or reverses with age. Learmonth et al. (2017) reported related findings, supporting an age-related decline of the right hemisphere's superiority with regard to spatial attention, similar to neglect patients. The advantage of left-sided processing in younger adults thus seems to disappear with age or is reversed (Märker, Learmonth, Thut, & Harvey, 2019). Several studies found support for a reversed bias or a reduction of the leftward bias (Benwell et al., 2014; Failla et al., 2003; Schmitz & Peigneux, 2011). Lee et al. (2004) assessed pseudoneglect by administering a solid-line task (SBT), and a character-line (CBT) bisection task to different age groups. Based on the findings, Lee et al. (2004) argue for a mitigating impact of age and support the notion that pseudoneglect changes to the opposite direction. Results from their CBT experiment indicated that older participants demonstrated significantly more rightward biases. In young participants, deviations were to the left of the true centre. Older adults thus make more rightward errors compared to younger subjects. Findings from a study conducted by Schmitz and Peigneux (2011) revealed that there appears to be an age-related change from a leftward attentional bias towards a reversed bias amongst older adults. It was argued that older adults appear to suppress the usual leftward bias. The authors hypothesized that this is due to the weakening of the right hemisphere in conjunction with the compensation of the left hemisphere as cerebral imbalances seem to weaken with age (Schmitz et al., 2013). It was however noted that deterioration of the corpus callosum is also a viable explanation (Schmitz et al., 2013).

In contrast to the above findings supporting a rightward bias, other studies advocate for a continued leftward bias in older adults. The tactile rod bisection study conducted by Brookes et al. (2014) included participants from varying age groups and findings showed that all age groups demonstrated pseudoneglect except for the group approaching adolescence. Failla et al. (2003) report the observance of pseudoneglect amongst older and younger subjects, but the effects were moderated by hand use. A reduction in the leftward bias, as a result of aging, was found between older and younger adults only when the right hand was used (Brignani et al., 2018). Märker et al. (2019), produced findings that showed a significant leftward bias in a sample of older adults with two tasks, while other tasks produced rightward errors. Other research, however, advocates for no age-related differences or a stronger leftward bias with increasing age (Brooks, 2014; Varnava et al., 2013).

Failla et al. (2003) refer to a study conducted by Schenkenberg and colleagues who found that a group of participants, with an average age of 49, presented with symmetrical neglect. Symmetrical neglect is observed when participants are biased to the left when the left hand is used and biased to the right when the right hand is used (Bradshaw, Nettleton, Wilson & Pierson, 1987; Bradshaw, Nettleton, Nathan, & Wilson, 1985; Bradshaw, Spataro, Nettleton & Bradshaw, 1988). Similarly, Dellatolas, Cootin, and Agostini (1996) report changes in line bisection performance with age. Children younger than five years tended to bisect to the right of the midpoint when using their right hand and to the left when using their left hand but, older participants showed line bisection performance similar to adults, i.e., biased towards the left of the midpoint. Leftward biases were also observed by Hausmann et al. (2003) amongst different age groups when the left hand was used. When the right hand was used, some participants displayed a rightward bias. Accordingly, it was concluded that this finding "...suggests a shift from the contralateral to right-hemispheric control during puberty and may reflect maturation of the corpus callosum" (Hausmann et al., 2003, p. 155). Chiang, Ballantyne, and Trauner (2000) also report age-related changes in pseudoneglect, observing that the leftward bias seemed to increase in magnitude from about the age of six to ten years old. The observed changes were attributed to possible degeneration of the corpus callosum (Bradshaw et al., 1988; Failla et al., 2003; Friedrich, 2018) which emphasises the possible impact of structural age-related changes in brain functioning.

Brignani et al. (2018) investigated age-related changes in pseudoneglect using an enumeration task. It was reported that pseudoneglect was observed in both young and older populations with experiment one, but no significant differences were found in experiment two. The authors concluded that younger and older adults showed enhanced performance with an enumeration task when the items appeared in the left visual field. It was further reported that the leftward tendency disappeared as symptoms of dementia progressed (Brignani et al., 2018).

The leftward bias demonstrated by a neurologically healthy population means that the biased spatial representation of the right hemisphere is transmitted via the corpus callosum to the left hemisphere (Failla et al., 2003). This is, however, only true if the corpus callosum is intact and not damaged (Hinkley et al., 2012; O'Reillya et al., 2013). The corpus callosum is therefore important in understanding attentional asymmetries and any structural changes due to age can influence our attentional processing (Failla et al., 2003; Friedrich, 2018; Hinkley et al., 2012; Peters, 2006). Glisky (2007) supports this argument and states that changes in the physical structure of the brain are linked to changes in cognitive functioning, i.e. attention. Luders, Thompson, and Toga (2010) note that structural changes occur to the corpus callosum, especially during childhood and adolescence (Tanaka-Arakawa, Matsui, Tanaka, Uematsu, Uda, & Miura et al., 2015). As the corpus callosum is necessary for integrating attentional functions between the two hemispheres, changes in attentional bias in visuospatial tasks are expected as age changes (Learmonth et al., 2017).

In relation to representational pseudoneglect, this seems to increase with age (Brooks et al., 2011; Brooks, 2014). It is hypothesised that as we get older, our hemispheres become less lateralised, and more bilateral involvement is evident for tasks (Cabeza et al., 2002; Wilzeck & Kelly, 2012). Motor tasks may involve activation of the left or right hand, which in turn results in activation of either the left or right hemisphere in younger adults. For older adults performing the same task, however, it is expected that hemisphere activation is spread across the two hemispheres and less specialised to one side of the brain.

The above discussion highlights the contradictory findings regarding the impact of age on pseudoneglect. The age-related changes in pseudoneglect along with the underlying mechanisms involved are a debated topic. Some authors claim that the leftward bias is attenuated with age or argue for a reversal in pseudoneglect (Benwell et al., 2014; Brignani et al., 2018; Failla et al., 2003; Schmitz & Peigneux, 2011). Whereas others maintain that the leftward tendency is preserved in older adults (Brooks et al., 2014). Exploring if and how aging impacts perception across hemifields may be valuable in understanding pseudoneglect and the mechanisms associated with cognitive aging (Brignani et al., 2018; Brooks et al., 2014). The findings can also be applied to real-world contexts, like driving, especially amongst older populations (Friedrich, 2018).

The complex nature of pseudoneglect has been noted as many different factors influence the phenomenon. Varnava and Halligan (2007) reason that both gender and age impact the underlying neural mechanisms of cognitive processing and behavioural performance; hence, it can impact LBT demonstrations. Research on the role of gender in relation to LBT performance and lateral biases is limited (Forte, 2016; Hausmann et al., 2003). Findings seem to suggest that male subjects make larger leftward errors compared to females (Jewell & McCourt, 2000).

2.5.3 Gender and pseudoneglect

Hirnstein, Hugdahl, and Hausmann (2019) claim that gender differences have been observed for various cognitive skills including mental rotation and verbal memory, which is generally argued to stem from differences in hemispheric lateralisation (Ribolsi et al., 2013).

Research suggests that males are prone to show stronger spatial abilities compared to women who demonstrate better verbal skills. Rasmjou, Hausmann, and Güntürkün (1999) also emphasise the stronger verbal ability amongst females while males outperform females with regard to spatial activities. Currently, definitive conclusions pertaining to gender differences and hemispheric specialisation are insufficient. Nevertheless, it is reported that gender differences in hemispheric asymmetry are not the main functional component that underlies differences in relation to cognition (Hausmann, & Gϋntϋrkϋn, 1999; Hirnstein et al., 2019).

Hausmann et al. (2002) state that information about the relation between gender and pseudoneglect is inadequate, with only a few studies focusing on gender and visual line bisection Inconclusive findings are evident regarding the impact of gender on pseudoneglect (Forte, 2016; Friedrich et al., 2018).

Differences have been observed in the performance of numerous cognitive tasks between males and females, although similarities are also apparent (Varnava & Halligan, 2007). Similar abilities are observed between males and females in most cognitive activities and when differences are found, there is significant overlap in performance (Hirnstein et al., 2019; Rasmjou et al., 1999). Gender can, however, impact behavioural and cognitive functioning differently. Although numerous studies have produced evidence that lateralisation and cognitive performance are linked, findings are inconsistent and ambiguity still exists in terms of how lateralisation and cognitive performance are linked (Hirsntein et al., 2019).

Hellige (2001) reasons that resulting differences stem from hemispheric asymmetries with hormones impacting cognition and brain processing differently across the lifespan. Hausmann et al. (2003) state that "…the concentration of gonadal gender hormones changes as a function of age" (p. 279). Hormonal changes due to age occur in both men and women but the changes are more prominent amongst females with the experience of menopause. Gender differences manifest in hemispheric asymmetry due the effect of gonadal gender hormones on cognition and hemispheric lateralisation (Hausmann & Güntürkün, 1999). In relation to this, it is postulated that hemispheric asymmetries should be more noticeable amongst older women while remaining relatively stable amongst older males. Hausmann et al. (2003) examined the influence of gender on age-related differences in hemispheric asymmetries. The sample included males and females from different age groups. The women included in the study were postmenopausal and did not use any hormonal replacements. Three visual half-field tasks were included to measure left-hemisphere functioning (word-matching task) as well as right-hemisphere functions (Figure comparison and face-discrimination task). The nature of the task activates specific hemispheres. Participants were instructed to fixate on a cross after which stimuli would be shown in either the left or right visual field. According to the findings, the word-matching task was more accurate if stimuli were presented in the right visual field and this advantage appeared to increase with age. The Figure comparison task presented in the left visual field was linked to better performance. This advantage decreased with age amongst males but, increased in women. The researchers postulated that age-related changes with regard to hormonal levels account for the observed difference. The combined effect of age and gender can thus account for the asymmetrical changes observed in cognitive functioning (Varnava & Halligan, 2007).

Brookes et al. (2014) claim that males tend to show a stronger magnitude of pseudoneglect, making larger leftward errors, when compared to females. Hausmann et al. (2002) explored the relation between gender and pseudoneglect by taking handedness into account. Results showed that hand use and gender interact where females tended to exhibit a leftward bias with both hands while males mainly demonstrated the leftward bias with the left hand. It was further noted that the position of the lines significantly influenced the leftward bias in the LBT and was regulated by hand use.

Varnava and Halligan (2007) investigated the impact of age and gender on LBT performance. The researchers presented participants with 15 horizontal lines, with three different line lengths, printed on an A4 paper. The findings revealed that all cohorts bisected all three line lengths significantly away from the midpoint. Age and gender-related differences were found (Friedrich et al., 2018; Varnava & Halligan, 2007), and the results indicated variances in the magnitude and direction of bisection errors (Varnava & Halligan, 2007). According to the findings, older women deviated more towards the left of the centre as line length increased. Younger women, however, demonstrated similar leftward errors regardless of line length. Men, as a group, deviated towards the left on short lines but left and right errors were produced with longer lines (Varnava & Halligan, 2007). Men tended to bisect lines more symmetrically while women older than 30 demonstrated more deviations to the left. These observed changes may suggest that men score better than women on visuospatial tasks.

The observed changes can potentially be linked to the combining impact of both age-related changes, and gender as age impacts males and females differently. The observed changes in LBT performance amongst women may be due to cognitive related changes associated with aging, whereas the same cognitive functions appear to be unaffected by aging in men. Hormonal changes in a woman, that occur after the age of 30, could account for some of the observed gender differences (Varnava & Halligan, 2007). It is also reasoned that males and females may simply use different strategies during the LBT task. The strategies employed by males may thus result in more symmetrical bisections.

Roig and Cicero (1994) also report significant gender differences when they investigated pseudoneglect. The findings demonstrated that men showed a significantly greater left tendency compared to women.

Hausmann et al. (2002) conducted a similar study with male and female participants. Handedness was assessed and participants were requested to complete the LBT with both hands. The LBT included 17 horizontal lines, differing in length. Bultitude and Aimola Davis (2006) report, the position of lines appears to impact the demonstration of the leftward error. As a result, Hausmann et al (2002) placed seven lines in the middle of the paper, five lines near the left margin, and five lines near the right margin. Participants had to indicate the midpoint of each line. Results revealed that females demonstrated a significant leftward error with both the left and right hand, compared to males who only demonstrated a significant leftward bias with their left hand. In contrast to female participants, only a slight leftward bias was observed when males used their right hand (Haussman et al., 2002). Line position also impacted significantly on the observed bias, with the leftward bias increasing when lines were positioned more towards the left. Hand use and line position also interacted as results showed that differences between left and right hands lessened as the left bias increased. An interaction between gender and hand use was also observed. A significant difference in leftward bisection in men was observed when right – or left hand was used, while no difference was found for women. Gender differences were thus apparent in the leftward bias between males and females with regard to the right hand, but no differences were found when the left hand was used. (Hausmann et al., 2002).

Hausmann et al. (2002) "...hypothesized that the larger cross-section of the posterior corpus callosum in females enables a stronger inter-hemispheric connectivity of visuospatial cortical areas resulting in a strong left-sided bias in hand motor cortical areas of both hemispheres [while] in males, motor cortical activation would accordingly be mainly restricted to the right hemisphere" (p.235). Findings from lateralization studies show that functional cerebral asymmetry of various visuospatial functions, appear to be more distinct in males while it seems to be more balanced in women (Hausmann & Gűntűrkűn 1999; Rasmjou, Hausmann, Gűntűrkűn, 1999).

Most studies focusing on gender and lateral biases focus primarily on participants completing the task with their preferred hand. The current study endeavoured to explore the impact of gender on pseudoneglect performance with participants using both hands to complete the task.

2.6 CONCLUSION

It is important to note that regardless of the strategy used, participants appear to demonstrate a deviation towards the left. With reference to LBT performance, scan direction, reading direction, and strategy use fail to account for the observed leftward bias (Brookes et al., 2014; Sezelest, 2014). Brookes et al. (2011) confirm that a leftward bias is evident even when stimulus description starts on the right, suggesting that pseudoneglect is not simply influenced by reading patterns or scan paths. This chapter included an overview of past literature on pseudoneglect and offered a conceptualisation of all the variables involved.

For the purposes of this study, the focus was on visually presented stimuli i.e., overt attention, and how it is potentially moderated by a lateral bias, consequently impacting VLTM. We are constantly faced with various stimuli in our surrounding environment and given that all stimuli need to compete for attention, the attentional weight assigned to stimuli may govern additional processing. A preference for stimuli in the left hemifield can thus have implications for cognitive functions including memory (Chun & Johnson, 2011).

The dominant role of the right hemisphere in visuospatial attention accounts for the observed leftward inclination as assumed by the activation-orientation hypothesis. In addition, the theory of visual attention maintains that stimuli with higher attentional weights are more likely to be included for processing. The tendency to focus more on the left can suggest an impact on memory. The next chapter outlines a discussion on the theoretical framework used to guide the current study.

CHAPTER 3 THEORETICAL FRAMEWORK

This chapter provides an overview of the researcher's epistemological and ontological viewpoints followed by an outline of two prominent theories; the activation-orientation hypothesis and the theory of visual attention (TVA). Both theories informed the current research process and the interpretation of the research findings.

3.1 THE IMPORTANCE OF THEORY

Research should always be theory-driven and Grant and Osanloo (2014) equate this as the 'blueprint' to all research. The theory signifies the foundation from which knowledge is created and it functions as the structure and support that guides all research decisions.

Researchers have to position themselves in terms of insights into how things really are and how things should ideally function (Scotland, 2012). A researcher's epistemological and ontological viewpoints represent their personal views and understandings about the nature of knowledge (Cruickshank, 2012; Grant & Osanloo, 2014). It echoes the researchers' identity concerning how knowledge is created in conjunction with other observers, the different roles involved in the process of doing research, and the tools that can be used to facilitate the investigation. The theoretical framework ultimately provides the outline that guides the entire research process as Grant and Osanloo (2014) maintain, aiding the researcher to "… philosophically, epistemologically, methodologically and analytically approach the…" research (p.13). The selected theoretical framework impacts every research decision. The structure and justification for the investigation become lost without theoretical grounding (Grant and Osanloo (2014).

The first section of this chapter provides a brief overview of the researcher's ontological and epistemological views. The cognitive paradigm serves as the overarching framework under which the relevant conceptual theories are discussed, followed by a discussion of the main conceptual framework that guided the current research process and enabled the researcher to answer the research questions.

3.2 EPISTEMOLOGICAL AND ONTOLOGICAL VIEWPOINTS

There are different conceptions about what ontology entails but for Kivinen and Piiroinen (2004), ontology is described as constituting what reality is and how it exists. It essentially concerns assumptions about the nature of reality. Epistemology relates to knowledge creation and how reality can be discovered (Cruickshank, 2012). Scotland (2012) explains in agreement that ontological views essentially deal with what establishes reality, i.e., what is.

It can be argued that knowledge fallibly reflects reality. Scientific research, as Cruickshank (2012) argues, should not be regarded as producing certainty in knowledge. Despite theoretical departures representing appropriate ontological expectations, theories should always be viewed as fallible interpretations, open to critique and amendments, and even complete replacement.

Kivinen and Piiroinen (2004) emphasise a Bhaskarian perspective of ontology on the question about what the structure of the world should be for scientific knowledge to be feasible. According to Bhaskar, knowledge should imitate the structures of the world, and "…cumulative scientific knowledge should be understood as revealing more and more of the ontologically stratified reality that consists of levels irreducible to one another" (Kivinen & Piiroinen, 2004, p. 232). The authors note that Bhaskar recognised the fact that knowledge is socially produced and sets out to discover the mechanisms underlying the world out there. Researchers have different ontological views with different theorists thus assuming different approaches to reality. It is important to note in agreement with Cruickshank (2012), that knowledge application is ultimately grounded in imperfect theories and not definitive conclusions.

Epistemology explores the nature and forms of knowledge. Scotland (2012) explains that "epistemological assumptions are concerned with how knowledge can be created, acquired and communicated…[essentially] what it means to know" (p.9). It concerns the nature of the relation between the would-be knower and what can be known (Scotland, 2012). Epistemology is about how we know reality (Cruickshank, 2012) and Kivinen and Piiroinen (2004) stress the fact that no epistemology is possible without acknowledging some form of ontology. The link between epistemology and ontology is evident in that ontology considers the nature of reality while epistemology considers how knowledge about reality is possible.

Different perspectives about the nature of reality and knowledge are also possible given the theoretical assumptions the researcher made.

The researcher assumes the ontological position of a critical realist. Scotland (2012) describes realism as the assumption that objects exist independently of the knower and are discoverable by the researcher.

Critical realism involves attempts to explore an objective reality while realising that complete objectivity is not feasible (Wagner et al., 2012). Realism also encompasses the notion that the reality we explore is not only based on what we can see but also based on the unobservable features that are worth investigating (Barrett, 2010; Garner, Wagner & Kawulich, 2009). Critical realism is ultimately based on the premise that reality exists independently of our constructions, interpretations, and perceptions about it. But the subjective nature of knowledge is highlighted and captured by the value of social constructionism and the importance of language. Fleetwood (2004) states that critical realism rejects foundationalism, meaning that no certainty is possible: knowledge about reality cannot be reduced to simple observations as assumed by the empiricists. Accordingly, researchers should seek access to the real world but maintain that a world independent of researchers constructed and fallible knowledge exists. Access to this world involves a complicated relationship as "our knowledge of the world is always in terms of available descriptions or discourses, and we cannot step outside these to see how our knowledge claims compare to the things to which they refer" (Sayer, 2004, p.6). The fallibility of knowledge is emphasised by the critical realist perspective as the world is not simply the outcome of our thoughts, perceptions, and interpretations but is mediated and conceptualised based on various discourses. Critical realism essentially maintains that part of the world is accessible to us, even if it is arbitrated (Sayer, 2004).

Critical realists hold that knowledge should be positively applied, assisting with knowledge creation and growth (Cruickshank, 2012). More importantly, it is argued that the outcome of scientific research should not be conceptualised as inevitable knowledge, as all knowledge is by nature fallible and open to change and criticism. Maree (2020) explained that "…the things scientists theorise about might be real or eventually proven to be real" (p. 108). Knowledge should thus always be open for change.

Kivinen and Piiroinen (2004) maintain that critical realists view reality as including ontologically distinct levels with higher levels and objects emerging from lower ones. Accordingly, social structures develop from individual interactions and can therefore impact individuals but not necessarily determine them. A reciprocal relationship between individuals and social structures thus exists.

The nature of the link between individuals and their surrounding structures is reciprocal in that individuals can also exert an influence on these structures. Cruickshank (2012) in view of that argues that social reality is regarded as an open system that is flexible and able to change. Empirical research should thus rely on refutable theories that have their foundation in a stratified, open systems ontology (Cruickshank, 2012. Critical realists thus maintain that knowledge is imperfect and can be applied to criticise and change other knowledge structures. As a result, Cruickshank (2012) concludes that theories can always be evaluated, and as such, improved. Instead of arguing that theories are justified due to offering certain explanations, the ultimate goal should be to critique knowledge to explore better alternatives.

Viewing reality using a specific ontological lens has implications for the way knowledge is created. From a critical realist perspective, the researcher endeavours to describe an independent reality, observing from the outside while acknowledging that complete objectivity is not possible but approachable (Wagner et al., 2012). The critical realist argues that reality is independent of the human mind and the mind can therefore not constitute reality. The theories (Bhaskar, 1998) and knowledge proposed to explain reality are fallible and should not be interpreted as how reality is. The researcher thus recognises that the real world exists independently of our constructions and perceptions about it and strives to aim for theories that explain reality in its various levels. Critical realism recognises the subjective element in knowledge as it can be influenced by varying perspectives and insights assumed by the researcher (Willig, 2013). No research can ever be truly objective, as our personal experiences and perceptions will always distort our account of reality to a certain extent.

In line with the researcher's epistemological and ontological views, the current investigation relied on various scientific methods to explore the research questions to create knowledge. Participants were requested to complete various questionnaires and activities including the LBT and memory simulation. The objective was therefore to explore the participant's knowledge about the research topic, using specific measures.

To answer the research questions, the research process should be grounded in a specific theoretical framework acting as a blueprint to inform the investigation. Maree and Van der Westhuizen (2009) maintain that a paradigm constitutes a way of seeing the world based on a set of assumptions that constitute different systems of meaning and ways of interpreting the world. Maree (2020) offers various conceptualisations of what a paradigm entail. Broadly, it is defined as a conceptual framework that is more comprehensive than a specific theoretical model or theory. A specific theoretical model offers a limited description of a phenomenon while a theory is a conceptual framework that explains the phenomenon. A paradigm is defined as "…a collection of theories similar in theme, usually focused on a topic of investigation, but still different explanatory frameworks" (Maree, 2020, p.15). In the present study, the cognitive paradigm is regarded as the broader conceptual framework in which the TVA is embedded. Theoretical models are specific conceptual frameworks and the paradigm encompasses the broader understanding. A theoretical model is based on a theory that is rooted within a larger paradigm. Ontological and epistemological interpretations are based on theory (Bem & Looren de Jong, 2013), but irrespective of the epistemological and ontological orientations, scientific research concerning human behaviour is never absolute or complete and is always subject to change (Scotland, 2012).

The first part of this chapter is dedicated to a brief overview of the cognitive paradigm followed by a discussion of the main theoretical frameworks in the current study.

The activation-orientation model described by Siman-Tov et al. (2007) as well as the theory of visual attention (TVA) was applied under the main conceptual framework of the cognitive paradigm to guide the research process and the interpretation of the findings.

3.3 COGNITIVE PARADIGM

Sankey (2002) emphasises Kuhn's description of a paradigm as the theoretical framework within which all scientific thinking and practice function.

The cognitive paradigm guided the researcher in choosing a set of theories as a way to explicate attention and the potential impact of a leftward bias.

Turner and Laird (2012) emphasise that cognitive paradigms are not standardised but rather represent flexible ways of thinking. Cognitive paradigms may differ based on the choice of stimuli, timing and instructions conveyed to research participants, as well as the reactions the participants are expected to demonstrate. The paradigmatic point of departure impacts the entire research process.

Cooper (1993) describes the main assumptions of behaviourism as involving objectivism where understanding human behaviour is based on observing external events and the environment is viewed as important in determining human behaviour. The consequences of human behaviour were also argued to impact subsequent behaviour. The cognitive approach developed with the early understandings of STM and LTM. A model of the cognitive system is proposed to include the main areas of cognitive functioning including sensory receptors, WM and LTM components. The cognitive shift recognised that humans are dynamic interactive systems that interact with various components and also demonstrate individual differences about their behaviour. Fundamental to the cognitive model is the internal workings of the mind and the underlying mechanisms that filter the storage of information. Cooper (1993) highlights that the cognitive paradigm is less reductionist, more focused on the developing mind and the underlying cognitive structure, and not merely a focus on observable behaviour in reaction to environmental factors.

It is thus important to discuss various theories related to attention and WM to demonstrate the operationalisation of these variables. The cognitive paradigm collectively represents the various theories provided to discuss the study constructs.

How we think about our surroundings and how we attempt to make sense of the world have implications for our general functioning (Matern, 2018). More importantly, the way people process, interpret and memorise information impacts behavioural functioning. Carrasco (2011), Eimer (2014), and Theeuwes (2010) argue that people are not passive bystanders but rather active observers that attend to various stimuli. Incoming information is manipulated and processed in an attempt to make sense of the world (Bernstein, Penner, Clarke-Stewart, & Roy, 2006). Numerous theories have been proposed to explain how we process these experiences and ultimately understand the world around us.

The TVA attempts to explain how we allocate our attentional resources when faced with multiple stimuli.

3.4 THE THEORY OF VISUAL ATTENTION (TVA)

TVA asserts that only stimuli that are particularly salient or relevant for current task performance will be encoded for additional processing (Bundesen, 1990).

Despite the sophisticated nature of the visual system, the capacity to consciously perceive input from single fixations is very limited (Habekost & Starrfelt, 2009). The TVA framework highlights restrictions of capacity in its conceptualisation of visual perception (Bundesen, 1990; Habekost & Starrfelt, 2009). Two limitations of visual capacity have been proposed. Firstly, the total number of objects that can be perceived at a given time, i.e., visual span, is limited (Cowan, 2008). There are clear limits to the number of objects we can perceive simultaneously. The second limitation of the visual system includes the quantity of visual content that can be processed, i.e., visual processing speed (Habekost & Starrfelt, 2009).

TVA is based on the assumption of biased competition where all possible visual stimuli compete for representation in visual short-term memory (VSTM) (Bundesen et al., 2015). Two different types of biases are assumed: one related to objects and another associated with specific features. Attentional weights are assigned to encountered stimuli and are also influenced by perceptual biases. It is asserted that based on the TVA model, visual recognition and selection depend on categorising visual input. The visual system processes all objects in the visual field at a given time, separately and in a corresponding manner. The rate at which the objects are processed however varies (Habekost & Starrfelt, 2009), and impacts the likelihood that it will be encoded into VSTM, if capacity permits it. The attentional weights assigned to stimuli will thus impact encoding to VSTM. Information permitted to enter VSTM, and maintained and manipulated in WM can be processed and encoded to LTM. Attentional weights are generally based on the saliency of objects as well as the relevance of input in relation to current behavioural goals (Bundesen et al., 2015). A stimulus with a higher attentional weight will therefore receive preference for memory encoding. The selection and recognition of stimuli represent two important features of the same process (Bundesen, 1990; Bundesen et al., 2015). Consciously recognising visual input requires encoding various stimuli properties to VSTM and WM (Cowan, 2008, Forte, 2016). This encoding process results in conscious recognition of stimuli. It is equated with a race between the sensory input present in the visual environment.

The basic assumptions of TVA are that visual recognition and attentional selection are determined by making perceptual categorisations (Bundesen, 1990, Bundesen et al., 2015). An object is categorised in relation to certain features and is selected as part of a specified category when it is encoded to VSTM, similar to schemas in LTM. Examples of perceptual categories include a colour category, a shape category, and a location category (Bundesen, 1990; Bundesen et al., 2015). When visual input is categorised, it is selected and recognised as part of category. A category can be described as a schema, containing specific types of information by which incoming stimuli are classified. If the visual input is processed based on categorisation, it is then encoded to VSTM, if capacity permits it (Habekost & Starrfelt, 2009). The processing rate for each object represents the part of the total processing capacity that has been assigned to it and this distribution of weighting of capacity is a core feature of attention (Habekost & Starrfelt, 2009). Although visual capacity and processing speed represent two separate processing features, they correlate empirically and share neural pathways.

The TVA maintains that stimuli with the highest attentional weight will receive preferential processing and be encoded to memory. Psuedoneglect thus predicts that a higher attentional weight might be assigned to left-sided stimuli, increasing the likely memorisation of this content. In relation to the activation-orientation model, this will depend on the stimuli content in conjunction with the activated hemisphere.

3.5 THE ACTIVATION-ORIENTATION MODEL

A revised version of the activation-orientation framework was suggested by Siman-Tov et al. (2007) who reasoned that both neglect and pseudoneglect can be explained based on asymmetric interhemispheric neural activity. The proposal is based on neuroimaging results that show that two separate neural mechanisms are implicated. Firstly, right hemisphere activation shows dominance for spatial attention. Secondly, the connection between the two hemispheres shows a preference for information moving from the right to the left hemisphere. This explains that the right hemisphere’s superiority for spatial attention, together with a prominent right-to-left interhemispheric communication pattern, results in the observed leftward bias (Loftus & Nicholls, 2012; Siman-Tov et al., 2007).

Siman-Tov et al. (2007) theorise that pseudoneglect is due to asymmetric inter-hemispheric neural activation and connection. The activation-orientation model proposes that attention is more prominent on the side of space opposite to the activated hemisphere (Bultitude & Aimola Davies, 2006; Forte, 2016; Hatin et al., 2012; Loftus & Nicholls, 2012; Nicholls et al., 2008; Reuter-Lorenz, Kinsbourne, & Moscovitch 1990). Activation of the right hemisphere during visuospatial tasks, therefore, results in a leftward attentional bias emphasising stimuli in the left hemifield (Friedrich, 2018; Loftus & Nicholls, 2012). Siman-Tov et al. (2007) advocated that this originates due to two neural mechanisms. Firstly, the beneficial connectivity within the right hemisphere is seen as the dominant hemisphere for spatial attention, and secondly, the connectivity between the two hemispheres favours the transference of information from the right to the left hemisphere. As a result, the right hemisphere's dominance for spatial attention, together with a strong right-to-left interhemispheric transfer of information results in the leftward bias observed in pseudoneglect (Lotus & Nicholls, 2012).

The importance of the right hemisphere in the demonstration of pseudoneglect is supported by studies that include variables that change the activation between the two hemispheres. As the right hemisphere is dominant for spatial attention, resulting in a marked leftward bias, stimulating the left hemisphere minimises or inverts the asymmetrical bias. Accordingly, it is argued that the stimulation of the left hemisphere appears to rebalance the asymmetry between the two hemispheres (Lotus & Nicholls, 2012; Reutor-Lorenz et al., 1990; Siman-Tov et al., 2007). The magnitude of pseudoneglect is thus increased by variables that activate the right hemisphere (Bultitude & Aimola Davies, 2006; Lotus & Nicholls, 2012; McCourt & Jewell, 1999; Reuter-Lorenz et al., 1990) while the leftward bias is reduced by factors that activate the left hemisphere.

Hatin et al. (2012) highlighted the notion that the activation-orientation model also postulates why some factors negate the effects of pseudoneglect. The most common method used to assess spatial neglect and pseudoneglect involves using the LBT (Brodie, 2010; Brooks, 2014; Bultitude & Aimola Davies, 2006; Cocchini et al., 2007; Crollen & Noël, 2015; Dobler, Manly, Atkinson, Wilson, Ioannou, & Robertson, 2001; Failla et al., 2003; Fink, Marshall, Weiss, Toni & Zilles, 2002; Foulsham et al., 2013; Harvey et al., 2000; Hatin et al., 2012; Jewell & McCourt, 2000; Nuthmann & Matthias, 2014; Nicholls & Lotus, 2007). Neurologically normal participants tend to bisect the line more towards the left of the midpoint, thereby demonstrating a leftward bias i.e., pseudoneglect

(Brignani et al., 2018; Brodie, 2010; Dobler et al., 2001; Foulsham et al., 2013; Harey et al., 2000; Hatin et al., 2012; Hausmann et al., 2003; Hausmann et al., 2002; Nichols & Lotus, 2007; Nicholls et al., 2008; Toba et al., 2011). The LBT activates the right parietal lobes, which explains the observed leftward bias since this hemisphere is regarded as dominant with regard to visuospatial processing (Benwell et al., 2014; Benwell et al., 2013; Benedetto et al., 2013; Hatin et al., 2012; Loftus & Nicholls, 2012; Nicholls et al., 2008; Porac et al., 2006; Thiebaut de Schotten et al., 2005). As the right hemisphere is more active, more attention is directed towards the left side.

The activation-orientation model attempts to describe pseudoneglect in relation to asymmetric inter-hemispheric neural activation and connection (Hatin et al., 2012). Attention will be allocated to the side of space opposite to the activated hemisphere (Bultitude & Aimola Davies, 2006; Loftus & Nicholls, 2012; Nicholls et al., 2008; Reuter-Lorenz, Kinsbourne, & Moscovitch 1990). Activation of the right hemisphere during visuospatial tasks, therefore, results in a leftward attentional bias emphasising stimuli in the left hemifield (Loftus & Nicholls, 2012). More attention is allocated to the left hemispace (Bultitude & Aimola Davies, 2006; Hatin et al., 2012; Toba, Cavanagh, & Bartolomeo, 2011).

The presentation of pseudoneglect is task-related and depending on the task, either hemisphere may be more active in impacting the distribution of attention (Bultitude & Aimola Davies, 2006). Right hemisphere significance can thus be decreased by differing variables that increase activation of the left hemisphere (Loftus & Nicholls, 2012; McCourt & Jewell, 1999; McCourt et al., 2001; Reuter-Lorenz et al., 1990), reducing the extent of the leftward bias characteristic of pseudoneglect. The supremacy of the right hemisphere in the display of pseudoneglect is reasoned to be dependent on different neural mechanisms. The significant role of the right hemisphere with regard to spatial attention in conjunction with the right-to-left interhemispheric communication pathway increases the likely production of a left attentional bias. This provides additional support for the activation-orientation theory (Loftus & Nicholls, 2012) as stimulating the left hemisphere appears to attenuate the leftward bias, rebalancing the asymmetry between the hemispheres (Reutor-Lorenz et al., 1990; Siman-Tov et al., 2007). The prominent activation of one hemisphere is thus reduced, minimising the occurrence of pseudoneglect. As the bottom-up model suggests, significant features will receive preference concerning attentional resources (Broji & Itti, 2013; Heckler, 2011; Serences & Yantis, 2006). Accordingly, attention is allocated more towards the left, possibly accounting for the observation of pseudoneglect. The left side of the line in the LBT thus appears to be longer compared to the right (Bultitude & Aimola Davies, 2006; Loftus & Nicholls, 2012) and receives a higher attentional weight as TVA maintains.

The superior role of the right hemisphere in visuospatial tasks may explain the demonstration of pseudoneglect but it does not explicate the likely impact of leftward biases on memory. The TVA model may elucidate the potential memory effect observed in some reported cases of pseudoneglect. The activation-orientation model along with TVA was used as a theoretical framework to guide the present research process.

3.6 JUSTIFICATION FOR THE THEORETICAL PARADIGMS

Krüger, Tünnermann, and Scharlau (2017) emphasise the TVA as a prominent model in explaining the allocation of attention. It is regarded as one of the most influential theories in visual attention (Kreyenmeier, Deubel, & Hanning, 2020).

The TVA model reconciles the importance of both bottom-up and top-down processing, maintaining that attention is based on attentional weights assigned to incoming stimuli. The use of this theory within the context of the current study is based on assumption that a higher attentional weight may be assigned to left-sided stimuli. The processing of early visual features, based on bottom-up processing, is an important first step in allocating attentional resources aiding the creation of a salience map. Top-down activation plays a defining role in guiding subsequent attention distribution in conjunction with the salience map. According to the TVA model, it can be reasoned that the right and left sides of presented stimuli, compete for attentional resources (Bundesen et al., 2015). Early visual processing is prominently based on visual scanning, and first eye-movements are generally to the left. The salience of the left side, due to right hemisphere activation, skews the allocation of attention in favour of the left side. Correspondingly, the attentional weighting allocated to stimuli impacts the possibility of memory encoding.

From a neurological perspective, the activation-orientation hypothesis is considered a prominent theory attempting to explain pseudoneglect. Based on the lateralisation of the two hemispheres, a stronger activation to the contralateral hemispace is possible. If the right hemisphere is activated, the activation-orientation model maintains that more attention is directed towards the left. Stimuli in the left hemifield are then perceived as brighter, longer, and more colourful, than that of the right hemifield.

Information on the left thus receives more attention, and as the theories assume, the outcome may be that left hemispace items are preferentially allowed access to VWM and VLTM. The TVA and activation-orientation models provide a comprehensive framework for understanding the allocation of attention. Both models offer valuable contributions to explaining the allocation of attention and guided the interpretation of the current study findings.

3.7 CONCLUSION

This chapter outlined the ontological and epistemological viewpoints of the researcher and discussed the theoretical frameworks that informed the research methodology. The TVA model describes the process of attention allocation and the activation-orientation hypothesis provides a neurological perspective on the demonstration of pseudoneglect. Both theoretical frameworks informed the interpretation of the current study findings. The next chapter offers a detailed description of the research methodology applied in the current study.

CHAPTER 4 METHODOLOGY

This chapter offers a detailed account of the research process. A comprehensive discussion concerning the research methodology applied during this study is included.

The computerised version of the LBT is discussed along with details regarding the memory simulation and memory questionnaire used for assessment.

4.1 BACKGROUND TO THE STUDY

Attention and memory comprise important abilities in our daily cognitive functioning. Psychologists need to understand the workings of the brain and cognition in order to develop interventions on how we can improve these functions. The phenomenon of pseudoneglect is not yet well understood (Forte, 2016; Friedrich et al., 2018; Märker et al., 2019) and uncertainty still exists with regard to age and how this impacts lateral biases.

