The Social Space Around Us: the effect of social distance on spatial attention

Ancrêt L. Szpak

The School of Psychology
Faculty of Social and Behavioural Sciences
Flinders University
Adelaide, South Australia

A dissertation presented to the Faculty of Social and Behavioural Sciences
in partial fulfillment of the requirements for the degree of Doctor of Philosophy
in the subject of Psychology.

December 2015

Principal advisor: Professor Mike Nicholls Ancrêt L. Szpak

The Social Space Around Us: the effect of social distance on spatial attention

Abstract

Experimental cognitive psychology has predominantly investigated the effects of psychological processes on behaviour in individuals. This knowledge has advanced our understanding of how individuals perceive, orient and attend to objects in their environment and how the environment can also shape perception. Within these experimental paradigms social influences are deliberately reduced. Individuals are typically studied in isolation in order to decrease measurement noise associated with influences occurring outside the laboratory. Although this approach has provided the basis for understanding perception in individuals, it has limited applicability to social conditions that occur naturally in everyday experiences. This limitation is directly related to the research question that is at the core of this thesis: how do an individual's perceptions and behaviours change under social situations? The focus of this thesis is to investigate how people in our environment can shape our perceptions. This thesis is comprised of several studies and published works that compare spatial performance under individual and paired conditions.

Because of the nature of my research question, there is a large overlap between cognitive and social psychology. The first three chapters in my thesis focus on bringing concepts from these two areas together. The first chapter reviews disordered perceptions in individuals with neurological damage. The chapter discusses how an understanding of disordered perception informs current knowledge about the neurological underpinnings of attention in healthy individuals. The second chapter examines perceptions in healthy individuals with a specific focus on spatial attention and conditions that lead to shifts in attention. The third review chapter highlights relevant knowledge from social psychology that suggests social conditions can affect the spatial constructs discussed in the review chapters one and two. The chapter also hypothesises about the influence of interpersonal proximity on shifts in spatial attention.

The remaining chapters in my thesis contain experiments that I have conducted throughout the course of my PhD. I developed a new spatial methodology that enabled two participants to complete a spatial task in close proximity to each other. Core findings of these experiments demonstrate that interpersonal discomfort leads to a withdrawal of spatial attention away from the other person. I hypothesised that a withdrawal of attention occurs in order to increase the perceived distance between oneself and the other person, thereby making unwanted close interpersonal proximities more tolerable. I also observed that participant pairs who were given separate tasks were able to conceptually distance themselves from each other. I hypothesised that because participants were allowed to engage in their own solo activity, social discomfort was decreased. This thesis also contains two new single-participant methodologies that enabled me to directly compare with and extend existing literature on attention in proximal/distal spaces.

This thesis adds several significant contributions to the field of cognitive psychology. Firstly, published works in this thesis empirically demonstrate another person can influence shifts in spatial attention. This important observation opens up the possibility that close interpersonal proximities can also affect other aspects of attention. Secondly, new methodologies were developed to study joint spatial attention and could be easily employed in future research that seeks to build upon the studies disseminated in this thesis. The final section of this thesis develops a new model of social attention by synthesising all theoretical and experimental insights gathered in this thesis.

Contents

Listing of figures

This thesis is dedicated to three Dr Szpaks: Teresa, Waldemar and Zygmunt, without your love and support this thesis would not have been written.

Declaration

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

Research from this thesis has been published in the following articles:

- Szpak, A., Thomas, N. A., & Nicholls, M. E. R. (in press). Hemispheric asymmetries in perceived depth revealed through a radial line bisection task. *Experimental Brain Research*. `doi:10.1007/s00221-015-4504-5`
- Szpak, A., Loetscher, T, Bastian, J., Thomas, N. A., & Nicholls, M. E. R. (2015). Visual asymmetries for relative depth judgments in a three-dimensional space. *Brain and Cognition*, 99, 128–134. `doi:10.1016/j.bandc.2015.08.005`
- Szpak, A., Nicholls, M. E. R., Thomas, N. A., Laham, S., & Loetscher, T. (2015).“No man is an island”: Effects of social proximity on spatial attention. *Cognitive Neuroscience*. `doi:10.1080/17588928.2015.1048677`
- Szpak, A., Loetscher, T., Churches, O., Thomas, N. A., Spence, C. J., & Nicholls, M. E. R. (2015). Keeping your distance: attentional withdrawal in individuals who show physiological signs of social discomfort. *Neuropsychologia*, 70, 462–467. `doi:10.1016/j.neuropsychologia.2014.10.008`

Work from this thesis has also been presented at:

- Szpak. A., Loetscher, T., Churches, O., Thomas, N. A., & Nicholls, M. E. R. (September 2015). *Too close for comfort: The effect of interpersonal proximity of spatial attention*. Paper presented at the 6th International Conference on Spatial Cognition (ICSC). Rome, Italy.
- Szpak. A., Loetscher, T., Churches, O., Thomas, N. A., & Nicholls, M. E. R. (June 2015). *Sparks Flying: Attentional attraction, withdrawal and electrodermal activity*. Paper presented at the 2nd annual Australasian Social Neuroscience Society Meeting. Brisbane, Australia.

- Szpak. A., Loetscher, T., Churches, O., Thomas, N. A., & Nicholls, M. E. R. (April 2015). *The chemistry between us: Attraction, withdrawal and electrodermal activity*. Paper presented at the 42nd annual Australasian Experimental Psychology Conference (EPC). Sydney, Australia.
- Szpak, A., Loetscher, T., Bastian, J., Thomas, N. A., & Nicholls, M. E. R. (September 2014). *Attention in another dimension: Visual asymmetries in three-dimensional space*. Poster presented at the 4th biennial North Sea Meeting on Brain Asymmetries. Durham, United Kingdom.
- Szpak, A., Loetscher, T., Bastian, J., Thomas, N. A., & Nicholls, M. E. R. (April 2014). *Visual asymmetries in three-dimensional space*. Poster presented at the 41st annual Australasian Experimental Psychology Conference (EPC). Brisbane, Australia.
- Szpak, A., Loetscher, T., Thomas, N. A., & Nicholls, M. E. R. (April 2013).*Looking the other way: How others can bias spatial attention*. Poster presented at the 40th annual Australasian Experimental Psychology Conference (EPC). Adelaide, Australia.

In addition, the work was also communicated in the following seminars:

- Szpak, A. (May 2015), *The Sparks Between Us: attraction, withdrawal and electrodermal activity*. The University of South Australia, Adelaide, Australia
- Szpak, A., (October 2013) *"No Man is an Island": the effect of social distractors on the perception of space*. Flinders University, Adelaide, Australia

Signed ____________________ Date ____________________

Acknowledgments

My PhD has been an amazing journey on which I was accompanied by truly wonderful, kind, wise and talented researchers. In particular, I would like to thank my supervisors: Mike, Nicole and Tobias; without your wisdom, encouragement and guidance I may not have completed this incredible journey.

Professor Mike E. R. Nicholls I am truly thankful that you accepted me into your Brain and Cognition Laboratory for my honours year, and that you have continued to mentor me throughout my PhD. You have supported and encouraged me in every endeavour and helped me to grow as a researcher. I have learnt so much from you, and I will take all that I have learnt with me for the rest of my career.

Dr Nicole A. Thomas Thank you so much for being a part of my academic journey and supporting me throughout the course of my studies. You have always been there when I needed help and your many talents and insights continue to inspire me.

Dr Tobias Loetscher Thank you for many fruitful discussions, and your patience in explaining new concepts. I am grateful for your general support and encouragement throughout my studies. Your meticulous, analytic and comprehensive approach to research has made a lasting impression upon me.

Dr Owen Churches Your enthusiasm and encouragement has kept me thinking of new ideas. Thank you for injecting energy into my work.

The Brain and Cognition Laboratory Thanks to Liz Saccone, Nathan Leggett, Daniel Carragher, Sophie Wignall and Alison Simpson. Thank you for all the chats, coffee and most of all friendship.

I am very grateful to Dr John Bastian from the Australian Centre for Visual Technologies for his collaboration and help in creating three-dimensional stimuli in Chapter Eight of this thesis.

I would also like to thank Lauren Nicholls for creating Figures 6.2 and Dr Danielle Clode for creating Figure 9.1 in the likeness of Liz Saccone and I.

Lastly, I like to thank Zygmunt, Teresa and Waldemar for their love and support. This thesis is dedicated to you because I might not have made it without you. Thank you to my dear husband Zygmunt for always encouraging me and supporting me, especially in the final stages of my PhD.

This thesis was compiled using the LaTeX Dissertate template which has been released under the permissive AGPL license, and can be found online at github.com/asm-products/Dissertate or from its lead author, Jordan Suchow, at suchow@post.harvard.edu.

Sometimes the questions are complicated and the answers are simple.

Theodor Seuss Geisel (Dr Seuss)

1

Thesis Overview

The title of this thesis—'The Social Space Around Us', was inspired by a scientific publication written by some of the most influential researchers in the area of cognitive neuroscience (Rizzolatti, Fadiga, Fogassi, & Gallese, 1997). In their article, Rizzolatti and colleagues discussed the behavioural and neurological factors underlying the spatial coding for actions. Moreover, the authors examined how 'the space around us' provides the necessary visual and somatosensory stimulation for generating a neurological spatial representation. It has become generally accepted in the cognitive neuroscience community that this neurologically represented space around our bodies is a prerequisite for the actionability of objects.

As humans are highly social beings, when we move and interact with our environment we are not only interacting with objects but with other people too. Numerous studies in social psychology have shown that the space around us is just as important for social interactions as it is for actions. Hence, the social space around us is the neurologically represented social area of space in close proximity to our bodies, which we use to interact with other people in our environment.

The research question that is at the core of this thesis is: Can the social space around us impact on spatial attention? Addressing this question requires synthesising the knowledge of body space from two relatively disconnected areas: cognitive neuroscience and social psychology. This thesis consists of twelve experiments designed to identify how space is represented and how other people in close proximity can influence the representation of space.

1.1 Issues to be addressed

The interplay between social space and cognition is a relatively new and emerging area of research in cognitive neuroscience, with many unanswered questions and challenges that need to be addressed. In order to develop a comprehensive understanding of 'social space' knowledge from multiple disciplines needs to be integrated. Even though multiple disciplines may share a conceptual overlap there are many methodological, experimental, theoretical and focal differences that make inter-discipline integration challenging. For example, typical cognitive neuroscience methodologies study individuals in isolation which leads to a limited understanding of the cognitive and neurological mechanisms in a social environment. On the other hand, social psychology focuses on addressing contextual influences on social behaviour which diminishes the cognitive and neurological involvement in these social processes.

1.2 Contribution of the thesis

This thesis makes several key contributions that extend the current understanding of the allocation of attention in social space.

- Research from multiple disciplines has been synthesised to create an extensive and unified representation of social space.
- New and modified methodologies were designed to address the research question: Can the social space around us impact on spatial attention? For example, well-known single-participant paradigms such as the Landmark task were modified to create a joint version, and were utilised to test spatial behaviours which have not been examined before in the attention literature. Another notable contribution was the development and deployment of a new three-dimensional task which revealed important insights into biases in depth perception.
- This thesis also contributes novel research that provides original empirical and theoretical knowledge to both cognitive and social psychology. Four peer-review publications have originated from the research conducted throughout the course of my PhD.
- This thesis proposes a new model of social attention which draws upon an extensive literature review and new insights which emerged from my experimental results.

1.3 ORGANISATION OF THE THESIS

This thesis consists of: three literature review chapters; five experimental chapters with a total of twelve experiments, which are thematically organised; and the general discussion which ties together all unique contributions.

1.3.1 CHAPTER 2

Important neurological concepts of spatial attention are introduced in the second chapter. In particular, the second chapter discusses how disordered perceptions of space inform the current understanding of the neurological mechanisms of spatial attention in healthy individuals. Themes that are explored in this chapter include: models of spatial attention, neuro-cognitive assessments of spatial attention, the relationship between perception and action, different spatial dimensions and distractibility.

1.3.2 CHAPTER 3

The third chapter mirrors the themes covered in Chapter Two with emphasis on spatial attention in healthy individuals. Attentional asymmetries in healthy individuals are discussed in depth. The third chapter provides the foundation for subsequent experimental chapters that discuss and employ cognitive concepts.

1.3.3 CHAPTER 4

The fourth chapter brings together relevant knowledge from both social and cognitive psychology that is important for social space. The chapter discusses the potential impact of top-down social processing on spatial attention and recounts the limited research that can make inferences about the effects of interpersonal distance on spatial attention.

1.3.4 CHAPTER 5

The fifth chapter consists of four single-participant experiments designed to identify whether social distractors can influence pseudoneglect. Each experiment employed a different spatial task to establish a general understanding of how social distractors can influence pseudoneglect.

1.3.5 CHAPTER 6

The sixth chapter contains three experiments that have been published in *Cognitive Neuroscience*. These experiments examined the impact of task interdependency between participant pairs on spatial attention in a joint Landmark task.

1.3.6 Chapter 7

The seventh chapter employs the same joint Landmark task utilised in Chapter Six, but with different social demands. A cooperative and competitive joint Landmark task was developed for this chapter in order to test whether positive and negative social demands affect spatial attention differently.

1.3.7 Chapter 8

The eighth chapter is a methodological chapter that consists of two single-participant experiments both of which have been published. The first experiment of this chapter used a novel single-participant radial Landmark task that was later used as a joint paradigm in Chapter 9. The empirical contributions of Chapter 8 primarily add to the current understanding of attentional asymmetries in perceived depth.

1.3.8 Chapter 9

The ninth chapter adopts the single-participant radial Landmark task constructed in Chapter Eight and modified the methodology to incorporate a second participant in a turn-based joint paradigm. This chapter includes two experiments that examine individual differences in social discomfort on spatial attention.

1.3.9 Chapter 10

The tenth and final chapter provides the concluding narrative that combines all the insights developed in this thesis to create a model of social attention. This new proposed model of social attention has been developed by combining knowledge from both cognitive neuroscience and social psychology, as well as new theoretical insights explored in this thesis. Key contributions of this thesis are outlined in this chapter and directions for future research are also proposed.

When the brain is whole, the unified consciousness of the left and right hemispheres adds up to more than the individual properties of the separate hemispheres.

Roger Wolcott Sperry, 1987

2

Clinical attentional asymmetries (Neglect)

The aim of this chapter is to discuss and develop an understanding of disordered perceptions which inform current knowledge about the neurological underpinnings of spatial attention in healthy individuals.

2.1 HEMISPATIAL NEGLECT

The two halves of the brain are functionally asymmetric. Generally, the left hemisphere (LH) is considered to represent verbal functions, whereas the right hemisphere (RH) controls non-verbal (spatial) functions. The left and the right halves of the brain, however, share a complex interconnected network that is essential to execute even the simplest of actions. Investigations into the neurological pathologies of cognition have provided unique insight into this complex network of connections in normal functioning brains.

A particularly salient example of how functional asymmetries in the brain have been better understood is through the various studies on patients with hemispatial neglect. Neglect patients show severe behavioural deficits in orienting, attending, perceiving and responding to objects in the contralesional hemispace (Bartolomeo, 2014; Driver & Mattingley, 1998; Ferber & Karnath, 2001; Halligan, Fink, Marshall, & Vallar, 2003; Halligan & Marshall, 1998; Loetscher, Nicholls, Brodtmann, Thomas, & Brugger, 2012). Classically, these behavioural deficits were thought to occur because of parietal lobe damage —especially in the right hemisphere (Brain, 1941; Vallar & Perani, 1986); however, subsequent studies have shown that other cortical areas such as temporal (Karnath, 2001; Karnath, Ferber, & Himmelbach, 2001) and even frontal (Vallar, 2001) damage can also result in neglect (see Bartolomeo, 2014; Molenberghs, Sale, & Mattingley, 2012, for a review). More recent studies, that have access to advanced neuroimaging equipment and techniques, have shown that neglect can also arise as a result of damage along the subcortical networks (see Chica et al., 2012; De Schotten et al., 2011). A common finding amongst neglect studies is that severe and persistent neglect occurs mainly in patients with right hemisphere lesions (Mesulam, 1981, 1999). Consequently, patients with damage to the right hemisphere have contralesional deficits in the left side of space that will interfere with their ability to successfully carry out simple everyday tasks. These patients exhibit neglect behaviour in everyday tasks such as neglecting people on the left, only grooming and dressing the right side of their body, only eating on the right side of a plate and when navigating bumping into objects on the left.

There are three different subtypes of neglect-like symptoms; depending on the extent of the lesion, these symptoms can occur concomitantly (see Figure 2.1):

Sensory disruption Sensory disruption occurs when the primary visual cortex is damaged and often leads to contralesional blindness (hemianopia).

Sensory inattention Unlike hemianopics, patients with sensory inattention can see objects on the left side, but cannot direct attentional resources to them. Doricchi and Tomaiuolo (2003) proposed that damage to the right parietal-frontal boundary, and the area between the rostral section of the inferior parietal lobule and the inferior post-central gyrus, produces chronic spatial neglect without concomitant hemianopia.

Sensorimotor impairments Patients that have lesions to the inferior parietal lobe not only present with visual inattention, but also exhibit motor impairments contralateral to their lesion (Driver & Mattingley, 1998; Heilman, Bowers, Coslett, Whelan, & Watson, 1985; Mattingley & Driver, 1997). These sensorimotor impairments produce an uncertainty or inability to direct actions to the left side.

In some cases, patients with hemispatial neglect can have anosoagnosia where they show an unawareness or lack of concern for their neglect symptoms. Patients with anosoagnosia are less likely to report attentional deficits after developing a brain lesion, which therefore makes hemispatial neglect difficult to diagnose (Bartolomeo, 2014; Barrett et al., 2006).

Sensory inattention observed in hemispatial neglect patients is regarded as a higher-order pathology. A. J. Harris (1999) succinctly describes left neglect as 'a cognitive refusal to acknowledge perception of left-sided visual and somatosensory space' (pg 1464). Neglect patients inattention to the contralesional side occurs in the absence of visual field or motor impairments (Driver & Mattingley, 1998; Mennemeier et al., 2005; Brain, 1941) and can also occur for imagined stimuli (Ortigue, Megevand, Perren, Landis, & Blanke, 2006; Bisiach & Luzzatti, 1978). Patients with spatial neglect are able to pre-attentively process low level visual information (Vuilleumier & Schwartz, 2001; Halligan et al., 2003; Driver & Mattingley, 1998), which suggests that the neglect brain does receive visual information, but is unable to attend or direct visual attention to these objects (Driver & Mattingley, 1998; Halligan et al., 2003; Kristjánsson, Vuilleumier, Malhotra, Husain, & Driver, 2005). This inability

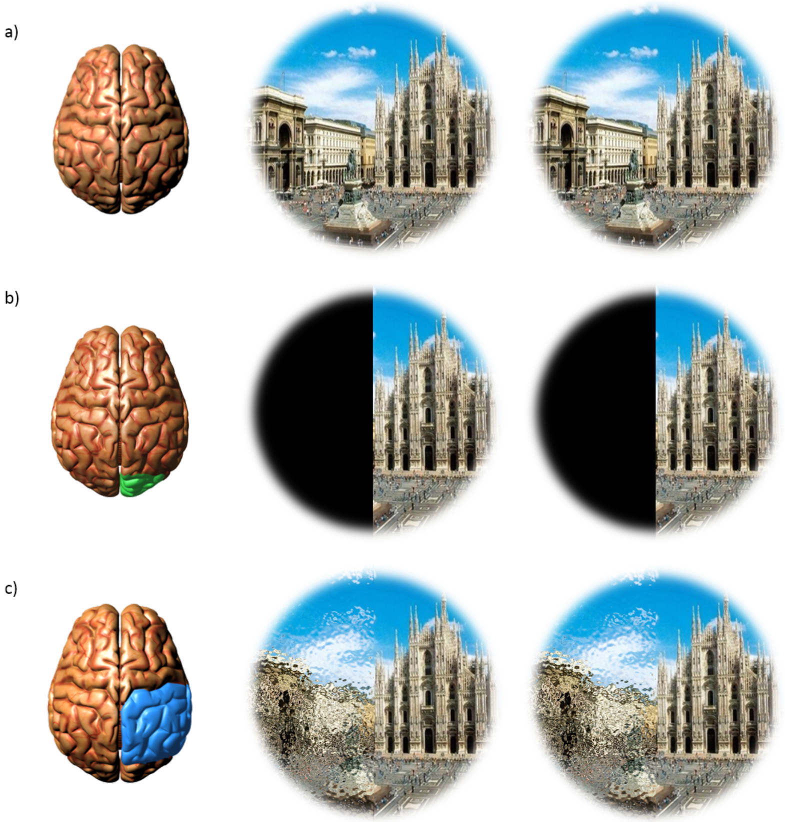


Figure 2.1: Illustration of the visual field differences and typical lesion regions for hemianopia and hemispatial neglect. Panel (a) represents the visual field of the left and right eyes in the intact brain. Panel (b) represents visual field loss in patients with hemianopia. Hemianopics are unable to see the left halves of each visual field as lesions in the visual cortex cause deficits along the sensory pathways. Panel (c) shows an impairment in engaging attentional resources to the left side of space as observed in patients with hemispatial neglect.

prevents neglect patients from using low level information to judge the location, distance or size of objects on the neglected side.

2.2 Models of attention

There are various models of attention, but for the purpose of this thesis only two relevant theories will be discussed: activation-orienting and attentional network models. Although the activation-orienting and attentional network models will be reviewed separately, the attention literature does not consider them to be mutually exclusive.

Kinsbourne (1970) proposed the activation-orienting model to explain visual attentional asymmetries. Each hemisphere in the brain controls the contralateral hemispace and actions. For example, the left hemisphere controls the right hemispace and actions by the right arm and the converse is true for the right hemisphere (see Figure 2.2). Preparatory activation of one hemisphere gives an attentional advantage to the contralateral hemispace, thereby resulting in superior performance in that hemispace (Kinsbourne, 1970). If the right hemisphere acquires damage the left hemisphere will become overactive leading to hyperattention in the right hemispace and hypoattention in the left hemispace (Kerkhoff, 2001). According to this model, people with right hemisphere lesions will neglect the left hemispace, and people with left hemisphere lesions will neglect the right hemispace. But, right neglect following left hemisphere lesions are infrequent and less persistent than right hemisphere lesions (Mesulam, 1981; Mark, 2003).

Subsequent to Kinsbourne's activation-orienting model, Heilman (1995) and Mesulam (1999) proposed a theoretical modification suggesting that the right hemisphere may be dominant for attention in both the left and right hemispaces, whereas the left hemisphere only controls the right hemispace. Attentional asymmetries occur because of an imbalance of hemispheric activation, and the more active hemisphere predisposes attention to be oriented to the contralateral hemispace (Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). This hypothesis better explains how lesions to the right hemi-

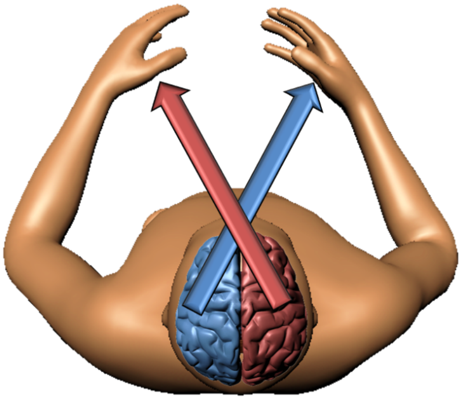


Figure 2.2: Illustration of how the left and right hemispheres control contralateral actions.

sphere lead to left neglect, whereas lesions to the left hemisphere have a lower incidence rate and are less severe. If the right hemisphere controls attention to both hemispaces, when a lesion occurs in the left hemisphere the right hemisphere can compensate and direct attention to both hemispaces. But, if the left hemisphere can only direct attention to the right hemispace, damage to the right hemisphere cannot be compensated for by the left hemisphere (Halligan et al., 2003; Drain & Reuter-Lorenz, 1996; Mesulam, 1981).

Since Kinsbourne proposed the activation-orienting theory, many studies have supported his hypothesis showing that engaging in activities that preferentially activate one hemisphere results in shifts of attention towards the contralateral hemispace. Neglect symptoms, for example, are ameliorated by monocular patching the right eye, but exacerbated by left eye patching (Butter, 1992; Barrett, Crucian, Beversdorf, & Heilman, 2001; Serfaty, Soroker, Glicksohn, Sepkuti, & Myslobodsky, 1995; Barrett & Burkholder, 2006). Presumably, this occurs because left hemispace engagement reduces the imbalance in hemispheric activity, whilst right hemispace engagement increases cerebral asymmetry. Similar patterns of hemispheric asymmetries are observed in neglect patients by left-right limb activation (Frassinetti, Rossi, & Ladavas, 2001; Eskes, Butler, McDonald, Harrison, & Phillips, 2003) or lateral cueing (Milner, Harvey, Roberts, & Forster, 1993; Vuilleumier, 2002).

The parietal-frontal network in neglect patients has been shown to be hyper-excitable compared to other stroke patients (Koch et al., 2008; Levine et al., 2006). This hyper-excitability in the intact hemisphere is thought to be a compensatory reaction to brain injury (Bonnì, Mastropasqua, Bozzali, Caltagirone, & Koch, 2013). Koch et al. (2008) applied this model of hemispheric overactivity in neglect patients to investigate the usefulness of transcranial magnetic stimulation (TMS) for rehabilitative purposes (see also Bonnì et al., 2013; Koch et al., 2012). Applying theta-burst stimulation over the left posterior parietal cortex for several session over two weeks demonstrated a significant global improvement of visuospatial neglect (Bonnì et al., 2013; Koch et al., 2012). Bonnì et al. (2013) propose that the theta burst stimulation over the left hemisphere may have counteracted the hemispheric imbalance between the two hemispheres by decreasing the hyper-excitability of the left hemisphere and thereby improving neglect symptoms. The authors also noticed an improvement in intrahemispheric connectivity thus providing support for the next model of discussion—the attentional network model.

Recent research has identified the importance of neural attentional networks in the allocation of spatial attention, as well as the role of subcortical damage to the severity and subtypes of hemispatial neglect (Verdon, Schwartz, Lovblad, Hauert, & Vuilleumier, 2009; Doricchi, de Schotten, Tomaiuolo, & Bartolomeo, 2008; Bartolomeo, De Schotten, & Doricchi, 2007). Growing evidence from lesion mapping and neuroimaging studies has shown that lesions along the dorsal (Committeri et al., 2007; Corbetta & Shulman, 2002) and the ventral visual stream (Grimsen, Hildebrandt, & Fahle, 2008; Corbetta & Shulman, 2011) can result in visual neglect. The dorsal stream relays visual information starting from the primary visual cortex and extending dorsally to the parietal lobule. The ventral stream relays visual information also starting from the primary visual cortex and extending ventrally to the temporal lobule. Both of these subcortical visual streams play an important role in visual attention. Until recent advances in neuroimaging, the impact of damage along these pathways has been studied somewhat indirectly. Advances in neuroimaging, such as diffusion tensor imaging (DTI), have allowed a more direct examination of cortical damage to the intrahemispheric transfer of visual information.