Similarly, Hausmann et al. (2002) and Forte (2016) reasoned that the role of gender in the demonstration of pseudoneglect is still ambiguous. Friedrich et al. (2018) maintained that "…continued examination of gender…" (p.436) in relation to pseudoneglect is recommended. The inconsistencies regarding the effects of gender on pseudoneglect performance are echoed by Asenova and Andonova-Tsvetanova, (2019) and warrant additional research.

The motivation behind the current research was to explore the way we allocate attention in relation to pseudoneglect and to determine the subsequent impact it has on VLTM. Given the contradictions related to age, gender, and lateral biases, the study also endeavoured to further explore these variables. The resulting information can be applied in various ways to inform future interventions regarding the enhancement of such functions. The notion of understanding whether we recall more items based on location thus holds potential practical implications in various fields. It can, for example, inform decision-making about where important information should be located with regard to educational practices and everyday functioning like traffic signs. The present findings may offer clarification on the mechanisms of pseudoneglect and contribute to enhanced understanding of the phenomenon.

4.2 JUSTIFICATION, AIMS AND OBJECTIVES

The visual system is constantly overwhelmed with sensory information that requires processing (Harris & Shepherd, 2015) but only some of the stimuli we encounter reach conscious awareness. Only relevant features require detailed processing in order to guide behaviour. Lateral biases may impact what stimuli we are inclined to attend to and encode into memory. Chun and Turk-Browne

(2007), Jarodzka et al. (2013), Summerfield et al. (2006), and Theeuwes et al. (2009) reason that a potential leftward bias can skew the distribution of attention and subsequent memorisation.

Foulsham and Kingstone (2012) emphasised that the strong link between attention and eye-movements (Duchowski, 2007; Theeuwes et al., 2009; Van Gog et al., 2009; Wedel & Pieters, 2000) results in an eye-movement-based memory effect. Eye-movements are viewed as indicators of attention and saccades create attentional pathways (Duchowski, 2007).

Disagreement about how pseudoneglect and the underlying processes change with age is still evident (Brignani et al., 2018; Friedrich et al., 2018), with some authors (Benwell et al., 2014; Failla et al., 2003; Schmitz & Peigneux, 2011) advocating for a reversal or a reduction of pseudoneglect. Others report that the leftward bias seems to increase with age (Brooks et al., 2014; Friedrich et al., 2018; Varnava, & Halligan, 2007).

Males and females have demonstrated differing performance with regard to various cognitive tasks (Varnava, & Halligan, 2007), ascribed to hemispheric differences (Gray, 2018). Failure of some pseudoneglect studies to specify the gender of their sample has contributed to the limited understanding of how this variable impacts lateral biases (Forte, 2016; Varnava, & Halligan, 2007).

The limited understanding of pseudoneglect is further emphasised by Friedrich et al. (2018), Schmitz et al. (2011), and Szelest (2014) along with Vogel et al. (2003), who report on the uncertainty that exists concerning whether pseudoneglect represents a leftward bias in attention or whether the leftward tendency is a factor of memory.

The lack of understanding of pseudoneglect itself as well as the attentional processes and underlying cognitive mechanisms involved inspire further investigation.

Apart from contributing to the general understanding of pseudoneglect, the findings may also prove useful in learning the foundation of attentional asymmetry and may thereby improve our knowledge of attentional disorders and how this can inform remedial intervention strategies. Further contributions can be made to understanding cerebral laterality (Siman-Tov et al., 2007). In accordance with the activation-orientation hypothesis, the prominent involvement of the right hemisphere in the observation of leftward favouritisms (Badok et al., 2014; Çiçek, et al., 2009; Driver, 2001; Foulsham et al., 2013; Gray, 2018; Helfer et al., 2020; Loftus & Nicholls, 2012), adds to the argument that the hemispheres are specialised for specific cognitive functions. The findings from the current study then also hold neurological value with regard to recognising the consequences of brain injury and dysfunction in relation to cerebral lateralisation (Vogel et al., 2003). The present study's findings can provide a foundation for future research to explore more information about the neurological pathways underlying spatial attention (Wilzeck & Kelly, 2012). Gigliotta et al. (2017) highlighted that the exact mechanisms underlying hemispheric asymmetries in the attentional network are unknown. If we can elucidate the neurological functioning of the brain, we may be better prepared to protect it and to improve attempts to resolve damage (Brooks, 2014).

Since our daily attentional functioning is influenced by lateral biases, the resulting implications of pseudoneglect can be explored in other important areas like motor vehicle accidents, sporting activities, and education as well. Nicholls et al. (2008), for example, suggested that a predominant focus on stimuli located on the left side of space, and the consequent neglect of the right side, may be linked to traffic-related accidents.

Within the educational sector, a prominent focus on leftward stimuli may predict improved memory and academic performance. Planning the outline of educational systems, media presentations, and academic material can benefit from the study findings. It may offer valuable input in guiding the development of online platforms, for example.

Based on the aforementioned, the researcher aspired to probe the potential impact of lateral biases in attention and VLTM. The focus of the research is set out in the following section.

Primary research question:

Does a leftward bias (pseudoneglect) impact VLTM and attention for visually presented stimuli?

Secondary exploratory research questions:

1. Does gender impact the demonstration of pseudoneglect?
2. Does age impact the demonstration of pseudoneglect?
3. How does hand use impact LBT performance?

Aims of the research:

The primary aim of the current study was to investigate the possibility of lateral biases in attention and VLTM for visually presented stimuli. A secondary aim encompassed the possible mediating role of gender in relation to lateral biases. Possible age differences in LBT performance and the impact of hand use was also explored.

In order to effectively reach the specified aims, the researcher constructed the following objectives.

The study objects are listed below:

- To measure handedness to establish whether participants are right/left-handed.
- To measure eye movements using an eye-tracker to determine left-to-right scan patterns.
  - The researcher attempted to establish whether more saccades or fixations were made to the left.
  - Eye-movement data was also used as an indication of attention with longer fixations and saccade movements representing attentional pathways.
- To measure pseudoneglect using a computerised version of the LBT
  - The LBT was used as a means to operationalise pseudoneglect
- To assess VLTM using a computerised memory test.
  - Participants watched a simulation containing various stimuli and they had to indicate whether they recall seeing a stimulus.
- To assess lateral biases in VLTM by comparing number of fixations and memory socres
- To assess lateral biases in VLTM by comparing LBT performance and memory scores
- To demonstrate possible gender differences in pseudoneglect performance by means of an Analysis of variance (ANOVA).
- To demonstrate differences in LBT performance based on hand used for task completion.

Hypotheses:

Hypothesis 1: A leftward bias impacts VLTM and attention for visually presented stimuli.

Hypothesis 2: Pseudoneglect manifests differently for males and females.

4.3 RESEARCH DESIGN, MODE OF ENQUIRY, METHODS AND MATERIALS

This section provides details regarding the research design and specifications regarding materials and methods.

4.3.1 Design

A quantitative research approach was used in the current investigation, specifically a post-test-only quasi-experimental research design. This design lacks random assignment, focuses on variables not manipulated by the researcher, and often excludes the use of a comparison/control group. A quasi-independent variable (Shadish et al., 2002) is defined as a pre-existing variable that relates to a characteristic inherent to the individual. This inherent feature then differentiates participants into different groups and is not controlled by the researcher. Subsequently, the design does not warrant the use of random assignment. In the current study, gender was a quasi-independent variable. The demonstration of pseudoneglect can, to some extent, be controlled by the researcher. Depending on the task used, different hemispheres can be activated and may then impact the direction or magnitude of lateral biases. Participants either demonstrate a leftward bias or they don't.

The current study excluded the use of a comparison/control group. Only one group was observed after a treatment, specifically the memory simulation. The design then constitutes a one-group post-test-only design (Shadish et al., 2002). A memory simulation, containing various stimuli, was presented to the sample of participants to assess their performance in relation to VLTM. No random assignment was possible as all participants were exposed to the same memory simulation. The dependent variables, attention, and VLTM, were measured for all participants in relation to the demonstration of pseudoneglect, which was assessed using the LBT.

The one-group post-test-only quasi-experimental design allowed the researcher to determine whether a relation exists between pseudoneglect and VLTM by exposing participants to a series of stimuli presented as part of a simulation.

4.3.2 Sample

The sample was selected from both a student and staff population at a local South African university. The reason to include both students and employees was informed the secondary research question, namely age.

4.3.3 Sampling procedure

Purposive sampling, a convenient sampling procedure, was used to obtain the sample. Purposive sampling is described as the most practical form of non-probability sampling (Wagner et al., 2012). Specific selection criteria were used to identify the individuals suitable for inclusion in the study. The following inclusion and exclusion criteria guided the sample selection.

The selection criteria for participants involved that they:

- were between the ages of 18 – 65
- included both male and female participants
- were computer literate
- were proficient in English

- had no history of neurological disorders and
- had corrected vision

Exclusion criteria:

- Visual deficiency that included blindness or other visual disorders that would compromise the eye-tracker recording
- The presence of neurological disorders that may impact memory or attention
- The presence of psychological disorders that may impact memory or attention

Participants were invited to participate by advertising the study during lectures, tutorials, and the University's internal communication system, ClickUp. Staff members received a faculty-wide email invitation sent by administrative staff. Confidentiality of personal information was maintained as the researcher had no access to the contact details of any of the students or staff members. The invitation used to invite participants is available in Appendix F. A booking system was created where students and staff could book 'n timeslot by completing the booking form located at the office of the researcher. Both students and staff were also able to contact the researcher via email to book a timeslot.

Details on the power analysis calculation is available in Appendix G. The sample size was adequate (with power of at least 80 %) for within subject factors and their interactions. Thus, as can be seen below, when a repeated measures with within subject factors were analysed (2 x 3 and 2 x 5 designs), both factors (main effects) and their interaction had sufficient power (.80) with a sample size of 35. However, when one factor of the repeated measures was a between subject factor, such as age or gender, the between subject factors were greatly under powered requiring a total samples size of between 120 to 134 or between 60 and 67 per group. The logistics of the study thus required a compromise with a focus on within subject analyses and limitations were indicated in the appropriate sections.

4.4 MEASURING INSTRUMENTS

The researcher relied on a survey method to gather data using self-reported questionnaires (Surendran, 2019; Wagner et al., 2012). All participants were required to complete various assessment measures including a demographic questionnaire, a handedness questionnaire, an LBT and, a memory questionnaire. An eye-tracker was used to record the participants' eye-movements during the memory simulation. The LBT was also completed on the eye-tracker computer. More details about the data collection process are outlined in the data collection procedure.

a. The demographic questionnaire

A demographic questionnaire was administered to obtain basic demographic details from participants including age, gender, history of psychological disorders, and any medical/neurological conditions. Information about age and gender was necessary to address the secondary research questions. The presence of psychological or neurological disorders could compromise the ability to allocate attention and it was necessary to determine the presence of any current psychological – and neurological disorders.

Participants were also asked if they were right– or left-handed. The Edinburgh Handedness Inventory was used to confirm their hand preference.

b. Edinburgh Handedness Inventory

The demographic questionnaire asked participants whether they were right – or left-handed. This was also corroborated by administering the Edinburgh Handedness Inventory (Mercer, 2012; Oldfield, 1971).

Chapter 2 emphasised details of the importance of hand use and the demonstration of pseudoneglect detaling that the hand used for LBT task completion activates different hemispheres. As a result, the extent of pseudoneglect may be mediated based on the most active hemisphere. To explore how handedness mediates LBT performance it was necessary to include this measure. Handedness relates to preferences for using one specific hand more than the other. Veale (2014) reports that the Edinburgh Handedness Inventory is the most widely used questionnaire to assess handedness (Fazio, Coenen & Denny, 2012; Ransil, & Schachter, 1994; Veale, 2014). The Edinburgh Handedness Inventory asks participants to tick their hand preference for mundane everyday tasks by indicating whether they use either their left or right hand. Ransil and Schachter (1994) reported test-retest reliability for the measure but additional statistical analysis revealed that some of the items were problematic, and Dragovic (2004) suggested accordingly, that the original 10-item scale be decreased to 7 items (Williams, 2017). The 7-item version was used in the current study. Participants were asked whether they were right – or left-handed and the Edinburgh Handedness Inventory merely served as a supportive measure.

c. LBT

The most widely used method to assess unilateral neglect and pseudoneglect involves the LBT (Brodie, 2010; Brooks, 2014; Brooks et al., 2014; Bultitude & Aimola Davies, 2006; Çiçek et al., 2009; Cocchini et al., 2007; Crollen & Noël, 2015; Dobler et al., 2001; Failla et al., 2003; Fink, Marshall, Weiss, Toni & Zilles, 2002; Forte, 2016; Foulsham et al., 2013; Friedrich et al., 2018;

Harvey et al., 2000; Hatin et al., 2012; Jewell & McCourt, 2000; Nuthmann & Matthias, 2014; Nicholls & Loftus, 2007; Nicholls et al., 2008; Porac et al., 2006; Ribolsi et al., 2013). Participants are requested to indicate the midpoint of lines with various line lengths, ranging from 8cm to 30cm, by drawing through the centre (Brignani et al., 2018; Szelest, 2014; Zago et al., 2017). Patients with unilateral neglect often make rightward errors, demonstrating the centre of the line more towards the right (Nicholls & Roberts, 2002; Ribolsi et al., 2013). Neurologically healthy individuals show an inclination to indicate the midpoint more towards the left of the true centre (Brodie, 2010; Forte, 2016; Foulsham et al., 2013; Friedrich et al., 2018; Hatin et al., 2012; Ribolsi et al., 2013; Toba et al., 2011).

Park, Jee, Kim, Kim, and Kim (2015) explained that the traditional paper-and-pencil version of the LBT is easily administered but requires substantial manual assessment. To improve the efficiency of the LBT and to minimise human error, a computerised version of the LBT was created to measure pseudoneglect. An IT student was paid to computerise the LBT based on the instructions outlined below. The process of creating the computer version of the LBT used a technology stack tool consisting of the following: for the front-end part, pure HTML-5 or JavaScript with vanilla was used. For the back-end, an asp.net web application written in C# was used, which serves the front HTML pages with information using JSON formatted data. To generate the reports, a library known as EPPLUS was incorporated, which is an open-source library that generates and edits Excel spreadsheet documents using Microsoft's Open XML library.

The horizontal lines to be bisected were positioned in the centre, or to the left or right, of a computer screen, and participants were instructed to bisect the midpoint of each line using a touch screen. The test was scored by measuring the deviation of the bisection from the true centre of the line. A deviation from the midpoint to the left was indicative of pseudoneglect. Negative values comprised errors to the left, and positive values comprised errors to the right of the mid-point.

Different factors influence the demonstration of lateral biases apart from handedness, including, line length and the spatial presentation of lines can also moderate the degree of bias observed (Benwell et al., 2014; Kinsbourne, 1993; Loftus et al., 2009; McCourt & Jewell, 1999; Mitchell et al., 2020). The leftward tendency seems to increase with line length. McCourt and Jewell (1999) and Loftus et al. (2009) found that normal participants demonstrate a leftward tendency when the length of lines is increased. It was reported that starting the LBT on the left side of space results in a greater degree of error towards the left compared to starting the task on the right (Brookes et al., 2014; Varnava et al., 2013).

The researcher thus decided to incorporate different line lengths and also presented all different line options in numerous locations in hemispace, given the inconclusive findings in this regard. The test consisted of 15 lines in total. Three lines with differing line lengths were presented in different locations. Each set consisted of three lines: Line A = 5cm in length; Line B = 9cm in length and Line C = 13cm in length. Jewell and McCourt (2000) emphasised the importance of line length and reasoned that it is an essential theoretical component for assessing the neurological origin of bisection errors in neglect patients (Harvey et al., 1995; Jewell & McCourt, 2000; Luh, 1995; Manning et al., 1990).

Line A was presented 0cm from the edge, Line B 3cm from the edge and, Line C 5 cm from the edge. This pattern was repeated in different locations on the computer screen using the same measurements: top left; bottom left; top right; bottom right and all three lines in the centre of the page. The horizontal lines were presented in various locations as this constitutes different visuospatial locations, known to impact the resulting distribution of attention based on the most active hemisphere.

The computerised version consisted of the various lines presented in different locations with a slider bar present on the left side of each line. A touch screen was used, and participants were explicitly instructed not to slide the slider bar but to simply bisect the centre of each line by clicking on the specific location on the screen which then automatically moved the slider bar to the touched location. All participants were requested to complete the LBT task with both the left and the right hand, thereby comprising two LBT conditions for each participant.

The results were exported to an Excel spreadsheet and all deviations were automatically calculated for each line. A negative value measured in mm represented errors to the left of the true centre, i.e., pseudoneglect, and positive values indicated rightward errors. The data was recorded using the eye-tracker computer screen as this included the touch screen. Mitchell et al. (2020) maintained that due to participant variance often observed in LBT performance, bisection data can benefit from an additional assessment.

The computer version of the LBT was piloted before formal assessment began. Some authors solved the problem of determining the reliability of the LBT by administering the same test a few weeks to the same sample and calculating a coefficient of stability (Jee, Kim, Kim, Kim, & Park, 2015). However, some reflection would show that the nature of the LBT items is not all that different from a usual psychometric instrument and that even internal consistency can be calculated. It is also practical to combine internal consistency with another form such as test-retest or alternate form reliability (Nunnally & Bernstein, 1994). In this case, one can determine internal consistency for both the left and right-hand forms, as well as the correlation between the two.

The LBT scoring is based on the deviation in millimetres to the left or right of the midpoint. Thus, the level of measurement is ratio. One may recode either left or right to the midpoint as 0 and zero, this means that an item would be dichotomous, but amenable to psychometric analysis. However, too much information will be lost because the exact deviation from the midpoint is indicated in mm. The range of items is not open, making it difficult to analyse as if it were. In this instance, the range would be the range of the item(s) with the widest starting and ending points which in this study does not exceed 1.2 mm.

Given a certain range and variation across the midpoint, this allows correlations to be calculated which means a Cronbach can be determined. The internal consistency estimate for the Left-Hand test was .74 for 15 items and for the Right-Hand items, .70 for 15 items.

In this study, two forms of the test were utilised. To be exact, the same test was applied twice, once with each hand indicating the midpoint. It is thus the hand of completion that constitutes the two "forms". A Cronbach alpha can thus be determined for each hand. In addition, the correlation between the two "forms", similar to alternate or parallel forms can be calculated. One way of doing this is to use the total score of each test, which one would normally do with scales and subscales of a proficiency test. However, because each item is known to be exactly the same in the Left and Right-hand forms, a more precise measurement of the relationship can be obtained by correlating each item with its corresponding item and then combining the item correlations linearly and dividing by the number of items per form (i.e., 15) (Nunnally & Bernstein, 1994). Another way of doing this is to total all items per left and right forms and correlate the total scores with each other. This last strategy provided a correlation coefficient of .47 (p = .004). Thus, the alternate form reliability is .47 and its low reliability may be explained by the effect of handedness on scores.

The computerised version of the LBT was developed based on literature on previous versions of the LBT, taking into account the various factors, i.e. line length and position that can impact the magnitude of lateral biases (Harvey et al., 1995; Loftus et al., 2009; McCourt, & Jewell, 1999). Eye-tracking data was also used to supplement the measure of a leftward bias in attention. Although the eye tracker was not able to record the eye-movements of participants during the completion of the LBT, the eye-movement recordings captured during the memory simulation adds an additional measure of possible leftward biases in attention.

d. Eye-tracker

Carter et al. (2014) reasoned that another potentially modulating factor in the presentation of pseudoneglect comprises scanning direction. The value of eye-movements in demonstrating attention is discussed in Chapters 2 (Duchowski, 2007; Eimer, 2014; Hartmann, 2015; Itti & Koch, 2001; Nuthmann & Matthias, 2014; Szelest, 2014; Theeuwes et al., 2009; Wedel & Pieters, 2000; van Gog et al. (2009). Eye-tracking provides valuable information about the distribution of attention. An eye-tracker was used to record eye-movements as a measure of visual attention.

The Tobii Pro X3-120 Eye Tracker version 1.0.7 and the applicable software developed in 2017 were used. The eye-tracker weighs only a 118g and is 324mm in length. The eye-tracker is a non-invasive device, mounted at the bottom of the computer screen. It records eye saccades and produces numerical information consisting of various aspects, including the number of gazes/fixations and heat maps. The resulting eye-tracking data was used as a measure of visual attention and was used to track the number of left – or right gazes.

According to Tobii (2017) the output from the eye-tracker provides detailed information including the following:

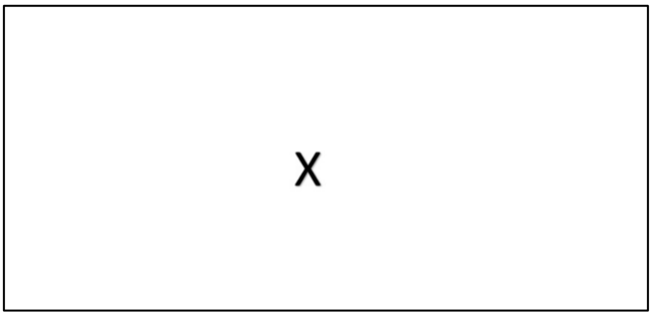
- Timestamp: measured in microseconds
- Gaze point Left X (Horizontal), Y (Vertical) coordinates of gaze point for the left eye
- Gaze point Right X (Horizontal), Y (Vertical) coordinates of gaze point for the right eye
- Eye position: 3D position of the left and right eye in relation to the eye tracker.
- Pupil Diameter for both the left and right eye: estimated diameter of the pupil in millimetres.
- Validity codes for left and right: whether or not left/right eye was correctly identified by the eye tracker. The validity code has two values: 0 – the eye was identified and 4 – the eye was not identified.

The above-mentioned information guided the use of eye-tracking data and the validity codes were used as an indication of validity.

e. Memory simulation: a measurement of VLTM

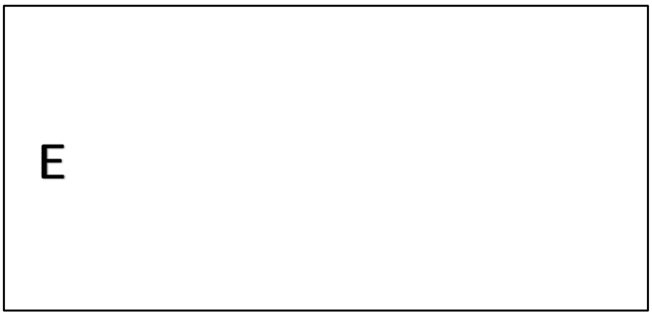
The images used in the simulation were first created using Microsoft PowerPoint slides. The slides were then saved as JPEG images that were uploaded to the eye-tracker programme. There were 37 slides in total, including the instruction slides and the focus point slides. Items were presented on either the right or left side of the fixation point ‘x’, or on both sides. Visual stimuli are generally presented briefly to the left or right of a central fixation point since unilateral hemispheric presentation results in the activations of the contralateral hemisphere (Nicholls et al., 1999). Single and multiple items were presented. The researcher attempted to match the sizes of the items as closely as possible. To control the distance from the edge of the screen, the same distance spacing from the edge of the screen was used for both the left and right conditions (refer to Appendix A for details).

Before a new stimulus was presented the image below, with a focus point in the middle of the screen was presented for two seconds. The goal for presenting an image with a fixation point is to direct participants’ gaze to the centre of the screen.

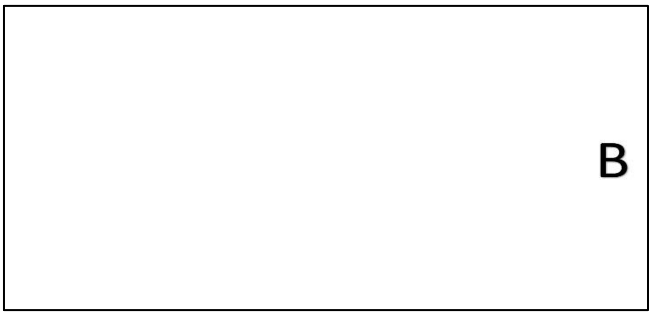


The first condition included showing various letters to participants. The first few slides consisted of a single letter presented for three seconds, either on the left or the right side of the focus point. The second set included showing a single letter simultaneously on both the right and left side. The third set involved presenting two letters on the left of the fixation point and a single letter on the right side, and vice versa. The last set showed two letters on both the left and right side of the fixation. The multi-letter slides were projected for five seconds.

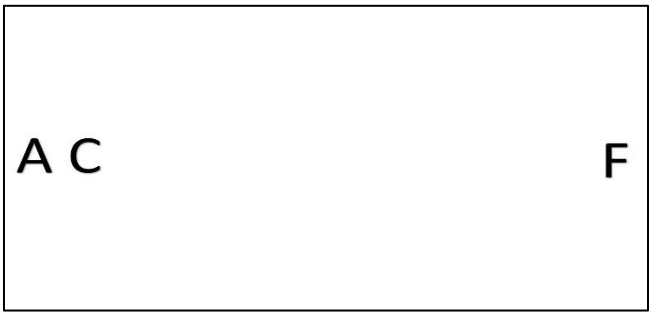
The images displayed for condition 1:



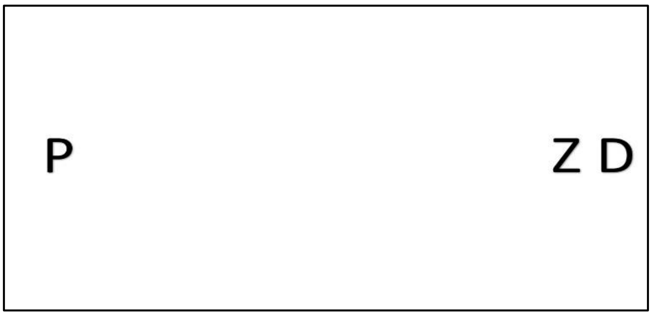
SLIDE 3



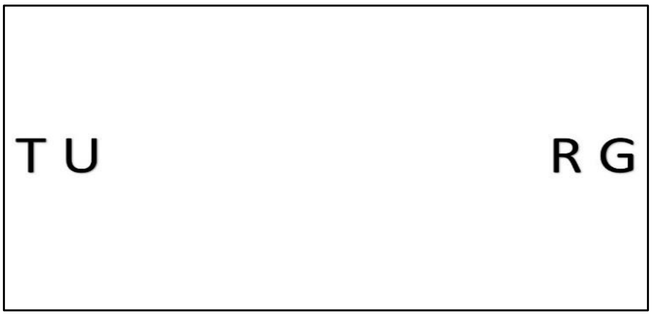
SLIDE 5



SLIDE 7



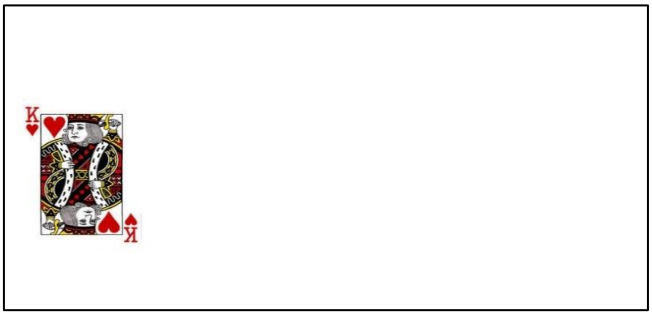
SLIDE 9



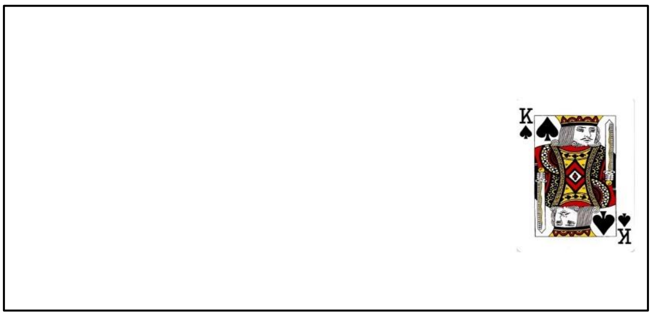
SLIDE 11

The second condition followed the same setup as the first. The only difference was the stimuli displayed. Instead of letters, images of a deck of cards were used: Jack, Queen and King Cards were displayed from different suits.

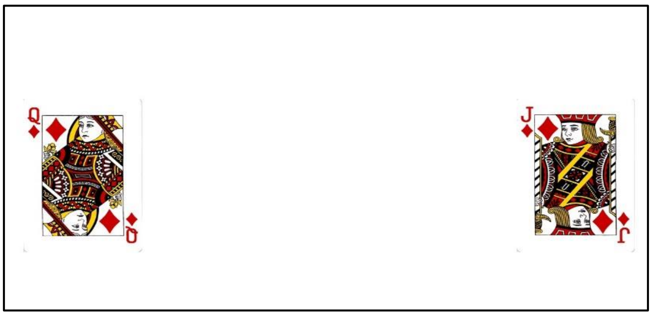
The images displayed for condition 2



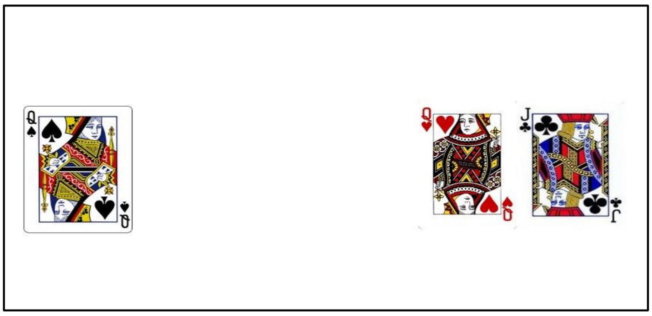
SLIDE 13



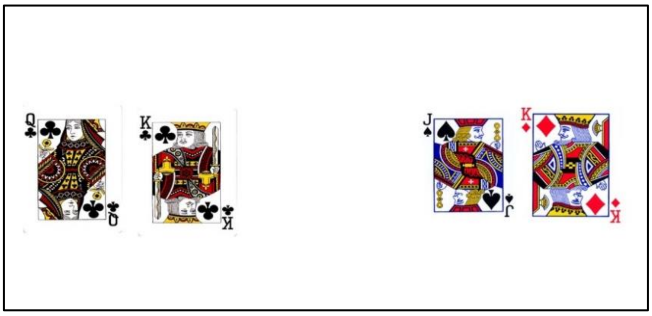
SLIDE 15



SLIDE 17



SLIDE 19



SLIDE 21

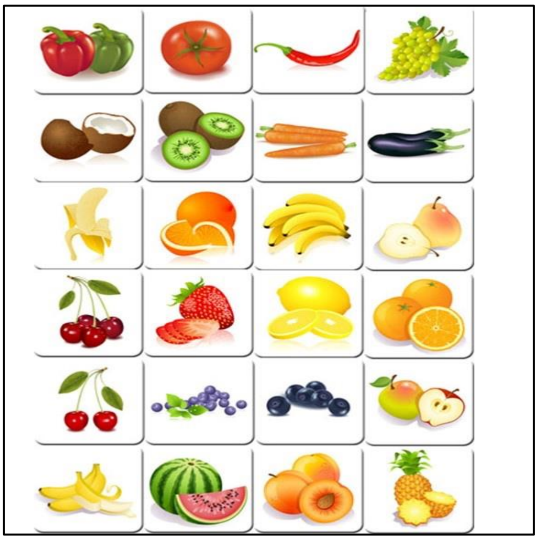
The third condition included showing images containing a road sign for three seconds. The two images with a road sign: one with the sign on the left and the other with the sign on the right, was presented for three seconds each.

Images displayed during condition 3

SLIDE 23

SLIDE 31

The fourth condition consisted of an image of a Table displaying images of various fruit and vegetables, presented in four columns, displayed for 12 seconds. The entire Table was displayed at the centre of the screen.



SLIDE 26

The fifth condition comprised an image of a Table with four columns containing random words. Two columns were displayed on the left of the fixation point and two columns to the right. This slide was presented for 15 seconds.

academic	comfortable
calm	clean
capable	casual
dynamic	efficient
eager	elated
fashion	formal
alert	friend
ambitious	sad
confident	beautiful
strong	books

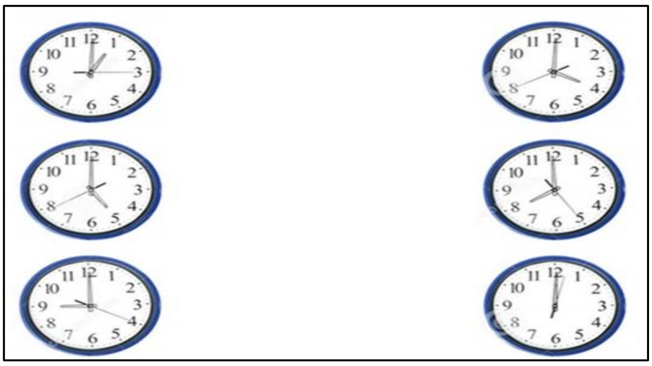
SLIDE 29

devoted	business
study	brain
adventure	happy
decent	work
ethical	health
determined	flower
mother	ocean
dynamic	change
family	great
dog	read

The following display presented a cartoon image of a dog on the right side and a cartoon image of a cat on the left side of the ‘x’, for five seconds.

SLIDE 33

The last condition showed six clocks, each indicating a different time, with three clocks located on the left of the fixation and three clocks located on the right. The last slide was displayed for 12 seconds.



SLIDE 36

The reason for using different time periods is based on the study conducted by Foulsham et al. (2013) and Della Sala et al. (2010). The authors presented shapes, one on each side of a focus point, for two seconds. When more items were presented, the display lasted for three seconds. Due to the nature of the current study's memorisation task, the conditions including the fruit and vegetables and the list of words were displayed for twelve seconds as more stimuli were presented.

f. Memory test: a measurement of VLTM

VLTM can be assessed by means of a forced-choice test (Schurgin, 2018). The forced-choice test includes showing various objects to participants and asking them to indicate whether they have seen the item before. The current investigation involved using a self-constructed memory questionnaire using the paradigm of the forced-choice test (Schurgin, 2018). Specifically, the test was designed to assess memory recall related to the memory simulation items. Participants were asked to answer seven questions with different options provided. The instruction was to tick the box for each item they recall seeing based on the memory simulation detailed in section e). Refer to Appendix B for the memory questionnaire items.

The memory questionnaire included the exact image of the item shown in the simulation, thus increasing the association between the projected stimuli and the items in the questionnaire. This could, potentially, have aided the participants with recalling the items. The questions included asking participants to simply tick the box of the item they remembered seeing. The total scores were calculated based on accuracy. The number of correct responses was thus calculated. If a participant ticked a box of an item that they recalled seeing and the item was presented during the simulation, they received a correct score. If they ticked items that were not presented, these items were not considered and they scored 0. An incorrect response, i.e., ticking the box of an item not shown or neglecting to tick a correct item resulted in receiving 0 for that particular question. The total score obtained was used as an indication of the number of items recalled. The researcher considered the total score, and also scored participants for correctly recalling items presented on the left only and for items presented on the right only.

The scoring included the following:

The total possible score for items correctly recalled on the left was 22.

- Question 1 had 6 correct responses
- Question 2 had 5 correct responses
- Question 3 had 1 correct response
- Question 4 had 4 correct responses
- Question 5 had 3 correct responses
- Question 6 had 1 correct response
- Question 7 had 2 correct responses

The total possible score for items correctly recalled on the right was 25.

- Question 1 had 6 correct responses
- Question 2 had 6 correct responses
- Question 3 had 1 correct response
- Question 4 had 4 correct responses
- Question 5 had 5 correct responses
- Question 6 had 1 correct response
- Question 7 had 2 correct responses

The memory questionnaire was scored by assigning a score when an item was correctly chosen. An item chosen that was incorrect was scored a 0 and an item not chosen that was correct, was also scored a 0. The reliability analysis of the VLTM questionnaire produced a Cronbach α coefficient of .59, indicating an acceptable level of reliability. Due to the small sample size, the reliability is not adequate (alpha = 0.59) but is also influenced by the non-standardised-type items. A diverse and larger sample would be required to determine the reliability adequately. Field (2009) argued that generally Cronbach alpha values of .7 to.8 indicate good reliability, however, values below .7 are also acceptable when psychological constructs are considered.

4.5 DATA COLLECTION

Participants were invited via the internal communication system at the university. A general announcement containing the purpose of the study is available in Appendix F. The invitation was posted to various psychology module pages and employees were invited via email. The email contained details of the study and was sent to staff from the Faculty of Humanities by administrative support. The researcher had no contact information of the staff or student population. A booking system was created where both students and staff could schedule a time to participate in the study, either by completing the booking form located in front of the researcher's office or via email correspondence with the researcher.

The data collection took place at a computer laboratory located on campus.

The computer laboratory consists of a large room with a two-way mirror viewing room. Tables and chairs were organised in a U shape and the eye-tracking computer was setup at one specific location, and a second laptop was setup at a different location.

4.5.1 Data collection procedure

Two stations were created for data collection: an eye-tracking station and the questionnaire station.

a. The questionnaire station

The questionnaire station included only a laptop connected to the local Wi-Fi system. Google Forms was used to create the questionnaires and participants completed the questionnaires online.

On arrival, participants were seated at the questionnaire station and the informed consent document was discussed and signed. The participants were then instructed to complete the handedness questionnaire followed by the demographic questionnaire at the questionnaire station. After this, they were instructed to move to the eye-tracking station.

b. The eye-tracking station

The eye-tracking station included two computer screens: a touch screen for the participant containing the eye-tracker and a second computer screen for the researcher. A keyboard and a mouse were available for the researcher to control the simulation, but no mouse or keyboard was available for the participant. The eye-tracker was mounted at the bottom of the computer screen and required no physical connection to the participants.

At the eye-tracking station, participants were required to perform the LBT first. The computer screen was a touch screen and all participants were required to indicate the midpoint for each line by simply ticking the midpoint. The slider bar, located on the left of each line, then automatically moved to the indicated midpoint. The LBT session included two measures: participants were requested to complete the LBT, first using their left hand and again using their right hand. On completing the LBT, participants remained seated in front of the eye-tracking screen. The memory simulation then commenced.

Participants were seated comfortably in front of the computer screen and each session started with a calibration session to ensure that eye-movements were being recorded. The calibration session required participants to follow a red dot using only their eyes.

The memory simulation requested participants to read the displayed instructions and they were informed to simply observe the simulation. The instruction was to memorise as much of the content as they could.