Diffusion Tensor Imaging shows that there are three white-matter tracts called the superior longitudinal fasciculus (SLF) I, II and III, that have been implicated in visual neglect (De Schotten et al., 2011; Vuilleumier, 2013; Molenberghs et al., 2012; Doricchi et al., 2008). The SFL I connects the superior parietal cortex with superior frontal areas, thereby overlapping with the dorsal stream. The SLF III connects the inferior parietal cortex with inferior frontal areas, thereby overlapping with the ventral stream and the SLF II may possibly connect the two streams. Neglect patients that have damage along the SLFII, which is responsible for intrahemispheric communication, have more severe spatial neglect (Karnath, Rorden, & Ticini, 2009; De Schotten et al., 2011). Vuilleumier (2013) suggests that the disrupted communication within and between the hemispheres may lead to an atypical integration of visual information playing a major role in the incidence and manifestation of neglect.

Arousal also plays an important role in dynamic inter- and intrahemispheric interaction and is a strong predictor in the incidence and persistence of visual neglect (Vuilleumier, 2013; Chica, Bartolomeo, & Valero-Cabré, 2011; I. H. Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Arousal is thought to be important in the orienting and distribution of attention and modulated by the noradrenergic system (Coull, 1998; Clark, Geffen, & Geffen, 1989). Increased arousal allows for the faster orienting and processing of spatial information, regardless of its location (Fernandez-Duque & Posner, 1997). Neglect patients with damage along right ventral areas exhibit impairments in arousal, detection and reorienting of attention (Corbetta & Shulman, 2011, 2002). Corbetta and Shulman (2011) proposed that a decrease in arousal leads to atypical interactions between the dorsal and ventral streams, which results in an imbalance of dorsal stream activity. Furthermore, the authors suggest that this imbalance in the dorsal attention network favours the left hemisphere driving attention and eye movements to the right visual field.

Arousal is also important for the voluntary maintenance of alertness over time known as 'sustained attention' (Sturm & Willmes, 2001). Deficits in sustained attention can also contribute to the incidence and severity of neglect (I. H. Robertson et al., 1997). Manipulating arousal in neglect patients has been shown to ameliorate neglect symptoms (I. H. Robertson et al., 1997; Malhotra, Parton, Greenwood, & Husain, 2006). This shows the direct effect of arousal on spatial attention and the importance of the dynamic communication between the ventral and dorsal attentional networks.

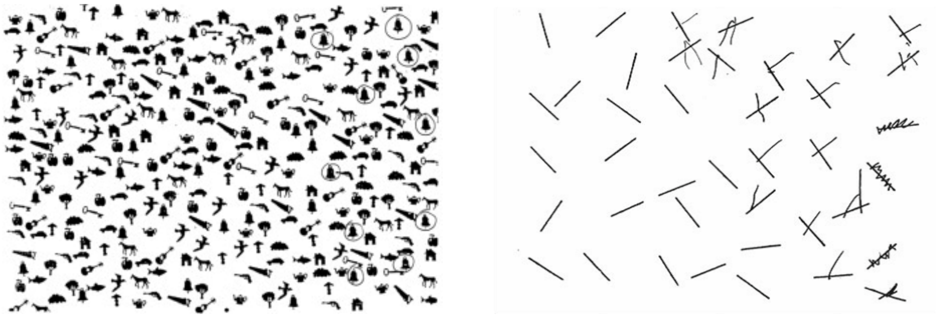
2.3 ASSESSMENTS OF HEMISPATIAL NEGLECT

Hemispatial neglect can lead to a wide range of cognitive and behavioural deficits. As a result standardised tests such as the Behavioural Inattention Test (BIT) have to incorporate various tasks to accurately assess these impairments (Hartman-Maeir & Katz, 1995). Commonly used tasks that assess cognitive impairments in neglect patients are paper and pencil tests such as: cancellation tasks, line bisection tasks, and copying or drawing tasks (Reuter-Lorenz & Posner, 1990; Morris, Mickel, Brooks, Swavely, & Heilman, 1985; Bisiach, Ricci, Lualdi, & Colombo, 1998; Harvey, 2004; Halligan et al., 2003; Loetscher et al., 2012; Hartman-Maeir & Katz, 1995; Gauthier, Dehaut, & Joanette, 1989; Parton, Malhotra, & Husain, 2004).

Line bisection A line bisection is a classic method used to assess perceptual biases. When asked to bisect the centre of a horizontal line, patients with spatial neglect place their bisections considerably to the right. This bisection behaviour is thought to reflect an overattention to the right side of the line (see Bartolomeo, 2014, for a review).

Cancellation task A cancellation task is a search-like task where patients are presented with an array of small targets and distractors on paper and are instructed to cancel out one type of target within the array. This task assesses patient's ability to find and cancel targets in their neglected hemispace, often targets on the left are overlooked whereas targets on the right are not (see Figure 2.3).

Copying or drawing task The copying or drawing task is another common assessment task. Various images have been used in this task, where a patient is asked to draw a copy of an image and



(a) Bell's cancellation reproduced from Sarri, Greenwood, Kalra, and Driver (2009)

(b) Line cancellation task reproduced from Bartolomeo (2014)

Figure 2.3: Neglect on two types of cancellation tasks. (a) Example of Bell's cancellation task. Most of the bells that were detected by the patient were on the right of the array. All the bells on the left were omitted.(b) Example of a line cancellation task. Most of the lines on the right were cancelled and the lines on the left were untouched.

their graphical omissions and errors in replicating the image are assessed for neglect. A typical example of a copy or drawing task is the clock drawing task. In this task, patients are shown an image of a clock face and asked to redraw it. Patients with hemispatial neglect usually place most of the numbers on the right and omit numbers on the left (see Figure 2.4).

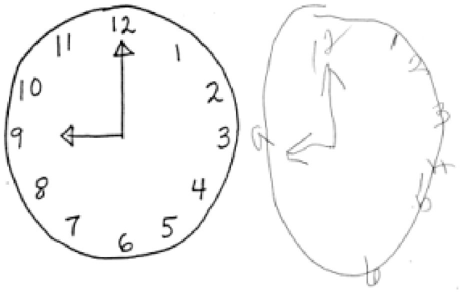


Figure 2.4: Example of a neglect patient drawing a clock face. The patient was shown the clock image on the left and instructed to redraw it. The right image shows the patients attempt to replicate the clock face. Most of the numbers were placed on the right of the clock face and numbers on the left of the clock were omitted. Image taken from Mark (2003).

The BIT also comprises of various everyday behavioural tasks such as: dialling on a telephone, reading a menu, coin and card sorting, telling and setting the time, map navigation, reading and copying sentences and picture scanning (Hartman-Maeir & Katz, 1995). Although, the line, cancellation, drawing and behavioural tasks can give an accurate indication of neglect symptomology, these assessments cannot differentiate between the underlying causes that produce neglect (Loetscher et al., 2012).

2.4 Neglect in input and output modalities

Perception (input) and action (output) processes are very closely coupled. Successful visually guided actions rely on the rapid and continuous online updating of sensory information. When one of these processes breaks down, serious sensory and behavioural consequences transpire. Lesions to the right parietal lobe cause left side neglect, resulting in marked right line bisections. While line bisection is a valuable assessment tool, it has a limited capacity to differentiate between input (attention) and output (motor) neglect. Chronic bisections to the right can occur in neglect patients for the following reasons: the left side of the line is underestimated (input deficit); unsuccessful attempts to direct actions to the left side (output deficit) or a combination of these deficits (Loetscher et al., 2012).

Disentangling visually guided actions (output) from a corresponding target location (input), is a challenge for neglect researchers. Various methodologies have been developed to try and differentiate between input and output components of neglect (Reuter-Lorenz & Posner, 1990; Tegner & Levander, 1991; Nico, 1996; Na et al., 1998; Bisiach, Geminiani, Berti, & Rusconi, 1990). Unfortunately, there are major criticisms to each of these methodologies (see Loetscher et al., 2012; Harvey, 2004, for a review). Loetscher et al. (2012) hypothesised that output neglect affects guided actions to the left, but leaves perceptual faculties relatively intact. Under this assumption the authors instructed patients to judge their own bisections. If patients bisected lines and then judged the accuracy of their bisections then it is possible to distinguish between perceptual and motor neglect. To this end, Loetscher et al. (2012) showed that patients with output neglect were able to correctly identify their misbisections, whereas those with perceptual neglect could not. Differentiating between input and output subtypes of neglect can be useful in identifying suitable rehabilitation techniques.

2.5 NEGLECT ACROSS HORIZONTAL, VERTICAL AND RADIAL AXES

On horizontal line bisection, the left-right asymmetry is clear in neglect patients where the line bisection task only tests one dimension at a time. But, on the cancellation task—which can test performance across a full array, many left neglect patients are particularly poor at cancelling out targets in the lower-left quadrants (Morris et al., 1985; Halligan & Marshall, 1989; Mark & Heilman, 1998, 1997; Halligan & Marshall, 1989; Mark & Heilman, 1997, 1998) or responding to salient cues in the lower-left (Làdavas, Carletti, & Gori, 1994). This suggests that RH damage can also affect orienting along the vertical axis.

Previc (1990) proposed the role of separate neural networks for the functional specialisation of the upper and lower visual fields along the vertical axis. There are two neural pathways—the dorsal and ventral streams. Each stream specialises in carrying out different tasks that are typically performed in the upper and lower hemispaces. Both pathways start in the primary visual cortex (V1). The dorsal pathway extends dorsally to the parietal regions and the ventral pathway extends ventrally to the temporal regions. Previc hypothesised that because searching behaviours usually occur in the upper visual field, the ventral pathway has evolved to specialise in far vision and that the dorsal pathway has adapted to specialise in near vision. Evidence from neglect patients supports Previc's hypothesis where patients with damage to areas along the ventral circuitry show attentional deficits in far space (Shelton, Bowers, & Heilman, 1990; Adair, Williamson, Jacobs, Na, & Heilman, 1995; Committeri et al., 2007), whereas patients with damage to dorsal areas show chronic biases in near space (Mennemeier, Wertman, & Heilman, 1992; Berti & Frassinetti, 2000).

Drain and Reuter-Lorenz (1996) postulated the importance of inter- and intra-hemispheric processes in vertical orienting. Analogous to Kinsbourne's hypothesis of inter-hemispheric processes for lateral orienting, Drain and Reuter-Lorenz thought that damage to areas along the dorsal and ventral circuitry would result in a deficient inhibition of the other circuit and an overactivity of the intact pathway. Typically, patients with damage to parietal areas along the dorsal stream neglect lower space

(Rapcsak, Cimino, & Heilman, 1988; Halligan & Marshall, 1995; Pitzalis, Spinelli, & Zoccolotti, 1997; Bender & Teuber, 1948; Làdavas et al., 1994). Patients with lesions to temporal areas along the ventral stream show neglect in upper space (Shelton et al., 1990; Mennemeier et al., 1992). More recent neuroimaging studies show that neither the dorsal or ventral networks in isolation control attention processes, but rather the dynamic and flexible interaction between these two networks allows for the successful integration of top-down attention and bottom-up sensory information (De Schotten et al., 2011; Chica et al., 2012; Vossel, Geng, & Fink, 2014).

In some cases of neglect, patients can show an unusual dissociation in proximal and distal spaces along the radial axis (Shelton et al., 1990; Committeri et al., 2007; Cowey, Small, & Ellis, 1994). Williamson et al. (2014) conducted a horizontal line bisection study with patients with unilateral LH or RH damage. Patients in their study bisected horizontal lines presented at proximal and distal distances of 300mm and 1678mm. Patients with RH damage bisected lines similar to controls in proximal space, but in distal space they bisected the lines farther to the right. In contrast, patients with LH damage bisected lines similar to controls in distal space, but in proximal space they bisected the lines more rightward. This study demonstrates the influence of the LH on proximal space and RH on distal space. Heilman, Chatterjee, and Doty (1995) argued that visual activities that are performed closer to the body such as reading, writing or tool use are carried out by the LH, but visual exploration occurs away from the body and is performed by the RH. This explains why some patients with LH damage neglect proximal (peripersonal) space and some patients with RH damage neglect distal (extrapersonal) space.

Visual attention is spatially and asymmetrically distributed along the horizontal, vertical and radial axes. The brain activates a combination of inter- and intra-hemispheric processes to distribute attention along a single or multiple spatial axes. Neurological damage to areas along the attentional network can have serious behavioural consequences for activities that require the allocation of attention along left-right, upper-lower and near-far dichotomies or a combination thereof.

2.6 Spatial maps and neglect: personal, peripersonal and extrapersonal spaces

The brain not only integrates visual and motor information to carry out actions, it also has specialised neural maps for coding reachable and non-reachable space (Rizzolatti, Riggio, & Sheliga, 1994; Berti & Frassinetti, 2000; Goodale & Milner, 1992). Brain (1941) was the first to propose distinct neural links for reaching and walking (non-reachable) distances. He found that in some cases of right hemisphere damage patients had neglect in reachable space, whereas in another case there was neglect beyond reachable space. Subsequently, many other researchers have found similar cases of neglect and have extended this research. Based on neuropsychological and behavioural evidence, it is now widely accepted that the brain has specialised neural maps for three main areas around one's body: personal, peripersonal and extrapersonal.