The data collection session lasted for about 15 – 20 minutes. The researcher assessed each participant individually and only the researcher and the participant were present in the laboratory during the time of assessment. All data collection took place in the same laboratory and conditions for all participants were standardised.

Participants were thanked for their willingness to take part in the study and were informed that a summary of the findings would be available to discuss should they be interested.

4.6 QUANTITATIVE DATA ANALYSIS

Quantitative data are analysed by means of both descriptive and inferential statistical procedures.

The collected raw data needs to be converted into a manageable form before it is entered into the statistical analysis programme. Wagner et al. (2012) describe data analysis as the process of making sense of the gathered information in order to answer the research questions stated. This process involves examining the data and determines how it links together to create something meaningful.

In quantitative data analysis, the following steps are followed:

- Data preparation
- Analysis:
  - Descriptive statistics
  - Inferential statistics
  - Data reduction
  - Quality assurance of analysis and interpretation

4.6.1 Data preparation

Data collection was open for a period of three months. The demographic questionnaire data and memory questionnaire data were collected using Google Forms. The data were exported to Excel and organised to make the worksheet manageable before the data were imported to SPSS. The preferred hand indicated on the demographic questionnaire was corroborated by the Edinburg Handedness Questionnaire. All personal information was removed to ensure that confidentiality was maintained. The data were examined to ensure that no past neurological conditions were had been reported and that all participants had corrected vision.

The LBT was computerised and the data was saved in Excel format.

The memory questionnaire data was also exported to Excel and the researcher removed unnecessary information like the time, date and personal information. Pseudonyms were used to link all the participants' data. Chapter 5 includes more details on the analysis process. The researcher calculated the memory scores as follows: all correctly recalled items were calculated as a total memory score; all correctly recalled items located only to the left of the simulation were calculated as a left memory score: and all correctly recalled items located only on the right of the simulation were calculated as a right memory score. A variable for each memory score was created before the information was imported to the Statistical Package for Social Sciences (SPSS) version 27.

The researcher organised the LBT data according to left- and right-hand conditions and according to locations presented: Top left (TL); Bottom left (BL); Top right (TR); Bottom right (BR) and Centre (C). Variables were also created based on line length and position of presentation.

a. LBT data preparation:

As noted in section 4.5, the LBT data were automatically calculated via the programme created and exported to Excel. Negative scores indicated a deviation towards the left of the true centre and positive scores represented deviations towards the right of the midpoint. The closer the value was to 0, the more accurate the bisection. Higher negative values indicate stronger leftward biases, i.e., pseudoneglect.

The importance of hand use in assessing pseudoneglect is discussed in Chapter 2. The researcher had participants complete the LBT with their left and right hands. The data was therefore organised based on the left- and right-hand conditions. More details are available in Chapter 5.

In order to determine if there was an interaction between the hand used and line position, factors were created for an ANOVA analysis.

To assess pseudoneglect the average for each of the lines, in relation to position, was calculated. A right/left hand factor was then analysed in relation to line position: TL; BL; TR; BR and C. Three lines of varying lengths were presented in each position: Line (L) L1, L2, and L3. The average for L1 – L3 in each position was calculated and assessed for an interaction with the hand condition. It was calculated as follows:

Average TL = L1 + L2 + L3

Average BL = L1 + L2 + L3

Average TR = L1 + L2 + L3

Average BR = L1 + L2 + L3

Average C = L1 + L2 + L3

This information was used to operationalise the magnitude of pseudoneglect for the left and right hand. A second round of analysis included comparing the left/right hand condition with varying line lengths. All the 5cm lines in the different positions were assessed for pseudoneglect. The same was done for the 9cm lines and the 13cm lines. Each participant thus had a measure for the left- and right-hand for each of the lines in varying positions. The 5cm line for TL; BL; TR; BR and C was calculated. The same was calculated for the 9cm line, as well as the 13cm line (refer to Figure 1 below). This information was analysed to see if line length impacted pseudoneglect in relation to line position and according to the hand used. According to the literature longer lines should show evidence of a stronger leftward bias and lines located on the left side should also show a stronger magnitude of pseudoneglect. The results are provided in Chapter 5.

Figure 1 *Line length and line position*

Top Left	Bottom Left	Top Right	Bottom Right	Centre
5cm	5cm	5cm	5cm	5cm

Top Left	Bottom Left	Top Right	Bottom Right	Centre
9cm	9cm	9cm	9cm	9cm

Top Left	Bottom Left	Top Right	Bottom Right	Centre
13cm	13cm	13cm	13cm	13cm

One participant's LBT data did not record as a result, the participant was excluded from the study.

b. Eye-tracking data preparation

Fixations and gaze durations were calculated for each slide that contained a stimulus. As discussed, stimuli were presented on either the right or the left side of a centred focus point, or on both sides. Fixations were labelled as left or right if smaller than half of the screen or greater than half the screen size, measured in pixels. The average gaze duration was measured in milliseconds (ms) for both the left and right sides. The objective was to determine whether there were significant differences between the left and right in relation to gaze duration. A total of 35 participants viewed 16 slides containing various stimuli presented on different sides of the fixation point. Eye-tracking data for slide 36 containing the clocks were not recorded due to technical difficulties.

Information about the number of fixations per slide was also calculated. Similar to the gaze duration data, the fixation results were calculated for both the left and right sides. The average number of fixations was analysed per slide. Chapter 5 includes more details about the analysis and the results.

4.6.2 Analysis

This section includes a description of the descriptive – and inferential statistics applied and the important statistical assumptions considered. Responses from the demographic – and memory questionnaires were captured on an Excel file. The LBT results were also captured on an Excel spreadsheet and all content was imported to SPSS for analysis version 27.

a. Descriptive statistics

The following descriptive statistics were reported for the current study: the measures of central tendency including the mean. Measures of variability, including: standard deviation, variance and the minimum and maximum values were also reported.

b. Inferential statistics

Data analysis methods that align with the research objectives were used. To answer the research questions stated, ANOVA analysis was used, the statistical technique that measures potential differences in a scale-level dependent variable by a nominal-level variable with more than one category (Field, 2009; Pallant, 2013; Statistical Solutions, 2013). ANOVA analysis is where an independent variable is measured in relation to a dependent variable. The null hypothesis for an ANOVA usually assumes that there is no significant difference among the groups i.e., levels of the factor. The alternative hypothesis proposes at least one significant difference among the groups. ANOVA is used to assess differences between two or more means (Field, 2009; Pallant, 2013). An independent variable, known as a factor, includes different levels which correspond with different conditions.

In comparing the performance of pseudoneglect various factors influence the demonstration of leftward biases. To analyse pseudoneglect in relation to handedness, line length and position different factors were created. Handedness comprised one factor constituting two levels: left-hand and right-hand. Similarly, line length comprised a factor with three different levels representing each line length, and position of presentation included five different levels based on the location of presentation.

To analyse differences in the items memorised, a dependent sample *t*-test was performed to compare the left and right memory conditions.

To determine differences related to gender and age, a two-way repeated-measures ANOVA was used with pseudoneglect (line length, and position) as the dependent variable and age and gender constituting different factors. As noted, before any statistical measure is used, it is important to ascertain that test assumptions have not been violated. After the cleaning and preparation of the data as discussed in section 4.6.1, the researcher tested the assumptions of ANOVA (Pallant, 2013) to make sure that all test assumptions have been met. The following assumptions are important in ANOVA procedures (Field, 2009; Statistical solutions, 2013):

- Normal distribution of the data
- Homogeneity of variance (equal variance among the groups)
- Observations are independent
- Control for confounding is emphasised.

Research is governed by certain rules to ensure the rigour of the research process and to support the scientific value of the findings. Validity and reliability constitute two essential criteria for assessing the integrity of research and this is discussed in the sections to follow.

4.6.3 Ensuring quality of analysis and interpretation of data

Quantitative research is often aimed at establishing a relation between different variables. The present research attempted to determine the impact of pseudoneglect on memory and attention. As discussed during 4.3, the study was quasi-experimental and therefore does not represent a true experiment. No cause-and-effect conclusions are made. The researcher did, however, endeavour to determine whether there is a relation between the different variables. By questioning the association between variables, one may attempt to explain the link and debate about the directionality of this link, i.e., one causes the other. The following questions may arise given the current topic:

- Do lateral biases cause differences in memory encoding?
- Are differences in lateral biases caused by age variances?

The researcher cannot make any cause-and-effect conclusions given the study design limitations. The findings from the present investigation can therefore not answer these questions. Future research can be guided by the current findings to design studies that address these causal questions.

When interpreting the findings, it is important to ensure that the data was collected by means of valid assessment measures and that the required assumptions were met for running applicable statistical procedures. The instruments as well as the overall research design should also adhere to the requirements of statistical conclusion validity. The measurement instruments used should thus have measured what it had intended to measure (Shadish et al., 2002).

After completing the analysis phase, the researcher interpreted the data using the TVA model and the activation-orientation hypothesis as guidance. The analysis and interpretation of the data allowed the researcher to gain more insight into the phenomenon of pseudoneglect and how it relates to memory and attention. The findings and interpretation of the data are discussed in Chapter 6.

4.7 VALIDITY AND RELIABILITY

Research within the social sciences field often includes the measurement of constructs that are not directly measurable. To measure the construct, researchers rely on different techniques to gain information about the construct, which may include: surveys, interviews, or observations (Mentz & Botha, 2012). Quantitative research is dependent on different measurement techniques to enable data collection but it is essential for researchers to attest to the validity and reliability of the measurements used. Heale and Twycross (2015) reason that well-conducted, quality research is determined by producing findings that are valid and reliable. The scientific value of the research along with the quality of the tools used is based on how valid and reliable the results may be. It is for this reason that researchers should reflect on the rigour of the overall research process (Heale & Twycross, 2015). Without ensuring validity and reliability, Mentz and Botha (2012) argue that your results may be meaningless. This section provides details about the psychometric validity and reliability of the measurement instruments as well as the design validity of the current study.

4.7.1 Validity

Validity pertains to whether the methods used to collect data are actually gathering the data the researchers intend to collect (Mertler, 2012; Metntz & Bortha, 2012). Heale and Twycross (2015) describe validity as the extent to which an accurate measurement of a construct is obtained. Validity in psychometric terms refers to the validity of the measurement instruments used and whether it was sufficient in measuring the constructs it was designed to measure.

Heale and Twycross (2015) along with Mentz and Botha (2012) describe three important types of validity which are outlined below.

a. Content validity

This type of validity is about whether the assessment tool sufficiently covers the content it should with regard to measuring the variable it was designed to capture (Heale & Twycross, 2015). There should be a strong correlation between the content of the instrument and the content domain of the construct (Mentz & Botha, 2012). A measure will demonstrate adequate content validity if it includes items known to be linked to the construct it intends to measure. Researchers should therefore determine whether the questionnaire or tool covers a sufficient domain related to the variable (Heale & Twycross, 2015). A closely related category of content validity is face validity where experts provide input about the level to which the tool measures the intended construct.

b. Construct validity

Construct validity concerns the degree to which the operationalisation of a construct adequately covers the theoretical domain associated with the construct to be measured (Mentz & Botha, 2012). Heale and Twycross (2015) assert that it is based on the corollaries about the test scores linked to the construct under investigation, thus the conclusions that can be made about the construct as indicated by the data. Construct validity then involves firm and acceptable definitions and measurement procedures for the variables assessed (García-Pérez, 2012).

Two subsets of construct validity have been identified: convergent - and discriminant validity (Mentz & Botha, 2012). Convergent validity is demonstrated when a measure is related to other measures attempting to assess the same construct. The tool should thus be able to measure similar concepts to that of other instruments (Heale & Twycross, 2015). Discriminant validity is about showing that measures that should not be related are in reality not correlated (Mentz & Botha, 2012). The relation between instruments measuring different constructs should therefore be low. Heale and

Twycross (2015) also explain that it is important for measures to have homogeneity in that they only measure one construct. Theory evidence is also highlighted as an important aspect where what is being measured should be closely correlated with theoretical assumptions of the construct measured.

c. Criterion validity

It is also necessary to compare an assessment tool to a set of predetermined criteria. This means that the designed measure of the construct should be associated with theoretical content related to the construct (Mentz & Botha, 2012). The criterion can include any other measurement that is known to measure the same construct domain, and in order for criterion validity to be established, a close correlation between the two measures should be evident (Heale & Twycross, 2015). In order for this to occur, convergent validity, i.e., the tool should correlate highly with instruments measuring the same variable, is necessary. There should also be minimal association between the measure and instruments measuring different constructs, i.e., divergent validity. Mentz and Botha (2012) distinguish between different types of criterion validity: predictive validity and concurrent validity. The instruments capacity to predict inferences it should theoretically be able to predict constitutes predictive validity. Concurrent validity relates to a link between two or more concurrent constructs. Chen et al. (2019) assessed the relation between different assessment measures used to measure pseudoneglect and found that commonalities exist between the different techniques used.

d. Statistical conclusion validity

García-Pérez (2012) reason that the purpose of research is to create knowledge and provide support that can be used to guide subsequent decisions regarding the topic explored. Statistical conclusion validity (SCV) relates to the conclusions made by the research and is demonstrated when the conclusions are based on acceptable analysis of the data, meaning that appropriate statistical methods were applied to analyse the findings. The statistical procedures used should be accurate and logically capable of answering the research questions posed.

In relation to the other types of validity addressed above, SCV has recently received more emphasis as some studies often employ inappropriate analysis tools and procedures to produce conclusions that would not be obtained if adequate statistical measures were used (García-Pérez, 2012). SCV concerns the degree to which the data can reasonably be seen as demonstrating a connection between the independent and dependent variables in relation to statistical applications. Three domains are discussed by García-Pérez (2012) in relation to SCV: whether the study has adequate statistical power to detect an effect if it is present; questions concerning whether the data may produce an effect that does not actually occur: and how the magnitude of the effect can be confidently estimated. Essentially, Shadish, Cook and, Campbell (2002) maintain that SCV relate to the conclusions made about covariation given the α level provided and the observed variances. Aspects related to SCV are important when the goal of the study involves the demonstration of covariation and causation, i.e., whether the suggested cause and effect covary and how strong this covariation is (Shadish et al., 2002). Another important factor relates to overestimating or underestimating the magnitude of covariation and the degree of confidence related to these inferences. This form of validity encapsulates the issues associated with Type I and Type II errors that may arise from quantitative research (García-Pérez, 2012) given the inappropriate use of statistical methods and the ultimate effect size found. The essence of SCV is further linked to the degree to which pre-experimental designs offer support for cause-and-effect relations.

García-Pérez (2012) maintains that SCV is focused on sources of random error and evidently concerns the question about whether suitable statistical procedures were used to support the conclusions made by the research findings. Various threats to SCV have been identified and a brief outline of applicable threats is addressed below.

Shadish et al. (2002) argue that numerous explanations can be offered as to why inferences about covariation may be faulty. Low statistical power relates to the idea that insufficiently powered experiments may result in mistakenly concluding that a relation between a treatment and outcome does not exist or is insignificant. This is addressed by setting confidence intervals, which is generally set at α =.05 in social sciences (Shadish et al., 2002). Sample size is also important in this regard. The α level for the current study was set at .05 and results were reported in accordance.

It is possible to do a priori or post hoc determination of effect size, power and sample size. However, a priori determination of power for factorial repeated measure ANOVAS is difficult due to not having accurate ways to calculate error variance (Potvin & Schutz, 2000). Some simulated information is available and recently R methods have been developed to do this but knowledge about cell sample sizes, standard deviations, correlations between variables and expected means for each cell is required (Lakens & Caldwell, 2019; Potvin & Schutz, 2000). Because these indices cannot be based on previous studies it was decided to do post hoc estimations. In this study, due to the data collection restrictions, sample size has been limited (N = 35). The indices of power, effect size, level of significance and sample size are related and, for instance, the power of a test such as a *t*-test is dependent on sample size, level of significance and effect size (Cohen, 1992). The current power of an independent *t*-test for the current sample of N were 36 (thus, 18 per group) would be 0.65 if the desired effect size was large (0.8) and α set at .05. Thus, sample size and power are given which means that effect size were calculated post hoc. In the case of *t*-tests, usually with Bonferroni correction when doing multiple pairwise comparisons, the effect is indicated by Cohen's d. The general guideline for Cohen's d is small = 0.2, medium= 0.5 and large = 0.8 (Cohen, 1992; Pallant, 2016). Given the restriction of sample size in this study an effect size of larger than 0.8 would be desired for a *t*-test.

In the case of factorial repeated measures ANOVAS effect size is indicated by eta squared (η^2) and partial η^2. Effect size interpretation for ANOVAs and more complex designs such as factorial ANOVA, including repeated measures and ANCOVA is riddled with complexities and misinterpretation, to such an extent that even Field's (2018) usage of η^2 and partial η^2 were incorrect in earlier versions of his textbook (Richardson, 2011). Eta squared indicates

"*the proportion of the total variance in a dependent variable that is associated with the membership of different groups defined by an independent variable. Partial eta squared is a similar measure in which the effects of other independent variables and interactions are partialled out*" (Richardson, 2011, p.135).

In the latter instance it would be used in the current study to indicate within effects in the factorial repeated measures ANOVA whilst controlling for between group effects. This would apply to analyses where gender or age were used as between group factors. For the remainder factorial repeated measure ANOVAS η^2 can be used because both factors can be argued to be within factors (such as handedness and line position). For the current study Cohen's general guideline for η^2 as small = .0099, medium = .0588 and large = .1379 would be used (Richardson, 2011).

Violated assumptions of statistical tests can result in overestimating or underestimating the size of an observed effect (Shadish et al., 2002). The researcher, however, made sure that all statistical assumptions were met before using specified statistical processes. Where assumptions were violated, the researcher addressed the issue by using appropriate alternative options for data analysis. The requirement of sphericity in ANOVA was violated in some cases and the researcher relied on the Greenhouse-Geisser data of the Mauchly's Test of sphericity to address the violation (Field, 2009). The detailed findings are provided in Chapter 5 and reference is made in specific sections where sphericity has been violated.

The use of unreliable measurements can also impact the findings and the extent to which inferences can be made based on the results. Shadish et al. (2002) reason that erroneous conclusions about covariation are possible if either variable has been measured unreliably. It is for this reason that emphasis is placed on ensuring the reliability of measures used.

Eye-tracking data was interpreted according to the Tobii guidelines and the validity codes provided information about whether an eye was correctly identified by the eye-tracker. Skinner, Hübscher, Moseley et al. (2018) reported that few studies have focused on the reliability of eye-tracker research. The purpose of the study, the setting used for administration, and the sample size can guide decisions regarding consistency. The data collection for the current study was standardised and the Tobii guide was used during the interpretation of the eye-tracking data. Skinner et al. (2018) note that a sample size smaller than 20 may compromise reliability, which is not the case for the present investigation.

The implementation of certain procedures during data collection can also impact the effect size (Shadish et al., 2002). The current data collection procedure was standardised, all participants received the same instructions, and all data collection took place in the same room using the same setup. Although not a true experiment, the researcher did attempt to minimize the impact from confounding variables, characteristic of a quasi-experimental design. Extraneous variance within the study environment may also impact the covariance found. As much as it was possible, the researcher attempted to minimise any possible external factors that may have influenced the performance of participants. This involved assessing all participants within the same room under similar conditions. Factors including noise, temperature and lighting was controlled. It is however noted that controlling for all potential extraneous factors was not feasible.

The present investigation was quasi-experimental in nature in that the researcher had no control over the independent variables and as a result the study comprised a single group with no random assignment. The statistical methods used consisted of basic descriptive statistics and inferential statistics. With regard to threats of validity, this is addressed in the limitation section in Chapter 6, but the researcher ensured that all statistical assumptions were met before various analysis procedures were applied.

e. External validity

The extent to which the study results are applicable to groups and settings other than that included in the research is important where the findings are to be applied to a population other than that included in the actual research (García-Pérez, 2012; Mertler, 2012). The use of random assignment is noted as a method used to improve on the external validity of research, which was not possible in the present case.

The study sample was small and included only 35 participants. The researcher did not assess different treatment conditions based on the manipulation of an IV, as such random assignment was not applicable in the current study. The researcher is cautious about generalising the results to larger populations, due to the small sample assessed and the variability often observed in LBT performance. The study sample was also selected from a pool of university staff and students and was based on voluntary participation and convenience. Accordingly, the results may not translate to populations with different characteristics than those encompassing the present sample. As Mertler (2012) explain, personological variables may impact the external validity as the results may be linked to some people but apply poorly to others. Despite the significance of the study findings, the data can provide an indication of possible tendencies underlying the data which may guide further investigation. This study developed and adapted two tests (LBT and Visual Memory) that can be explored in further studies with regard to valdity and reliability. A non-random sample such as the current would not afford conclusive evidence but allow some inferences regarding relationship tendencies between variables of interest.

f. Internal validity

This type of validity is important for quantitative research and is aimed at controlling all extraneous variables to prevent the potential of confounding results.

Threats to the internal validity of the study constitute any factors that may impact the researcher's final conclusion based on the findings. Any plausible alternative explanation for the observed findings, other than the hypothesis represents a threat to the internal validity of the study. The researcher should thus attempt to minimise any threats to internal validity by controlling for all extraneous variables (García-Pérez, 2012).

General threats to internal validity include differential selection of participants, history effects, maturation, testing, regression, instrumentation, temporal precedence, and attrition (Mertler, 2012; Shadish et al., 2002). The researcher will only reflect on the threats that were relevant to the current study.

An essential feature of experimental and quasi-experimental research involves the control over extraneous factors, i.e., any variables that may change along with the study variables during the course of the research (Mentz & Botha, 2012; Mertler, 2012; Shadish et al., 2002). The prospect of confounding is thus an important aspect of experimental research. The researcher recognises that, due to the absence of a comparison group and the lack of random assignment, no cause-and-effect conclusions can be made. Participants were required to perform the LBT with both hands and it is possible that doing the test a second time could have potentially improved their performance with the second round, attenuating the effects of pseudoneglect. Age-related cognitive decline may have implications for the memory test results. The main aim with including both older and younger participants was, however, not related to memory test performance, but rather to observe possible changes in the demonstration of pseudoneglect. The researcher refrained from concluding cause-and-effect but rather described the potential relation between the study variables.

Validity and reliability are closely related and both comprise essential requirements to quality research. Reliability will be discussed in the next section.

4.7.2 Reliability

It is maintained that no measure will produce absolute consistent results due to many factors, but the results produced during different times, under similar conditions, should be closely related. Different types of reliability have been proposed and a few are discussed in relation to the present investigation.

Statistical analysis about the reliability of the computerised version of the LBT and the VLTM questionnaire was conducted. Mitchell et al. (2020) report that considerable individual variance is often observed in LBT performance and supplementary testing is recommended. The computerised version of the LBT was piloted before formal assessment commenced. Small variances in performance are possible due to individual variance and technicalities embedded in the programme. The conditions under which the assessments were completed were similar for all participants. They all received the same instructions and the procedure was standardised.

Similarly, the self-constructed memory questionnaire was tailored according to the memory simulation presented to the participants. The questionnaire content was specific to the simulation and the researcher can reasonably argue that the measure will yield consistent results. All participants received the same questionnaire and were exposed to the same simulation, and used the same tools for completion.

The rigour with which researchers attempt to establish validity and reliability is an important component in critiquing the research as well as the final decision regarding the value of the investigation's overall findings (Heale & Twycross, 2015). The researcher has an ethical responsibility to ensure that the measures used are scientifically valid and reliable. The application process of these measures and the resulting data should be unbiased. Good quality research will offer support for how the issues pertaining to validity and reliability have been addressed.

The reliability and validity of the measurement instruments used along with the suitability of the study design to answer the stated research questions are important to ensure the scientific value of the results. The ethical conduct of the researcher is equally important and key ethical principles are discussed in the next section.

4.8 ETHICAL CONSIDERATIONS

The Research Ethics Committee at the Faculty of Humanities approved the research (Reference number: GW20160825HS). Refer to Appendix D for the approval letter.

Participation in research should always be the personal choice of the individuals invited to partake in the study based on the potential risks and benefits associated with the investigation. A thorough understanding of the research process itself, as well as the purpose of the research, is, therefore, necessary to enable potential participants to make an informed decision. Research is generally aimed at improving our understanding of specific variables or the relation between different variables and ultimately to use this information to enhance human functioning. Knowledge creation is thus a core focus of most research. The National Institutes of Health (NIH) (2016) emphasises the importance of the research participant and the ethical principles that have been proposed to guide research decisions. These principles essentially guide researchers to take precautions in the planning and implementation of research in order to protect participants from any physical, social, or psychological harm. Ethical guidelines have been established to safeguard those who volunteer for research and help to maintain the scientific integrity of research (NIH, 2016).

The NIH (2016) highlights seven principles to ensure the ethical conduct of research. These are described below.

a. Social and clinical value

Research is aimed at answering a specific research question and the NIS (2016) argues that the answer should be important enough to warrant asking individuals to accept certain inconveniences. The outcome of the results should thus be of such a nature that it makes a valuable contribution and justifies the need to undertake the research.

b. Scientific validity

Research should be designed to such an extent that the results produce a clear answer to the questions posed. NIS (2016) argues that the question should be answerable, valid research methods should be used, and reliable measures should be employed. The scientific validity of research is also related to the value of the research. It should be done for a specific purpose, make a useful contribution and not merely represent a waste of resources.

c. Fair subject selection

The sample selection should be based on the scientific goals of the study and not the vulnerability, privilege or unrelated factors of the participants. No person should be excluded from the research without valid scientific reasons. Any benefits associated with the research should also be shared by the participants.

d. Favourable risk-benefit ration

It is important for researchers to ensure that the risks involved in undertaking the study will be worth it. Every precaution should however be taken to minimise the experience of risk or inconvenience to the participant. Ultimately, the benefits involved should outweigh the risks, maximising the potential advantages.

e. Independent review

NIS (2016) explains that an independent review board should evaluate the research proposal to ensure the ethical conduct of the research and to limit possible conflicts of interest. The review panel is responsible for ensuring that the research is conducted free from bias and to ensure that all measures have been taken to maintain the safety of the research participants.

f. Informed consent

As highlighted, participation should always be voluntary and individuals need to be able to make informed decisions about whether they want to participate in the study or not. The process of informed consent involves providing people with sufficient details about the purpose of the study, the methods used, the potential risks and benefits involved, and any alternative options linked to the research available. It is further necessary to ensure that the information is communicated in a manner that is easily comprehensible by the participants and that they are able to voluntarily make the decision to participate.

g. Respect for potential and enrolled participants

NIS (2016) stresses the importance of respecting participants at all times, from the start of recruitment throughout the research process and until their participation concludes. It is important for researchers to respect the privacy of all participants and to ensure confidentiality. Respecting the rights of participants' decisions to cease participation is also important and researchers have the responsibility to inform participants of any changes during the research process that may impact their further assessment and participation. It is also necessary for researchers to monitor the wellbeing of participants and to ensure that appropriate measures are taken if any risks arise.

The researcher followed the necessary guidelines to maintain the ethical conduct of the research process. Gravetter and Forzano (2012) along with Willig (2008) explained that the researcher should always convey information honestly and with respect and take responsibility for ensuring the wellbeing of all those involved in the research. Ethics is something that needs to be deliberated throughout the research process including the design and execution of the study (Ogletree & Kawulich, 2012). Failure to follow ethical rules may disadvantage, not only the participant, but also the researchers involved as well as any other stakeholders including funding bodies and tertiary institutions.

4.8.1 Ethical principles of the current study

The study proposal was submitted to the ethical board at the university and approval was given by the Faculty Research Committee (See Appendix D). The researcher ensured that the research process was carried out in accordance with the details stipulated in the research proposal and the following guidelines were adhered to:

a. Informed consent

Each participant was given an information sheet and informed consent document containing the necessary details of the study. Before the start of the data collection process, the researcher explained the process and details of the study to the participants. Deception was therefore not evident in the current study and full disclosure of information regarding the purpose of the research was maintained. Those who decided not to participate were not disadvantaged in any way.

b. Privacy and Confidentiality

Participants were ensured that all their details were private and confidential. No personal information was connected to the data. Only the researcher and supervisor had access to the data that is stored in a secure location at the university archives. The information will be safely stored in the Department of Psychology for 15 years. The data will be available for future research and participants were informed about the future use of the data in the consent form, available in Appendix E.

c. No physical or psychological harm

No physical or emotional harm was evident in conducting the research. The eye-tracker posed no risk or threat to the individuals. The eye-tracker is securely mounted on the computer screen and does not involve an invasive procedure.

The researcher ensured that the safety and well-being of all participants was a core focus during data collection.

d. Scientific integrity

The researcher also set out to uphold the scientific integrity of the research and the resulting data. The interpretation of the findings and the dissemination of the final report were for the purposes of completing a Ph.D. and to contribute further knowledge to elucidate the understanding of the phenomenon, pseudoneglect.

4.9 QUALITY CRITERIA

Specific measures were taken to improve the validity and reliability of the research study. The assessment measures effectively addressed the construct it intended to measure. Appropriate statistical methods were used to answer the research question and an applicable research design was used. The inferences made are based on statistical analysis with the aim of answering the research question. Standards of procedure were followed to ensure that data collection occurred under similar circumstances for each participant.

4.10 CONCLUSION

This chapter described the methodological approach, including the research design, sampling method, data collection, data analysis, and integration. Details regarding the measurement instruments used as well as the data collection procedure were also discussed. A quasi-experimental design was used and given that it lacks the rigour of a true experiment, the researcher acknowledges the potential threats to the internal validity of the study. Caution was, however, taken to ensure that data collection was consistent for all participants, and where statistical assumptions were violated, the researcher followed the necessary alternatives to ensure the scientific integrity of the findings.

The quasi-experimental design was used as the researcher was not able to manipulate the variables, only one group was included and all extraneous variables were not controlled. All participants were exposed to the same memory simulation and assessment measures and no comparison group was included. The quantitative results of the study are deliberated in the next chapter.

CHAPTER 5 FINDINGS

This chapter provides an outline of the results obtained based on the statistical analysis applied in the present study. The findings are provided in relation to the structure detailed below.

The chapter is structured as follows:

Five sections are provided where the researcher firstly summarises the demographic questionnaire. The purpose of the first section is to describe the study sample.

The second section provides a detailed description of the memory simulation along with the memory questionnaire analysis and results. This section was guided by the following:

- Participants watched a simulation containing various stimuli
- VLTM was assessed by using a computerised memory test to determine the number of items recalled based on the simulation.

The third section includes the LBT analysis procedure and results. This section presents the findings of pseudoneglect and offers details regarding the impact of gender, age and handedness on LBT performance. The following guided section three of this chapter:

- Pseudoneglect was measured using a computerised version of the LBT
- Handededness was measured to explore its effect on LBT performance
- Male and female performance on pseudoneglect was compared
- Details on pseudoneglect performance and age are provided although the sample was too small to make any conclusions based on the current sample

The fourth section provides the findings for the eye-tracking data based on gaze duration and the number of fixations organized per image/slide viewed.

- Eye -movements were measured to determine left-to-right scan/gaze patterns
- Eye -movements were measured to determine the number of left/right fixations
- Eye-movement data were interpreted as indications of attention with longer fixations and saccade movements representing attentional pathways

The final part of the chapter offers the inferential statistical analysis in order to address the main aim of the present investigation.

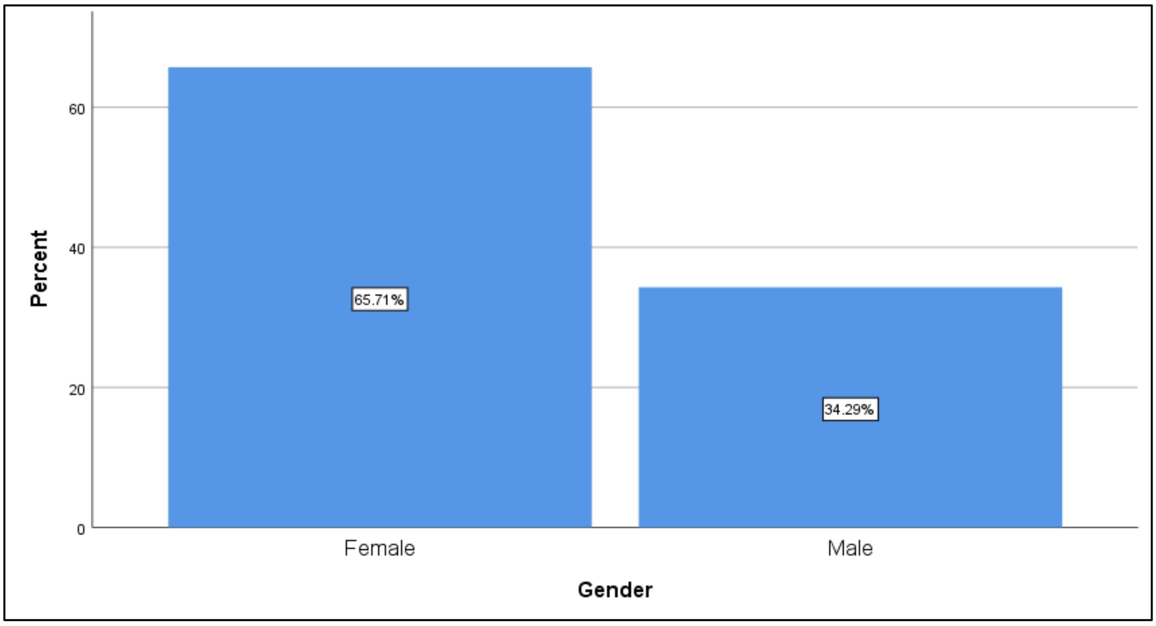
5.1 DEMOGRAPHIC QUESTIONNAIRE

The demographic questionnaire is available in Appendix (A) and was used to obtain basic information regarding participants' demographic details along with information about any past neurological and psychological disorders. A summary of the results will follow.

a. The sample

The sample consisted of a total of 36 participants. Refer to Figure 2 below. One female participant was excluded from analysis due to missing LBT scores due to a technical error. The final sample thus consisted of N = 35: females (n = 23) and males (n = 12). The sample was obtained from a local South African university and included both students and staff members. The sample consisted of 20 undergraduate students, 3 postgraduate students; 9 academic staff members were assessed along with 3 support/administrative staff.

Figure 2 *Sample characteristics based on gender*



b. Age

The researcher attempted to include both older and younger participants as limited research on age and pseudoneglect demonstration is available. The sample obtained is, however, too small to make any conclusions but may offer recommendations to improve future research. Age was organised into three groups as the number of participants in the older age groups were limited. The majority of the sample was from the younger age group comprising 62.8% of the sample. Age categories were also created to group the data for descriptive purposes (refer to Figure 3).

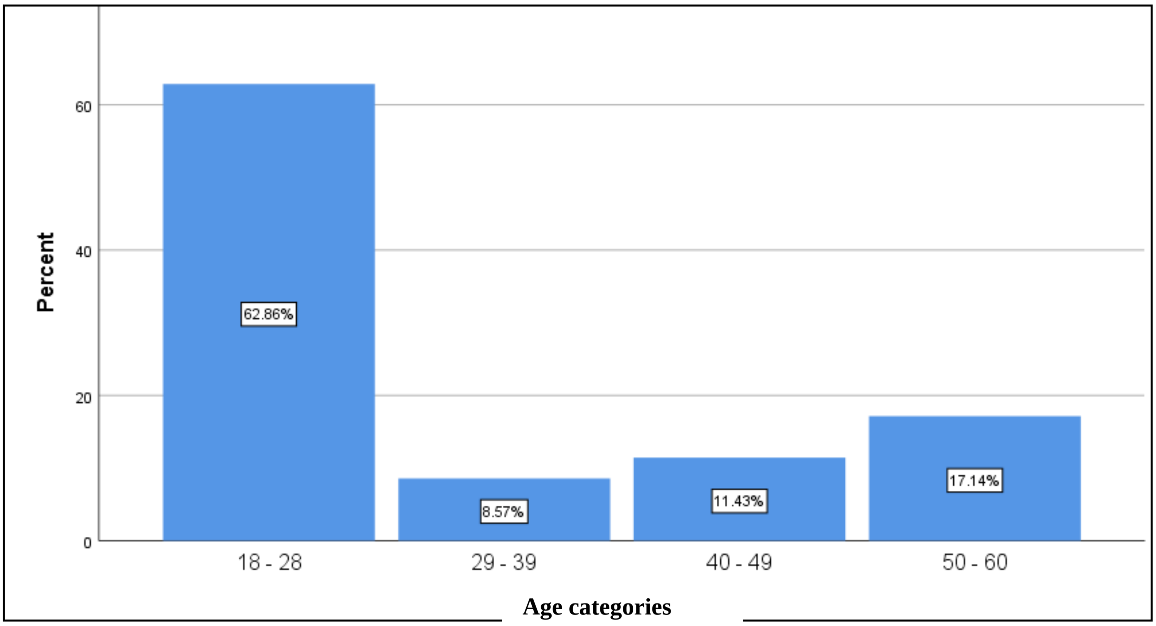
1 = 18 – 28

2 = 29 – 39

3 = 40 – 49

4 = 50 – 60

Figure 3 *The sample age categories*



c. Handedness

As noted, pseudoneglect can be influenced by various factors including handedness. The researcher asked participants to indicate whether they were right/left-handed as part of the demographic questionnaire. The Edinburgh Handedness Inventory (EHI) was also included as a supplementary measure for hand use. The majority of the sample was right-handed (94.3%) with only one left-handed participant and one participant indicated that they are ambidextrous. Participants were requested to complete the LBT using both their left – and right hands to explore the effect of handedness on LBT performance.

d. Neurological and Psychological health

The presence of current psychological and neurological disorders may interfere with attention and memory. It was therefore necessary to ensure that no current physical or mental disorders could impact cognitive functioning.

All participants had normal or corrected vision i.e., wearing glasses or contact lenses. No visual problems of concern were therefore reported. Only three participants reported a history of concussions, but no present neurological concerns were stated and merely 20% of the sample reported a history of psychological disorders, mostly related to depression and generalised anxiety.

The researcher concluded based on the provided demographic information, that all participants were neurologically and psychologically fit to participate in the study and that no medical/mental concerns could potentially confound the observed findings.

5.2 MEMORY SIMULATION AND QUESTIONNAIRE

An outline of how the memory simulation was designed using PowerPoint is available in Appendix A, part 2. The memory questionnaire items are available in Appendix B.

The memory simulation images are detailed in chapter 4 (see section, 4.4 part e, page, 98). The findings per memory questionnaire item are discussed below.

a. Question 1

Condition one included showing different letters in either the left or right hemifield or both.

A total of 62.9% indicated seeing the letter ‘E’ compared to 74.3% who recalled ‘B’ which was presented in the right hemifield. The results showed that 74.3% participants recalled seeing the letter ‘A’ and 54.3% remembered the letter ‘C’ while 65.7% noted that they saw the letter ‘F’. The findings show that 57.1% of the sample indicated seeing the letter ‘P’ compared to only 28.6% who recalled seeing ‘D’ and 45.7% seeing ‘Z’. More people reported seeing the letters ‘R’ (60%) and ‘G’ (62.9%) in comparison with ‘T’ and ‘U’ both reported by 57.1% of the sample.

b. Question 2

A total of 20 participants (57.1%) noted that they saw the King of hearts compared to 85.7% who recalled seeing the King of spades. The Queen of diamonds was reported by 65.7% of the sample while 71.4% recalled seeing the Jack of diamonds. In both the above scenarios more items located to the right of the focus point was recalled. With the multiple presentations of stimuli on the right side 68.6% recalled the Queen of spades compared to 42.9% who indicated seeing the Queen of hearts and 60% the Jack of spades. The results for multiple stimuli on both the left and right side of the focal point revealed that 57.1% recalled the Queen of clubs and 45.7% the King of clubs in relation to 51.4% recalling the Jack of spades and 65.7% the King of diamonds.

c. Question 3

Question 3 of the memory questionnaire asked participants to tick the road signs they recall seeing. In the above pictures the road sign is located more to the left in the first picture and more to the right in the second picture. A third picture of a stop sign located more to the left was included as a distractor. The results showed that all the participants recalled seeing both signs and none reported a recollection of the stop sign.

d. Question 4

This question asked participants to recall the fruits and vegetables they remember seeing. The image was presented as above in the centre of the screen A few distractors were also included in the question item (see Appendix B). The findings revealed that 77.1% of the sample recalled seeing the pineapples located towards the right of the screen in comparison to 97.1% who remembered seeing the cranberries located towards the left of the screen. The peppers in the left part of the image were recalled by 82.9% of the sample with 82.9% remember seeing the grapes and 88.6% the eggplant on the right. A large part of participants (80%) recalled the watermelon and 77.1% the strawberries compared with 97.1% who recalled seeing the oranges on the right side of the image.

The researcher notes that the images presented might have been interpreted differently or linked to previous experiences hence making them more memorable irrespective of the location in which it was presented. The researcher did include distractors as part of the options for this particular question and some participants did recall seeing the items not presented. This may represent a source of confounding for which the researcher did not control.

e. Question 5

This question requested participants to memorise as many words as they can. Similar to previous questions, a few distractors were included in the memory questionnaire. As the image above shows, two columns of words were presented on the left and right side of the screen. The results show that 94.3% of the sample recalled the word *academic*, located in the left hemifield. A large part of the sample (71.4%) also indicated that they remembered seeing the word *comfortable* and 54.3% the word *books*. In relation to word presented in the right hemifield, 45.7% recalled the word *work* and 48.6% the word *family*. The word *adventure* was remembered by 37.1% and 42.9% recalled the word *brain*. Only 28.6% of participants noted seeing the word *flower*.

f. Question 6

The questioned asked participants to indicate the colour of the dog that was presented towards to right side of the focus point. Most of the sample, 58.8% recalled that the dog was blue compared to 8.8% who noted black, 14.7% white and 11.8% grey. The majority of the sample therefore recalled the colour of the dog.

g. Question 7

The last question asked participants to indicate the recalled clocks as shown in the above image. A few distractors were included showing clocks with times not included in the simulation. The majority of the sample (94.3%) recalled the first clock on the left portraying 13h00. A large part of participants (45.7%) also recalled 21h00 and 48.6% reported seeing 20h00 and 68.6% 16h00.

The main goal of the present study was to determine whether participants recalled more items on the left compared to the right. The following subsection will provide details of the memory scores obtained based on the memory questionnaire. The memory questionnaire data was divided into two conditions since the main aim was to establish whether more items on the left were recalled.

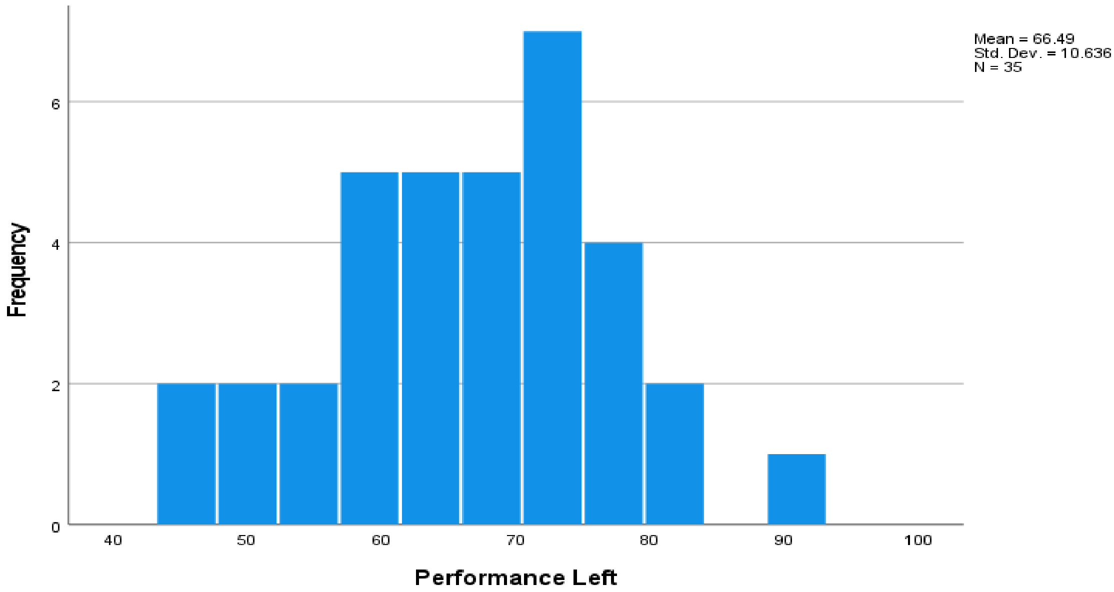
Memory scores were calculated based on the number of responses remembered as they were presented during the simulation. A correct score was assigned if a participant selected a particular item that was part of the simulation. The data below depicts the results of two conditions: left condition, and right condition. The number of correct responses for the left condition was 22 and for the right condition it was 25. Each condition's score was calculated as a percentage: Left condition = Score/22 x 100; Right condition = Score/25 x 100

Participants scored higher in the left condition (M = 66.49, SD = 10.64) compared to the right condition. (M = 62, SD = 12.16).

The left condition:

A correct score was given if the participants recalled an item that was presented on the left side of the focal point during the memory simulation and no mark was assigned for any other stimuli recalled. Referring to Figure 4 below, 11 participants scored below 60%. The data show that 10 participants scored between 60% – 68%. The majority of participants, 14 scored 73% and higher.

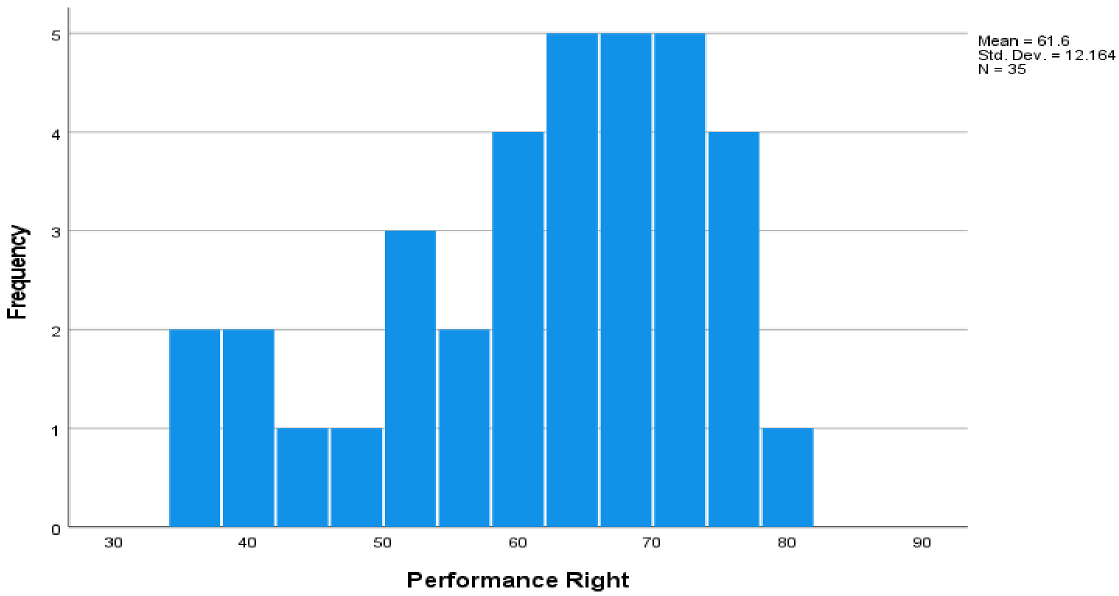
Figure 4 *Left condition performance*



The right condition:

A correct score was given if the participants recalled an item that was presented on the right side of the focal point during the memory simulation and no mark was assigned for any other stimuli recalled. Figure 5 below shows the data for the right condition. The data show that 11 participants scored below 60%. The majority of participants, 14 participants, scored between 60% – 68%. Only 10 participants scored 72% and higher.

Figure 5 *Right condition performance*



To determine whether the differences between the memory conditions were significantly different a paired sample t-test was conducted. The left only and right only conditions were compared. There is a significant difference between the two memory conditions. On average, participants recalled more items on the left (*M* = 66.49, *SE* = 1.8) than on the right (*M* = 61.60, *SE* = 2.1), $t(34) = 2.86$, $p = .004$ (one-tailed). The eta squared (.483) indicated a small to medium effect size. Participants thus recalled more items presented in the left hemispace compared to what was presented on the right side. The mean increase from the right memory scores to left memory scores was 4.89 with a 95% confidence interval ranging from 1.4 to 8.37.

There were significant differences between the memory performance of the participants with regard to the amount of information recalled between the left and right side.

The eye-tracking data provides additional support with regard to gaze information and number of fixations. The following section will provide a brief outline of the eye tracker results.

5.3 EYE-TRACKING DATA

The data includes measurements about gaze duration and number of fixations.

a. Gaze duration

The average gaze duration measured in milliseconds (ms) was calculated for each slide left/right. The objective was to determine whether there were significant differences between the left and right with regard to gaze duration. Gaze duration is a measure of how long a person focuses on a particular stimulus.

A total of 16 slides containing various stimuli presented on different sides of the fixation point were viewed by 35 participants. Eye-tracking data for slide 36 containing the watches was not recorded due to technical difficulties.

Table 1 contains a summary description of the slides presented during the simulation. The slide numbers not included contained instructions and the x fixation point presented before each new stimulus.

Table 1 *Stimulus description per slide number*

SLIDE	Recode Nr.	STIMULUS DESCRIPTION			Duration Presented (ms)
		Left Side	Centre	Right Side	
3	1	E			3
5	2	B			3
7	3	AC		F	5
9	4	P		ZD	5
11	5	TU		RG	5
13	6	King of Hearts			3
15	7			King of Spades	3
17	8	Queen of Diamonds		Jack of Diamonds	5
19	9	Queen of Spades		Queen of Hearts Jack of Clubs	5
21	10	Queen of Clubs King of Clubs		Jack of Spades King of Diamonds	5
23	11	60km Road Sign			3
26	12		Fruit and Vegetables		12
29	13	Word Columns		Word Columns	12
31	14			30km Road Sign	3
33	15	Cat		Dog	5
36			Watches		12

Table 2 describes the detailed data for each slide that contained a stimulus in relation to a **leftward** gaze, while Table 3 details the **rightward gaze** duration. The total duration of gaze is represented by n.

Slide 2 contained instructions hence the longer duration observed (n =1809).

Slide 3, for example, contained only a stimulus on the left which explains the gaze duration (n=232) observed for the leftward gaze (*M* = 711.04, *SD* = 1106.47) compared to no measurement for the rightward gaze.

Referring to the Tables below, slide 7 contained a stimulus on both the left and right side of the fixation point. Two letters were presented on the left and one letter on the right side. The data shows that the average gaze duration was longer for the leftward gaze (*M* = 555, *SD* = 966.34) compared to the right side (*M* = 347, *SD* = 335).

Slide 21 contained two card images on the left and two card images on the right. Although the total number of gaze duration was longer on the left (621ms) the average gaze duration for stimuli on the right was longer (*M* = 342, *SD* = 332.75).

Slide 26 contained pictures of fruits and vegetables. The image was a single image presented in the centre of the screen but the fruits and vegetables were arranged in left and right columns. This means that participants could focus their gaze on either side. The data show that the total gaze duration towards the left was n = 2187ms compared to the total gaze duration towards the right n = 5ms. The average gaze duration for slide 26 for the left side was (*M* = 309, *SD* = 221) compared to (*M* = 175, *SD* = 90.29) for the right side.

Slide 33 contained an image of a cat on the left and a picture of a dog on the right side. The data shows that the average gaze duration for the left side i.e., the cat was (*M* = 423, *SD* = 633) compared to the average gaze duration observed on the right side (*M* = 341, *SD* = 303). Generally, the average gaze duration for the left side stimuli appears to be longer compared to the right side. The Tables to follow will provide more details about whether this difference is statistically significant.

Table 2 *Average gaze duration for each slide Left*

Slide	n	M	SD
2	1809	317.23	226.42
3	232	711.04	1106.47
5	95	1041.64	1607.07
7	351	554.74	966.34
9	302	517.81	905.32
11	419	459.96	706.11
13	332	516.07	857.69
15	51	1325.57	1505.4
17	365	420.95	720.44
19	607	370.99	608.9
21	621	333.1	474.48
23	333	416.44	546.83
26	2187	308.91	221.24
31	325	441.39	618.1
33	294	423.35	632.92

Note. n refers to the total gaze duration measured in milliseconds (ms).

Table 3 *Average gaze duration for each slide Right*

Slide	n	M	SD
3			
5	181	426.63	626.91
7	149	346.54	335.01
9	234	334.43	313
11	269	360.19	388.42
13			
15	308	312.12	332.4
17	219	344.38	425.2
19	239	308.56	307.06
21	204	342.44	332.75
23	15	342.27	166.73
26	5	175	90.29
29	314	320.63	179.63
31	2	137.5	77.07
33	259	341.15	303.28

Note. n refers to the total gaze duration measured in milliseconds (ms).

Table 4 below provides the descriptive statistics of the average gaze duration data in ms per slide in relation to right and left gazes.

Table 4 *Gaze duration descriptive statistics per slide*

	n	M	SD
Slide 3 Left	34	1037.15	865.16
Slide 3 Right	23	1767.19	1792.10
Slide 5 Left	20	1756.53	1884.72
Slide 5 Right	34	889.37	781.34
Slide 7 Left	34	439.66	252.99
Slide 7 Right	34	693.73	538.56
Slide 9 Left	34	421.31	260.82
Slide 9 Right	33	612.51	468.04
Slide 11 Left	34	462.23	266.06
Slide 11 Right	34	497.06	325.59
Slide 13 Left	34	455.67	214.14
Slide 13 Right	23	2073.35	2000.11
Slide 15 Left	15	1223.47	1285.93
Slide 15 Right	34	567.21	440.56
Slide 17 Left	34	448.17	320.86
Slide 17 Right	34	598.18	550.60
Slide 19 Left	34	442.95	253.44
Slide 19 Right	34	451.51	345.05
Slide 21 Left	34	374.31	201.18
Slide 21 Right	34	437.75	386.07
Slide 23 Left	34	514.94	343.88
Slide 23 Right	33	518.81	421.59
Slide 26 Left	34	323.09	96.99
Slide 26 Right	34	345.75	127.71
Slide 29 Left	34	345.52	111.25
Slide 29 Right	32	312.83	78.62
Slide 31 Left	29	564.58	492.81
Slide 31 Right	34	464.59	294.51
Slide 33 Left	34	435.40	291.66
Slide 33 Right	34	430.83	239.49

Note. n refers to the average gaze duration for each slide.

To determine whether the differences between right and left gaze duration were significant a two-way repeated measures ANOVA was conducted. Specifically, 2 x 15 Hand x slides for gaze duration. The recoded slide numbers were used. At least three conditions are needed for sphericity to be a concern (Field, 2009). In this case there are only two levels and sphericity are met.

The data shows that there were no significant differences with the slides and left or right gaze duration (p > .05). No significant interaction effect was observed: F(14, 28) = 1.40, p = .219, η^2 = .41, indicating a large effect size. The data show no main effect for the slides F(14, 28) = 1.40, p = .20, η^2 = .42. Similarly, the results for the left/right gaze duration were also not significantly different F(1, 2) = .07, p = .82, η^2 = .03. There was thus no significant interaction effect observed for the position i.e., right/left gaze duration and the slides (p > .05). There were thus no significant differences between the left and right gaze durations according to each slide.

Figure 6 *Average gaze duration per slide plotted by position*

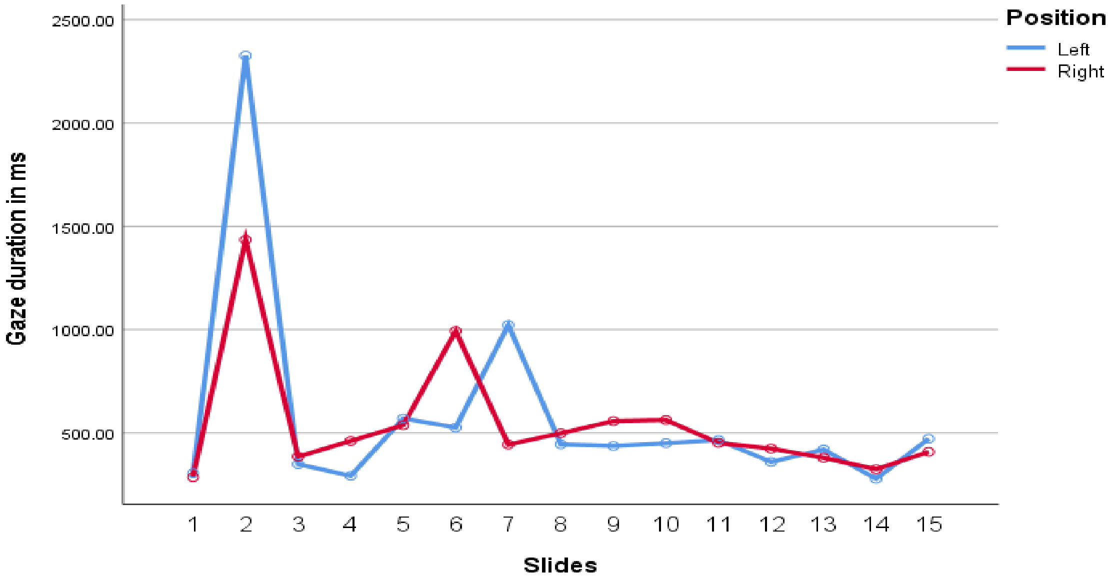
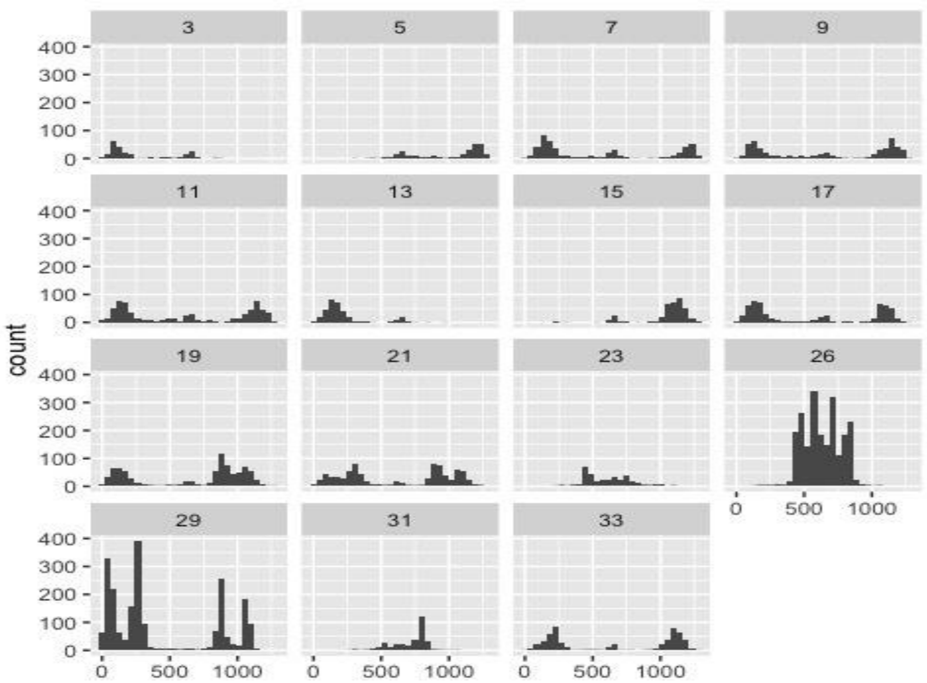


Figure 6 shows the average gaze duration per slide by position i.e., left/right. The left and right gaze durations for each slide are presented in ms. Figure 7 provides a detailed graphic representation of the gaze duration data per slide, showing both the left and right gaze recordings. The graph shows that for some slides the leftward gaze duration was longer whereas for other slides a longer rightward gaze duration was observed. Slide 2 and Slide 7 for example contained only a stimulus on the left which explains the predominant leftward gaze. Slide 6 only contained a stimulus on the right and shows a longer rightward gaze.

Figure 7 *Gaze duration per slide*



b. Number of Fixations

Eye-tracking data also provided information about the number of fixations per slides. The number of fixations equate to the number of times a participant made fixations to the stimuli on the left or right side of the slide. The average number of fixations were analysed per slide. The actual slide numbers used in the study are represented, and not the recoded slide numbers.

Table 5 includes the overall fixation data per slide. The average number of fixations for slide 11 containing two letters on the left and two letters on the right was (*M* = 10, *SD* = 4.9). It is important to note the duration of time that each slide was presented as indicated in Table 1. Slide 26 was presented for 12 seconds and the average number of fixations was (*M* = 32, *SD* = 10.5).

Table 5 *Average number of fixations per slide*

Slide	n	M	SD
3	57	4.07	4.23
5	54	5.11	5.55
7	68	7.35	3.32
9	67	8.00	4.66
11	68	10.12	4.85
13	57	5.82	4.97
15	49	7.33	5.95
17	68	8.59	4.74
19	68	12.44	7.94
21	68	12.13	5.59
23	67	5.19	3.08
26	68	32.24	10.47
29	66	32.17	18.08
31	63	5.19	3.78
33	68	8.13	3.53
Total	956	11.21	11.32

Note. The total number of fixations is indicated by the n values.

Table 6 below details the average number of left fixations per slide as well as the number of right fixations per slide. Looking at the data slide 29 contained words. Two columns of random words were presented on both the left and right side of the focal point. The data below shows that average number of fixations was higher on the left (*M* = 41, *SD* = 18.7) compared to the right (*M*= 22.5, *SD* = 11.2). Similarly, for slide 26 containing the fruits and vegetables more fixations were observed for the left side (*M* = 34, *SD* = 9.54) in relation to the right side *(M* = 30, *SD* = 11.1). Additional analysis will reveal whether these differences were significant, but it seems that participants fixated more on items on the left when items on the right were also present. A two-way repeated measures ANOVA was conducted: 2 x 15 Hand x slides for the number of fixations.

Table 6 *Average number of left and right fixations per slide*

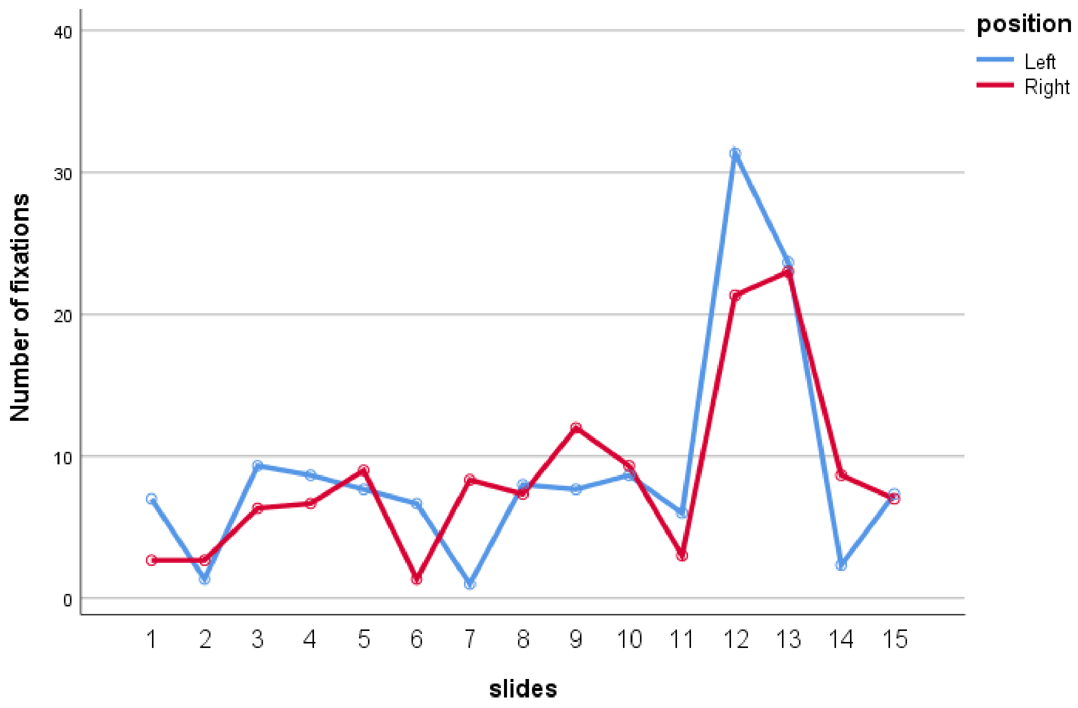
	Slide	n	M	SD
Left	3	34	5.85	4.67
	5	20	1.55	.83
	7	34	8.88	3.16
	9	34	7.59	5.08
	11	34	10.38	5.55
	13	34	9.00	4.00
	15	15	1.20	.41
	17	34	9.71	5.02
	19	34	9.00	5.45
	21	34	11.91	5.74
	23	34	5.88	3.23
	26	34	34.21	9.54
	29	34	41.26	18.70
	31	29	2.97	1.66
	33	34	7.94	3.17
Right	3	23	1.43	1.00
	5	34	7.21	6.06
	7	34	5.82	2.76
	9	33	8.42	4.22
	11	34	9.85	4.1
	13	23	1.13	.34
	15	34	10.03	5.18
	17	34	7.47	4.22
	19	34	15.88	8.59
	21	34	12.35	5.50
	23	33	4.48	2.80
	26	34	30.26	11.10
	29	32	22.50	11.20
	31	34	7.09	4.06
	33	34	8.32	3.90

The assumption of sphericity was met and the sphericity assumed value was reported. The results show that a significant interaction effect was found when the slides and left vs. right fixations were compared $F(14, 28) = 2.74$ p =.01, $\eta^2 = .58$, indicating a large effect size. A significant main effect for the slides was found: $F(14, 28) = 50.6$, $p = .00$, $\eta^2 = .926$. No significant main effect was found for the left and right fixations: $F(1, 2) = .48$, $p = .56$, $\eta^2 = .19$. The number of fixations per slide was significantly different for left and right fixations. Accordingly, it is argued that the findings show that participants demonstrated significantly different fixation patterns given the slides and number of left and right fixations.

The results show that when the recoded slides were compared for main effects only slide 2 and slide 12 showed a significant difference ($p = .034$). None of the other comparisons produced significant differences ($p > .05$). Slide 2 contained a single stimulus to the left only and slide 12 included the fruits and vegetables presented in the centre of the slide. A significant difference was thus observed in the number of fixations produced when these two slides were compared. The difference may be due to the amount of time the slides were displayed, as noted above, slide 2 was displayed for three seconds compared to slide 12 that was presented for 12 seconds.

Figure 8 below provides a graphical representation of the total number of left and right fixations per slide. Line blue represents the average number of left fixations compared to line red that comprises the average number of right fixations. Slide 12 containing the fruits and vegetables shows a higher number of left fixations compared to the right. This is an interesting finding since participants were able to move their gaze in both directions and fixate on either left or right stimuli as both hemifields contained stimuli. The average number of left fixations was, however, higher despite the presence of information on the right side as well. The results show a significant difference in this regard. Slide 14 contained an image more towards the right, explaining the prominent right fixation.

Figure 8 *Right vs Left average fixations per slide*



5.4 LBT PERFORMANCE

5.4.1 Hand use and position of line presentation

Table 7 outlines a brief summary regarding the demonstration of pseudoneglect. Each position contained three lines of various lengths and the mean score indicates the measure of deviation from the true midpoint measured in mm. The mean scores include the average LBT performance for all three lines based on the position it was presented. All three line lengths' bisection scores were thus averaged.

Table 7 *Descriptive statistics for line position and hand used*

LEFT HAND	Pseudoneglect	N	M	SD
Average Top Left	Y	35	-.16	.18
Average Bottom Left	N	35	.035	.23
Average Bottom Right	Y	35	-.14	.24
Average Top Right	Y	35	-.15	.22
Average Centre	Y	35	-.07	.18
RIGHT HAND				
Average Top Left	Y	35	-.05	.23
Average Bottom Left	N	35	.01	.21
Average Bottom Right	Y	35	-.09	.23
Average Top Right	N	35	.03	.20
Average Centre	N	35	.04	.15

The data captured in the Table above provides information about the nature of pseudoneglect performance in relation to the different line positions. The Table shows that when the left hand was used a leftward deviation was made with all the line positions. The lines presented in the bottom left did however not produce a leftward error but rather rightward deviations. During the right-hand condition, only lines presented in the top left and bottom right positions were bisected more towards the left. The other three line positions demonstrated a rightward bias. The activation-orientation hypothesis proposes that when the right hand is used to complete the LBT a less pronounced leftward bias will likely be observed.

To determine the significance of hand use and LBT performance, based on line position, a two-way repeated measures ANOVA was conducted: 2 x 5, hand x position. The results show that there was a significant main effect for hand: $F(1, 34) = 12.95$ $p = .00$, $\eta^2 = .28$, indicating a large effect size. A significant main effect for line position was found: $F(4, 136) = 8.37$ $p = .00$, $\eta^2 = .198$. This result suggests a large effect size.

A significant interaction effect was found for hand use and LBT position: $F(4, 136) = 4.04$ $p = .00$ $\eta^2 = .106$. This result suggests a large effect size. The findings indicate that regardless of the hand used to complete the task, the position of the lines had a significant impact on how participants bisected the lines. Hand use thus interacted with the position of the lines which means that the hand used to bisect the lines had a different effect depending on the position the lines were presented in.

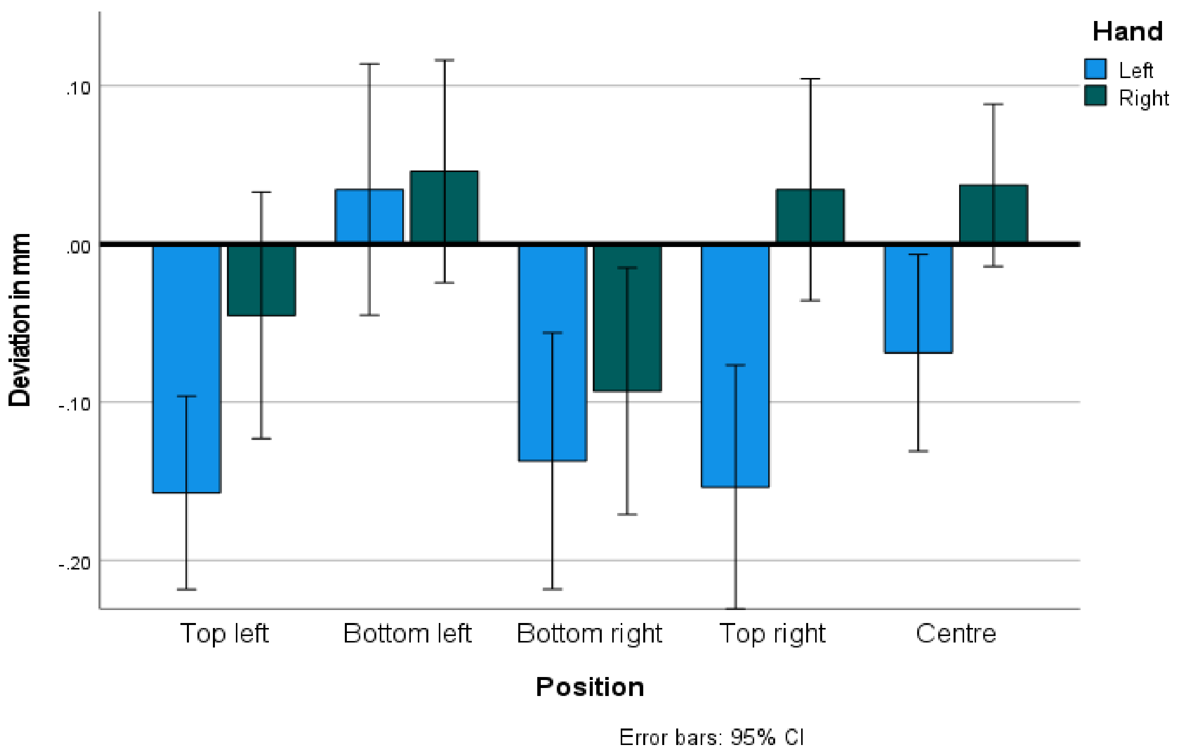
The data show that there are statistically significant main effects for LBT position. This means that there are differences among the different line positions. The findings indicate that the significant main effect reflects a significant difference between line position top left, and bottom left. There is thus a significant difference between lines presented in the *Top left* and *Bottom left* conditions (*p* = .00). A significant difference between line position *Bottom left* and *Bottom right* was also found (*p* = .00). A significant difference (*p* = .03) is also reflected between *Bottom right* and *Centre*.

In accordance with the above-mentioned it can therefore be argued that the position of the lines significantly influenced how participants bisected the lines, regardless of hands used to complete the task.

A significant main effect was found between the right- and left-hand conditions. This means that participants bisected the lines differently depending on the hand that was used. Theoretically, when the left hand is used, it should show a stronger leftward bias. The data in Table 7 show that the left-hand condition produced more leftward biases compared to the righ hand condition.

Figure 12 demonstrates the interaction graphically for to the left and right hand. Based on the graphical presentation it can be deduced that when the left hand was used participants showed a stronger presentation of pseudoneglect, especially when the lines were located on the top left and bottom right regions as well as the top right.

Figure 9 *Line position compared to hand used*



5.4.2 LBT performance based on line length

As noted in chapter 4, the LBT included 15 lines presented in different locations. The LBT performance was based on hand used, the line length and position of the lines. Hand: left or right hand and position: (TL; BL; TR; BR & C). Each location included three lines of different lengths (5cm; 9cm and 13cm). LBT performance in relation to hand use and line length is discussed in this section. Table 8 provides the descriptive results for LBT performance in accordance with the different line lengths.

Table 8 *Pseudoneglect performance and line length*

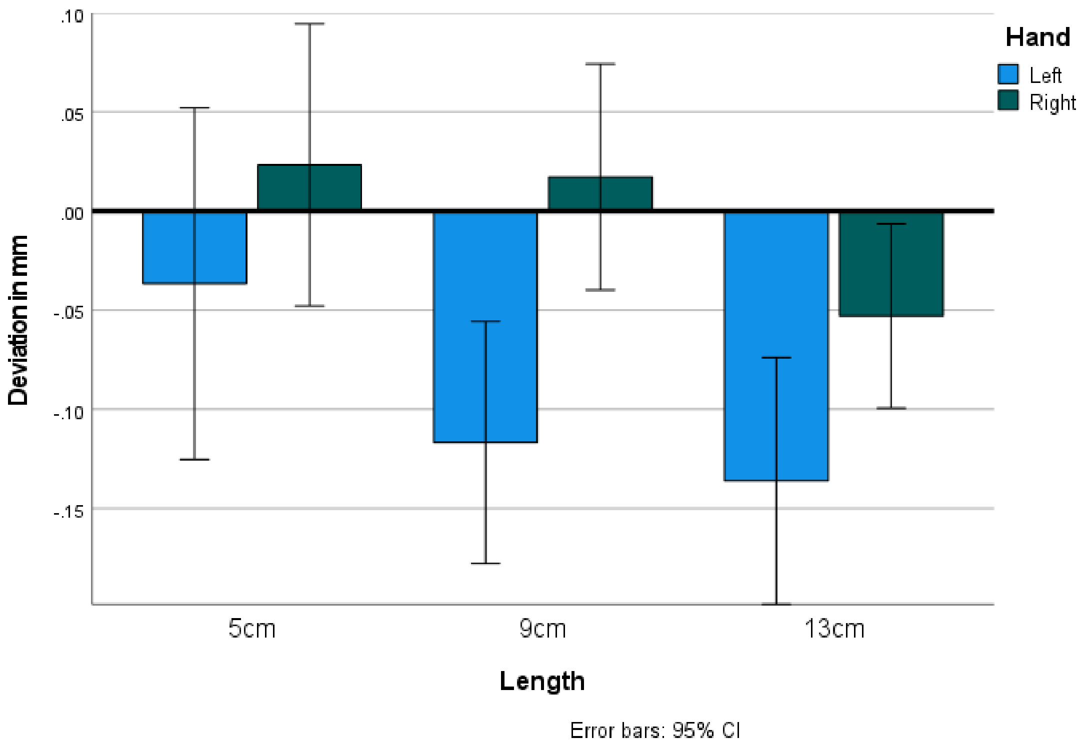
	Pseudoneglect	N	M	SD
LEFT HAND				
5cm Average	Y	35	-.04	.26
9cm Average	Y	35	-.12	.18
13cm Average	Y	35	-.14	.18
RIGHT HAND				
5cm Average	N	35	.02	.21
9cm Average	N	35	.02	.17
13cm Average	Y	35	-.05	.14

The average deviation for each of the three lines was calculated in the five different positions. The data shows that when the left hand was used all participants made leftward errors. In comparison, when the right hand was used only the longer line produced a leftward deviation while the shorter lines demonstrated rightward biases.