Personal space is the area occupied by and immediately around the body (Vaishnavi, Calhoun, & Chatterjee, 2001; Committeri et al., 2007; Kennedy, Gläscher, Tyszka, & Adolphs, 2009). Patients with right inferior parietal damage frequently exhibit personal neglect, particularly in the supramaginal and post-central gyri (see Committeri et al., 2007). This type of neglect is when patients are unable to attend to half of their personal space so that they only groom or dress the ipsilesional half of their body. Despite being essential to attend to one's own body, personal space also has a vital protective function. When potentially threatening objects invade one's personal space the body will automatically engage reflexive and defensive reactions to prevent serious bodily harm. The amygdala plays a crucial role in employing the fight-or-flight response to rapidly process sensory information about potential dangers and to respond to these threats (Graziano & Cooke, 2006). Even though patients with neglect may have undamaged amygdalae, inattention to contralesional space means they will also neglect incoming threats in personal space. Consequently, neglect patients will not be able to protect themselves from threatening objects in contralesional space. Although personal space has an important protective function, there is evidence to suggest that threat assessment occurs beyond personal space before it reaches this defensive barrier (Graziano & Cooke, 2006; Cléry, Guipponi, Wardak, & Hamed, 2015).

Peripersonal space is often described as reachable space (Brain, 1941; Rizzolatti et al., 1994; Vaishnavi et al., 2001; Cléry et al., 2015). Based on neglect studies, Brain (1941) was one of the first researchers to suggest that there are different areas in the brain for reachable and unreachable space. Seminal neglect studies have shown that peripersonal space can expand to incorporate tools too. Berti and Frassinetti (2000) showed in a case study that when they gave a neglect patient a laser pointer to bisect a line she displayed a rightward bias in near, but not in far space. But, when they gave her a long stick to bisect the line in far space she exhibited neglect again. Berti & Fransenetti's patient had lesions in the RH, thereby giving rise to neglect in peripesonal space, however, when they gave her a long stick she could now reach objects in far space. The stick had changed her boundary of what is considered reachable. This example demonstrates that the brain continually updates and relays visual information to top-down areas such as the prefrontal cortex and the lateral intraparietal regions (Baluch & Itti, 2011). These areas can lead to a contraction or expansion of peripersonal space under the influence of contextual information.

Extrapersonal space is the area outside of arm's reach (Varnava, Dervinis, & Chambers, n.d.). Patients that have had damage to areas along the ventral network such as the temporal regions or the middle frontal gyrus demonstrate neglect symptoms in far space (Shelton et al., 1990). Previc postulated that far space is important for search behaviours. Other activities, for example, navigating through an environment, relies on inter-hemispheric activity between the dorsal and ventral pathways. When navigating, neglect patients tend to bump into objects on the left side of their environment (I. H. Robertson & Halligan, 1999). De Schotten et al. (2011) proposed that this inter-hemispheric communication occurs in the middle superior longitudinal fasciculus tract known for goal-directed attention. Although the dorsal areas are largely responsible for identifying the location of objects and the ventral areas are important for object recognition and search behaviours, many researchers have argued that executing visuomotor actions in three-dimensional space requires effective intra- and interhemispheric communication from both pathways (Goodale & Milner, 1992; De Schotten et al., 2011).

2.7 EFFECT OF DISTRACTORS ON NEGLECT

So far, I have discussed how damage to various areas along the attentional network can impair interconnected visual maps in the brain, and result in various subtypes and manifestations of neglect across different axes. Although damage to these attentional areas leads to an inability of stimuli on the contralesional side to reach awareness, undamaged attentional areas can still unconsciously process neglected information. There is increasing behavioural and neurophysiological evidence suggesting that the properties of stimuli, such as shape (McGlinchey-Berroth, Milberg, Verfaellie, Alexander, & Kilduff, 1993) , colour (Kristjánsson et al., 2005) and emotional valence (Halsband, Gruhn, & Ettlinger, 1985; Vuilleumier, 2002; Vuilleumier & Schwartz, 2001), can still be pre-attentively processed in the left hemispace despite these stimuli failing to reach awareness.

On line bisection measures, patients with severe spatial neglect can be influenced by configural illusions such as the Judd and Muller-Lyer illusions (Ro & Rafal, 1996; Mattingley, Bradshaw, & Bradshaw, 1995) and even basic shapes can impact on bisection performance (Corbetta & Shulman, 2002). Furthermore, neglect patient's bisections are also sensitive to lateral cues presented at the ends of the line, where left cues decrease rightward shifts (Riddoch & Humphreys, 1983; Milner, Brechmann, & Pagliarini, 1992; Bonato, Priftis, Marenzi, & Zorzi, 2008). Right parietal lesions, observed in neglect patients, leave the ventral pathway intact. Driver and Mattingley (1998) argue that the intact ventral stream results in residual processing for object recognition in neglect patients.

The inferior parietal cortex and its interconnected cortical and subcortical areas have been implicated in the orienting of spatial attention to relevant stimuli (Halligan et al., 2003; Mesulam, 1999; Posner & Petersen, 1990). The interference from distractors when orienting attention have also been shown to engage the cortical areas surrounding the inferior parietal cortex (Marois, Leung, & Gore, 2000). There is a general consensus that there are two distinct types of orienting attention: exogenous and endogenous (Posner, 1980; Theeuwes, 1991). Exogenous orienting is the automatic, rapid, reflexive attraction of attention to some basic attributes of stimuli. This type of attention orients without voluntary control and is particularly important for orienting attention to threatening stimuli. In contrast, endogenous orienting is slower, voluntary and purposeful attention. Endogenous orienting is necessary for guided actions, processing the abstract qualities of stimuli and extracting meaning from these qualities.

2.8 Concluding remarks

Perceptual asymmetries observed in neglect patients occur as a result of a higher-order deficit (Driver & Mattingley, 1998; Halligan et al., 2003; Kristjánsson et al., 2005). Cerebral damage to these areas lead to a hemispheric imbalance between the two hemispheres. Accordingly, this leaves the intact hemisphere overactive thereby producing chronic ipsilesional attentional asymmetries. Moreover, pathological hemispheric imbalances can also give rise to extreme biases in vertical and radial dimensions. Although these attentional asymmetries in neglect patients are extreme they share similarities with the smaller and less noticeable asymmetries observed in non-clinical populations. Lesions to attentional areas appear to exacerbate the behavioural tendencies observed in the intact brain, therefore providing important insight into the engagement of mechanisms that underlie the orienting of attention (Drain & Reuter-Lorenz, 1996). The next chapter focuses on the functional and attentional asymmetries in the intact brain and the insights researchers have gleaned from lesion studies that can provide a better understanding of the perceptual asymmetries in non-clinical populations.

Our brain is mapping the world. Often that map is distorted, but it's a map with constant immediate sensory input.

Edward Osborne Wilson, 1998

3

Non-clinical visual asymmetries (Pseudoneglect)

In order to establish a complete and comprehensive picture on attentional asymmetries in healthy individuals, this chapter mirrors topics outlined in the previous chapter on attentional neglect. These topics are core to subsequent chapters and will be referred to throughout the content of this thesis.

3.1 VISUAL ASYMMETRIES

Attentional asymmetries are not unique to patients with brain damage, but small reliable attentional biases are also observed in people without neurological damage. Healthy participants demonstrate an overestimation across three dimensions in the horizontal, vertical and radial axes. These attentional asymmetries cannot be explained by low-level visual processing as they still persist under visual deprivation (Bowers & Heilman, 1980; Chewning, Adair, Heilman, & Heilman, 1998) and also occur for imagined stimuli (Darling, Logie, & Della Sala, 2012; Loftus, Nicholls, Mattingley, & Bradshaw, 2008; McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007). Biases in orienting attention are thought to occur because of an imbalance in hemispheric activity (Foxe, McCourt, & Javitt, 2003; Le, Stojanoski, Khan, Keough, & Niemeier, 2015; Loftus & Nicholls, 2012; Reuter-Lorenz et al., 1990; Siman-Tov et al., 2007) and their subcortical connections (Chica et al., 2011; Corbetta & Shulman, 2011; De Schotten et al., 2011). Although these visual biases can be exacerbated by motoric influences (Leonards, Stone, & Mohr, 2013; Vossel, Eschenbeck, Weiss, & Fink, 2010), they are predominantly perceptual in nature as they still occur for purely perceptual tasks (McCourt & Olafson, 1997; Milner et al., 1992; Nicholls et al., 2012).

3.2 MODELS OF ATTENTION

Neuroimaging studies show preferential right hemisphere (RH) activation in the fronto-parietal network during visuospatial tasks (Çiçek, Deouell, & Knight, 2009; Fink, Marshall, Weiss, Toni, & Zilles, 2002; Foxe et al., 2003; Le et al., 2015; Shulman et al., 2010). These data are consistent with neglect studies, which demonstrate the importance of the RH in allocating visuospatial attention (Barrett, Beversdorf, Crucian, & Heilman, 1998; Doricchi & Tomaiuolo, 2003; Driver & Mattingley, 1998; Heilman & Van Den Abell, 1980; Molenberghs et al., 2012). There are various models of attention that debate the underpinnings of attentional control; however, only the models that have directly contributed to the contemporary understanding of attention will be discussed in this chapter.

In Kinsbourne's (1970, 1972) activation-orienting hypothesis, he proposed that asymmetries in processing visual input are as a direct result of the specialisation of each hemisphere. To support this hypothesis, Kinsbourne referred to language studies showing that verbal information is better reported from the right ear than the left (Kimura, 1961; Satz, 1968). He argued that language tasks show a right-sided superiority, whereas non-verbal spatial tasks show the opposite pattern—a left-sided superiority (Braine, 1968; Bryden & Rainey, 1963; Kimura, 1966; Kinsbourne, 1970). Based on the evidence that each hemisphere controls that contralateral hemisphere (Brain, 1941; Kinsbourne, 1972; Munk, 1890), Kinsbourne suggested that the right hemisphere is dominant for non-verbal spatial tasks.

In support of the activation-orienting model, a large body of literature has demonstrated that the right hemisphere shows greater activation during spatial tasks (Çiçek et al., 2009; De Schotten et al., 2011; Foxe et al., 2003; Le et al., 2015; Loftus & Nicholls, 2012; Longo, Trippier, Vagnoni, & Lourenco, 2015; Loughnane, Shanley, Lalor, & O'Connell, 2015; Shulman et al., 2010; Nicholls, Bradshaw, & Mattingley, 1999). Furthermore, recent studies show neuroimaging evidence that left visual field superiority on spatial tasks is associated with greater right hemisphere activation (Siman-Tov et al., 2007). Notably, greater right hemisphere activation does not only lead to left visual field superiority, but also contralateral left visual field overattention (Çiçek et al., 2009; Foxe et al., 2003; Jewell & McCourt, 2000; Loftus & Nicholls, 2012; Longo et al., 2015; McCourt, 2001). This overattention produces an overestimation in the length, size and distance of objects in the left visual field (Brian Krupp, Robinson, & Elias, 2010; Jewell & McCourt, 2000; Roth, Lora, & Heilman, 2002; Suavansri, Falchook, Williamson, & Heilman, 2012; Szpak, Loetscher, Bastian, Thomas, & Nicholls, 2015).

Building upon the activation-orienting model Kinsbourne also proposed the 'opponent-process' model, where the left and right hemispheres are kept in balance by inter-hemispheric inhibition (Kinsbourne, 1982). This model hypothesised that the strength of activation in each hemisphere determines the level of attention allocated to the contralateral hemispace. Heilman and Valenstein (1979) and Mesulam (1999) adapted Kinsbourne's model based on clinical observations with neglect patients. They observed that left hemisphere damage led to no or mild spatial neglect, whereas right hemisphere damage caused the most severe forms of neglect. They hypothesised that whilst the left hemisphere directs attention to the contralateral right visual field, the right hemisphere is extraordinary as it has the ability to attend to both the left and right visual fields.

The attentional network model is largely based on neuroimaging data that have identified functional and anatomical roles in orienting spatial attention. This model argues for two attention networks, the dorsal and ventral networks, which continually interact with each other during the allocation of spatial attention. The dorsal network starts in the occipital lobe, runs dorsally through the parietal lobe to the frontal lobe and connects to the frontal eye field (Corbetta & Shulman, 2011; Duecker & Sack, 2014). This network is responsible for orienting attention and the top-down processing of sensory information (Corbetta & Shulman, 2011; Shulman et al., 2010; Vossel et al., 2014). The ventral network originates in the occipital lobe and runs ventrally through the lower regions of the cortex through areas connecting the parietal and frontal lobes, the temporal parietal junction and the ventral frontal cortex (Duecker & Sack, 2014). The ventral network is responsible for reorienting attention to unexpected or salient stimuli (Chica et al., 2011, 2012; Driver & Mattingley, 1998; Vossel et al., 2014). Neuroimaging data shows that the ventral network is right lateralised, which may explain left visual field superiority (Corbetta & Shulman, 2011; De Schotten et al., 2011).

A review by Duecker and Sack (2014) introduced a hybrid model of attentional control that hypothesised two distinct sources of hemispheric asymmetry. This model is inspired by theories from Kinsbourne (1970), Heilman and Valenstein (1979), and Corbetta and Shulman (2011). They hypothesised that the left and right parietal areas in the dorsal network compete for attentional control via hemispheric inhibition. Because the ventral network over the fronto-parietal regions is right lateralised (De Schotten et al., 2011), an imbalance in intra-hemispheric communication over this region leads to an indirect effect on the dorsal fronto-parietal network. The dorsal fronto-parietal network is right hemisphere dominant and is able to direct attention to both hemifields. These two distinct hemispheric asymmetries over the dorsal fronto-parietal network may explain the subtle biases observed in healthy participants when orienting attention to space (see Figure 3.1).