To determine the significance of hand use and LBT performance, based on line length, a two-way repeated measures ANOVA was conducted: 2 x 3, hand x line length for each of the different lengths. Sphericity has been violated for line length, the Greenhouse – Geisser values were used in this regard. The findings show a significant main effect for the hand used $F(1, 34) = 12.95$, $p = .00$, $\eta^2 = .277$, indicating a large effect size. A significant main effect for line length was also found $F(1.44, 48.88) = 4.81$, $p =.02$, $\eta^2 = .124$. The data show no significant interaction effects for hand use and line length: $F(2, 68) = 1.47$, $p = .237$, $\eta^2 = .234$, $\eta^2 = .04$. This result suggests a small effect size.

The LBT performance of participants in terms of line length was averaged for each of the different lines for both the left- and right-hand condition. Figure 10 shows the differences in pseudoneglect performance for the different line lengths in relation to the right and left hand. From the data it can be inferred that participant bisected the lines significantly different based on the length of the lines, regardless of the hand used for task performance. No significant interaction effects were found between line length and the hand used to complete the task.

Figure 10 *Pseudoneglect performance based on line length*



All the line lengths (5cm; 9cm & 13cm) demonstrated differences in performance and were bisected differently. The left-hand condition produced leftward errors, i.e., pseudoneglect for all three lines lengths compared to the average performance of the right-hand condition where only the 13cm line demonstrated a leftward bias.

5.4.3 LBT performance according to hand, line length and position.

The position of presentation also demonstrated differences in how the midpoint for each line was indicated. This means that participants bisected the three lines in each position differently. The assumption of sphericity was violated for hand, line and position, the corrected *F* value was consulted.

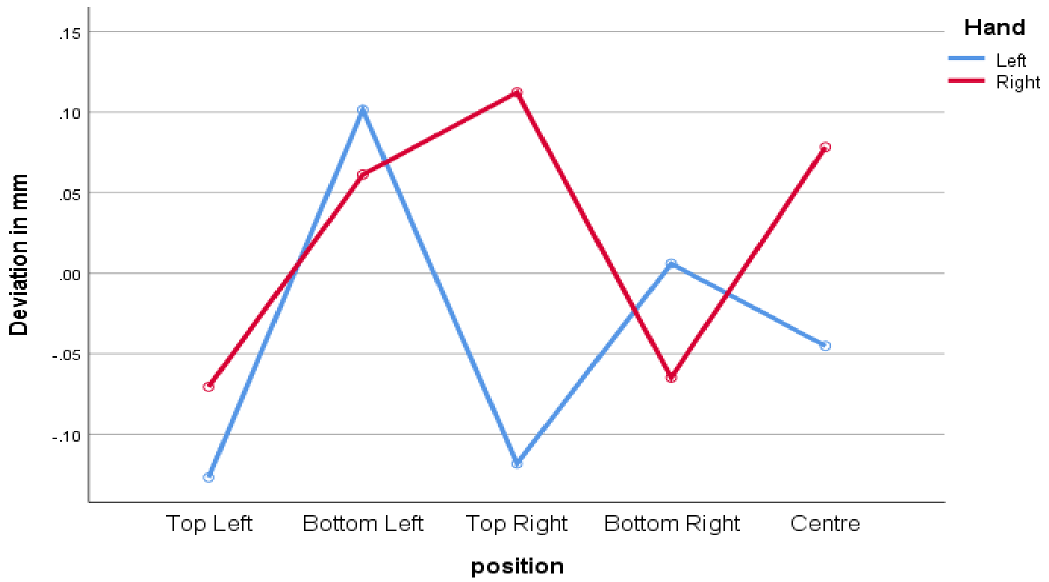
The data from the three-way repeated measures ANOVA (2 x 5 x 3, hand and position for each of the line lengths), show that there were no significant interaction effects between the right and left hand conditions and how participants bisected the different line lengths located in different position: $F(5.7, 193,7) = 1.211$, $p = .303$. Chapter 6 provides a more comprehensive discussion on the impact of line length and line position.

The graphs below provide information about the LBT performance based on hand use left (line blue) and right (line red) as well as the position of line presentation (Top Left; Top Right; Bottom Left; Bottom Right and Centre). Line 1 represents the 5cm condition; Line 2 the 9cm condition and Line 3 depict the data for the 13cm condition. Negative values indicate pseudoneglect i.e., deviation from the true midpoint towards the left.

<u>Referring to Figure 11: 5cm line</u>

- **Position 1 Top left:** participants demonstrated pseudoneglect with both hands
- **Position 2 Bottom left:** No pseudoneglect for right/left hand
- **Position 3 Top Right:** No pseudoneglect for the right hand. Pseudoneglect for the left hand
- **Position 4 Bottom Right:** Pseudoneglect for the right hand. No leftward bias when the left hand was used.
- **Position 5 Centre:** No pseudoneglect demonstrated for the right hand but when the left hand was used.

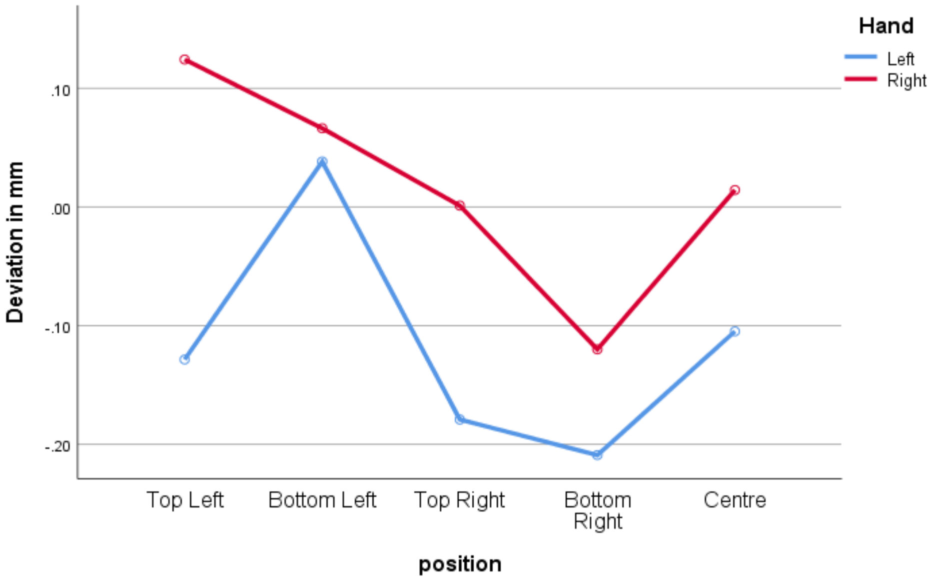
Figure 11 *Deviation for 5cm line based on position*



<u>Referring to Figure 12: 9cm line</u>

- **Position 1 Top left:** participants demonstrated pseudoneglect with left hand not the right
- **Position 2 Bottom left:** No pseudoneglect for right/left hand
- **Position 3 Top Right:** No pseudoneglect for the right hand. Pseudoneglect for the left hand
- **Position 4 Bottom Right:** Pseudoneglect for both the left and right hand.
- **Position 5 Centre:** No pseudoneglect demonstrated for the right hand but when the left hand was used.

Figure 12 *Deviation for 9cm line based on position*



<u>Referring to Figure 13: 13cm line</u>

- **Position 1 Top left:** participants demonstrated pseudoneglect with both hands
- **Position 2 Bottom left:** Pseudoneglect for the left hand but not the right.
- **Position 3 Top Right:** Pseudoneglect for both hands but the right hand demonstrated a smaller leftward bias.
- **Position 4 Bottom Right:** Pseudoneglect for both hands.
- **Position 5 Centre:** No pseudoneglect demonstrated for the right hand but when the left hand was used.

Figure 13 *Deviation of line 13cm based on position*

The data presented in the three graphs show that generally a stronger leftward bias was observed when the left hand was used i.e., the blue line. The findings also show more pronounced leftward errors as the lines become progressively longer. Left and right positions also had an impact on the extent to which lines were bisected but the interaction effects were not significantly different ($p > .05$).

5.4.4 Memory and Attention

a. Memory, Fixation and Gaze duration

To determine if more fixations to the left are linked to a higher memory score for items presented on the left a one-tailed bivariate correlational analysis was performed. The objective was to determine if a higher number of leftward fixations correlate with a higher memory score in the left memory condition. The total number of fixations was also correlated with the right – and total memory scores. The data revealed no significant correlations between the higher number of fixations and the items recalled on the left.

The data show no significant correlations between the number of fixations and the memory scores in each of the conditions ($p > 0.5$). Based on the findings, the total number of fixations is not related to the number of items recalled.

Similarly, the data show no significant correlations between gaze duration and the memory scores in each of the conditions ($p > 0.5$). Based on the findings, the duration of gaze did not seem to impact the memory encoding of the simulation items. Longer or shorter durations was therefore not significantly correlated with the number of items recalled. Although the data revealed no significant differences, the data suggest a negative correlation between the left memory condition and the total amount of right gaze duration ($r = .-25$, p (one-tailed) = .08). Longer gaze durations to the right thus suggests a lower recall for memory items on the left. No formal conclusions are made based on the current findings, but future research should explore this in more detail.

b. Memory and LBT performance

The eye-tracking data revealed that more fixations were made to the left and the memory results showed that more items located on the left side of the memory simulation was recalled. It was hypothesised that lateral biases, i.e., pseudoneglect should show a similar bias in memory. LBT results and the memory test scores were analysed by means of a regression analysis to determine the extent to which a leftward bias, i.e., pseudoneglect, impacts memory. The *b*-values provide an indication of the relation between the dependent variable, left memory scores and the predictor, LBT performance. Data show both negative and positive relations between LBT performance and memory. LBT performance in terms of line position and line length were compared with memory test results. Although the eye-tracking data supports a higher number of leftward fixations and the memory questionnaire produced a higher number of recalls for items on the left, the regression analysis did not reveal any statistically significant relations ($F(10, 24) = .583$, $p > .05$, $R^2 = .2$, $R^2_{adjusted} = -.14$.) between LBT performance and memory test results.

5.4.5 Gender and pseudoneglect

As secondary research questions, the researcher wanted to determine whether there were differences in pseudoneglect performance in relation to gender. This section provides an overview of the results based on male and female performance taking the different line lengths and different positions of presentation into account.

a. The effect of gender and line position

Table 9 and Table 10 provides the pseudoneglect performance for males and females based on the position of the lines. When the left hand was used leftward bisections were made by both males and females when lines were presented in the top left position as well as the bottom right, top right and centre positions. Females demonstrated a rightward bias when the lines were presented in the bottom left position. During the right-hand condition, pseudoneglect was observed for line positions top left and bottom right for both males and females. Male and female participants made rightward errors in the bottom left line position and females also produced rightward errors in the top right position and centre positions.

Table 9 *Gender and LBT performance based on line position: left hand*

	Gender	N	M	SD
Top Left	Male	12	-.18	.20
	Female	23	-.15	.18
Bottom Left	Male	12	-.02	.19
	Female	23	.06	.25
Bottom Right	Male	12	-.11	.18
	Female	23	-.15	.26
Top Right	Male	12	-.21	.20
	Female	23	-.13	.24
Centre	Male	12	-.01	.14
	Female	23	-.10	.20

Table 10 *Gender and LBT performance based on line position: right hand*

	Gender	N	M	SD
Top Left	Male	12	-.01	.23
	Female	23	-.07	.23
Bottom Left	Male	12	.02	.19
	Female	23	.06	.22
Bottom Right	Male	12	-.07	.20
	Female	23	-.10	.24
Top Right	Male	12	-.04	.19
	Female	23	.07	.21
Centre	Male	12	-.02	.13
	Female	23	.07	.15

The first comparison involved comparing LBT performance between males and females by taking the hand used into account. A two-way repeated ANOVA was performed: 2 x 5, hand and line position, for the males and females. The findings show that there was a statistically significant main effect for hand $F(1, 33) = 10.62$, $p = .00$, $\eta^2 = .244$, indicating a large effect size. A significant main effect was also observed for the position of the lines: $F(4, 132) = 6.59$, $p = .00$, $\eta^2 = .17$, demonstrating a large effect.

No significant interaction effect was observed for gender and line position: $F(4, 132) = 1.47$, $p = .216$, $\eta^2 = .04$. A significant interaction effect for hand and line position was observed: $F(3.02, 99.66) = 3.54$, p = .017, $\eta^2 = .10$. This means that there was a change in pseudoneglect performance when hands were changed, and where the lines were presented.

No significant interaction effect was found for gender and the hand used: $F(1, 33) =.13$, $p = .721$, $\eta^2 = .00$. Likewise, no significant interaction effects were observed between males and females with regard to the hand used and line position: $F(4, 132) = 2.07$, $p = .09$, $\eta^2 = .59$. There were no significant differences with male and female performance when either their left/right hand was used in relation to how the lines were bisected in the different positions. There were thus no differences in pseudoneglect performance when hand use and line position were considered. Given the small sample included in the current study, no definitive conclusions are reported. The findings suggest, overall, that gender did not impact the LBT performance ($p > .05$) in the current study sample.

Figure 14 and 15 below illustrate the interaction between gender and hand use for each of the five positions

Figure 14 *Gender and LBT performance based on line position with the left hand*

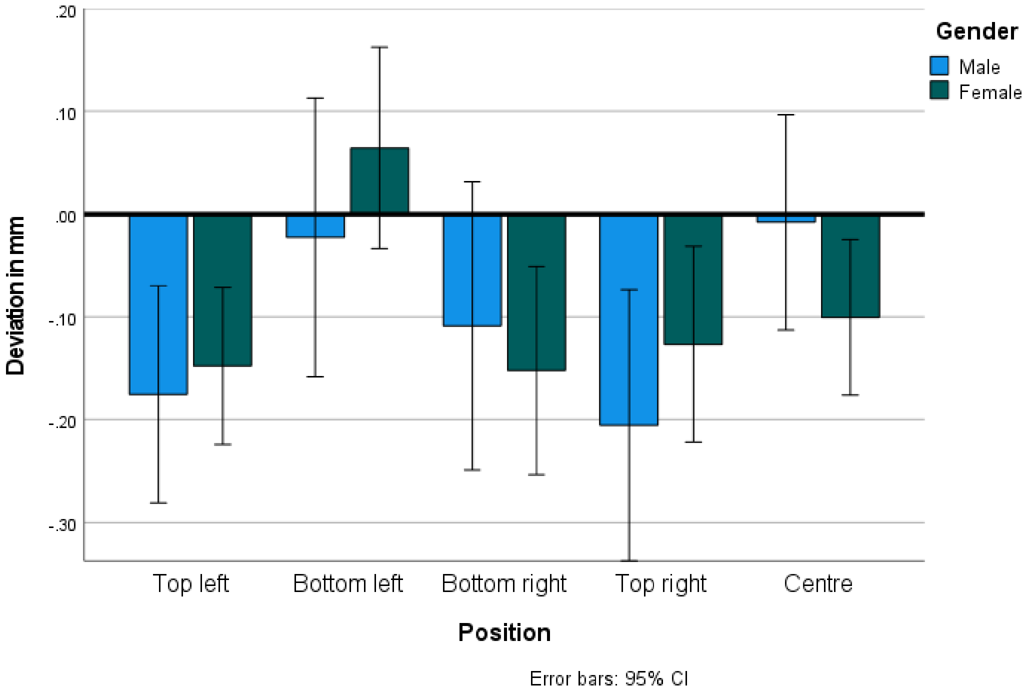
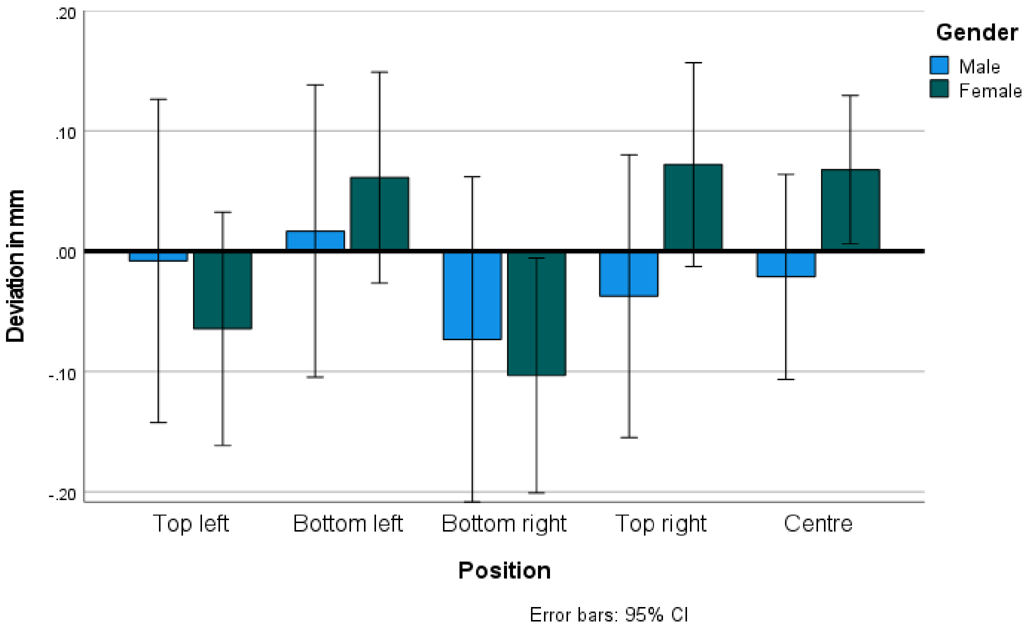


Figure 15 *Gender and LBT performance based on line position with the right hand*



b. The effect of gender and line length

This section provides the results for the impact of gender on the LBT performance taking the different line lengths into account.

Table 11 shows that when the left hand was used both male and female participants demonstrated pseudoneglect for all the different line lengths. Table 12 shows that only males produced a leftward bias for the 9cm line compared to females who made rightward errors when the right hand was used. For the 5cm line neither males, nor females demonstrated pseudoneglect. Leftward biases were, however, observed for the 13cm line for males and females.

Table 11 *LBT performance based on line length for males and females: Left hand*

	Gender	N	M	SD
5cm Average	Male	12	-.046	.20
	Female	23	-.032	.29
9cm Average	Male	12	-.15	.08
	Female	23	-.10	.21
13cm Average	Male	12	-.12	.16
	Female	23	-.15	.20

Table 12 *LBT performance based on line length for males and females: Right hand*

	Gender	N	M	SD
5cm Average	Male	12	.02	.16
	Female	23	.03	.23
9cm Average	Male	12	-.03	.17
	Female	23	.04	.16
13cm Average	Male	12	-.06	.10
	Female	23	-.05	.15

A two-way repeated measures ANOVA was conducted: 2 x 3, hand and line length for both males and females. Sphericity was violated for line length and the corrected Greenhouse-Geisser values were consulted. A significant main effect for hand was found: $F(1, 33) = 10.62$, $p = .00$, $\eta^2 = .24$, showing a large effect size. A significant main effect for line length was also found: $F(1.39, 46) = 4.01$, $p = .04$, $\eta^2 = .11$, indicating a large effect size.

The interaction between gender and line length was not significant: $F(2, 66) = .668$, $p = .516$, $\eta^2 = .02$. No significant interaction effect was observed for male and female performance with regard to line length and the hand used to complete the task: $F(2, 66) = .127$, $p = .88$, η2 = .00. The length of the lines and the hand used to complete the task was therefore not significantly influenced by gender.

Based on the statistical analysis, the data show that no significant gender differences were found in the present study. Given the small sample size, no definite conclusions are made based on the present findings. The results suggest that gender differences are evident when the length of lines are considered, but more research is needed.

Figure 16 and 17 below illustrate the LBT performance for males and females for the right and left hand, and the different line lengths.

Figure 16 *LBT performance for males and females based on line length: Left hand*

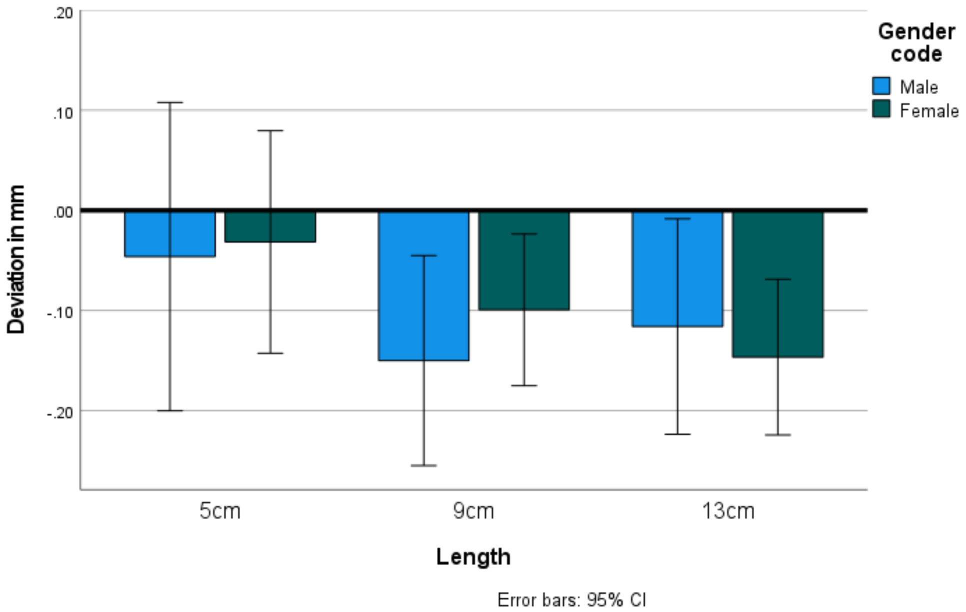
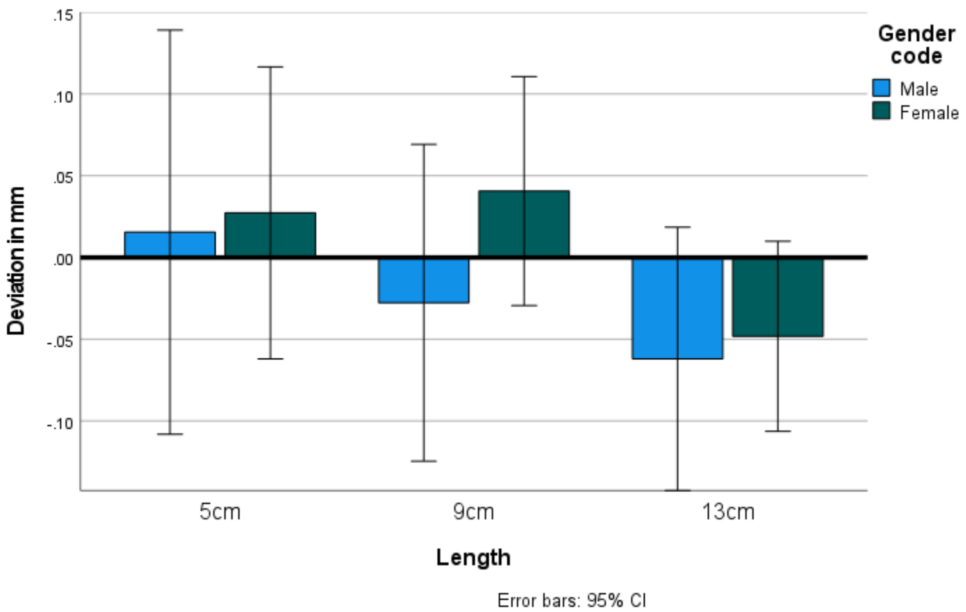


Figure 17 *LBT performance for males and females based on line length: Right hand*



5.4.6 Age and pseudoneglect

It is noted that currently not much is known about the impact of ageing on spatial attention (Märker et al., 2019). Chapter 2 provided literature that supports possible differences in the demonstration of pseudoneglect in terms of age. Some studies find support for age-related differences while others fail to replicate the findings. Märker et al. (2019), reported that young adults show a preference for the left side, while older adults show no inclination or a stronger rightward bias. Likewise, Learmonth et al. (2017), reported leftward attentional biases in young adults while older adults tended more towards the right. Friedrich et al. (2018) motivated future research to include smaller age range groups. Forte (2016) and Friedrich (2018) reasoned that the debate and inconsistency in literature warrant more age-related research with pseudoneglect demonstration.

The present study only consisted of 35 participants. As a result, the statistical analysis and resulting interpretation of age and pseudoneglect will be used to direct future research as the current study is underpowered in relation to between subjects comparison. The assumptions made based on the current study findings are thus tentative and should be interpreted within the limited study sample. Table 13 details the number of participants in each age category.

Due to the small sample only two age categories were defined:

- Younger adults = 18 to 35
- Older adults = 36 to 60

Table 13 *Age categories*

Age classification	n	%
Younger adutls	23	65.7
Older adults	12	34.3

a. Age and line position

The first section discusses the LBT data from the different age groups in relation to line position followed by a discussion on LBT performance in terms of the different line lengths.

The data in Table 14 and Table 15 provide the extent of pseudoneglect in relation to younger – and older participants, based on the position of the lines. Referring to the left-hand condition, pseudoneglect was observed in both young and old participants, for all the line positions, excluding the bottom left line. A rightward bias was demonstrated by older adults with the bottom left line.

Table 14 *LBT performance based on line position and age: Left hand*

	Age	N	M	SD
Top Left	Young	23	-.14	.18
	Old	12	-.18	.18
	Young	23	-.001	.25

	Age	N	M	SD
Bottom Left	Old	12	.10	.17
Bottom Right	Young	23	-.13	.21
	Old	12	-.16	.29
Top Right	Young	23	-.15	.20
	Old	12	-.17	.28
Centre	Young	23	-.07	.14
	Old	12	-.06	.25

Referring to the right-hand condition (Table 15) rightward errors were observed for both young and old age groups when the lines were presented in the bottom left; top right, and centre position. Leftward biases were found, for both young and old participants, with the lines in the top left and, bottom right positions.

Table 15 *LBT performance based on line position and age: Right hand*

	Age	N	M	SD
Top Left	Young	23	-.03	.23
	Old	12	-.08	.23
Bottom Left	Young	23	.06	.20
	Old	12	.02	.22
Bottom Right	Young	23	-.06	.20
	Old	12	-.15	.28
Top Right	Young	23	.03	.20
	Old	12	.05	.22
Centre	Young	23	.10	.15
	Old	12	.071	.16

To determine the significance of LBT performance within the young and old age groups, a two-way repeated measures ANOVA was conducted: 2 x 5, hand and line position for each age group. No significant interaction effect was found for the different age categories and the presentation of line position: $F(4, 132) = .908$, $p = .46$, $\eta^2 = .027$. No significant interactions were found for hand used, the position of the lines and the different age categories: $F(4, 132) = 1.16$, $p = .33$, $\eta^2 = .03$. There was no significant interaction between the hand used and the different age categories: $F(1, 33) = .257$, $p = .62$, $\eta^2 = .01$.

Based on the current results age did not significantly impact the way participants bisected the lines based on the different line positions. There were no differences found between younger and older participants with regard to the hand used for task completion. The small sample size, and the restricted age range, limits the extent to which the present findings can provide conclusive results. A larger sample within each age category is needed.

Figures 18 and 19 provide a graphical presentation of the findings. Figure 18 refers to LBT performance based on the different line positions using the left hand. Figure 19 presents the data for the right-hand condition.

Figure 18 *LBT performance between different age groups: Left hand*

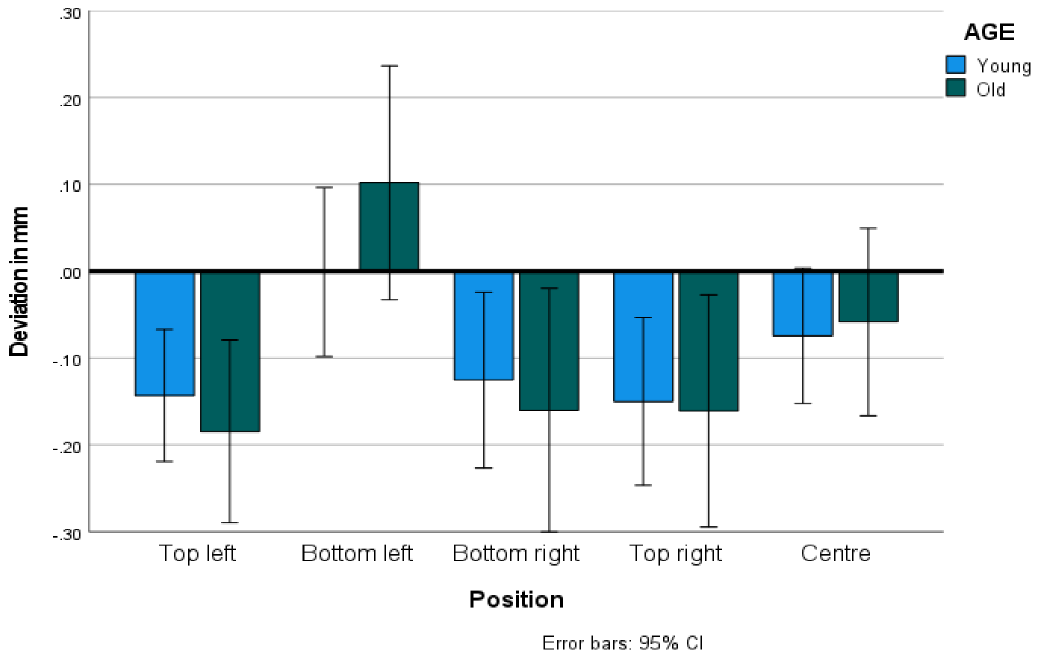
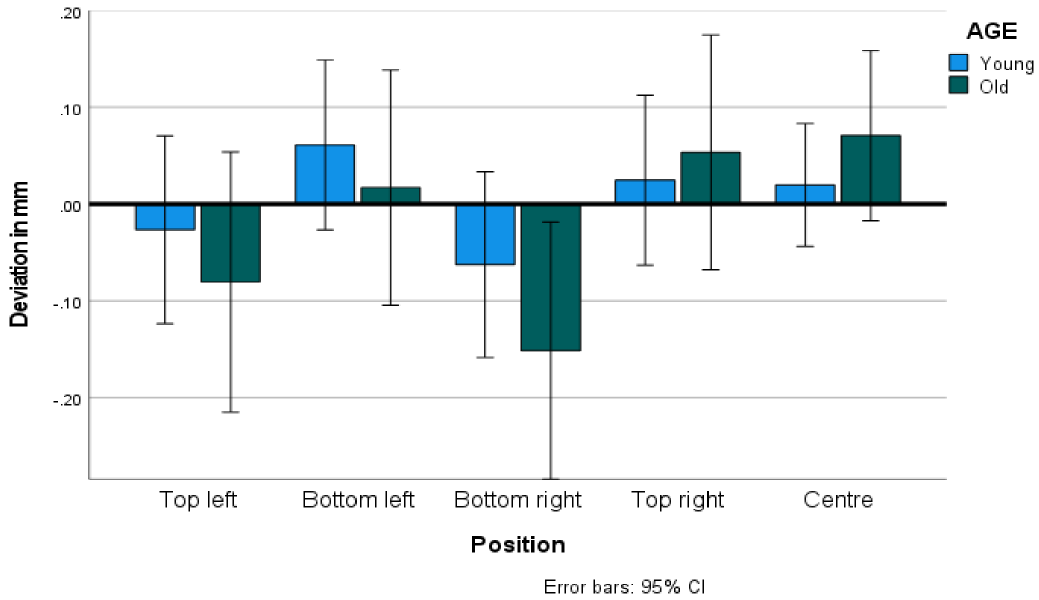


Figure 19 *LBT performance between different age groups: Right hand*



b. Age and line length

This section provides the findings for the impact of age on pseudoneglect performance with regard to the different line lengths. As discussed, three different line lengths were assessed in the present investigation. The average deviation measured in mm was calculated for each line for both the left- and right-hand conditions.

Table 16 shows the left-hand condition. Leftward biases were observed for all the line lengths for the younger participants. The older participants also demonstrated pseudoneglect with the 9cm line, and the 13cm line. The 5cm line was, however, bisected slightly more towards the right. Referring to the right-hand condition (Table 17), only the longer 13cm line produced leftward errors for both young, and older participants. The shorter lines were bisected more toward the right of the midpoint, by both young and old participants, when the right hand was used. A more comprehensive discussion is offered in chapter 6, but research suggest that longer lines produce more leftward errors compared to shorter lines.

Table 16 *Pseudoneglect performance for the different age groups in relation to line length: Left hand*

	Age	N	M	SD
5cm Average	Young	23	-.10	.27
	Old	12	.0002	.25
9cm Average	Young	23	-.12	.17
	Old	12	-.11	.20
13cm Average	Young	23	-.12	.17
	Old	12	-.17	.21

Table 17 *Pseudoneglect performance for the different age groups in relation to line length: Right hand*

	Age	N	M	SD
5cm Average	Young	23	.02	.16
	Old	12	.04	.29
9cm Average	Young	23	.02	.15
	Old	12	.01	.20
13cm Average	Young	23	-.03	.12
	Old	12	-.11	.16

To determine the significance of pseudoneglect, based on line length, and age, a two-way repeated measures ANOVA was conducted: 2 x 3, hand and line length for both younger and older age groups.

The data show no significant interaction effects for the different line lengths and age categories $F(2, 66) = 1.55$, $p = .22$, $\eta^2 = .045$. This means that young and older participants did not bisect the lines significantly different when the line length was considered. No significant interaction effect was observed for the different age groups based on line length and hand use: $F(2, 66) = .013$, $p = .987$ $\eta^2 = .00$.

Figure 20 below shows the different age groups with regard to LBT performance based on line length for the left hand. Figure 21 shows the interaction of the different age categories during the right-hand condition.

Figure 20 *Pseudoneglect performance based on line length for different age groups: Left hand*

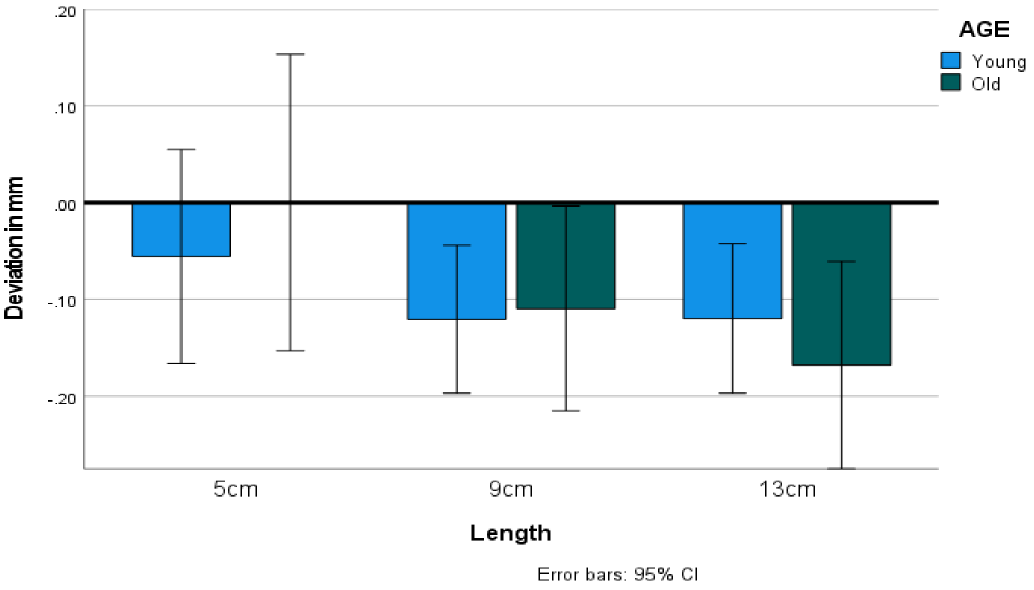
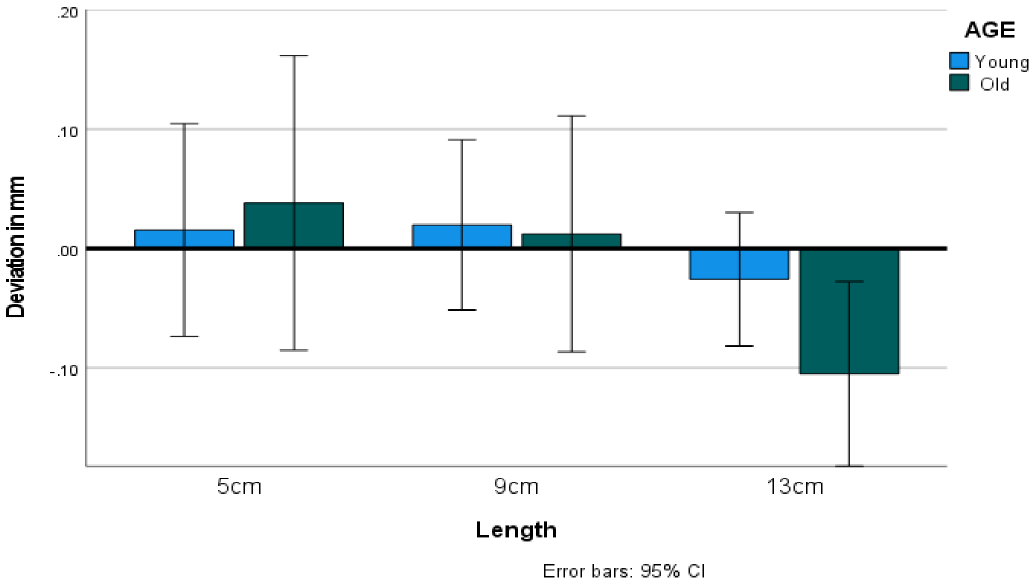


Figure 21 *Pseudoneglect performance based on line length for different age groups: Right hand*



No significant interactions were observed for the different line lengths and age. Older and younger participants thus bisected the lines similarly when different line lengths were considered. No conclusive arguments are provided based on the current findings. The number of participants in each age group is limited, as a result, no definitive conclusions are reported. Differences in LBT performance given line length was observed, with longer lines, but more research is needed to explore this finding.

5.5 CONCLUSION

This chapter provided the data obtained from the study based on the quantitative data analysis. In this chapter, the researcher firstly described the study sample. The memory scores for the participants, in relation to the memory simulation, were discussed. The memory scores were used as a means to determine if more items presented on the left were remembered, compared to what was presented on the right side during the memory simulation. The dependent sample *t*-test showed that there were significant differences between the average memory performance of participants in the left and right memory conditions. Participants recalled more of the items presented on the left compared to the right.

Eye-tracking data was reported in terms of the average gaze duration and the total number of fixations and was used as a measure of attention. The gaze duration data did not yield any significant differences in terms of left and right gaze patterns. The data showed no significant differences between the overall left and right fixations but the results showed a significant interaction effect when the slides and left vs. right fixations were compared. The number of fixations per slide was different for left and right fixations. Accordingly, it is argued that the findings show that participants demonstrated significantly different fixation patterns given the slide content and the number of left and right fixations. Generally, more leftward fixations were observed.

Pseudoneglect was measured using the LBT. Overall, pseudoneglect was demonstrated by all the participants. This means that participants consistently bisected the lines more to the left of the true centre. The position of line presentation produced a significant main effect for pseudoneglect performance and a significant main effect was found for line length. The data showed that the hand used for task completion produced a significant main effect on LBT performance for line position. The hand used to complete the LBT according to the different line lengths, however, did not produce significantly different results. Descriptive data from the left-hand condition indicated a larger magnitude of pseudoneglect when compared to the right hand. A significant interaction effect was also found for the hand used, and both the position of the lines and the length of lines. Handedness therefore significantly influenced LBT performance.

Correlational analysis revealed no significant relations between the number of fixations, gaze duration, and memory performance. Similarly, there was no relation between memory performance and LBT performance. This suggests that despite the higher number of leftward fixations, and the higher number of left-sided items recalled, a leftward attentional bias does not impact memory.

The data were analysed to determine whether any gender differences were found. The data revealed the magnitude of leftward biases demonstrated by male and female participants based on their LBT performance. The results showed that no significant differences were observed with regard to the pseudoneglect performance between males and females. Similarly, no significant interaction effects were observed for the LBT performance in relation to line position and age, or, line length and age. No conclusive arguments regarding age and gender, concerning pseudoneglect performance in the current study, are reported due to the small sample size. The study sample is inadequate and underpowered for making between subjects comparisons. The data may, however, contribute to guiding future research.

The interpretation of the findings is discussed in the next chapter along with the limitations of the present study and recommendations for future research.

CHAPTER 6 INTERPRETATION AND DISCUSSION

This chapter includes a discussion of the interpretation of the research findings as documented in Chapter 5 and aims to answer the research questions outlined in Chapter 1. The last part of the chapter is dedicated to delineating the limitations, conclusion, and recommendations pertaining to the study.

This chapter attempts to answer the primary and secondary research questions by taking the aim and objectives into account. The findings will be discussed in different subsections followed by a final concluding section.

The first part of the chapter provides a discussion on the nature of pseudoneglect observed in the present study sample. This section includes a discussion on the effect of handedness. Differences in male and female performance are covered. Although the small sample size prevents making any conclusions based on age, a discussion on the present study findings related to age and pseudoneglect is included. A discussion regarding the eye-tracking data and findings is also provided. The impact of pseudoneglect on attention and VLTM is comprehensively described before a conclusion is offered.

The last part of the chapter includes the limitations of the study and recommendations for future research. The section concludes with the significance of the present study.

6.1 THE MAGNITUDE OF PSEUDONEGLECT

The present investigation was motivated by the need to explore the impact of a leftward bias, as demonstrated by pseudoneglect, on attention and memory. The underlying view is that healthy individuals may recall more items from the left hemifield due to the tendency to exhibit a stronger focus to the left during the allocation of attention. Young adults, in particular, tend to focus more on the left side of space, resulting in advantageous processing of left-sided stimuli (Märker et al., 2019). Given the intricate relation between attention and memory, the prominent focus on the left can impact the encoding process.

LBT has made important contributions to understanding the mechanisms of visuospatial and perceptual biases (Brignani et al., 2018; Mitchell et al., 2020; Szelest, 2014; Zago et al., 2017). Patients with unilateral neglect tend to make rightward errors, which means that they indicate the centre of the line more to the right (Nicholls & Roberts, 2002; Ribolsi et al., 2013). Neurologically normal participants, on the other hand, tend to bisect the line more towards the left of the midpoint, demonstrating a leftward bias i.e., pseudoneglect (Brodie, 2010; Forte, 2016; Foulsham et al., 2013; Hatin et al., 2012; Hausmann et al., 2003; Mitchell et al., 2020; Nicholls & Loftus, 2007; Nicholls et al., 2008; Ribolsi et al., 2013; Toba et al., 2011). Jewell and McCourt (2000) emphasised various research findings (Benwell et al., 2013; Brodie, 2010; Brooks, 2014; Foulsham et al., 2013; McGeorge et al., 2007; Schmitz et al., 2011; Szelest, 2014; Toba et al., 2011; Zago et al., 2017) concerning the demonstration of pseudoneglect, where neurologically healthy individuals consistently demonstrate a leftward tendency when asked to bisect the midpoint of horizontally presented lines. Eardley et al. (2017) and Märker et al. (2019) attribute this leftward attentional bias as a disturbance in the distribution of spatial attention.

There is sufficient research to support the demonstration of pseudoneglect (Brignani et al., 2018; Brignani et al., 2018; Bultitude & Aimola Davies, 2006; Failla et al., 2003; Hausmann et al., 2002; Jewell & McCourt, 2000; Varnava et al., 2013) but the nature of the lateral bias seems to differ based on numerous elements, one of the most prominent being handedness (Eardley et al., 2017). To determine the impact of pseudoneglect on memory, the researcher demonstrated the extent to which the participants exhibited a leftward bias based on various conditions including handedness; line length, and line position.

The first section will cover the impact of handedness followed by the influence of line position and length.

Referring to the findings presented in chapter 5, the participants demonstrated a leftward bias with most of the lines bisected. Line position, as well as line length, influenced LBT performance. Participants demonstrated pseudoneglect by bisecting lines more towards the left of the true midpoint.

a. Pseudoneglect and handedness

Chapter 2 highlighted that the demonstration of pseudoneglect is mediated by various factors, of which handedness is important. In relation to the present study sample, the majority of the participants were right-handed. Given the dominance of the right hemisphere with visuospatial tasks (Benwell et al., 2013; Benedett et al., 2013; Bultitude & Aimola Davies, 2006; Helfer, et al., 2020; Hatin et al., 2012; Hausmann et al., 2003; Hausmann et al., 2002; Learmonth et al., 2017), it is argued that participants should, theoretically, demonstrate a stronger leftward bias when the left hand is used. The activation-orientation hypothesis similarly maintains that right hemisphere activation is associated with a stronger leftward bias.

As discussed in Chapters 2, a negative value indicates a deviation towards the left from the true centre, i.e., pseudoneglect. The average score for the three lines, demonstrated in various positions, was calculated as a measure of pseudoneglect for both the right and left hands. The descriptive statistics show that participants demonstrated pseudoneglect when the left hand was used in four of the five line positions. When the left hand was used to bisect the three lines in each of the different positions, a leftward deviation was observed. A rightward bias was found when the lines were presented in the bottom left position. Supporting the assumption maintained by the activation-orientation hypothesis. When stimuli are presented on the left, and the left hand is used to complete the task, stronger activation of the right hemisphere is observed which should result in a more prominent leftward bias as assumed by the activation-orientation hypothesis (Kinsbourne, 1970; Lee et al., 2004; Szelest, 2014; Varnava et al., 2013). This was evident for most line positions, except the bottom left position. It is not clear why a rightward tendency was observed in this regard, but given that the majority of the sample is right-handed, the orientation of using the left hand to complete the task might have influenced how the lines in this position were bisected.

The right hand would activate the left hemisphere, and it is expected to mitigate the extent of pseudoneglect. The findings show that a leftward deviation was observed for only two of the position conditions, the top left and bottom right. When the lines were presented in the bottom left position, top right, and centre positions, rightward errors were made when the right hand was used. Lee et al. (2004) found similar results. Bultitude and Aimola Davies (2006) explained that the magnitude of pseudoneglect is alleviated by factors that minimise the activation of the right hemisphere, including using the right hand to complete tasks.

Based on the findings, the hand used influenced the LBT performance of participants producing a significant interaction effect for line position that demonstrated a large effect size. A significant main effect for the hand used to complete the task was also found. The position of line presentation was, therefore, significantly influenced by the hand used to complete the task. Considering the length of the lines, the hand used for task completion produced a significant main effect, but no significant interaction was observed.

Participants thus bisected the lines differently depending on the hand that was used for the five different positions, but hand use did not seem to impact pseudoneglect performance when the line lengths differed.

The lines of the LBT were positioned in various locations as research shows that the location of line presentation can influence how the lines are bisected (Hausmann et al., 2002; Märker et al., 2019; Mitchell et al., 2020; Reuter-Lorenz et al., 1990; Szelest, 2014).

b. Pseudoneglect and the position of line presentation

Hausmann et al. (2002) argued that the position of lines to be bisected can impact the extent of pseudoneglect. In order to determine whether lines are bisected differently depending on the position, the lines were presented in five different positions. Bultitude and Aimola Davis (2006) reported that the position of lines appears to impact the demonstration of the leftward error, as a result, Hausmann et al (2002) placed seven lines in the middle of the paper, five lines near the left, and five lines near the right margin. Similarly, Mitchell et al. (2020) had participants bisect lines presented either in the centre of the screen or 20mm to the left or right of the screen. The present study, as discussed in chapter 4 section 4.5 (b), included several lines in different positions of presentation. Pseudoneglect performance, based on line position, was measured by averaging the deviation scores from participants for the three lines.

In order to establish the impact of line position on participants' LBT performance the data was analysed to ascertain whether an interaction exists between the hand used to complete the task and the position of line presentation. A significant main effect was observed for line position and it is argued that the position of the lines, left vs. right and top vs. bottom, significantly influenced the nature of the deviation produced by participants. The deviation demonstrated a large effect size. Changes in line position, therefore, influenced the observed deviation from the true midpoint. Hausmann et al. (2002) found similar results where line position impacted significantly on how participants bisected the lines. Lines positioned to the left produced a stronger leftward bias as explained by the activation-orientation theory. Bultitude and Aimola Davies (2006) reported similar findings. As described, the left visual field is strongly linked to global attentional processing compared to the right visual field, which is linked to local processing (Brederoo et al., 2017). The right hemisphere has a processing advantage of left visual field stimuli and vice versa. The present study produced leftward biases for lines presented in the top left position, in agreement with stronger activation of the right hemisphere. The bottom left position did not yield a leftward bias, although it was presented to the left, which should theoretically, have produced a stronger leftward bias. The attentional features of the bottom left position may have been processed differently, thereby resulting in a rightward error instead (Brederoo et al., 2017).

A more detailed exploration of line positions shows a significant difference between the two lines presented in the *top left* and *bottom left* conditions. The results also showed a significant difference between two lines presented in the *bottom left* and *bottom right.* Significant differences were also found when the *bottom right* and *centre* lines were compared. Based on the present findings, the researcher notes that the position of the lines had a significant impact on how participants bisected the lines. Differential LBT performance for top and, bottom line positions may be related to the neural mechanisms activated during task performance. Chen, Lee, O'Neil, Abdul-Nabi, and Niemeier (2020) emphasised the importance of the right hemisphere in spatial attention and explained that specific regions in the right "…ventral parieto-temporal and frontal cortex" (p.1) become active where actions warrant attention to identify objects based on stimulus features, i.e. bottom-up processing. The same regions are activated when attention is re-directed to different locations (Chen et al., 2020). It is thus possible that given the top or bottom positions of the lines, different brain regions may be activated thereby producing different attentional biases. Milano et al. (2014) explored changes in vertical – and horizontal pseudoneglect. Differences were found in how the lines were bisected vertically vs. horizontally. This may also suggest differences in how lines in top and bottom positions are bisected.

Participants bisected the lines differently when different hands were used for different line positions, as indicated by the significant interaction effect for the hand used. Referring to the data, pseudoneglect was observed for the left hand when lines were presented in the TL, BR, TR, and C positions. According to the activation-orientation theory the results are expected since the left hand and left position presentation activates the right hemisphere (Bultitude & Aimola Davies, 2006; Chen et al., 2020). Szelest (2014) argued that right-handed participants show a higher degree of pseudoneglect compared to left-handed participants, especially when using the left hand to perform the task (Brignani et al., 2018; Brookes et al., 2014; Failla et al., 2003). The bottom left condition, as noted, did not produce a leftward bias. This may be due to the right hemisphere's ability to distribute attention to both hemifields as Porac et al. (2006), and Siman-Tov et al. (2007) maintained. It may also be related to global and local attentional stimuli processing. The rightward bias may result from processing direction during initial processing (Reuter-Lorenz et al., 1990; Szelest, 2014), or due to different neural activation (Chen et al., 2020).

In terms of right-hand performance, pseudoneglect was only observed with the TL and BR positions. As discussed, the right hand may produce more prominent activation of the left hemisphere, thereby minimising the observed leftward deviation resulting in a rightward bias instead. Changing the activation of the hemispheres thus influences the extent to which participants produce left, or right deviations (Lee et al., 2004; Varnava et al., 2013). The current findings are thus in agreement with previous research and the researcher documents that pseudoneglect performance was influenced by both hand use and the position of the lines with left-hand conditions, and left position presentation producing more salient leftward biases. Even with a small sample such as in the present study, the influence of line position and hand-use were confirmed, which appears to illustrate the robustness of the phenomenon.

Various theoretical assumptions have been proposed to explain pseudoneglect, generally grounded in hemispheric lateralisation. Each hemisphere is specialised for specific functions (Asanowicz et al., 2017; Brederoo et al., 2017), and each hemisphere contributes to attentional processing. In relation to attention, it is reasoned that the right hemisphere may be mediating the allocation of attention for both hemifields (Bultitude & Aimola Davies, 2006; Nicholls et al., 2004; Niemeier et al., 2008). The left hemisphere is assumed to play a prominent role in processing local stimuli features, while the right hemisphere is linked to processing global stimuli features. Left visual field presentation is thus associated with global attentional processing, and the right visual field is linked to stronger local stimuli processing (Brederoo et al., 2017). The Right-Hemisphere Dominance hypothesis, for example, maintains that pseudoneglect is due to prevailing orienting preferences for attention in the right hemisphere, contributing to a more pronounced representation of the opposite side, i.e., the left (Asanowicz et al., 2017; Mitchell et al., 2020). Alternatively, the Interhemispheric Competition hypothesis proposes that both the left and right hemispheres compete for superiority of spatial attention (Mitchell et al., 2020). As a result, asymmetries in attention are determined by the most active hemisphere. Local vs. global attentional processing of visual stimuli is therefore important and determined by the most active hemisphere.

The LBT is described as a visuospatial task, and the right hemisphere is activated, especially when the left hand is used for task completion. The prominent involvement of the right hemisphere in the LBT, as a visuospatial task (Brederoo et al., 2017), is highlighted and tasks that activate the right hemisphere can enhance the magnitude of the leftward bias. Placing lines in the left hemifield should theoretically produce a stronger deviation to the left due to right hemisphere activation, and lines presented in the right hemispace should then increase left hemisphere activation and mitigate the effect of pseudoneglect (Asanowicz et al., 2017; Porac et al., 2006; Siman-Tov et al., 2007; Szelest, 2014).

c. Pseudoneglect and line length

As described, three different line lengths were presented in different positions. The purpose was to establish whether different line lengths influence the magnitude of pseudoneglect.

Based on the findings, the descriptive data revealed that the length of the lines had an impact on how participants bisected the lines. Differences were observed in LBT performance given different line lengths. Benwell et al. (2014) describe this as a line-length effect.

The different line lengths had an impact on the observed deviation when participants were asked to indicate the midpoint. LBT performance in accordance with the different line lengths is based on the average deviation for each of the three line lengths. As detailed in chapter 5, when the left hand was used all three lines were bisected towards the left. When the right hand was used, only the longer 13cm line produced a leftward deviation, while the shorter lines demonstrated rightward biases. Benwell et al. (2014) found similar results explaining that overall left biases were found with long lines but not with short lines. The lines were bisected differently producing pseudoneglect, as supported by the significant main effect for line length that demonsrated a large effect size. Similarly, a significant main effect for the hand used was found for the LBT given the different line lengths, but no significant interaction effect was found. Performance based on the different line lengths thus produced significant differences in line bisection, but whether the left or right hand was used, did not yield differences in performance.

McCourt and Jewell (1999) and Loftus et al. (2009) explained that participants tend to demonstrate a more pronounced leftward tendency when the length of lines is increased. Neglect patients tend to bisect longer lines to the right, and shorter lines to the left of the centre. Errors with regard to indicating the midpoint seem to increase as line length increased. Line length can therefore significantly impact the bisection performance of participants (Harvey et al., 1995; Varnava & Halligan, 2007). More leftward errors were observed as lines became longer and to a greater extent when presented in the left hemispace (Luh, 1995). In the current study, pseudoneglect was observed for all the different line lengths when the left hand was used. More rightward errors were found when the right hand was used. Similarly, Manning et al. (1990) reported that some subjects made rightward errors and others showed stronger leftward tendencies but the magnitude of error increased in relation to line length. Manning et al. (1990), however, reported leftward errors with short lines and rightward errors with long lines, and no errors with medium length lines. In contrast to Manning et al. (1990), the current study findings found leftward biases for longer lines and rightward errors for shorter lines when the right hand was used. Misbisection errors appear to be more towards the right when long lines are presented but others found the opposite with leftward errors being more pronounced with medium to longer lines, as is the case in the present investigation.

It was reported that starting the line bisection task on the left side of space resulted in a greater degree of error towards the left compared to starting the task on the right (Brookes et al., 2014; Varnava et al., 2013). Chieffi et al. (2014) used a distractor when assessing LBT performance by placing a distractor on either the left or right end of the line. The findings show that attention was directed to where the distractor was placed, influencing LBT performance. In the present investigation a slider was placed on the left side and participants had to indicate the midpoint for each line by simply ticking the centre of the line and the slider moved automatically. As described in chapter 4, section 4.5, participants were not expected to move the slider. Although it is possible that the slider directed their initial scan path from left to right consequently impacting the resulting bias. The request not to move the slider may have alleviated the initial leftward focus.

In relation to line length and position of presentation, the findings revealed varied pseudoneglect performance. The findings show that on the short (5cm) line using the left-hand pseudoneglect was evident when lines were presented in the TL, BR, and C positions. During the right-hand condition, pseudoneglect was demonstrated when the 5cm line was presented in the TL, and TR positions. The 9cm line revealed a leftward bias when the left hand was used in the following positions: TL, TR, BR, and C. When the right hand was used to bisect the 9cm line, a leftward bias was observed only when lines were presented in the TR position. The 13cm line was bisected more towards the left when the left hand was used in all five positions. The longer line thus showed a more prominent leftward bias compared to the shorter lines, which is in agreement with previous findings (Manning et al., 1990; Luh, 1995). Varnava and Halligan (2007) reported similar findings as their results demonstrated that the degree of error increased as the lines became longer. In the present study, when the right hand was used to bisect the 13cm line, pseudoneglect was observed in the TL, TR, and BR positions.

Based on the findings in relation to LBT performance, the researcher concludes that pseudoneglect was demonstrated by all participants, especially when the left hand was used. Both line position and length significantly influenced the observed leftward errors. Accurately perceiving visual space is necessary for daily functioning and the prominent focus on stimuli located to the left has several implications. Considering online course design, content should ideally be positioned in the upper left space. Istrate (2009) also highlighted the significance of the upper left area. Similarly, Zheng et al. (2020) explained, the positioning of traffic signs is important for guiding spatial attention.

d. Gender and pseudoneglect performance

The impact of various factors on the demonstration of attentional biases was noted and Varnava and Halligan (2007) emphasised the bearing role of gender in cognitive processing and behavioural performance. Similarly, Forte (2016) and Friedrich (2018) highlight the inconsistent findings regarding differential pseudoneglect performance amongst males and females.

The current study sample is too small to make any definitive conclusions, but pseudoneglect performance on the LBT for gender was compared. No significant interaction effects were found for gender and LBT performance based on line length or position. Male and female participants did not bisect the lines of different lengths or positions differently. The findings showed a large effect size based on the eta squared results when line position was considered but a small effect size was found for line length and gender.

Although no significant differences were found between male and female performance, the data revealed differential leftward biases when line position was considered. When the left hand was used, leftward bisections were made by males in all positions of presentation. When the left hand was used, leftward errors were found by females when lines were presented in all the positions except the bottom left, where rightward errors were made.

When the right hand was used, male LBT performance showed leftward errors for all the line positions except the bottom left, where rightward biases were observed. Females made leftward errors with the right hand when lines were presented in the top left and bottom right positions. Rightward biases were found when females bisected lines in the bottom left, top right, and center positions when the right hand was used. Both males and females produced rightward errors when the right hand was used to complete the bottom left line. The line is presented in the left visual field which activates the right hemisphere. According to the activation-orientation hypothesis, this should elicit a stronger leftward error. As noted, different neural mechanisms may be activated if attention is oriented to various positions (Chen et al., 2020), thus producing differences in how lines are bisected in top vs. bottom positions.

The findings may show that different left- and right biases were observed between males and females based on line position but the differences were, however, not statistically significant. No formal conclusions are therefore made regarding the differences observed.

In relation to line length, males and females demonstrated pseudoneglect for all three line lengths when the left hand was used. Only males produced a leftward error when the right hand was used for the 9cm line, while females bisected the line more towards the right of the true centre. The shorter line did not reveal any leftward biases for either males or females but the longest line did produce a leftward tendency for both males and females. Line length did produce different magnitudes of pseudoneglect for males and females although the differences were not significantly different. No significant interaction effects were thus found between gender and LBT performance based on line length. Although the small sample size prevents formal conclusions, the data revealed interesting differences in pseudoneglect performance for males and females.

Controversial results have been reported regarding the effect of gender on the leftward tendency (Forte, 2016; Friedrich, 2018; Hausmann et al., 2003). The researcher endeavoured to describe potential differences between male and female participants in their demonstration of pseudoneglect despite the small sample obtained. Research findings generally suggest differences in LBT performance with males making larger leftward errors in comparison with females (Jewell & McCourt, 2000). Similar findings were found in the present study, where males exhibited more leftward errors compared to females. Although the findings are inconclusive, they suggest that it may be meaningful for future research to further explore significant differences in LBT performance between males and females.

Varnava and Halligan (2007) investigated the impact of age and gender on LBT with a sample consisting of men and women requested to bisect 15 horizontal lines. According to the findings, older women showed a larger leftward error when lines became longer. Younger women were prone to leftward errors with all line lengths. Men demonstrated pseudoneglect when shorter lines were bisected, and both left and right biases when longer lines were presented (Friedrich et al., 2018). Longer lines generally produce a larger magnitude of deviation (Varnava & Halligan, 2007). This was also observed in the present study, with both males and females producing leftward errors with the longer, 13cm line when either the left- or right hand was used. Based on their findings, Varnava and Halligan (2007) concluded that overall men bisected lines more towards the centre while women, especially older women, made more leftward errors. Roig and Cicero (1994) also found significant differences between males and females when pseudoneglect was investigated. According to their findings, men demonstrated a stronger leftward bias in relation to women. Significant interactions between hand use and gender were reported by Haussman et al. (2002), with females demonstrating pseudoneglect with both hands compared to males who made more leftward errors when the left hand was used. The current findings showed that males produced more leftward errors with both hands in terms of line position. Females, on the other hand, showed more rightward errors during the right-hand condition. Males also demonstrated more leftward errors during the right-hand condition, bisecting both the 9cm, and 13cm line more towards the left, while females only produced leftward biases with the 13cm line. In relation to hypothesis 2: pseudoneglect/leftward biases manifest differently for males and females; no significant differences were observed. The sample is too small to make any significant conclusions, although details regarding differential pseudoneglect performance, based on gender, were described. This increases support for the value of future research.

Chen, Goedert, Murray, Kelly, Ahmeti, and Barrett, (2011) and Barrett and Craver-Lemley (2008) also reported differences between male and female performance connected to age.

e. Age and pseudoneglect performance

Spatial attention is directed mostly to the opposite side of the most active hemisphere (Kinsbourne, 1993; Mitchell et al., 2020; Reuter-Lorenz et al., 1990). The inclination to overestimate the left side of the line during the LBT may thus stem from the more active right hemisphere. The phenomenon of pseudoneglect is not yet well understood in terms of age, mainly due to inconsistencies in research. Friedrich et al. (2018) emphasised the uncertainty about age and how this impacts lateral biases. The uncertainty regarding age is further acknowledged by Brooks et al. (2016) and Chieffi et al. (2014). Likewise, Forte (2016) agrees that inconsistent findings are evident when age and pseudoneglect are explored. This often relates to a focus on mainly the younger age group, which limits the impact of aging on lateral biases or neglecting to include a sample with various age ranges. Where differences are reported, questions are raised about the exact age at which this change in performance occurs, but Dellatolas, Cootin, and De Agostini (1996), Hausmann et al. (2003), and Bradshaw et al., (1987) maintained that age has an impact on the demonstration of pseudoneglect. Märker et al. (2019) further acknowledged the debate regarding age and highlight that the task used to assess pseudoneglect may activate different neural structures, thereby producing different findings regarding the impact of age. The neural mechanisms activated during LBT performance is significant as it guides the allocation of attention (Chen et al., 2020). Understanding age-related changes can thus help us understand the underlying mechanisms of visuospatial attention (Wilzeck & Kelly, 2012). Research on how age impacts pseudoneglect may suggest modifications to current cognitive models regarding ageing (Brooks, 2014). Märker et al. (2019) and Chen et al. (2020) emphasise that the task used to assess pseudoneglect may activate different neural functioning, potentially yielding different findings amongst various age groups.

Some studies argue for a reversal in pseudoneglect, with older adults making more rightward errors in LBT performance (Andrews, d’Avossa, & Sapir, 2017; Bradshaw et al., 1987; Bradshaw et al., 1988; Chen et al., 2011; Chiang et al., 2000; Dellatolas, et al., 1996; Hausmann et al., 2003; Learmonth et al., 2017; Lee et al., 2004; Märker et al., 2019; Schmitz & Peigneux, 2011; Schmitz et al., 2013). While others support a continuation of the leftward bias (Brooks, Darling, Malvaso, & Della Sala, 2016; Märker et al., 2019; Varnava & Halligan, 2007). The present study focused on perceptual pseudoneglect, although Brooks et al. (2011) found evidence that representational pseudoneglect appears to increase with age.

The data in the present study is based on a sample too small to yield any valuable conclusions, but the data may contribute to improving future research by highlighting the prospect of age-related changes. The findings detailed that no significant interaction exists between the different age groups, i.e., younger, and older participants, and how they bisected the lines based on line length and position. A small effect size was found based on (.027) eta squared.

Line position can impact the performance of pseudoneglect as reported by Bultitude and Aimola Davis (2006), Chen et al. (2011), and Mitchell et al. (2020). The present findings regarding, line position, showed a significant impact on pseudoneglect performance in general, but it did not produce significant differences when age was taken into account although variations in pseudoneglect performance were evident.

Considering the position of line presentation, no significant differences were observed between younger and older participants. But the data showed differential leftward biases between the age groups, despite the lack of significance. Pseudoneglect was, for example, observed during the left-hand condition for all the different line positions, for both the younger and older age group, with the exception of the bottom left lines. A rightward bias was found for the older age group when the lines in the bottom left position were bisected. Given the impact of age on right hemisphere functioning, it is possible that the bottom position activates different brain regions, producing rightward errors. When the right hand was used, rightward errors were observed for both younger and older participants, when the lines were presented in the bottom left, top right, and centre positions. Both age groups bisected the lines presented in the top left and bottom right positions more towards the left of the true centre. During the left-hand condition, performance from both the younger and older participants produced comparable results.

Research supports the notion that line length, similar to position, can produce differential pseudoneglect performance (Brooks et al., 2016; Chieffi et al., 2014; Learmonth et al., 2017) In considering pseudoneglect performance based on line length, no significant differences were found between younger and older participants, but differences in line bisection were observed in the data. During the left-hand condition, both younger and older participants demonstrated a leftward bias for the longer lines, both the 9cm and 13cm lines. The 5cm line was bisected more towards the left by the younger group, while older participants demonstrated a small rightward error on the short line. Brooks et al. (2016) found that longer lines showed a smaller leftward bias among older adults. Younger participants produced more leftward deviations for longer lines, similar to the current study. During the right-hand condition, both age groups demonstrated a leftward bias when the 13cm line was bisected. Although the small sample size prevents any conclusive arguments, the data may be valuable in contributing to the literature on age and pseudoneglect. No significant differences were found, but the findings are consistent with research regarding longer lines and leftward errors. Brooks et al. (2016) and Chieffi et al. (2014) found no significant differences between younger and older participants in LBT performance.

Compared to other research, this study found that the usual leftward deviation continues amongst older adults. The results from Brignani et al. (2018) and Varnava and Halligan (2007) also revealed that pseudoneglect continues amongst older adults. Rightward errors were only found when the right hand was used for LBT completion, similar to reports from other studies (Learmonth et al., 2017; Märker et al., 2019; Milano et al., 2014).

Age-related deterioration may be related to various factors as suggested by different cognitive aging models. This may account for possible age-related differences in pseudoneglect. The impact of aging is different for each hemisphere, but literature supports the assumption that tasks involving the right hemisphere show more observable differences (Lee et al., 2004; Schmitz and Peigneux, 2011). The left-hand condition in the present study, for example, showed leftward biases for both younger and older adults.

The HAROLD model maintains that cognitive specialisation becomes less pronounced as age increases (Brignani et al., 2018; Brooks et al., 2011; Brooks, 2014; Hausmann et al., 2003; Wilzeck and Kelly, 2012). Based on this model, the two hemispheres age bilateral which means that the specialisation of the two hemispheres change as people get older. The prefrontal cortex becomes less lateralised with age, influencing several cognitive functions (Brooks et al., 2016; Friedrich, 2018; Milano et al., 2014). Based on the HAROLD model, leftward biases would decrease in older age groups due to changes in hemispheric asymmetry (Brooks et al., 2016). Studies reporting a reduction in pseudoneglect is generally supported by the HAROLD model (Brooks et al., 2016; Learmonth et al., 2016).

The RHAM model assumes that more prominent changes occur within the right hemisphere with age (Brignani et al., 2018; Brooks et al., 2016; Brooks, 2014; Wilzeck and Kelly, 2012). The right hemisphere is more vulnerable to age-related decline, and the cognitive functions maintained by the right hemisphere should also demonstrate significant decline. Activities, like the LBT, that produce stronger right hemisphere activation, should therefore decline faster (Friedrich, 2018). The RHAM model predicts that the leftward bias would be reversed to produce more rightward errors (Brooks et al., 2016). Given the current small sample, no conclusive arguments are made, but leftward errors were observed for the left-hand condition amongst older adults, while rightward errors were found when the right hand was used. It is possible for the leftward bias to continue in older adults as explained by the CRUNCH model. Additional brain regions are activated to perform tasks (Broods et al., 2016; Learmonth et al., 2017), and is used to explain the continued attentional bias despite aging (Brignani et al., 2018; Friedrich et al., 2018). In agreement with Chen et al. (2020), the activation of certain brain regions may thus account for how attention is distributed. Older adults may recruit extra brain regions, compared to younger adults, to perform tasks and continue to produce a leftward bias comparable to younger adults (Friedrich, 2018).

In the present study, older and younger participants bisected lines similarly when line position and length were considered as no significant differences were found. The present study findings suggest that the different age groups did not bisect the lines significantly different, although variations in pseudoneglect were observed. The inability to make any conclusions based on age is emphasised, but the findings offer valuable literature regarding age and LBT performance.

To determine the impact of leftward biases on attention and memory, the extent of pseudoneglect was established first.

6.2 ATTENTION: EYE-TRACKING DATA

Attention allocation is based on behavioural objectives and knowledge, i.e. top-down processing, and stimulus features, i.e., bottom-up processing. Broji and Itti (2013) maintain that eye-movements are generally guided by top-down processing. Top-down processing requires a comprehensive understanding of the visual scene or task to be completed (Rajashekar, van der Linde, Bovik, & Cormack, 2008). When visual information is extracted from a scene, a representation is created which is held in WM to enable additional processing and to guide behaviour (Harrison, & Tong, 2009; Haxby et al., 2000; Luck & Vogel, 2013). In relation to visual information, VWM is implicated. Top-down applications of gaze selection are integrated into various WM representations (Rajashekar et al., 2008). Top-down implementations alone cannot explain gaze selection, and the role of bottom-up calculations is significant in determining how we process visual information. Image-based attention is not dependent on a specific goal, as in top-down activation. Higher-level cognitive processing is needed to guide subsequent attentional distribution (Hwang et al., 2009). Stimulus-driven attention allocation, together with top-down processing, directs our gaze and different elements of stimuli can draw attention influencing eye-movements i.e. attention (Rajashekar et al., 2008). We experience our visual world by using eye fixations creating different gaze pathways/patterns which involves sampling the visual scene with different fixations (Schneider, 2013). Gaze patterns consist of different fixations and thus constitute the number of times participants gaze at stimuli. Fixations, and eye-movements are the main elements of gaze patterns (van Renswoude, Raijmakers, Koornneef, Johnson, Hunnius, & Visser, 2018).

Tobii Pro (2020, para. 2) defines fixations as the most common aspect of looking. It refers to the experience where the eyes stop scanning the scene, maintaining the focus of vision in place so that the visual system can create a comprehensive account of what is observed (Tobii Pro, 2020, para. 2). Fixations consist of multiple gaze points and are generally interpreted in eye-tracking research. As Tobii Pro (2020) explains, “fixations are constructions, outputs of a mathematical algorithm that translates the sequence of raw gaze points into an associated sequence of fixations” (para. 2). Fixations are equated with perceptual experiences and enable us to process the visual information and encode the information in memory (van Renswoude et al., 2018).

Rajashekar et al. (2008) explained that visual information is integrated to create a detailed representation of the visual scene by scanning the visual world using fixations associated with rapid eye-movements. It is argued that most visual information is gathered during a fixation, while eye-movements interrupt fixations, and prevent the extraction of valuable information (Rajashekar et al., 2008; Schneider, 2013).

Our gaze patterns and the number of fixations are thus related to what we pay attention to (Borji & Itti, 2013), and the number of fixations relates to what we extract from a visual scene (Duchowski, 2007).

The present study calculated data consisting of the average duration of gaze as well as the number of fixations for each slide presented during the memory simulation. The average gaze duration was measured in ms and is discussed first. The intention was to determine if there were differences with left/right gaze patterns.

a. Gaze duration

The memory simulation consisted of slides containing different types of stimuli presented to participants for different time periods. The data revealed no significant differences between the left and right gaze patterns analysed according to slides. Based on the findings, it is reported that participants did not present with different gaze durations in relation to stimuli presented on the left or right side. Leftward biases did not appear to significantly impact gaze duration, i.e., longer durations were not observed for left-sided stimuli.

b. Total number of fixations

The number of fixations for the left and right sides of each slide was calculated. The average number of fixations was analysed per slide. A few differences in left and right fixations were found between the different slides. The difference is likely due to the nature of the content presented on the slides. Some slides contained only images on the left of the fixation point or a single image on the right. Dual presentation included images on both the left and right sides of the focal point. Statistical analysis regarding the interaction of the different slides and the number of left and right fixations produced significant results. The number of fixations recorded for each slide was thus significantly different for left and right fixations.

The findings show that slide 1, which contained a single image on the left, had a higher number of left fixations. Slide 3 and slide 4 both contained letters on both the left and right side of the focal point, yet a higher number of fixations were observed for the left side in both instances. The same applies to slide 8, containing a dual presentation of images, but participants appeared to fixate more on the image on the left. Of interest is slide 12 and slide 13. Slide 12 contained an image of fruit and vegetables organised in four joint columns which were presented in the center of the screen. Slide 13 contained four columns of words, two columns to the left of the screen, and two columns to the right of the screen. In both cases, participants were able to move their gaze between the stimuli presented on the left and right sides. The results showed that participants demonstrated a higher number of fixations when stimuli were on the left side.

A higher number of fixations represents stronger attentional pathways (Duchowski, 2007; Theeuwes, Belopolsky & Olivers, 2009; Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009; Wedel & Pieters, 2000). Referring to the data described, significant differences were found between the left and the right number of fixations per slide as indicated by the significant interaction effect. Participants seemed to demonstrate a higher number of fixations to stimuli present in the left hemifield even when stimuli on the right were present. Van Renswoude et al. (2018) argue that fixations allow us to capture the visual world and process and memorise what we experience. This information is then used to create a representation of the visual world (Rajashekar et al., 2008). The findings suggest a bias in attention by favouring the left side. Longer gaze durations and a higher number of fixations were found for stimuli on the left although the data did not reveal significant differences for gaze duration. More attention was directed to stimuli located on the left as the higher number of fixations suggest.

No causal conclusions are made, and the findings should be interpreted in the context of study limitations. The findings from the present study are regarded as tentative, and more research is needed to substantiate the findings. The higher number of fixations suggests that a higher attentional weight is assigned to stimuli in the left hemifield, suggesting a lateral bias in attention.

Research supports the notion that fixations can influence what is encoded to memory (Bochynska &, Laeng, 2015; Eimer, 2014; Foulsham & Kingstone, 2012; Laeng et al., 2014). The prominent focus on left-sided stimuli may thus be linked to what is memorised.