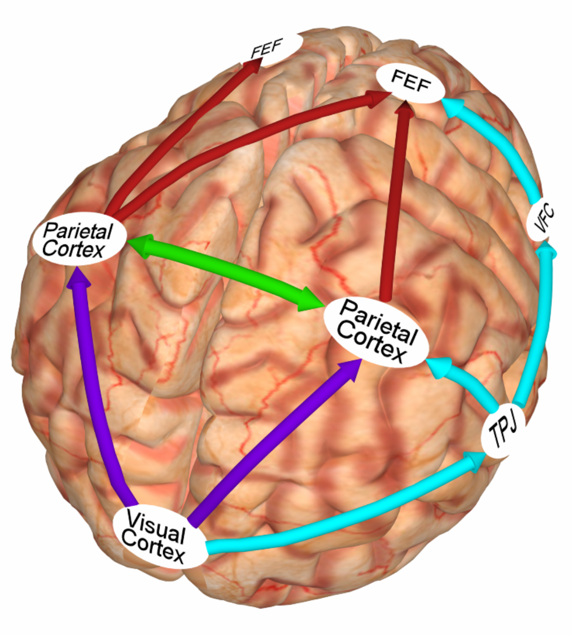


Figure 3.1: An illustration of the hybrid model of attentional control which has been adapted from Duecker and Sack (2014) and has been inspired by the three following models: activation-orienting, opponent-process and the attentional network models. Duecker and Sack (2014) proposed two separate sources of hemispheric asymmetries within the dorsal fronto-parietal network. The purple lines illustrate visual information relayed to the parietal cortex where top-down modulation is exerted within each hemisphere. The green lines represent inter-hemispheric competition where attentional control is exercised via hemispheric inhibition. The red lines demonstrate that the right hemisphere receives visual information from both hemispheres and is able to attend to both hemispaces, whereas the left can only attend to the right hemispace. The aqua lines show the ventral fronto-parietal network where visual information is also relayed to the TPJ (temporal parietal junction), VFC (ventral frontal cortex) and to the FEF (frontal eye field).

3.3 Spatial tasks assessing pseudoneglect

In the previous chapter, various cognitive impairments of hemispatial neglect and the clinical assessments commonly used to measure spatial impairments have been discussed. In this subsection, I will examine the spatial tasks used to measure subtle attentional biases resulting from asymmetrical hemispheric activation in normal participants. These tasks include the line bisection task, Landmark task and Greyscales task, all of which have been used in this thesis to measure shifts in attention. The non-clinical version of the line bisection task is identical to the clinical version created by Bisiach, Capitani, Colombo, and Spinnler (1976) to measure attentional deficits. Usually the line bisection task consists of a long line centred on a blank page and is approximately 120–200mm in length. In this task, a series of solid black lines are presented to participants, and they are asked to bisect the line with a pencil where they think the centre is. Because of functional asymmetries participants will mark the centre of the line to the left of true centre (see Figure 3.2).

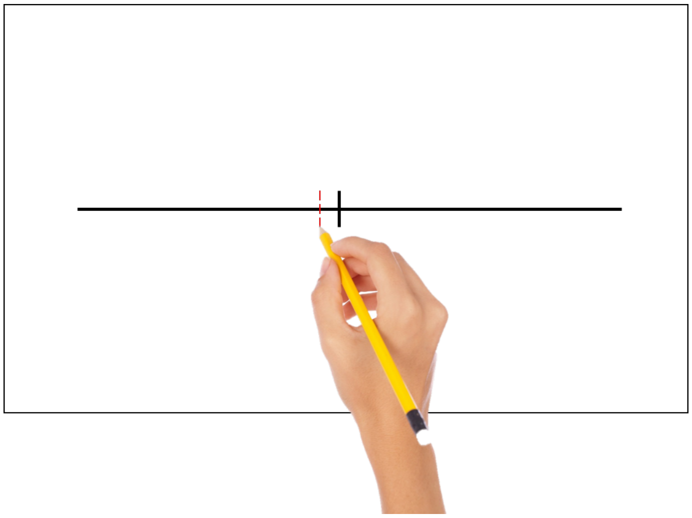


Figure 3.2: An example of a line bisection task. A line is presented on a blank sheet of paper and participants are asked to mark the centre of the line (red dashed line). Participants typically mark the perceived centre as being left of the true centre. The dark solid vertical line represents the true centre (not shown to participants).

The Landmark task is a pre-bisected variation of the line bisection task that was developed by Milner et al. (1993) to limit motor biases that may exist in the line bisection task. Milner et al. (1993) aimed to develop a task that only measured perceptual biases. Since the Landmark task was created, several variations of Landmark stimuli and task instruction have been used in the attention literature

(Fink et al., 2002; Varnava & Halligan, 2009). Milner and colleagues' version of the Landmark task consisted of a solid black line with a transector shifted from the midpoint at various locations along the line. Participants were asked to judge on which side of the transector the line segment is shorter. Other instructional variations require participants to judge which side is longer (Nicholls et al., 2012; Vossel et al., 2010), or whether the two line segments on either side of the transector are equal (Fink et al., 2002; Toraldo, Fiori, & Vanzan, 2010). McCourt and Olafson (1997) designed a well-known computerised version of the pre-bisected lines that have been frequently used to measure attentional asymmetries in healthy participants (see Figure 3.3).

Figure 3.3: An example of a pre-bisected line designed by McCourt and Olafson (1997). In this example, the transector has been shifted to the right of the true centre.

Because there are many different variations of the Landmark task, the effect of strategy on line bisection is an important methodological question. Fink et al. (2002) showed that common neural areas are activated when participants make judgements about either line length or transector position. Although slight differences in activation occur for each task strategy, no differences in bisection error rates were observed for the two judgement types. Varnava and Halligan (2009) asked participants to describe their bisection strategies and identified 3 strategies: comparing line segments, judging the centre of mass (midpoint) and using external reference points. Importantly, none of these strategies predicted line bisection performance suggesting that the use of any single strategy does not account for functional asymmetries.

The Greyscales task is another perceptual task that has been used to measure pseudoneglect (Learmonth, Gallagher, Gibson, Thut, & Harvey, 2015; Nicholls et al., 1999; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004). This task consists of two parallel bars each with a gradient in luminosity starting from black on the one side and gradually increasing in brightness to white on the other side (see Figure 3.4). The Greyscales are presented to participants as mirror-reversed luminescent pairs and participants are asked to indicate which of the two bars is darker. About 68% of the time participants will perceive the bar with the black gradient starting on the left as the darker of the two stimuli (Nicholls et al., 1999). Moreover, when the instruction is reversed and participants are asked to indicate which bar is lighter, participants will again choose the relevant feature on the left side of the stimulus. This suggests that the spatial mechanisms responsible for length judgements are also specialised for other spatial judgments relating to numerosity and brightness.

Figure 3.4: An example of the Greyscales stimuli. Participants are instructed to indicate which bar they think looks darker. Typically participants will perceive the relevant feature on the left as being darker i.e in this example participants will more likely choose the bottom bar as being darker overall.

Although healthy participants typically display a leftward asymmetry on all three of these tasks, there is minimal evidence demonstrating significant inter-task correlations (see Learmonth et al., 2015, for a review). A recent paper that employed all three tasks found, at best, a weak trend between the line bisection and Landmark tasks. At first glance this lack of inter-task correlation is concerning as all tasks are supposed to measure pseudoneglect, however, Learmonth et al. (2015) suggest that different task demands may lead to slight changes in how pseudoneglect is represented. Learmonth et al. (2015) also discuss the possibility that pseudoneglect may be a multi-faceted phenomenon. The authors argued that the direction and extent of the bias is strongly task-dependent, but that the performance on each of these tasks still share partially overlapping neural mechanisms. Learmonth et al. (2015) propose that their data is consistent with Kinsbourne's opponent-process model where the level of activation within the left and right hemispheres determines the extent of the bias in the spatial task.

3.4 Pseudoneglect in input and output modalities

In order to successfully carry out actions within the world, the brain relies on a rapid and reliable integration of information from both sensory (input) and motor (output) modalities. The previous chapter on neglect outlined this closely coupled relationship and the deficits that ensue when one of these processes breaks down. Akin to studies on neglect, the pseudoneglect literature has also had difficulties in differentiating the unique contributions of each of these two components. Due to the differences in task demands on the various spatial tasks, one particular question that has been of interest to attention researchers is, to what extent is pseudoneglect perceptual-attentional and/or motor-intentional?

Although line bisection is a reliable measure of attentional biases in both clinical and healthy populations, there is a known motor component to the task (Jewell & McCourt, 2000; Leonards et al., 2013; Vossel et al., 2010). As such, biases on this task are not solely attentional in nature, but can also be motor-intentional (Cavézian, Valadao, Hurwitz, Saoud, & Danckert, 2012; Hurwitz, Valadao, &

Danckert, 2011; N. A. Thomas & Elias, 2012; Vossel et al., 2010). It has been suggested that the motor component of the line bisection task, yields greater leftward biases than the Landmark task (Jewell & McCourt, 2000; Leonards et al., 2013; Vossel et al., 2010). To avoid confusing motor and perceptual biases, Milner et al. (1993) developed the Landmark task, which consists of pre-bisected lines and relies more heavily on perception by using verbal responses (Bisiach et al., 1998) or simple key presses to minimise motor involvement (McCourt & Jewell, 1999; Nicholls et al., 2012). Performance differences across diverse attentional and motoric task demands between the various spatial tasks further highlights the possibility of a multi-faceted pseudoneglect (Learmonth et al., 2015).

3.5 Asymmetries across horizontal, vertical and radial axes

Our perceptions and actions occur within the detailed three-dimensional environment we live in, and as a result the brain has adapted to process sensory information along three spatial axes: horizontal, vertical and radial. Accordingly, distinct functional and behavioural asymmetries arise across all three axes (De Schotten et al., 2011; Fink, Marshall, Weiss, & Zilles, 2001; Foxe et al., 2003; Heilman et al., 1995; Jewell & McCourt, 2000; Nicholls et al., 2004; Previc, 1990; Szpak, Loetscher, Bastian, et al., 2015; Weiss et al., 2000).

Horizontally orientated spatial stimuli, such as in Figures 3.2, 3.3 and 3.4 are able to measure pseudoneglect—an overrepresentation of the left side of these stimuli. This overrepresentation leads to perceptual biases where participants tend to think the left side of these stimuli are larger or darker than they objectively are. Models of attention suggest that left-sided biases occur because of right hemisphere dominance for spatial tasks (Duecker & Sack, 2014; Foxe et al., 2003; Kinsbourne, 1970; Siman-Tov et al., 2007) and/or an imbalance between subcortical communications (Chica et al., 2012; De Schotten et al., 2011). These biases are also observed in real world spatial tasks, such as walking through doorways; goal-kicking or golf putting (Nicholls, Loetscher, & Rademacher, 2010; Nicholls, Loftus, Mayer, & Mattingley, 2007; Roberts & Turnbull, 2010).

When the same spatial stimuli (Figures 3.2, 3.3 and 3.4) are rotated and orientated vertically, an overrepresentation of the top portion of the stimuli is observed. In a vertical orientation, the upper portion is perceived larger or darker than it objectively is (Fink et al., 2001; Nicholls et al., 2004, 2012; Suavansri et al., 2012). Surprisingly, there is no evidence to support that leftward and upward biases are related to one another (Churches, Loetscher, Thomas, & Nicholls, 2015; Heber, Siebertz, Wolter, Kuhlen, & Fimm, 2010; Nicholls et al., 2004). Researchers have suggested that different mechanisms are engaged when processing vertical stimuli compared to horizontal (Drain & Reuter-Lorenz, 1996; Nicholls et al., 2004; Previc, 1990). Visual asymmetries along the vertical axis have been explained in the attention literature by Previc's evolutionary model. Previc (1990) hypothesised that everyday spatial activities, such as grasping or searching, have shaped the visual system to evolve relative to space in which these activities occur. For example, the ventral pathway has evolved to specialise for searching behaviours that typically occur in the upper visual field and in extrapersonal space, whereas motor activities have influenced the dorsal pathway to specialise in activities occurring in the lower visual field and near the body. Visual biases in the upper and lower hemispaces are thought to reflect functional asymmetries in the ventral and dorsal visual pathways that occur due to their respective specialisations.

When the line bisection and Greyscales tasks are presented so that the stimuli radiate away from the participant's midline, they bias their attention towards the distal (i.e., furthest) end of the line (Barrett, Crosson, Crucian, & Heilman, 2002; Chewning et al., 1998; Geldmacher & Heilman, 1994; Graff-Radford, Crucian, & Heilman, 2006; Jeong, Drago, & Heilman, 2006; Nicholls et al., 2004; Roth et al., 2002). Based on neglect case studies, Shelton et al. (1990) argued for modality-specific attentional biases where attention is preferentially biased away from the body for visual exploration, but distributed near the body for tactile exploration. Support for Shelton et al.'s hypothesis comes from a tactile radial line bisection study that shows a proximal bias, suggesting that modality mediates the direction of radial bisections (Chewning et al., 1998). The functional cerebral asymmetry model can explain this modality-based shift (Heilman et al., 1995). The left hemisphere is specialised for proximal tasks performed involving local attention, such as reading and writing. In contrast, the right hemisphere is specialised for distal tasks involving global attention, such as face recognition and spatial navigation (Barrett et al., 1998; Heilman et al., 1995; L. C. Robertson, Lamb, & Knight, 1988).

Retinotopic influences can also affect the spatial orientation in which a stimulus is perceived. For example, radial lines that are presented below eye level project onto the retina as vertical lines (Suavansri et al., 2012). Along a vertical orientation objects would be perceived as up-down rather than distal-proximal. Identifying potential retinotopic influences is important, as the neurological mechanisms for radial and vertical are dissociative, where the former relies on cerebral specialisation (Heilman et al., 1995) and latter is associated with dorsal-ventral stream specialisation (Previc, 1990).

3.6 Spatial maps and pseudoneglect: personal, peripersonal and extrapersonal spaces

From a body spatial reference frame, there are three distinct areas around the body that are differentially represented in the brain: personal, peripersonal and extrapersonal (Caggiano, Fogassi, Rizzolatti, Thier, & Casile, 2009; Cléry et al., 2015; Gross & Graziano, 1995; Previc, 1998; Weiss et al., 2000). These neurological maps are pivotal for the most basic everyday functions of the human body—protection and sustenance. Although these behavioural functions may sound simple, they require a collection of complex sensorimotor calculations (Graziano & Cooke, 2006). Remarkably, these advanced sensorimotor calculations enable a person to walk around their environment without bumping into objects, keep their distance from potential dangers and reach for nourishment. The ability to distinguish distance from one's body to any object in one's environment, requires an integration of both rich perceptual maps and a wide range of spatially guided motoric functions. This sensorimotor integration is essential to perform these basic behaviours of navigation, defense and nourishment.

Personal space is the region anchored to the body's surface and is occupied by the body (Committeri et al., 2007; Graziano & Cooke, 2006; Vaishnavi et al., 2001). This space is particularly important in engaging appropriate defensive behaviours to threatening objects. Personal space requires attention to the body that is multimodal so that tactile, auditory and visual threats are detected and appropriately responded to. Essentially, Graziano and Cooke (2006) describe defense of the body's surface as a sensorimotor problem where the solution lies within rapid sensory integration to achieve flexible and spatially guided defensive behaviours. Primate studies have implicated several cortical and subcortical areas that work together to achieve appropriate defensive reactions to threatening stimuli, such as the ventral intraparietal, precentral gyrus, putamen, posterior parietal, superior colliculus, spinal cord, amygdala and hypothalamus (Graziano & Cooke, 2006; Gross & Graziano, 1995).

Peripersonal space is the area surrounding the body that is directly actionable, particularly by the arms and hands (Cléry et al., 2015; Longo & Lourenco, 2007). Higher level processes enable humans to determine what is considered within arm's reach. This function requires attention to low-level visual cues, such as size, length and depth, in order to determine the distance from one's body to an object. From this visual information, a person is able to determine what is near/reachable and what is far/unreachable. This suggests that there are specific top-down neural networks for interpreting these low-level cues that allow online updating of visually guided actions in peripersonal space. As a result of this function, peripersonal space has been shown to be a dynamic and plastic boundary that contracts or expands under the influence of contextual information (Berti & Frassinetti, 2000; Cléry et al., 2015; Lourenco & Longo, 2009; Lourenco, Longo, & Pathman, 2011; Teneggi, Canzoneri, Di Pellegrino, & Serino, 2013). Although peripersonal space is considered to be reachable space, it is not limited to arm's reach. Using a tool has been shown to expand peripersonal space to incorporate the tool (Cardinali et al., 2009; Farnè & Làdavas, 2000; Iriki, Tanaka, & Iwamura, 1996). Cardinali et al. (2009) showed that after using a tool to grab an object, the length of a participant's arm changed so that their arm was perceived to be longer than before they used the tool. The authors suggest that using a tool altered the body schema, which had been updated to incorporate the tool. Several other studies have also shown that using a tool alters one's perception of the size of objects (Gamberini, Seraglia, & Priftis, 2008;

Longo & Lourenco, 2006).

Extrapersonal space is the area of space that is beyond arm's reach (Brain, 1941; Cléry et al., 2015; Committeri et al., 2007; Heber et al., 2010). A study by Longo and Lourenco (2006) asked healthy participants to complete a horizontal line bisection task across varying distances that transitioned from near space to far space. Participant's bisected these lines using a stick or a laser pointer. Longo and Lourenco (2006) found that when participant's bisected the lines in reachable space with a stick, there was a leftward bias (pseudoneglect) across all distances. But, when participants used a laser pointer to bisect the lines there was a gradual shift in pseudoneglect from left to right as the lines transitioned from reachable (near) to unreachable (far). Although near space has been shown to activated areas along the right parieto-frontal network, these areas are involved to a lesser effect in far space (Bremmer, Schlack, Kaminiarz, & Hoffmann, 2013; Cléry et al., 2015; Durand et al., 2007). In accordance with Kinsbourne's model of attention, a decrease in right hemisphere activation would thereby decrease pseudoneglect as the hemispheric activity would be more functionally balanced.

3.7 EFFECT OF DISTRACTORS ON PSEUDONEGLECT

A core theme in this thesis is how attention is influenced by external stimuli or events occurring outside of a task, namely the effects of other people on attention. Because the research on the effects of other people and pseudoneglect are limited, I thought it would be necessary to include a brief subsection showing how cues and distractors influence attention. Furthermore, this subsection is directly related to the next chapter that investigated the effects of social distractors on attention.

Cues are task-relevant stimuli that require voluntary top-down processing and have been shown to attract attention in the visual field (Bultitude & Aimola-Davies, 2006; Jewell & McCourt, 2000; Mulckhuyse & Theeuwes, 2010). Cues on the left have been shown to increase pseudoneglect and cues on the right have been shown to decrease pseudoneglect (Bultitude & Aimola-Davies, 2006; Milner et al., 1992). According to the activation-orienting hypothesis, cues on the left increases right hemisphere activation, and cues on the right will increase left hemisphere activation. Increased contralateral activation from right cues will also lead to greater functional balance between the left and right hemispheres (Kinsbourne, 1972, 1982).

Distractors have been shown to effect attention differently. A distractor is a salient task-irrelevant stimulus or event that does not necessitate an action, and has the ability to automatically occupy attention outside of conscious control (Lavie, 2005). Distractors recruit bottom-up exogenous attention, where the level of influence from the distractor depends on attentional load (Lavie, 2005). A review by Mulckhuyse and Theeuwes (2010) on unconscious attentional orienting, propose that exogenous orienting towards a task-irrelevant stimulus is typically followed by inhibition. The effect of task-irrelevant distractors on pseudoneglect is varied, where some researchers show attention shifts contralateral to the distractor (Toba, Cavanagh, & Bartolomeo, 2011) and others show attention shifting towards the distractor (N. A. Thomas, Castine, Loetscher, & Nicholls, 2015). Chow, Gozli, and Pratt (2014) suggest that load capacity has a strong effect on attentional orienting.

An eye-tracking study by N. A. Thomas et al. (2015) investigated the influence of distractors and cues on attentional orienting on a line bisection task. They presented circular task-irrelevant distractors/cues in four different hemispaces (upper-left, upper-right, lower-left, lower-right) whilst participants judged line length. In the distractor condition participants rarely fixated on the distractors, however, they exhibited a strong attentional bias towards these distractors. In the cue condition the authors instructed participants to attend to cues (task-relevant), but did not find a relationship between cue fixation and the strength of the attentional biases. The authors suggested that the effects of covert (distractor condition) and overt (cue condition) orienting on pseudoneglect are also consistent with the load theory of attention. The load theory of attention proposes that all stimuli are processed automatically until attentional resources run out (see Lavie, 2005). In high load tasks, such as the overt cueing paradigm, attentional resources are engaged in processing only task-relevant information leaving no resources for processing task-irrelevant information. In low load tasks, like the covert distractor paradigm, any spare attentional resources are automatically engaged to process task-irrelevant distractors.

3.8 CONCLUDING REMARKS

This review demonstrates that subtle, yet consistent attentional asymmetries are observed along the horizontal, vertical and radial axes. While cues, distractors or motor influences can exacerbate these asymmetries, they do not drive pseudoneglect. Rather these attentional biases reflect functional asymmetries within the brain when orienting attention in a three-dimensional space. The remainder of this thesis focuses on how another person can affects attentional orienting during line bisection (Chapter Five); visual search (Chapter Five); Landmark (Chapter Five, Six, Seven and Nine); and Greyscales tasks (Chapter Five). Although previous research has shown that another person can produce facilitation or interference effects during stimulus-response compatibility paradigms, these tasks do not show how attentional orienting is affected. The next chapter (Chapter Four) reviews literature from both social psychology and cognitive psychology to determine how social influences fit into concepts from cognitive neuroscience and crucially, how social influences can affect spatial attention.

When it comes to exploring the mind in the framework of cognitive neuroscience, the maximal yield of data comes from integrating what a person experiences—the first person—with what the measurements show—the third person.

Daniel Goleman, 2004

4

The social space around us: a review of interpersonal spatial attention

While the previous two chapters reviewed concepts and models of spatial attention, this chapter will review the literature on social space and how this space relates to the attentional concepts discussed previously. Because social space is relatively new to cognitive psychology, relevant literature from both social and cognitive psychology will be incorporated in this chapter. Moreover, I will discuss the limited research that has investigated the effects of interpersonal proximity on spatial attention and draw together conceptual knowledge that is core to this thesis.

4.1 INTRODUCTION

Humans are highly social beings that are continually connecting, coordinating and interacting with other people in their environment. While it is possible to 'put yourself in someone else shoes', even from a distance, most social interactions are only possible because of the close proximity to others. Because of this social prerequisite, several sociocognitive reviews have remarked on the irony of studying social interactions using the 'minimalist' experimental approach where individuals are studied in isolation (Becchio, Sartori, & Castiello, 2010; Ochsner & Lieberman, 2001). Ochsner and Lieberman (2001) even went as far as to described social psychology and cognitive neuroscience as 'strangers passing on the street'. One particular example, where such inter-disciplinary dissociation is particularly apparent is by the disconnectedness in which body space is described in these literatures. The primary aim of my review is to bring knowledge of body space from these two literatures together, in order to understand how interpersonal proximity can influence spatial perception.

Around the same time both social psychology and cognitive neuroscience each conceptualised representations of body space that are important for interacting with one's environment. Social psychology called this space 'personal space' and cognitive neuroscience conceptualised 'peripersonal space'. Social psychology research on personal space boomed in the 60's through to 80's Aiello (1987). During the 60's, Hall (1966) developed his theory on personal space giving a name to the imaginary bubble around our bodies that we feel is 'my space' and that is an essential component in both positive and negative social interactions. In this space, people can choose to allow others to permeate their subjective boundary or choose to avoid social advancements (Evans & Howard, 1973; Felipe & Sommer, 1966; Hall, 1966; Hayduk, 1981). Furthermore, unwanted social intrusions into 'my space' will lead to feelings of discomfort (Aiello, Derisi, Epstein, & Karlin, 1977; McBride, King, & James, 1965).

In the early 80's influential cognitive neuroscientists, such as Rizzolatti and colleagues, wrote a revolutionary paper on the distinction between near and far spaces in primates (Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981). Later Rizzolatti and colleagues went on to develop their theory of peripersonal (near) space in humans, an invisible region of space that is considered near enough to the body for objects to be reachable and that is neurologically represented within the brain (Rizzolatti et al., 1997). With these two overlapping psychological constructs of the space surrounding our bodies, social psychology went on to debate sociability and cognitive psychology went on to discuss actionability.

Besides an overlap in the definition of 'the space around us' (Rizzolatti et al., 1997), recent research has shown that social psychology's preferred social distances and cognitive neuroscience's peripersonal space are highly related to one another (Brozzoli, Gentile, Bergouignan, & Ehrsson, 2013; Fini, Costantini, & Committeri, 2014; Iachini, Coello, Frassinetti, & Ruggiero, 2014; Iachini, Ruggiero, Ruotolo, di Cola, & Senese, 2015; Teneggi et al., 2013). These progressive papers suggest that higher-order social processing can impact on the perception of low-level sensory input. This conceptual overlap from social psychology and cognitive neuroscience will be discussed in the following subsections, in particular, reference to common perceptual and neural mechanisms that are engaged for judging the distance of objects and the distance between oneself and others. This review aims to bring together knowledge from both social and cognitive psychology to demonstrate that the reachable space surrounding our bodies is not only important for actions but also social interactions.

4.2 Behavioural and physiological responses to interpersonal distance

One particular salient example, that is familiar to most and suitably demonstrates the behavioural and physiological effects of interpersonal distance, is the 'commuter experience'. After work, a person may embark on to a train. If it is during peak hour, it is likely that they will share their personal space with several other people. This is an uncomfortable experience most people try to avoid. Some people may choose to distance themselves as far away from other people as possible (Evans & Wener, 2007; Felipe & Sommer, 1966; Hirsch & Thompson, 2011). Others may choose to distract themselves by reading a book, listening to music or even playing with their smartphone (Hirsch & Thompson, 2011;

Thompson et al., 2012). Some people may even choose to work late to avoid peak-hour altogether. Whatever the choice, one thing is certain, the close proximity of strangers is an uneasy experience that affects one's choices on what to do or where to sit (Evans & Wener, 2007; Hirsch & Thompson, 2011; Kim, Kwon, Wu, & Sohn, 2014; Tirachini, Hensher, & Rose, 2013).

Hall (1966) conducted many field observations where he witnessed both positive and negative reactions to close interpersonal proximity. As a result, he developed his theory on personal space as an imaginary bubble around our body that people seek to maintain between themselves and others. Since Hall developed his theory on personal space many social psychologists went on to measure the size of this imaginary bubble (see Aiello, 1987, for a review). The stop-approach methodology was developed to test personal space more rigorously in the laboratory than Hall's field observations. The stop-approach method requires a participant to walk towards a confederate and to stop when they feel they are at a comfortable conversational distance (Hayduk, 1981; Kennedy et al., 2009; Rawls, Trego, McGaffey, & Rawls, 1972) (see Figure 4.1). Recent measures estimate that the average preferred social distance is about 600 mm (Kennedy et al., 2009; Lloyd, Coates, Knopp, Oram, & Rowbotham, 2009; Tajadura-Jiménez, Pantelidou, Rebacz, Västfjäll, & Tsakiris, 2011). Intriguingly, various recent studies have shown that this social comfort distance is highly related to the bounds of reachable (peripersonal) space (Brozzoli et al., 2013; Iachini et al., 2014, 2015; Teneggi et al., 2013). Perhaps the English saying to 'keep someone at arm's length' is not as abstract as it seems, but may actually have a neurological basis.