6.3 ATTENTION AND MEMORY

Attention and memory comprise important abilities in our daily cognitive functioning and our ability to locate target stimuli in the visual world depends on processing at various stages in the visual system, and constant feedback between several memory systems, including, WM, and LTM (Eimer, 2014; Friedman et al., 2018). As visual input moves farther along the visual processing system, the process becomes more complex and the impact from higher-order cortical areas becomes more prominent. The significant association between attention and memory means that lateral biases in attention can potentially skew our attentional resources (Jarodzka et al., 2013; Jarodzka et al., 2017; Schmitz et al., 2013; Summerfield et al., 2006; Theeuwes et al.., 2009). How we allocate attentional resources is a product of the interaction between various cognitive processes. Both bottom-up and top-down attentional processes underlie the allocation of attention (Forte, 2016, Serences & Yantis, 2006).

The ability to focus attention, however, seems to be asymmetrical in nature (Nicholls et al., 2008). Pseudoneglect means that neurotypical individuals favour the left side (Benwell et al., 2013; Cocchini et al., 2007; Nuthmann &Matthias, 2014; Schmitz & Peigneux, 2011; Zago et al., 2017). From a bottom-up perspective, stimuli on the left may be experienced as having enhanced features, thereby drawing more attention. Top-down mechanisms are vital for guiding behaviour, and subsequent attentional focus, but Theeuwes (2010) maintains that attention is initially stimulus-driven. The TVA details that attentional weights are assigned to encountered stimuli and some stimuli may receive preference with regard to memory encoding (Vidal et al., 2015). Visual information is thus selectively weighted during visual processing (Eimer, 2014).

The main aim of this research study was to determine whether lateral biases impact attention and memory. The primary research question was: Does a leftward bias (pseudoneglect) impact visual long-term memory and attention for visually presented stimuli? The researcher attempted to explore how leftward biases may influence the allocation of attention and the encoding to memory, specifically VLTM. VLTM was assessed using a computerised memory test based on a memory simulation presented to participants. The main hypothesis was: a leftward bias impacts VLTM and attention for visually presented stimuli.

To determine the impact of leftward biases, the VLTM findings were considered in relation to left, and right memory items. The number of left fixations was also compared with VLTM findings as well as general LBT performance, i.e. pseudoneglect.

a. VLTM findings

In this study, the focus was on attention, related to visual content, and VWM and VLTM are implicated in cognitive processing (Schurgin, 2018).

Memory is regarded as a broad concept including many different subcomponents, defined as separate memory stores. The significance of LTM is highlighted by Friedman et al. (2018) and maintained as a central memory system for survival. LTM includes several subcomponents, including VLTM. Schurgin (2018) describes VLTM, as a long-term storage system for visual content. VWM includes the temporary storage and manipulation of visual information (Schurgin, 2018) and essentially guides further behavioural actions (Baddeley, 2003; Szelest, 2014), WM transfers content to, and from LTM, and are ultimately directed by LTM (Baddeley, 2012; D'Esposito & Postle, 2015; Erickson et al., 2015). What is maintained in WM is then based on active LTM representations, and the current focus of attention (Chai et al., 2018; Cowan, 2005). Essentially, VWM content is informed by VLTM. During visual experiences, people can disengage WM by activating LTM (Cowan, 2008; Schurgin et al., 2018).

To determine whether the lateral bias in attention influenced what was encoded to memory, participants were required to watch a memory simulation. The objective was to determine whether more items on the left were memorised compared to the right. The total number of items correctly recalled from the left side condition was the primary focus of the current study. Significant differences with regard to the items recalled in the left and right memory conditions were found. Based on the data, more items were recalled on the left compared to the right memory condition, and the eta squared statistic detailed a large effect size. On average, participants recalled more items on the left, scoring higher, as they correctly recalled more items on the left.

Della Sala et al. (2010), and Szelest (2014) also found that participants recalled more items on the left. Della Sala et al. (2010) reported that participants remembered more bindings between colours, and location and identified more objects located on the left compared to the right. Dickinson and Intraub (2009) found similar findings showing that more visual items were remembered from the left compared to the right when using naturalistic visual scenes.

VLTM and the number of fixations

The findings from the current study tentatively suggest that a lateral bias in attention is evident as demonstrated by the higher number of fixations to stimuli on the left.

The TVA proposes that only significant stimuli or relevant stimuli will capture attention and undergo additional processing (Budnesen, 1990; Habekost, & Starrfelt, 2009). Our ability to allocate attention is regulated by processing capacity. Significant features of stimuli, such as spatial location, can direct our attentional resources. Siman-Tov et al. (2017) maintain that the asymmetrical nature of attention distribution also controls our experience of the visual world. The templates maintained in VWM, and content from VLTM thus impact subsequent attention allocation. Restrictions in our cognitive functioning system prevent equal allocation of attention to all encountered stimuli. During visual experiences certain stimuli become more salient, attracting more attention (Chun & Johnson, 2011), causing the preferential allocation of attention to the location of the noticeable stimulus (Carter et al., 2014). The processing of visual information may thus be influenced by lateral biases (Szelest, 2014) as our ability to focus attention is not symmetrically presented in the brain (Nicholls et al., 2008; Nuthmann &Matthias, 2014; Schmitz & Peigneux, 2011). As a result, we seem to favour a specific side of the visual field (Benwell et al., 2013; Brodie, 2010; Brooks, 2014; Foulsham et al., 2013; McGeorge et al., 2007).

The findings from the present study contribute to the understanding that attention is not allocated equally across the visual field. Considering the eye-tracking data, participants demonstrated more fixations to stimuli presented in the left hemifield. The differences observed with right and left fixations were significantly different, as noted, and the bias did seem to impact the allocation of attention and the consequent encoding of information.

Bundesen et al. (2015) explain that all visual stimuli essentially compete for representation. The attentional weights assigned to visual information can also be prejudiced by perceptual biases. Taking the TVA model assumptions into account, the present study findings suggest that higher attentional weights may have been assigned to stimuli on the left. The higher attentional weight means that the information is more noticeable (Eimer, 2014). Appendix H contains images from the memory simulation with the gaze pathways and the number of fixations included. The images show that some participants focused exclusively on stimuli on the left, ignoring the right side or demonstrating minimal fixations toward the right.

The data from the VLTM memory assessment show that there were significant differences with regard to the number of items correctly recalled with participants, on average, recalling more items from the left side. A higher recall from the left is supported by the higher number of eye fixations to the left. Attention was directed more towards the left hemifield, potentially resulting in significant differences in memory recall. Data analysis, however, revealed no significant correlations between the number of fixations and the number of items correctly recalled. No significant correlations were found between memory performance and gaze duration. The current study sample may have limited the extent to which significant relations could be identified. The differences in memory recall and prominent leftward fixations suggest a valuable opportunity for future research to explore this in more detail.

b. VLTM and pseudoneglect performance

Pseudoneglect involves a preferential focus to the left side of stimuli, and it is reasoned that this may result in a tendency to ignore stimuli on the right side (Brooks et al., 2011; Çiçek et al., 2009;

Cocchini, et al., 2007; Hatin et al., 2012; Lee et al., 2004; Loftus & Nicholls, 2012; Loftus et al., 2009; Nicholls & Loftus, 2007; Nicholls et al., 2008; Nicholls et al., 2004; Toba et al., 2011; Porac et al., 2006).

According to the activation-orientation theory, a leftward bias in the LBT means that the left side of the line is perceived to be longer (Bultitude & Aimola Davies, 2006). Similarly, the stimuli presented in the left hemifield may be perceived as more significant. The stronger activation of the right hemisphere in visuospatial tasks implies that more attention is directed towards the opposite side. The current findings found no significant relation between pseudoneglect and memory. The LBT scores did not significantly predict a leftward preference in memory. It may be the case that the stimuli on the left are perceived as more noticeable, thereby attracting more of the attentional resources, i.e., eye-movements and fixations. More attentional resources may be devoted to stimuli on the left, so information on the left receives preferential cognitive processing and be encoded to memory, but LBT performance did not predict significant differences in VLTM performance.

6.4 CONCLUSION

In conclusion, the findings are summarised and should be interpreted within the current study context limitations.

The findings established that the results from the research provided answers to the questions stated. Both the primary and secondary research questions were addressed and answered. In considering the research questions set out the researcher made the following tentative conclusions:

Firstly, participants demonstrated pseudoneglect, consistently bisecting lines more towards the left of the true center. The left side of the presented lines may thus have been perceived as longer compared to the right, as the activation-orientation hypothesis details. The findings show that the hand used for task completion significantly influenced LBT performance. The data, supplements previous research findings that the position of the lines, as well as the length of the lines, significantly impact pseudoneglect performance. Pseudoneglect was observed for all the participants and, line position and line length influenced how the lines were bisected.

Secondly, the researcher was unable to replicate previous findings regarding gender differences in pseudoneglect due to the small sample, and limited representation of males and females. The study is underpowered with regard to between subject comparisons but a sufficient number of participants were included for within subject comparisons (refer to Appendix G). The conclusions are regarded as tentative and should be used to improve future studies. The data did not reveal significant differences between male and female participants but, differences were observed in how males and females bisected the lines. A larger representation of males and females in the sample may thus elucidate differential LBT performance. Similarly, age differences were not significant. But the data suggest that older and younger participants may bisect lines differently, especially when line length is considered. More research is, however, needed to determine the significance of these age differences.

Thirdly, the researcher endeavoured to measure attention by assessing eye-movements. The data revealed no significant differences with regard to left and right gaze duration. Some slides showed significant differences in relation to the number of left and right fixations, and overall significant differences were also found. The data revealed a prominent focus on stimuli located on the left side. The higher number of fixations to the left side suggests that attention appears to be biased to the left. More attentional weights may therefore be assigned to left-sided stimuli. A lateral bias in attention seems plausible.

Lastly, the findings show significant differences between the left and right items recalled. Participants recalled more items on the left when compared to the right memory condition, and eta squared results show a large effect size. It may likely be due to the lateral bias observed in attention, but the LBT performance and memory findings were not significantly correlated. Similarly, no significant correlations were found between the number of fixations and memory performance. Longer gaze durations were also not significantly correlated with memory recall.

In conclusion, the main aim of the research was to determine lateral biases in attention and memory. The findings reveal that pseudoneglect, i.e., a leftward bias, appears to impact the allocation of attention, as measured via eye-movements, and the subsequent encoding to memory, but no significant correlations were found. More research is needed to explore lateral biases in attention and their relation to memory.

6.5 LIMITATIONS

In order to provide a better understanding of the limitations noted, an overview of some of the challenges faced during this research project is outlined.

A key factor for the present research was to create a computerised version of the traditional paper-and-pencil LBT. Computerised versions have been used in several studies, but these instruments are not available for application and public use. As a result, it was necessary to create a computerised version of the LBT. Communication regarding this request was extended to the eye-tracker company

SMI, which is the model eye-tracker the researcher initially planned to use. Qualtrics, the online data collection site, was also approached for assistance. Neither *Qualtrics*, nor *SMI* was able to assist, noting that they did not have the expertise to create the test. An external programmer was approached and managed to create a computerised version of the test, but a lot of technical issues were present. Adding to that, the license of the eye-tracker expired and required renewal. The renewal was very expensive and not within the study budget. The licence was approved with support from the company without any cost. Unfortunately, the LBT computer version was created in a programme incompatible with the *SMI* eye-tracker. Contact with a colleague from another faculty, prominently involved with eye-tracking research, was made. The use of a newer model eye-tracker, the Tobii Pro, was extended. An IT student, able to re-design the initial computerised LBT, was also managed. The test was still not without problems but was significantly improved and the touch screen allowed for more accurate measurements, specifically regarding the use of both hands. As the expert in using the Tobii Pro eye-tracker, the colleague provided valuable guidance. Sadly, she passed away before data collection commenced.

The researcher acknowledges the following limitations of the current research project.

The sample included in the study consisted of only 35 participants. Data collection was open for several months, and the invitation to participate was shared on different occasions to both students and staff. No incentives were offered, and data collection required students and staff to be available for physical data collection. The laboratory, where data collection took place, was only available once a week as it is used for practicals on most days. The researcher was thus reliant on the availability of the laboratory, and the use of the eye-tracker during a limited time. Although a large number of potential participants were approached, only a limited number volunteered to partake in the research.

It is possible that the small number of participants assessed had an impact on the research findings. The power analysis revealed that a sufficient number of participants were included for within subject comparisons, however, more participants are needed for adequate between subject comparisons. The majority of the sample was also female, which may have skewed the results, explaining the lack of significant differences observed between males and females in pseudoneglect demonstration. The small sample also limited the range of the different age groups as the participants were predominantly from the 18-29 years age group, with only a few participants included in the older 50 – 60 years age group. The findings from the present study regarding age and gender are not reported as definitive conclusions, and emphasis is made regarding the extent to which the findings may be applied to other contexts. It is noted that the findings contribute to improving future research.

In relation to the difficulties noted to computerise the LBT, the researcher also highlights a few additional technical difficulties. The LBT was computerised, but due to the nature of the programme, errors occurred when it was used in conjunction with the eye-tracker. Eye-tracking data for the LBT performance could not be captured. A slider bar was presented on the left side of each line and participants were instructed to tick the midpoint of each line without moving the slider bar. If the slider bar was moved it prevented the data from recording and some participants had to redo the LBT task. Some participants thus had to do the LBT three times instead of the required two times. This was only the case for five participants, but practice effects may have influenced how they bisected subsequent lines. The design of the test prevented removing the slider. Technical difficulties thus impacted the nature of the data that was extracted.

Referring to memory test performance, age-related cognitive decline could have potentially influenced the test performance of older participants. The main aim with including both older and younger participants was, however, not related to memory test performance, but rather to observe possible changes in the demonstration of pseudoneglect. The memory questionnaire was not standardised and assessed for reliability and validity. It was, however, designed specifically for the current study and based on the memory simulation used during the study. The aim was to assess VLTM. The format of the questionnaire was determined by the position of presentation and a standardised memory questionnaire could not be used. The design of the VLTM assessment is similar to that used by Brady et al. (2008).

Despite the limitations detailed, the research findings offer a valuable contribution to the literature regarding pseudoneglect. The eye-tracking data presented in Appendix H provide interesting findings regarding the predominant focus on stimuli on the left. The findings also demonstrated that the lateral bias is evident in the distribution of attentional resources. Future research can use the current findings as a foundation to improve on the limitations and provide in-depth analysis of the eye-tracking data. The preferential focus on stimuli on the left and the observance of pseudoneglect can benefit from further exploration.

6.6 RECOMMENDATIONS FOR FUTURE RESEARCH

The findings from the present study should be regarded as preliminary findings, given the limited sample. As detailed in Appendix G, the study is underpowered with regard to between subject comparisons. A larger sample size would be needed to make adequate judgements about between subject analyses. The study failed to provide significant differences with regard to gender and, age in relation to LBT performance. Differences in LBT performance were, however, observed, but the small sample size prevents any definitive conclusions. It is, therefore, proposed that future research include a larger, more diverse sample to account for a wider age range, and gender representation. Modifications to the computerised version of the LBT should afford an opportunity to record eye-movements during LBT performance to ascertain whether more fixations are directed to the left side of the line. The use of eye-tracking data can provide valuable insight into lateral biases defined by eye-movements and, it is suggested that advanced eye-tracking instruments be included to improve further research.

6.7 THE SIGNIFICANCE OF THE RESEARCH

The current study findings contribute to understanding the nature of pseudoneglect. Research questions whether the bias is related to memory itself, or a product of attention. This research enhances the understanding of spatial attention in a neurotypical population and, additionally supplements the understanding of hemineglect and cerebral laterality. The interpretation of pseudoneglect research can aid the understanding of cognitive functioning, specifically related to attention and memory. The size of the study and some significant findings show the relative robustness of the phenomenon of pseudoneglect. It was demonstrated that line position and length influenced pseudoneglect performance. Similarly, gender differences were also observed. Although age did not seem to have an effect, the nature of the sample (all active in the field of academic work), might have countered any differences. Thus, future studies should take age and gender representation into account when devising experiments. Follow-up studies may confirm the real effect of pseudoneglect on encoding visual information. The findings also contribute to increasing awareness within a South African context regarding lateral biases and, the consequent impact it may have on human cognition. Likewise, the findings can practically be applied to improve the academic domain by guiding the design of online learning platforms. The findings furthermore offer new ways of perceiving attentional and perceptual asymmetries and how this may potentially relate to sporting activities, and driving. In addition, the study also developed two assessments that may be used for future research.

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ADDENDUM DETAILED INFORMATION

APPENDIX A: ASSESSMENT MEASURES

PART 1: Demographic questionnaire

Demographic Questionnaire

Please complete the demographic questionnaire

Participant: *

Short-answer text

1. Gender *

- [ ] Male
- [ ] Female

Nationality *

- [ ] South African
- [ ] Other...

Race *

- [ ] Black
- [ ] White
- [ ] Coloured
- [ ] Indian
- [ ] Other...

What is your age? *

Short-answer text

What is your home language? *

- [ ] English
- [ ] Afrikaans
- [ ] Zulu
- [ ] Xhosa
- [ ] Tswana
- [ ] Venda
- [ ] Sotho
- [ ] Tsonga
- [ ] Pedi
- [ ] SiSwati
- [ ] Ndebele
- [ ] Other...

What is the highest level of education you have completed? *

- ☐ Matric/Grade 12
- ☐ 3 Year Degree
- ☐ Honours/ 4 Year Degree
- ☐ Masters
- ☐ Doctorate/ PhD
- ☐ Other...

Occupation *

- ☐ Undergraduate student
- ☐ Postgraduate student
- ☐ University staff member: Academic
- ☐ University staff member: Administrative support
- ☐ Other...

What kind of area were you raised in? *

- [ ] Rural
- [ ] Small town
- [ ] Urban
- [ ] Semi-urban
- [ ] Other...

Are you left handed or right handed? *

- [ ] Left handed
- [ ] Right handed
- [ ] Both (Ambidextrous)

Do you have any history of brain injuries? *

- [ ] NO
- [ ] YES

If yes, please specify

Short-answer text

Do you have problems with your vision? *

☐ NO

☐ YES

If yes, please specify

Short-answer text

Do you have a history of psychological disorders? *

☐ NO

☐ YES

If yes, please specify

Short-answer text

Are you currently diagnosed with any medical disorders? *

☐ NO

☐ YES

If yes, please specify

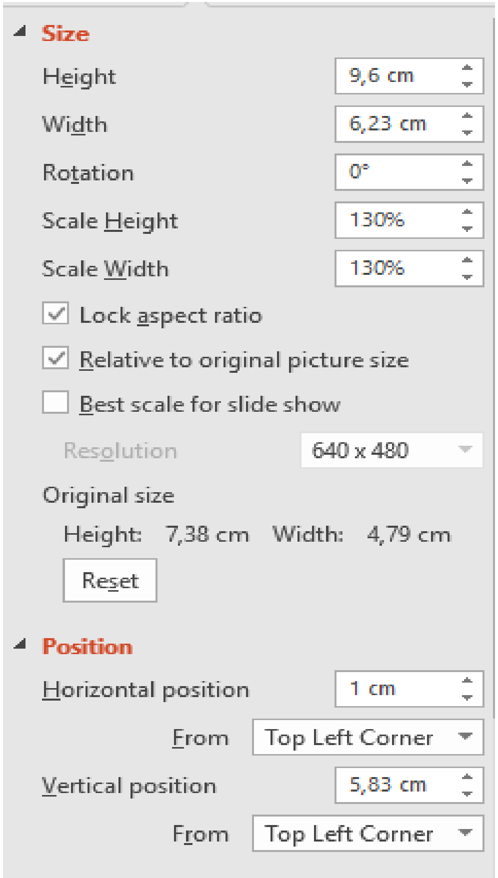
Short-answer text

PART 2: Image simulation details:

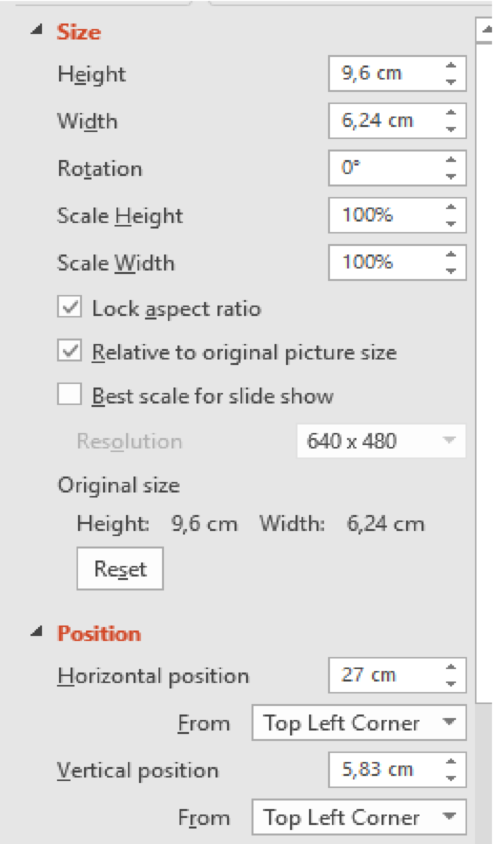
This is a description of how the researcher created the slides projected during the memory simulation.

Condition 1:

Left stimulus

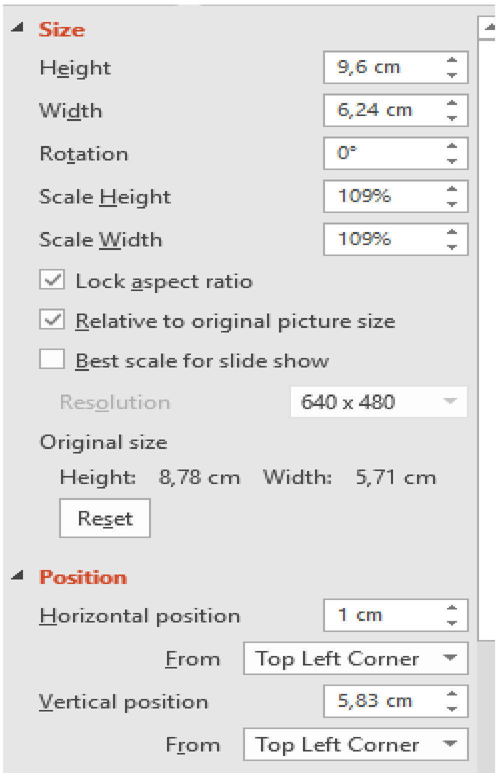


Right stimulus

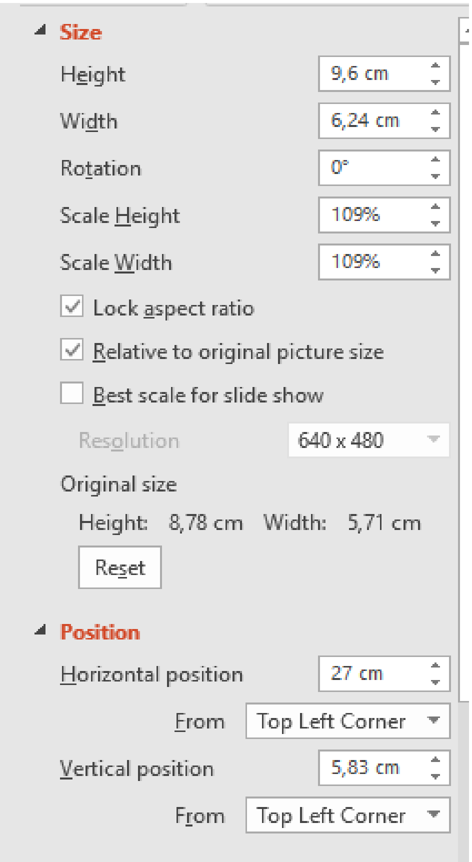


Condition 2:

Left stimulus

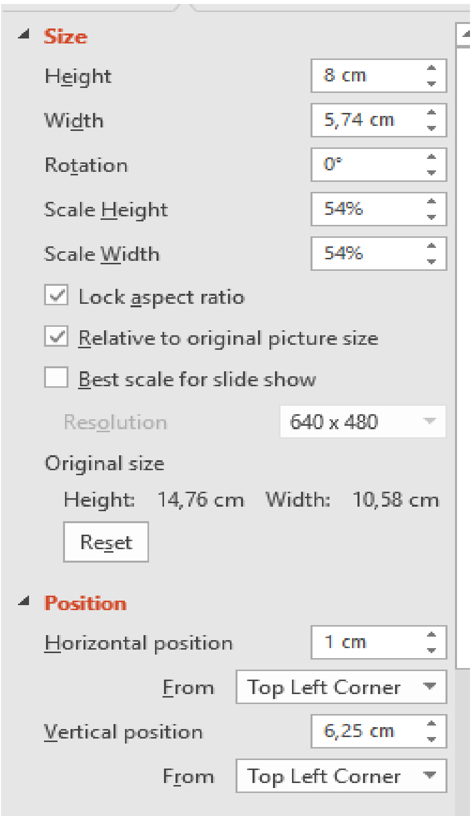


Right stimulus

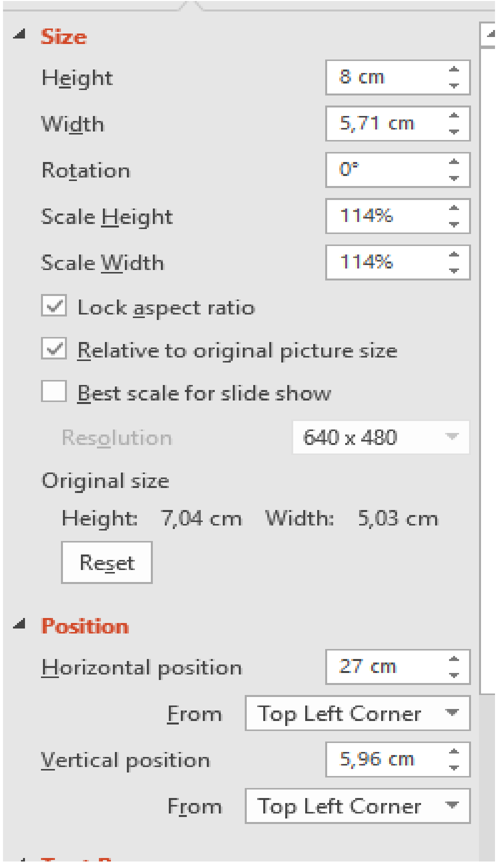


Condition 3:

Left stimulus

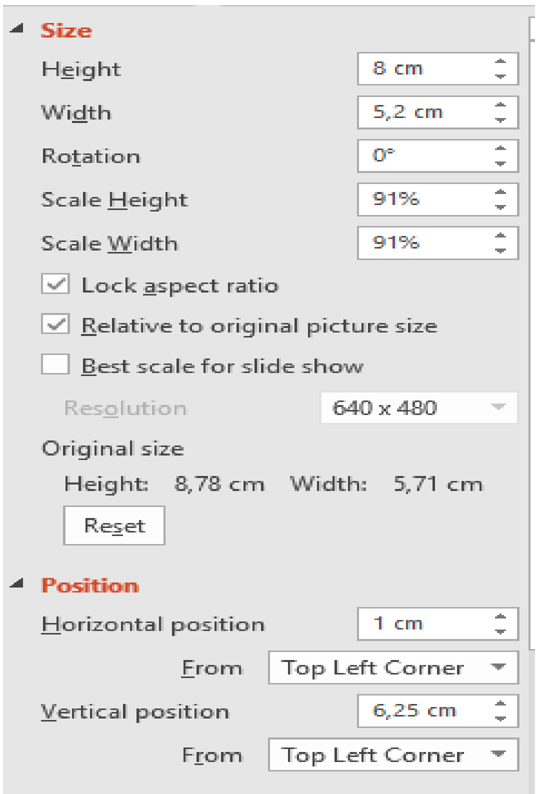


Right stimulus

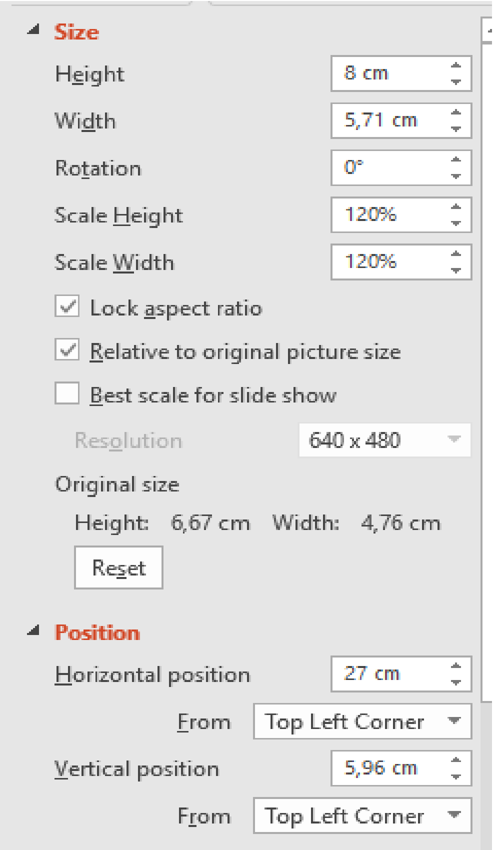


Condition 4:

Left stimulus

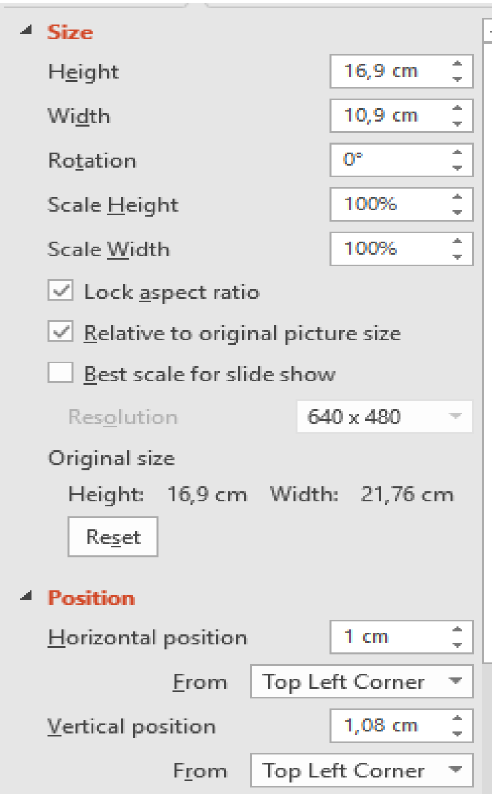


Right stimulus

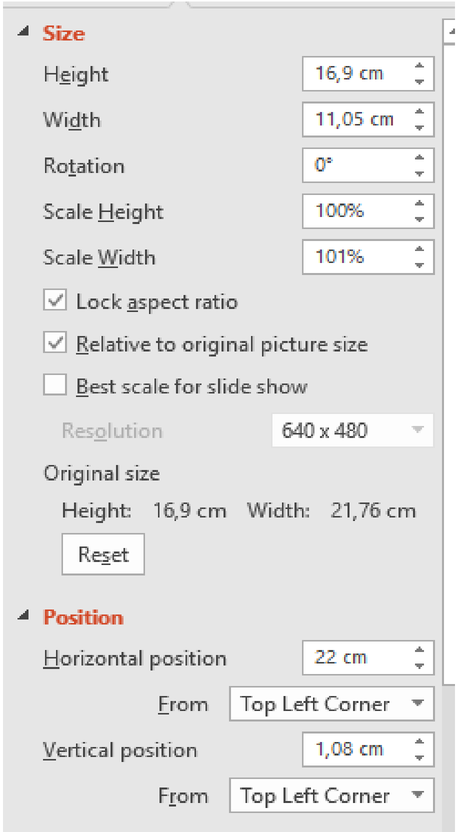


5. Study the image below and memorise as many words as you can.

Left

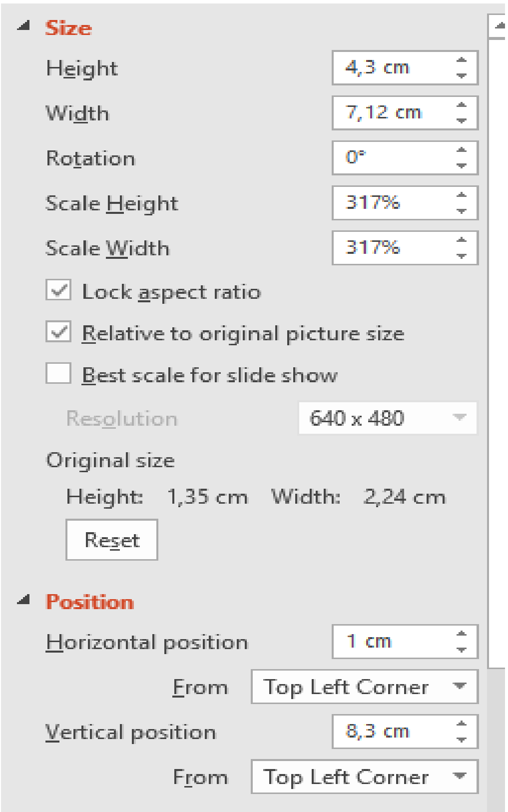


Right

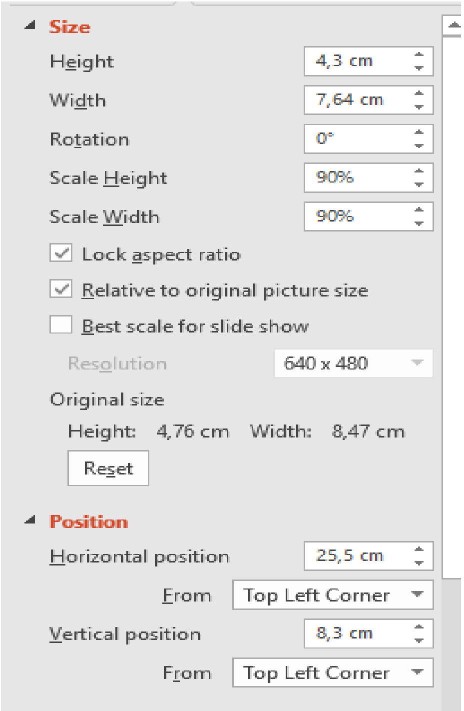


6. Memorise details of the two images below.

Left



Right


Size
Height
4,3 cm
Width
7,64 cm
Rotation
0°
Scale Height
90%
Scale Width
90%
Lock aspect ratio
Relative to original picture size
Best scale for slide show
Resolution
640 x 480
Original size
Height: 4,76 cm Width: 8,47 cm
Reset
Position
Horizontal position
25,5 cm
From
Top Left Corner
Vertical position
8,3 cm
From
Top Left Corner

APPENDIX B: MEMORY QUESTIONNAIRE ITEMS

Memory Questionnaire

Please complete the following questions based on the simulation you saw.

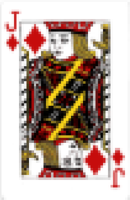
1. Please indicate which of the following letters you remember seeing by ticking the appropriate box.

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E
- ☐ F
- ☐ G
- ☐ H
- ☐ I
- ☐ J
- ☐ K
- ☐ L
- ☐ M
- ☐ N
- ☐ O
- ☐ P
- ☐ Q

- [ ] R
- [ ] S
- [ ] T
- [ ] U
- [ ] V
- [ ] W
- [ ] X
- [ ] Y
- [ ] Z

2. Please tick the images you recall from the simulation.

- [ ] Option 1



- [ ] Blank1

- [ ] Option 2

- [ ] Blank2

- [ ] Option 3

☐ Option 4

☐ Blank4

☐ Option 5

☐ Blank5

☐ Option 6

☐ Option 7

☐ Blank7

☐ Option 8

☐ Blank8

☐ Option 9

☐ Option 10

☐ Blank10

☐ Option 11

☐ Blank11

☐ Option 12

3. Please tick the street signs you remember seeing.

☐ Option 1

☐ Blank1

☐ Option 2

☐ Blank2

☐ Option 3

4. Select the fruit options that you remember seeing.

☐ Option 1

☐ Blank1

☐ Option 2

☐ Blank2

- [ ] Option 3

- [ ] Blank3

- [ ] Option 4

- [ ] Blank4

- [ ] Option 7

☐ Option 5

☐ Blank6

☐ Option 6

☐ Blank7

☐ Option 8

☐ Option 9

☐ Blank9

☐ Option 10

☐ Blank10

☐ Option 11

☐ Blank11

☐ Blank11

☐ Option 12

5. Tick the corresponding box of the words you can recall.

- ☐ academic
- ☐ work
- ☐ family
- ☐ assertive
- ☐ flower
- ☐ books
- ☐ adventure
- ☐ children
- ☐ comfortable
- ☐ brain
- ☐ shoes
- ☐ explore

6. Please indicate the colour of the dog?

- ☐ Black
- ☐ White
- ☐ Blue
- ☐ Grey
- ☐ Purple
- ☐ Red

7. Select the clock you can recall from the simulation.

☐ Option 1

☐ Blank1

☐ Option 2

☐ Blank2

☐ Option 3

Option 4

Blank4

Option 5

Blank5

Option 6

☐ Blank6

☐ Option 7

Thank you for participating in the study. Please contact the Researcher for any further information: Sonja Mostert: Sonja.Mostert@up.ac.za

TOTAL Memory questionnaire memo:

1. A B C D E F G P R T U Z

(12)

2. King of spades

Jack of diamonds
Queen of hearts
Jack of clubs
Jack of spades
King of diamonds
King of hearts
Queen of diamonds
Queen of spades
Queen of clubs
Kind of clubs
(11)

3. 30km road sign

60km road sign
(2)

4. Pineapple

Oranges
Egg plant
Grapes
Peppers
Cherries
Watermelon
Strawberries
(8)

5. Work

Family
Flower
Adventure
Academic
Books
Comfortable
Brain
(8)

6. Blue – dog
Black – cat
(2)

7. 16:00
20:00
13:00
09:00
(4)

TOTAL: 47

Memory questionnaire LEFT condition memo:

1. E
A C
P
T U
(6)

2. King of hearts
Queen of diamonds
Queen of spades
Queen of clubs
King of clubs
(5)

3. 60km road sign
(1)

3. Peppers
Cherries
Watermelon
Strawberries
(4)

4. Academic
Books
Comfortable
(3)

6. Black
(1)

7. 13:00
09:00
(2)
<u>TOTAL: 22</u>

Memory questionnaire RIGHT condition memo:

1. B
F
Z D
R G
(6)

2. King of spades
Jack of diamonds
Queen of hearts
Jack of clubs
Jack of spades
King of diamonds
(6)

3. 30km road sign
(1)

4. Pineapple
Oranges
Egg plant
Grapes
(4)

5. Work
Family
Flower
Adventure
Brain **(5)**

6. Blue
(1)

7. 16:00
20:00
(2)

TOTAL: 25

APPENDIX C: LBT FILE USED FOR COMPUTERISATION

Page 1

A 0cm from side 5cm in length

B 3 cm from side 9cm length

C 5cm from side 13cm in length

A 0cm from side 5cm in length

B 3 cm from side 9cm length

C 5cm from side 13cm in length

Page 2

A 0cm from side 5cm in length

B 3 cm from side 9cm length

C 5cm from side 13cm in length

A 0cm from side 5cm in length

B 3 cm from side 9cm length

C 5cm from side 13cm in length

Page 3

A center 5cm in length

B center 9cm in length

C center 13cm in length

APPENDIX D: ETHICAL APPROVAL

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

21 November 2016

Dear Prof Maree

Project:	**Lateral biases in attention and working memory in neurologically healthy adults**
Researcher:	**SN Mostert**
Supervisor:	**Prof D Maree**
Department:	**Psychology**
Reference number:	**25131754 (GW20160825HS)**

Thank you for the application that was submitted for ethical consideration.