Analogous to peripersonal space, personal space also seems to function as a safety region (Cléry et al., 2015; Graziano & Cooke, 2006). Personal space has been likened to an invisible yet permeable boundary with which one can choose who to allow or disallow access (Evans & Howard, 1973; Felipe & Sommer, 1966; Hall, 1966; Hayduk, 1981). For example, studies have shown that people have closer conversational distances with friends than strangers (Hall, 1966; Ickes, Patterson, Rajecki, & Tanford, 1982; Willis, 1966). Besides acting as a gateway for conversations, other behaviours suggest that personal space may act as a safety buffer between strangers. Generally, because the close prox-

(a) The confederate is approaching the participant.

(b) The participant has told the confederate to stop at a comfortable distance.

Figure 4.1: Illustration of the stop-approach task.

imity to a stranger is an uncomfortable experience most people try to avoid it. Studies looking at seating behaviours show that when choosing where to sit in a public space, such as a library, people seat themselves as far away from others as possible (Patterson, Mullens, & Romano, 1971). Similarly, commuters on public transport would rather opt to stand than sit between two strangers (Evans & Wener, 2007; Hirsch & Thompson, 2011). Avoidant behaviours are even observed when walking past strangers, where people tend to deviate their walking path so as to give themselves and others greater space (Efran & Cheyne, 1973; Soper & Karasik, 1977). These are a few examples that demonstrate the behaviours people try to modify in order to avoid the close proximity of strangers. This raises an interesting question, if this safety margin is invisible then how does one determine when someone invades it?

Personal space invasions trigger physiological reactions such as increased stress levels measured by cortisol, skin conductance or EEG arousal (Aiello et al., 1977; Evans & Wener, 2007; McBride et al., 1965; Perry, Nichiporuk, & Knight, 2015). Perhaps increased arousal is a physiological cue that indicates to the observer when someone enters one's personal space. Systematic increases in physiological arousal have been shown to accompany closer interpersonal proximities (Aiello et al., 1977; McBride et al., 1965). Physiological responses to anxiety are mediated by the central nervous system and efferent input from brain structures such as the hypothalamus and amygdala. If a threat is perceived the amygdala sends a distress signal to the hypothalamus, which activates the sympathetic nervous system evoking an appropriate fight-or-flight response. The amygdala in particular has been implicated in personal space regulation (Graziano & Cooke, 2006; Kennedy et al., 2009). Kaitz, Bar-Haim, Lehrer, and Grossman (2004) suggested that personal space regulation plays an important role in shaping comfortable and appropriate social encounters. Kennedy et al. (2009) investigated personal space regulation in a woman with bilateral amygdala damage. When asked to approach the experimenter to the point at which she felt uncomfortable, they found that her preferred chin-to-chin distance was substantially smaller than controls. When a confederate stood very close to her she rated the encounter as comfortable, whereas the confederate found it unpleasant. This lesion study demonstrates the role of the amygdala in shaping appropriate social encounters.

Sometimes personal space invasions cannot be avoided, in this case, people have been shown to reduce feelings of discomfort through many different compensatory behaviours (Aiello, 1987; Felipe & Sommer, 1966; Hall, 1966; Hirsch & Thompson, 2011; Patterson et al., 1971). Even in the 60's Hall recognised the potential influence modern technology, such as the telephone, can have on social distance. The telephone made it possible to indirectly bring others closer regardless of how far they may be (Hall, 1966). Although in the 21st century, we now have mobile phones that can shorten social distances, the use of new technologies, such as smartphone capabilities, also make it possible to keep others at a distance (Bull, 2005; Hirsch & Thompson, 2011; Sommer, 2002). Research on crowding on public transport shows that people retreat into their own private space by engaging in personal activities such as reading, listening to music or playing with smartphones (Hirsch & Thompson, 2011). These technologies have been shown to reduce feelings of social discomfort and allow others to approach us more closely (Tajadura-Jiménez et al., 2011). One working hypothesis is that feeling more in control of one's personal space makes these intrusions more tolerable (Duke & Nowicki, 1972; Heckel & Hiers, 1977; Tajadura-Jiménez et al., 2011; Hirsch & Thompson, 2011). Using mobile phones as a means to reduce the discomfort of crowding may explain its prevalence on public transport (Thompson et al., 2012). It has also been suggested that music may reduce the size of one's personal space allowing others to approach more closely (Tajadura-Jiménez et al., 2011) —this is explored further in the next section on the plasticity of the space around us.

4.3 Effects of interpersonal distance on the plasticity of peripersonal space

From a neurocognitive perspective, peripersonal space is the reachable space surrounding the body (Cléry et al., 2015; Rizzolatti et al., 1997). This region of space is important for interacting with objects in one's environment. Peripersonal space has predominantly been studied in terms of the actionability of objects. It is thought that the body functions as a perceptual ruler in which low perceptual cues are interpreted in terms of their distance from the body (Cléry et al., 2015; Proffitt, 2013). Depending on whether these objects are reachable or unreachable, distinct neural maps in the brain activate that subserve an appropriate interaction (Gallivan, Cavina-Pratesi, & Culham, 2009; Weiss et al., 2000).

Under different situations, peripersonal space has been shown to contract or expand. For example, claustrophobic fear has been shown to contract space (Lourenco et al., 2011), whereas tool use has been shown to expand space (Berti & Frassinetti, 2000; Cardinali et al., 2009; Farnè & Làdavas, 2000). To demonstrate how peripersonal space changes under such conditions and the underlying neurological mechanisms, consider the example of tool use. Tools are important for interacting with one's environment. Studies have shown that when a person is given a rake, peripersonal space elongates to incorporate this tool (Berti & Frassinetti, 2000; Farnè & Làdavas, 2000) (see Figure 4.2). Presumably this occurs because when an object is unreachable and also unactionable, the use of a tool can bring

(a) Without a tool, the wooden cube on the table is unreachable and unactionable.

(b) With a tool the cube is reachable and actionable.

Figure 4.2: An illustration of the expansion of peripersonal space with tool use. In panel (b) peripersonal space has expanded to incorporate the rake and the area of what is reachable in order to interact with the cube.

this object into near space and therefore make it actionable (Berti & Frassinetti, 2000).

Neuroimaging studies have shown that distinct areas in the brain are activated for near (reachable) and far (unreachable) spaces (Gallivan et al., 2009; Weiss et al., 2000). An fMRI study by Gallivan et al. (2009) investigated the role of the superior parieto-occipital cortex in peripersonal and extrapersonal space. They examined brain imaging data whilst participants either actively reached for an object or passively viewed near (reachable) and far (unreachable) objects. These data showed that the superior parieto-occipital cortex was activated for both active reachable and passive reachable, but not for passive unreachable objects. These data suggest that objects do not have to be acted upon in order to be represented in the brain, but rather the distance of objects may automatically be encoded with respect to their distance from the body.

When we move around and interact with the world we are not only interacting with objects but with other people too (Fini, Brass, & Committeri, 2015; Iachini et al., 2014). Interestingly, soon after Rizzolatti and colleagues developed the construct of reachable space they further went on to describe the basis of social cognition located in the mirror neuron system (Gallese, Keysers, & Rizzolatti, 2004). The mirror neuron system is a remarkable neural network that engages areas in the motor system when an observed action is performed by another person (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Rizzolatti & Craighero, 2004). These motor areas are not only reserved for performing one's own action, but are also activated when observing an action being performed by another. This suggests that when observing an action, neural areas in the observer are activated as if the observer was executing the same action they were observing (Fadiga et al., 1995; Ishida, Nakajima, Inase, & Murata, 2010; Rizzolatti & Fabbri-Destro, 2008). Neuroimaging support for a shared spatial reference frame in humans comes from a study by Brozzoli et al. (2013). They presented a moving object near a participant's own hand or near another person's hand. They found common regions in the ventral premotor and parietal cortices, which activated regardless of whether the object was located near the self or the other person's hand. In addition, single cell recording studies with primates show that mirror neurons differentially encode actions observed in peripersonal and extrapersonal space (Caggiano et al., 2009). Although this suggests that peripersonal space plays an important role in sociality, one may ask, what is the benefit of mapping out the peripersonal spaces of both the self and other?

Analogous to the tool use example previously described, peripersonal space has been shown to adjust under different social contexts by appropriately shrinking or expanding in response to social interactions (Heed, Habets, Sebanz, & Knoblich, 2010; Maister, Cardini, Zamariola, Serino, & Tsakiris, 2015; Teneggi et al., 2013). A study by Teneggi et al. (2013) measured participant's peripersonal boundaries with irrelevant approaching or receding auditory stimuli and responses to a tactile stimulus. Once peripersonal space had been measured, participants were seated in front of another person or a mannequin and again participant's peripersonal space was measured. They found that participant's peripersonal space shrank when they faced another person in near space, but not for the mannequin. Furthermore, when participants engaged in a cooperative economic game peripersonal space boundaries expanded to incorporate the other person. This research suggests that Hall's idea of personal space and the neurocognitive concept of peripersonal space share many similarities when it comes to interacting in a social environment. Modulating the size of peripersonal space through social interactions is a prime example of how top-down social processing can influence the perception of sensory input. Given these data, it is reasonably plausible that social proximity can also impact on spatial attention.

4.4 Effects of interpersonal distance on spatial attention

Because of the 'minimalist' approach in cognitive neuroscience, where individuals are studied in isolation, few studies in this area can make inferences about the effects of interpersonal distance on spatial attention. An interpersonal spatial phenomenon that has recently been observed, which illustrates differences between studying spatial attention in individuals versus pairs, is the Simon effect and the social Simon effect, respectively.

In a single-participant paradigm, a typical Simon effect emerges when task-irrelevant spatial properties of a stimulus influence the reaction times of a response (Simon & Rudell, 1967). For example, imagine a participant is instructed to respond as quickly as possible to green circles with a left button and blue circles with a right button. The order of the coloured circles are randomised and presented to the left and right of a central fixation on the computer screen. Although the participant is only instructed to respond to the coloured circles, left button presses are faster when they correspond to stimuli on the left of the screen compared to when they are on the right, and vice versa for right button presses. The referential-coding hypothesis suggests that when the brain processes visual information, at the response selection stage the response is coded in terms of a reference frame of left or right. Therefore if the stimulus and the selected response spatially correspond, performance is facilitated, whereas if they do not corresponded performance is inhibited (Hommel, 1993).

In a social Simon task, a similar stimulus-response effect emerges when two participants are instructed to each carry out one half of the two-choice colour responses. For example, if two participants are sitting next to each other and the participant on the left side has one button to respond to green circles only and the other participant on the right has one button to respond to blue circles only. The order and position of the coloured circles are randomised and participants are only instructed to respond to their assigned colour as quickly as possible. Each participant's response is automatically coded onto the task-irrelevant spatial position of the stimulus (Sebanz, Knoblich, & Prinz, 2003). That is, the *left participant* will respond faster to green circles appearing on the left compared to the right, and in contrast the *right participant* will respond faster to blue circles on the right compared to the left. This stimulus-response effect suggests that participants both perform as though one participant is acting left and the other acting right (Sebanz, Bekkering, & Knoblich, 2006). Moreover, the social Simon effect is an automatic task-irrelevant behaviour that does not add to the efficiency of this task. Perhaps this automatic social behaviour is necessary for coordinating actions with other people (Knoblich, Butterfill, & Sebanz, 2011; Sartori, Bucchioni, & Castiello, 2013). Importantly, the social Simon effect does not occur outside of peripersonal space (Guagnano, Rusconi, & Umiltà, 2010), which indicates proximity is important for interacting with other people on shared tasks.

Interpersonal proximity has also been shown to affect crossmodal integration of visual and tactile information (Heed et al., 2010). In a typical single-participant crossmodal integration task, visual distractors can interfere with the response to tactile stimulation—this is called the crossmodal congruency effect. In this case, participants will respond faster to tactile stimulation if the visual distractors are congruent and slower if they are incongruent. Heed et al. (2010) demonstrated that if another person is introduced into the task and performs the same task in peripersonal space, the crossmodal congruency effect is reduced. If, however, the other person is not in peripersonal but in extrapersonal space instead, the crossmodal congruency effect reappears. This suggests that top-down social processing can modulate the integration of visual-tactile information close to the body.

Based on the literature reviewed thus far, there appears to be a close link between the spatial representation of one's body, multisensory information and social processing. Recent papers have suggested that when two people shared sensory experiences there is a remapping of space around the other's body (Maister et al., 2015; Teneggi et al., 2013). Teneggi et al. (2013) suggests that such shared experiences may be important for coordinating actions in a cooperative environment. Moreover, they demonstrated that peripersonal space of the self and other merged in a cooperative task. Although shared sensory experiences may be neurologically represented and important for establishing a 'common perceptual ground' in which cooperation can occur (Sebanz et al., 2006), there are additional 'private' neural areas reserved for self-relevant information only (De Vignemont, 2014; Maister et al., 2015).

Up to this point, the effects of shared experiences on spatial attention have been reviewed, however, not all social events are shared or positive. Hall (1966) discussed in great length the psychological effects of negative social encounters such as crowding or personal space invasions. Perhaps these negative social experiences have shaped the need for a 'private' representation of the self. There is minimal research, however, that has explored the effects of personal space invasions on spatial attention. An early study by Terry and Lower (1979) hypothesised a withdrawal of attention away from an uncomfortable personal space invasion. In this study, the experimenter sat next to participants in close proximity and administered an array of horizontal figures. The attention task required participants to choose which figure first attracted their attention. The results showed that participants consistently chose figures distal to the experimenter. They hypothesised that participants withdrew their attention away from the experimenter in order to reduce their feelings of social discomfort during a personal space invasion. These findings were recently supported in a study by Szpak, Loetscher, Churches, et al. (2015), who found that increased physiological arousal induced by close interpersonal proximity was related to increased attentional withdrawal (see Figure 4.3). Because participants were unable to move away from the source of social discomfort, the authors hypothesised that shifting one's attention away may act to reduce discomfort by increasing their perceived distance between themselves and the other. This research will be explored in more detail in Chapter Nine.