I am pleased to inform you that the above application was **approved** by the **Research Ethics Committee** on 20 November 2016. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

The Committee requests you to convey this approval to the researcher.

We wish you success with the project.

Sincerely

pp.

Prof Maxi Schoeman
Deputy Dean: Postgraduate Studies and Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail:tracey.andrew@up.ac.za

Kindly note that your original signed approval certificate will be sent to your supervisor via the Head of Department. Please liaise with your supervisor.

APPENDIX E: Informed consent

UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA	Participant Number (To be completed by researcher)

Participant Information Sheet and Consent Document

RESEARCH STUDY:

Lateral biases in attention and working memory in neurologically healthy adults

There are two parts to this informed consent form:

- An information sheet (provides information about the study)
- A consent form (sign if you choose to participate)

You will receive a copy of the information sheet.

Part 1: Information sheet

The purpose of the study

The researcher, affiliated with The University of Pretoria, is conducting a study aimed at investigating possible lateral biases in working memory and attention for visually presented stimuli. A secondary aim is to explore whether there are differences between younger and older participants and males and females concerning the demonstration of lateral biases.

Participation

Should individuals agree to take part in the study, each individual participant will be agreeing to a basic eye-test which is non-evasive. They will be agreeing to participate in a short experiment, which will involve a computer using an eye tracker. They will also be agreeing to complete a demographic questionnaire, a handedness questionnaire and a memory questionnaire after watching an experimental simulation.

Eye Tracker: For the purposes of the experiment, an eye-tracker will be used. The device has a little camera and light which will closely monitor your eye-movements. This device will cause you no harm in any way and will not damage your eyes. It has been tested in many countries around the world and found to be safe. Please note that the device holds a camera which will record your eye-movements and all actions made on the computer.

Participation in the study and all the results will be kept confidential. The researcher will assist you throughout the experiment and in completing your questionnaires but thereafter, there will be no information that will connect you personally to the study. All identifiable information will be removed with the final capturing of the data. All the data collected from your participation will be stored in safe place behind lock and key, and password where necessary. Only the researcher will have access to the data. The information gathered during the course of the research process will only be used for the purpose of research and will be stored in a safe location at the University of Pretoria for 15 years for archiving purposes. If you wish to remain informed on the results of the study, you may contact the principal researcher for further information (contact details provided below).

You participation in this study is voluntary, which means that you may withdraw at any time without having to offer an explanation and without any consequences to you. If you experience any discomfort during the course of the experiment, please notify the researcher and assistance will be provided where necessary.

If some of the words or concepts contained within this document are not familiar to you, or if you do not understand some or any of the information provided, please inform the researcher of this so that they may provide a clear explanation.

Any further questions regarding the research study may be directed to the principal investigator:

Sonja Mostert

sonja.mostert@up.ac.za

Research Study

Lateral biases in attention and working memory in neurologically healthy adults

Part 2: Consent to Participate

I hereby confirm that I have been informed about the nature and procedures, of the study. I also give permission for the eye-tracker to be used and for my eye-movements to be recorded, as explained in the information sheet. I am aware that the information will only be used for research purposes, and for future research and that confidentiality will be protected. I agree to voluntarily participate in the study and I am aware that I can withdraw at any time without offering any explanation or suffering any consequences.

Participant Name and Surname: ____

Participant signature _________________________

Date _________________________

Researcher Name and Surname: _________________________

Researcher Signature: _________________________

Date _________________________

Thank you for your participation!

APPENDIX F: Invite to participate

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Humanities 100.
1919 - 2019
Department of Psychology

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

The purpose of the study

The researcher, affiliated with The University of Pretoria, is conducting a study aimed at investigating possible lateral biases in working memory and attention for visually presented stimuli.
Ethical clearance was obtained from the Humanities Postgraduate and Ethics committee. The document dated November 2016 is available on request.

Participation

Should individuals agree to take part in the study, each individual participant will be agreeing to participate in a **short experiment**, which will involve a computer using an eye tracker. They will also be agreeing to complete a demographic questionnaire, a handedness questionnaire and a memory questionnaire after watching an experimental simulation.

Data collection details: Every Tuesday from 09:00 – 13:00 in the **Eye tracking laboratory** located in the **IT building floor 4** at the back – follow the arrows. The experiment only takes 10 minutes.

Please contact the researcher if you need more information: **Sonja Mostert**

Sign-up sheet:

Date	
Time	**Participant name**
09:00 – 09:30	
09:40 – 10:10	
10:20 – 10:50	
11:00 – 11:30	
11:40 – 12:10	
12:20 – 12:50	

APPENDIX G: Power Analysis:

1. Introduction

Power analysis for studies is often neglected because of the argument that the calculations involved are complex (Lakens & Caldwell, 2019). Recent developments made it possible to do fairly apriori and post hoc analyses of the power of study (Mayr et al., 2007). G*Power 3.1 is a software tool and that can manage fairly complex designs. A third use for power analysis is compromise analyses when the logistics of a study requires a relaxation of some parameters such as power or sample size (Mayr et al., 2007). Ideally one would do an apriori power analysis to determine the required sample size for a suitable level of power but it can also be utilised to determine the power of an analysis given a certain sample size, the significance level and effect size, although Field (2018) correctly points out that if results were significant post hoc, power was demonstrated to be sufficient thus not necessary to calculate.

In this study the following analyses were done and the apriori sample size for each result can be determined given a power of .80 and significance level of .05:

a. Pearson correlation
b. Multiple regression
c. Factorial analysis of variance especially repeated measures. In this case most combined the hand with which the LBT was done (i.e., left and right hand), and characteristics of the LBT, namely, position of the line (5) or line length (3). This amounted to 2 x 5 and 2 x 3 factorial ANOVAs. Both factors in each design were within-subject or repeated measures. In addition, gender (two levels) and age (two levels) were also analysed separately. In these cases, left and right hand were analysed separately which means the 2 x 5 and 2 x 3 factorial ANOVAs had fixed effects on the first factor: gender and age comprised between groups and the repeated measures were thus on the second factor, namely, line position and line length.

2. Different designs

In the following section the required sample was calculated for each design in the study. The different required parameters were kept similar throughout and for the factorial designs the between group, within group/subject and interaction requirements are provided. In the first 2 x 5 factorial design sample size estimation, a between subjects on both factors were used as a baseline example of the required sample size. The required size is 128 but as can be seen in subsequent analyses, the required size for repeated measures were greatly reduced.

a. 2 x 15 repeated measures (position x slides)

F tests - ANOVA: Repeated measures, between factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	15
	Corr among rep measures	=	0.5
Output:	Noncentrality parameter λ	=	8.1000000
	Critical F	=	3.9306919
	Numerator df	=	1.0000000
	Denominator df	=	106
	Total sample size	=	108
	Actual power	=	0.8051645

F tests - ANOVA: Repeated measures, within factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	15
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	21.6000000
	Critical F	=	1.7361464
	Numerator df	=	14.0000000
	Denominator df	=	224
	Total sample size	=	18
	Actual power	=	0.8532142

F tests - ANOVA: Repeated measures, within-between interaction

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	15
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	21.6000000
	Critical F	=	1.7361464
	Numerator df	=	14.0000000
	Denominator df	=	224
	Total sample size	=	18
	Actual power	=	0.8532142

b. 2 x 5 repeated measures (hand x position)

	Pos1	Pos2	Pos3	Pos4	Pos5
Hand1					
Hand2					

The table above illustrates the design of the two repeated measures factors. It should be noted that most repeated measures had two within subject factors as opposed to the the analyses with gender and age which constituted a between subjects' factor as indicated below.

F tests - ANOVA: Fixed effects, special, main effects and interactions

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.25
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Numerator df	=	1
	Number of groups	=	10
Output:	Noncentrality parameter λ	=	8.0000000
	Critical F	=	3.9214782
	Denominator df	=	118
	Total sample size	=	128
	Actual power	=	0.8010495

F tests - ANOVA: Repeated measures, within factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	.2
	α err prob	=	0.05
	Power (1-β err prob)	=	.80
	Number of groups	=	2
	Number of measurements	=	5
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	12.8000000
	Critical F	=	2.4472365
	Numerator df	=	4.0000000
	Denominator df	=	120
	Total sample size	=	32
	Actual power	=	0.8135321

F tests - ANOVA: Repeated measures, between factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	.2
	α err prob	=	0.05
	Power (1-β err prob)	=	.8
	Number of groups	=	2
	Number of measurements	=	5
	Corr among rep measures	=	0.5
Output:	Noncentrality parameter λ	=	8.0000000
	Critical F	=	3.9214782
	Numerator df	=	1.0000000
	Denominator df	=	118
	Total sample size	=	120
	Actual power	=	0.8010495

F tests - ANOVA: Repeated measures, within-between interaction

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	5
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	12.8000000
	Critical F	=	2.4472365
	Numerator df	=	4.0000000
	Denominator df	=	120
	Total sample size	=	32
	Actual power	=	0.8135321

c. 2 x 3 repeated measure (hand x line)

F tests - ANOVA: Repeated measures, between factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	3
	Corr among rep measures	=	0.5
Output:	Noncentrality parameter λ	=	8.0400000
	Critical F	=	3.9128750
	Numerator df	=	1.0000000
	Denominator df	=	132
	Total sample size	=	134
	Actual power	=	0.8036806

F tests - ANOVA: Repeated measures, within factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	3
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	10.0800000
	Critical F	=	3.1107662
	Numerator df	=	2.0000000
	Denominator df	=	80.0000000
	Total sample size	=	42
	Actual power	=	0.8031391

F tests - ANOVA: Repeated measures, within-between interaction

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.2
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Number of groups	=	2
	Number of measurements	=	3
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	10.0800000
	Critical F	=	3.1107662
	Numerator df	=	2.0000000
	Denominator df	=	80.0000000
	Total sample size	=	42
	Actual power	=	0.8031391

d. 2 x 5 x 3 repeated measures (hand x position x line)

The number of levels complicated the calculation for this design (Lakens & Caldwell, 2019).

e. Memory, fixation and gaze duration

Exact - Correlation: Bivariate normal model

Options:	Exact distribution		
Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Correlation ρ H1	=	0.5
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Correlation ρ H0	=	0
Output:	Lower critical r	=	-0.3672777
	Upper critical r	=	0.3672777
	Total sample size	=	29
	Actual power	=	0.8139420

Exact - Correlation: Bivariate normal model

Options:	Exact distribution		
Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Correlation ρ H1	=	.5
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Correlation ρ H0	=	0
Output:	Lower critical r	=	0.3515312
	Upper critical r	=	0.3515312
	Total sample size	=	23
	Actual power	=	0.8103534

f. Memory and LBT

Regression DV Left mem score, DV LBT consisted of 10 variables (line position of each hand)

F tests - Linear multiple regression: Fixed model, R^2 deviation from zero

Analysis:	A priori: Compute required sample size		
Input:	Effect size f^2	=	0.15
	α err prob	=	0.05
	Power (1-β err prob)	=	0.80
	Number of predictors	=	10
Output:	Noncentrality parameter λ	=	17.7000000
	Critical F	=	1.9203099
	Numerator df	=	10
	Denominator df	=	107
	Total sample size	=	118
	Actual power	=	0.8012597

g. Remainder of repeated measures designs

The following designs can be assumed to be similar to the 2x5 and 3x5 designs as above because a power analysis was able to be calculated for a 2 between group (fixed effects) x 3 or 5 within repeated measures factor.

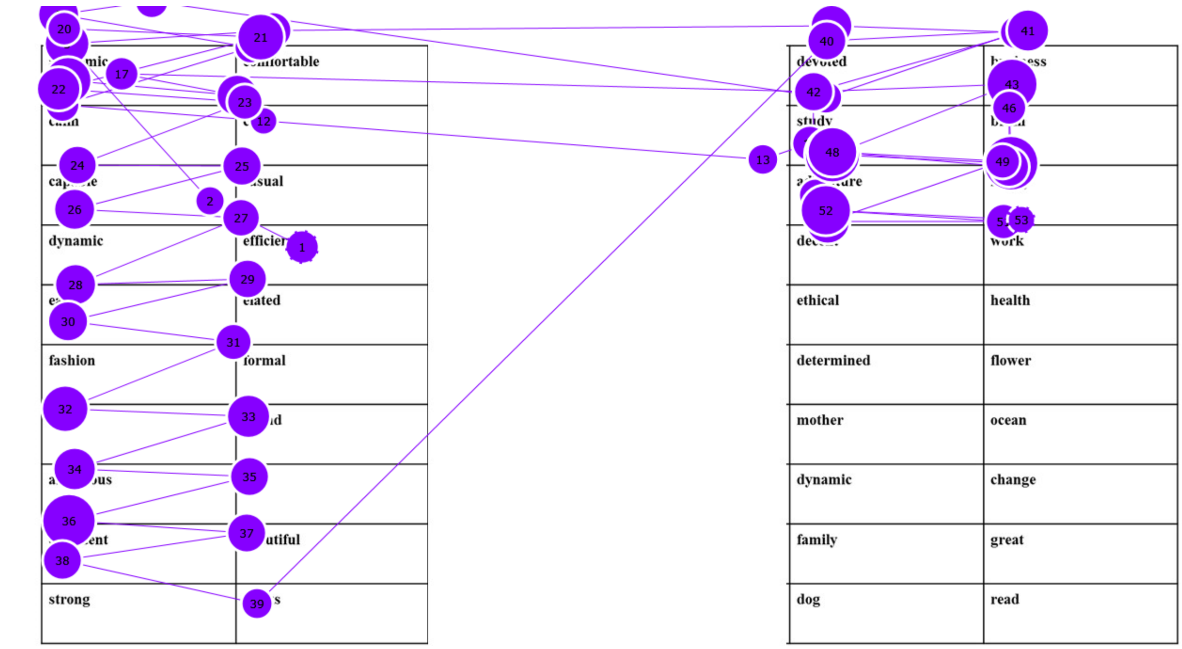
- Left 2 x 5 repeated measures (gender x line pos)
- Right 2 x 5 repeated measures (gender x line pos)
- Left 2 x 3 repeated measures (gender x length)
- Right 2 x 3 repeated measures (gender x length)
- Left: 2 x 5 repeated measures (age x position)
- Right: 2 x 5 repeated measures (age x position)
- Left: 2 x 3 repeated measures (age x length)
- Right: 2 x 3 repeated measures (age x length)

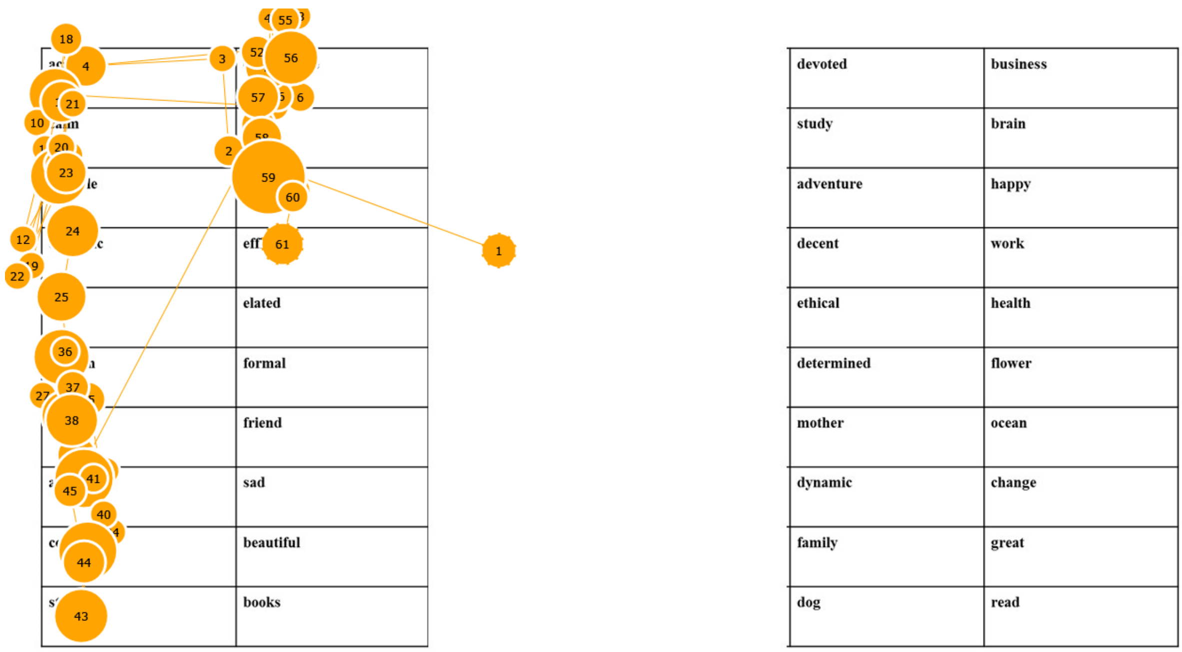
3. Conclusion

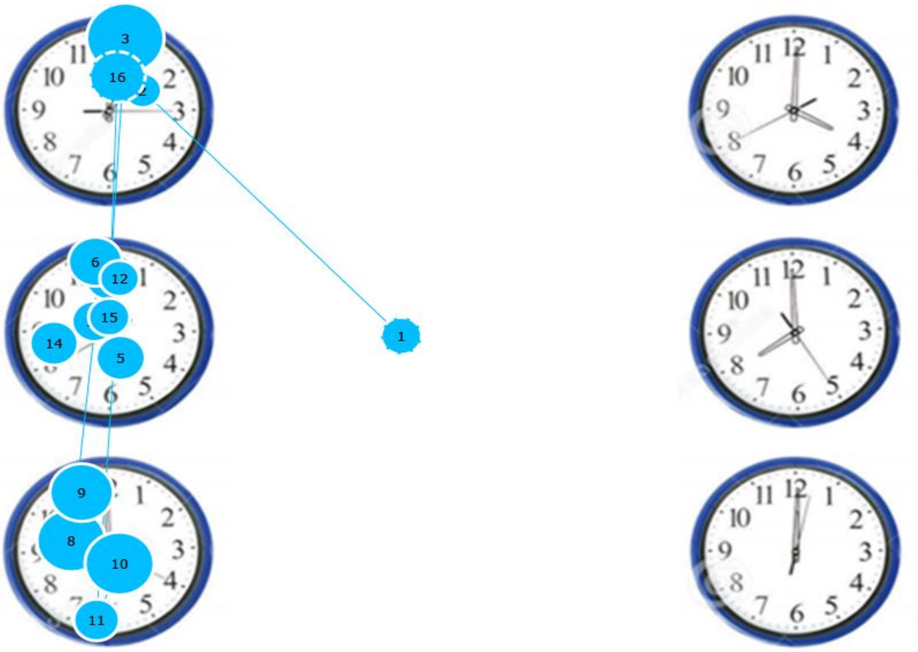
It can be seen from the above that the between groups analyses would be greatly underpowered since each group would in principle have approximately 16 per level for the fixed factor. A large number would be required for between group or subject comparisons. The repeated measures or within subjects factor would be relatively appropriate with around 30 to 40 persons, which is also the case with the correlation analyses but not for the regression analyses which would require a larger sample (Faul et al., 2009; Faul et al., 2007). One would assume that adequate power was obtainable for the repeated measures on both within subjects factors of at least 32 subjects in the total sample given that the required sample size decreases remarkedly if a within rather than a between subjects design is followed. The interpretation of results of the within subjects on both factors would be more reliable than when the two level between subjects factor is included such as age and gender.

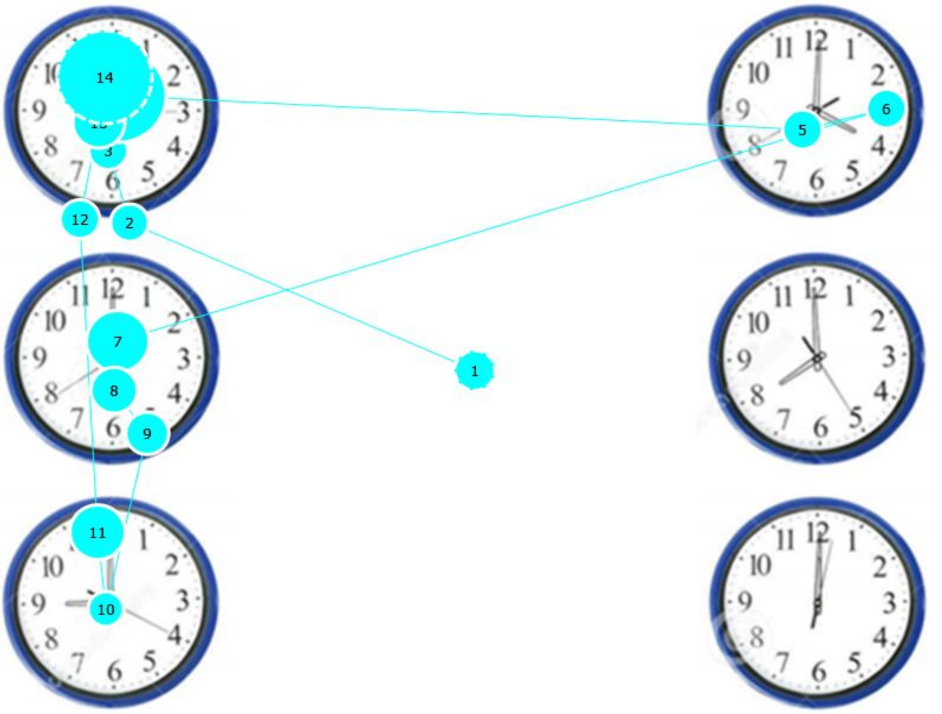
APPENDIX H: Memory simulation images:

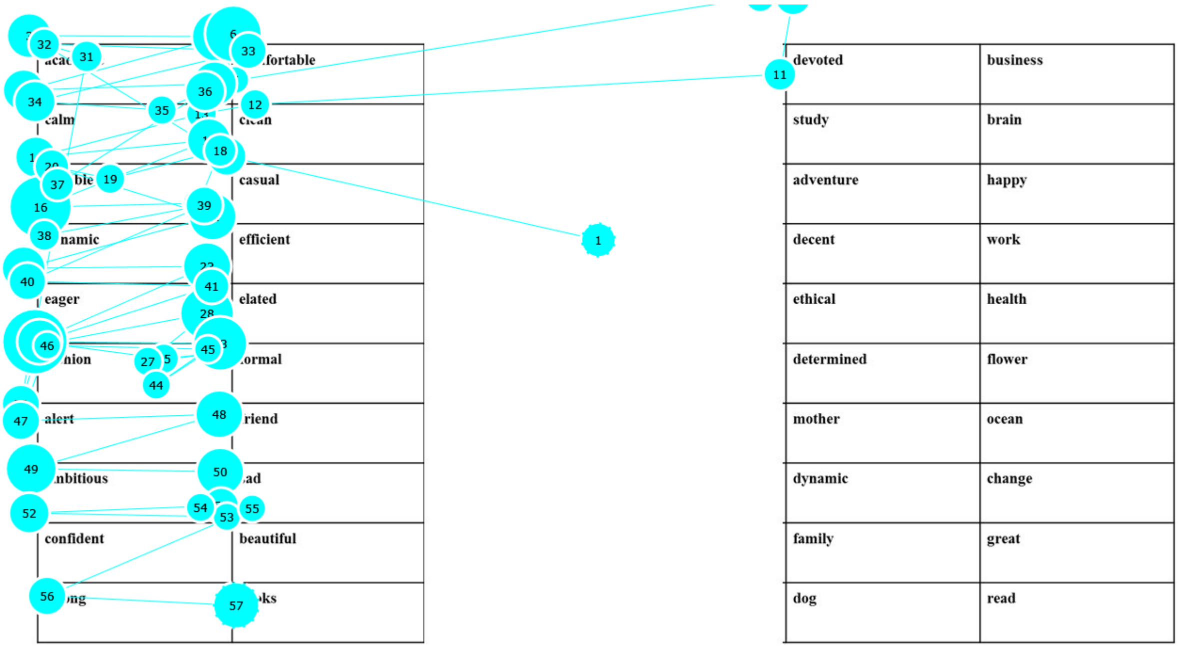
Gaze scan patterns and number of Fixations










calm
eager
alert
confident
casual
efficient
elated
beautiful
devoted
business
study
brain
adventure
happy
decent
work
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determined
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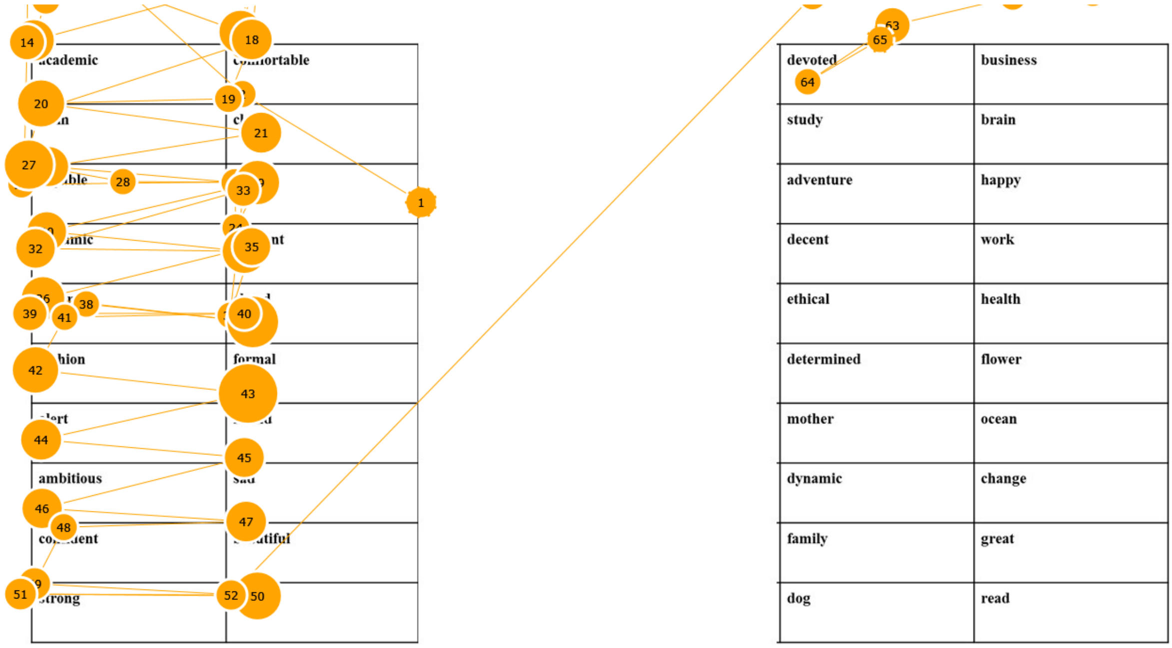
change
family
great
dog
read


academic
ambitious
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formal
devoted
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decent
work
ethical
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determined
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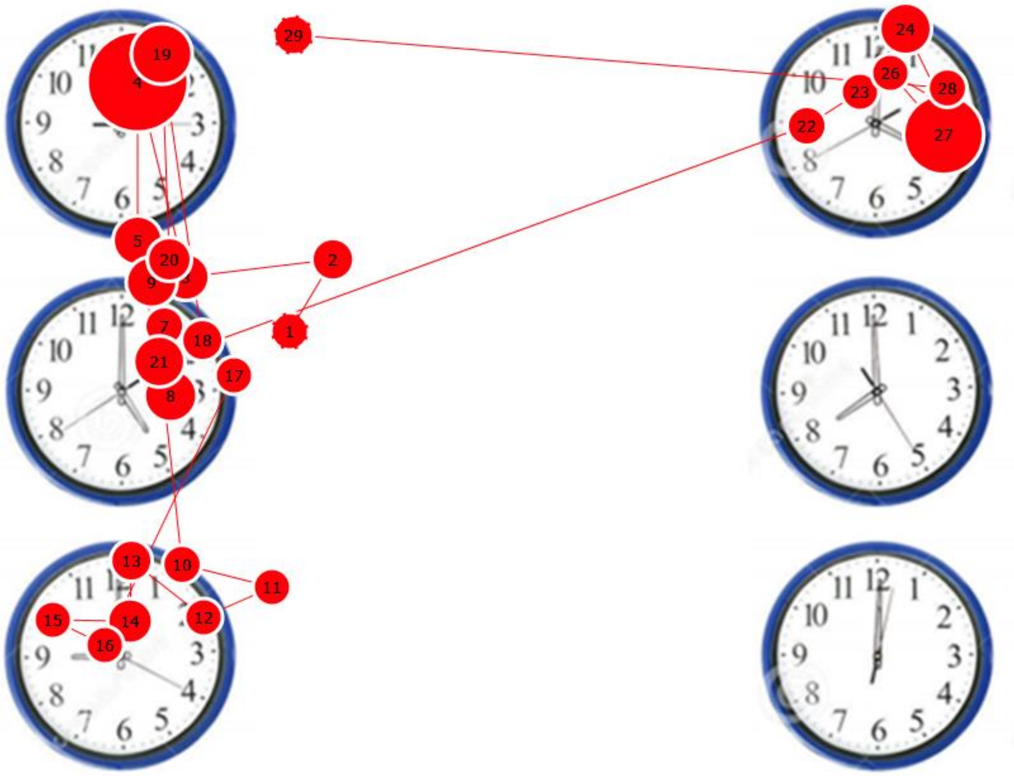
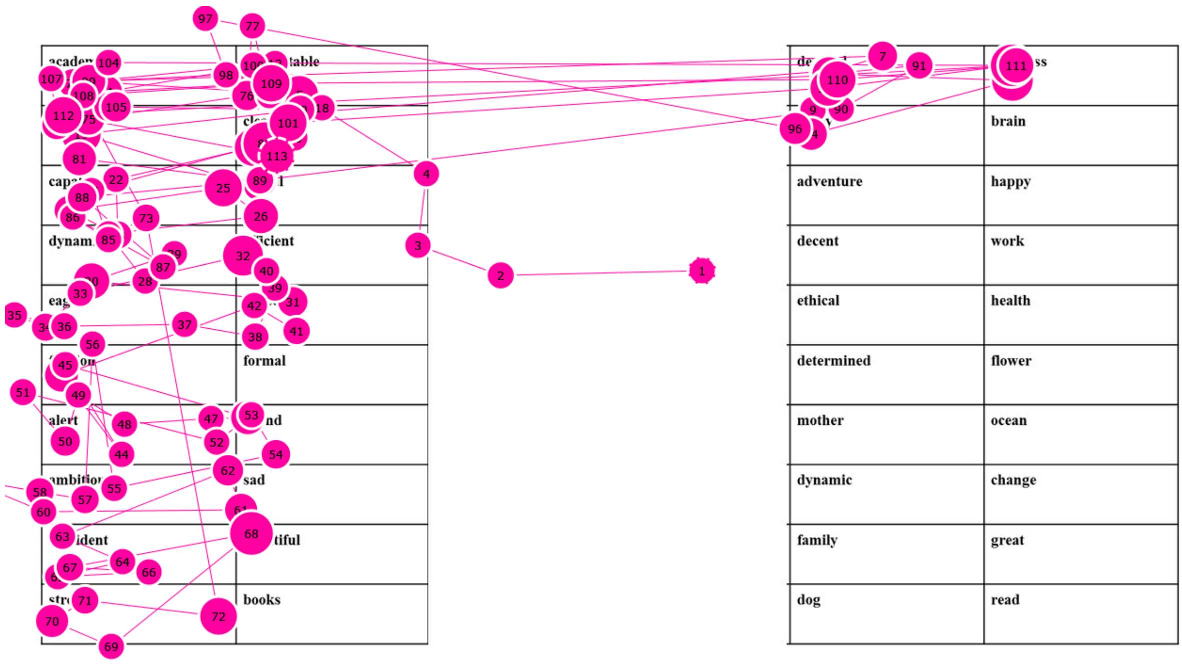
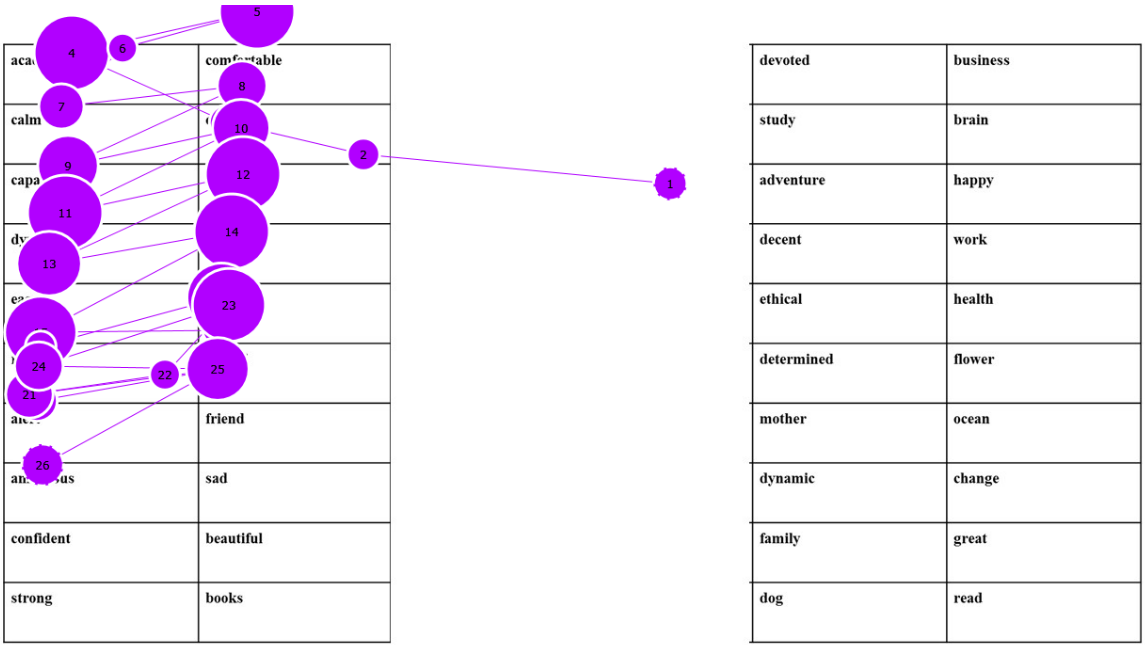



brain
adventure
happy
decent
work
ethical
health
determined
flower
mother
ocean
dynamic
change
family
great
dog
read
formal
sad
books


calm
friend
sad
confident
beautiful
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books
devoted
business
study
brain
adventure
happy
decent
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ethical
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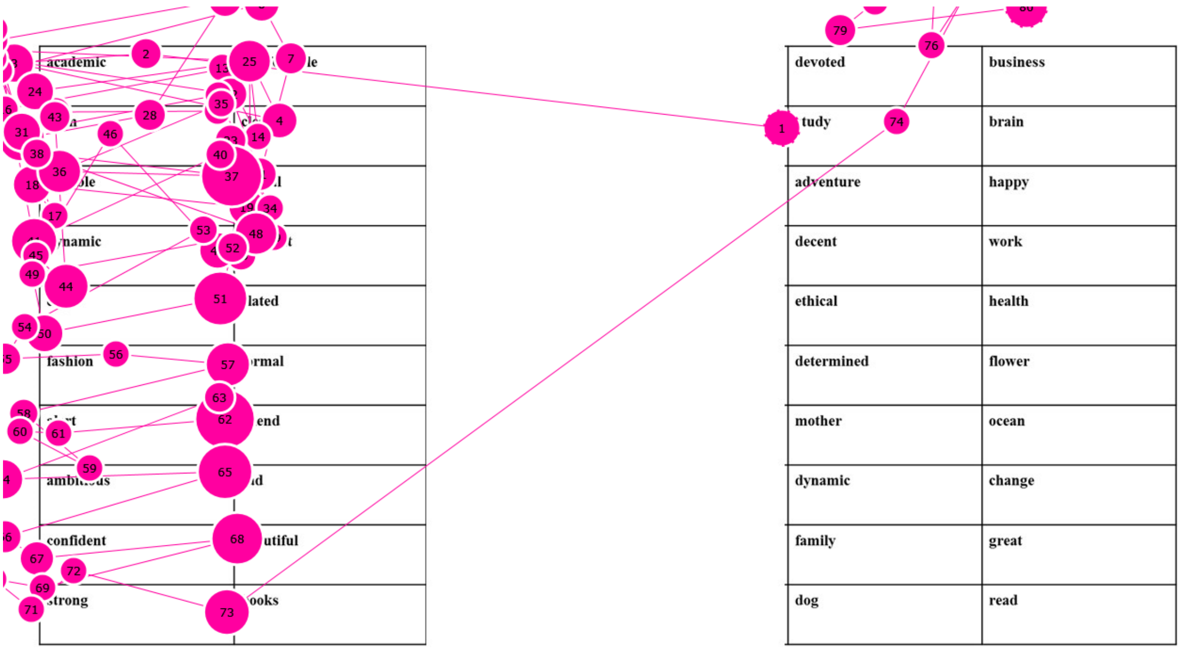
flower
mother
ocean
dynamic
change
family
great
dog
read


academic
fashion
confident
devoted
business
brain
adventure
happy
decent
work
ethical
health
determined
flower
mother
ocean
dynamic
change
family
great
dog
read