A common compensatory reaction to dealing with personal space invasions in a crowded environment, is to subjectively establish a 'privatised' area where one can engage in solo activities (Hirsch & Thompson, 2011). Szpak, Nicholls, Thomas, Laham, and Loetscher (2016) investigated whether there

(a) Side view of the joint line condition where participants stood across from each other in close proximity and completed a line bisection task.

(b) Top-down view of the experimental setup.

Figure 4.3: An illustration of the experimental setup used in Szpak, Loetscher, Churches, et al. (2015).

are any benefits of engaging in a solo- versus same-task paradigm on attentional withdrawal whilst participants completed a spatial task in close proximity to each other (see Chapter Six for further details). They found that when participants were given the same task an attentional withdrawal emerged. But when participants were given different tasks on the same shared stimuli, attentional withdrawal was reduced. These results indicate that when participants are able to conceptually differentiate themselves from the other in a solo task, even when participants were sharing a space, social discomfort was reduced. This is consistent with research in social psychology that suggests feeling more independent and in control can contribute to feeling more comfortable sitting close to strangers (Duke & Nowicki, 1972; Heckel & Hiers, 1977).

While self-other integration may be important for engaging in joint activities, there are also advantages for maintaining distinct social boundaries that 'keep others at arm's length'. Perhaps investigating the social triggers of the contraction/expansion of peripersonal space and the effects these triggers may have on perception, will be an exciting new challenge for future researchers.

4.5 CONCLUDING REMARKS

The social space around us is an extraordinary neurologically based mechanism that plays a key role in shaping social interactions. An examination of a large body of research has revealed that personal and peripersonal space share many similarities, including the ability to contract or expand under different situations.

Positive social experiences, such as joint activities, can expand personal space. The expansion of one's personal space may create a shared space in which joint activities can occur. Spatial tasks, such as the social Simon task, demonstrate that in a shared space the action potentialities of both the self and other are neurologically represented.

Negative social encounters, such as personal space invasions, may engage the need for a more explicit differentiation between oneself and the other. When one's personal space is invaded by another person, physiological cues prompt a contraction of personal space. This contraction of space may help to create a privatised space in which one can withdraw further into one's space, and thereby more easily differentiate between oneself and others. The current research on this hypothesis is limited.

This review integrates knowledge of personal and peripersonal space in order to identify the impact of interpersonal proximity on spatial attention. Because this is a relatively new area of research, many questions remain to be investigated. Uncovering the mechanisms that underlie the relationship between personal and peripersonal space during close social interactions may pose an interesting challenge to future researchers. Shifting experimental research away from isolated individuals will advance researcher's one step closer to identifying this link in social space.

The next chapter will examine how social presence can shift spatial attention by employing various spatial tasks that measure attentional orienting. Subsequent chapters in this thesis examine attentional withdrawal under different task demands and reflect on the neural mechanisms of social space.

Any occurrence requiring undivided attention will be accompanied by a compelling distraction.

Robert Bloch

5

Social distractibility

The primary theme of this thesis is to investigate how other people in one's environment can shift attention. A study by Garza, Eslinger, and Barrett (2008) was one of the first studies to demonstrate that a social distractor can influence shifts in attention—pseudoneglect. The authors showed that pseudoneglect increased by a left social distractor and decreased by a right social distractor. Most studies that measure the effects of external stimuli on pseudoneglect, examine individuals in isolation. Chapter Five aims to measure the effects of social distractors on pseudoneglect under different task demands. Four experiments were conducted to determine the underlying attentional mechanisms involved in processing social distractors.

5.1 Introduction

Everyday environments are so rich with visual information that it would be impossible to achieve any goals without an appropriate selection mechanism directing our attention to potentially relevant information. But, not all information that attracts our attention is relevant. For instance, a distractor is a salient object or event that automatically attracts attention but is irrelevant to the task at hand (Lavie, 2005; Mulckhuyse & Theeuwes, 2010; N. A. Thomas et al., 2015). By drawing attention away from the primary task the distractor occupies important attentional resources that could be used for processing task-relevant information (Lavie, 2005).

When the neurological mechanisms involved in filtering out distractors is deficient, devastating impairments on attention can follow. For example, Barrett, Schwartz, Crucian, Kim, and Heilman (2000) published a case study of a woman who had a left thalamic infarction. This patient reported that when she drove a car she would frequently deviate towards people and objects on the right hand side of the road. During neurocognitive testing she did not show any signs of attentional neglect as measured by line bisection and cancellation tasks in near space. Barrett and colleagues decided to explore her symptoms of distractibility further by employing a line bisection task whilst the experimenter stood on the left and right sides of the line. The authors showed that their patient's attention strongly deviated towards the right experimenter-distractor. While the case study by Barrett and colleagues cannot determine whether the patient's bias was perceptual-attentional or motor-intentional, their study nevertheless demonstrates that attention can deviate towards a social distractor on a line bisection task. Barrett and colleagues proposed that the damage to the areas of thalamus that project extensively to the dorsolateral frontal cortex may explain their patient's tendency to bias towards distractors. Other lesion studies support this hypothesis showing increased distractibility in patients with dorsolateral frontal lesions, which suggests that the dorsolateral frontal cortex is crucial for gating distracting information (Chao & Knight, 1995; Woods & Knight, 1986).

In a follow up study with healthy participants, Garza et al. (2008) wanted to determine whether a social distractor influenced perceptual or motor performance. They argued that if a social distractor engaged bottom-up visual systems then perceptual-attentional performance would be affected; in contrast if a social distractor engaged top-down motor systems then motor-intentional performance would be affected. In order to distinguish between these two systems, Garza and colleagues used a reverse-feedback line bisection paradigm in near and far space. The author's experimental setup included a monitor positioned in either near or far space with a specialised screen on the floor in front of participants. Garza and colleagues experimental procedure required participants to point a laser to the specialised screen, which either relayed normal or reversed visual feedback to the monitor in front of them. Three experimental conditions were evaluated wherein the experimenter acted as a distractor: (1) on the left, (2) right, or (3) was absent. If a social distractor affected perceptual-attentional systems then feedback-dependent errors would occur, but if motor-intentional (aiming) systems were affected then feedback-independent errors would be observed. Garza et al. (2008) only found evidence for feedback-dependent errors suggesting that perceptual-attention was drawn towards the social distractors. Accordingly, left social distractors increased pseudoneglect, but right distractors decreased it. These results are consistent with numerous pseudoneglect studies showing that a cue attracts attention towards it (Bultitude & Aimola-Davies, 2006; Jewell & McCourt, 2000; Sosa, Clarke, & McCourt, 2011).

The idea that other people can influence individual performance on a task, is one of the oldest concepts in social psychology (Aiello & Douthitt, 2001; Triplett, 1898). Up until the 70's, the effects of social presence on cognitive processes, such as attention, had not investigated. In the 70's, however, Baron (1978) developed a cognitive theory called the distraction-conflict hypothesis which proposed that another person can have a distracting effect on an individual's attention, thus individual performance is facilitated on simple tasks and impaired on complex tasks. Facilitation/impairment occurs because the presence of another person can attract attention away from the task and the individual is unable to focus entirely on the task at hand. In order to clarify why increasing the amount of distractors progressively impairs performance, Baron adapted the distraction-conflict hypothesis to include 'cognitive overload' (Baron, 1986). He proposed that cognitive overload from social distractors in the environment leads to a narrowing of focused attention, which results in a facilitation for simple tasks and impairment for complex tasks. Cognitive overload on simple tasks enables participants to direct their attention to relevant stimuli and filter out task-irrelevant information. Conversely, on complex tasks cognitive overload leads to decreased performance because participants neglect task-relevant information.

Although Barrett et al. (2000) and Garza et al. (2008) may be the first studies to demonstrate the influence of social distractors on attentional orienting, they used relatively complex stimuli with multiple factors i.e visual feedback (normal, reversed), distance (near, far), start position (left, right), distractor (left, right, none), and sex (male, female). The experiments presented in this chapter sought to examine the effects of social distractors on attention by using a much simpler methodology. Moreover, the aim the current experiments was to determine whether a social distractor is processed in the same way as a non-social distractor or whether a social distractor is processed differently. I attempted to achieve this aim by seating the social distractor on the lateral sides of the participant so that the social distractor was outside of focal attention. This study used this basic paradigm with four different spatial tasks to investigate the effect of social distractors on pseudoneglect.

5.2 Experiment 1: social distractor on a Landmark task

5.2.1 Introduction

Garza et al. (2008) suggested that a social distractor affects perceptual attention rather than motoric performance on a line bisection task. I sought to test this hypothesis by measuring lateral shifts in spatial attention with a perceptual Landmark task in social-present and social-absent conditions. The

Landmark task requires a forced two-choice discrimination and does not rely on motor acuity like a line bisection task does. Experiment 1 aimed to discern the 'purely' perceptual influence of a social distractor on pseudoneglect that is independent from motor biases.

In Garza and colleagues study, the social distractor was positioned to the immediate left and right sides of the line trials. One potential oversight with this experimental setup is that social distractors facing participants would have been subjected to gaze cues, and it is well known that gaze cues can shift attention (Bayliss, di Pellegrino, & Tipper, 2004; Bonato et al., 2008; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). Because Experiment 1 is concerned about the effects of social distractors presence on attention, gaze cues were eliminated by positioning the social distractor next to the participant.

My first experiment investigated whether pseudoneglect is affected by a social distractor sitting to the left or right side of the participant. I predicted that a social distractor may attract attention towards itself in accordance with the studies of Garza et al. (2008) and Barrett et al. (2000), and other non-social cueing studies (Bultitude & Aimola-Davies, 2006; Milner et al., 1992). If attention is drawn towards the social distractor then a left distractor will increase pseudoneglect and a right distractor would decrease pseudoneglect.

5.2.2 METHOD

SUBJECTS

Twenty-two ($m = 6; f = 16$) university students participated in the experiment in exchange for $10. Ages ranged between 18–61 years of age ($M = 22.86$; $SD = 9.13$). All participants were right-handed (Oldfield, 1971) and had normal or normal-to-corrected vision acuity. The experimenter was female. Participants gave informed consent prior to the start of the experiment, and were unaware of the exact purpose of the study.

APPARATUS

Stimuli were presented to participants on an LCD screen (550 mm diagonally). E-prime software 2.0 controlled stimulus presentations and ran the experiment. A serial response box model 200A PST was placed horizontally in front of participants and recorded participant's responses. A chin rest was used to ensure that participant's heads were kept in the same position throughout the experiment.

STIMULI

Stimuli were based on horizontal lines used by McCourt and Olafson (1997). Lines were 180mm in length and 5mm in height and subtended a visual angle (VA) of 16.7°in length and 0.48°in height. Each line consisted of two black and white diagonally opposite bars on a grey background. Lines were bisected to the left or the right of the true centre by 1, 2, and 3 mm. While the vertical position of the lines on the screen was kept constant (vertical centre), the horizontal position was jittered 9mm (VA = 0.86°) to the left or 9mm to the right or in the true centre of the screen. These jittered lines prevented subjects from using strategies, such as using an external marker on or around the page, to assist their decision. Factorial combination of bisection shift (−3, −2, −1, +1, +2, +3 mm), jittering position (9 mm left, 0 mm, 9 mm right) and polarity (upper left portion black, upper left portion white) resulted in 36 stimuli. Each stimulus was presented twice resulting in a total of 72 randomised trials.

PROCEDURE

Participants completed the Landmark task in three different blocks: (1) with the experimenter sitting to their left, (2) alone (experimenter outside the testing room), or (3) with the experimenter sitting to their right (see Figure 5.1). The distance from the participant to the screen was 600 mm and the experimenter was positioned at demarcated locations 450 mm to the left and right from the screen centre. The order in which the blocks were administered was balanced between-subjects.

(a) Experimenter present.

(b) Experimenter absent.

Figure 5.1: An illustration of the experimental setup used in Experiment 1. Participants completed a Landmark task where the experimenter sat to the left, to the right or was absent.

Each trial started with a blank grey screen for 500 ms, followed by a pre-bisected line stimulus for 2000 ms in which participants had to respond. On each trial, participants indicated whether the left or right sides of the line appeared longer. If participants thought the left side of the line looked longer they were instructed to press the leftmost button on the response box, if they thought the right side looked longer they pressed the rightmost button. During experimenter-absent blocks, the experimenter started a stopwatch and walked out of the testing room. During experimenter-present blocks, the experimenter sat next to participants and then started a stopwatch. Once a block had been completed, the experimenter stopped the stopwatch and handed participants the Edinburgh handedness questionnaire (Oldfield, 1971) after the first block, and a filler task with incomplete sentences after the second block.

5.2.3 RESULTS

In order to calculate the subjective centre in which a participant perceived both the left and right sides of the line to be of equal length, a point of subjectively equality (PSE) was calculated for each individual's responses in each of the three seating conditions (experimenter-left, experimenter-right and experimenter-absent). This was done by fitting a cumulative Gaussian distribution to the proportion of left-side-longer responses for all transection points ranging from -3 to +3 mm. Negative values represent a leftward bias and positive values represent a rightward bias. Goodness of fit between the cumulative curve and the proportion of left-side-responses was measured using R^2 and ranged from .882 to .996 with a mean of .976.

One-sample t-tests showed pseudoneglect for the experimenter-left ($M = -.499$ mm, $SD = .765$) [$t(21) = 3.058, p = .006$, $Cohen's\ d = 1.335$], experimenter-absent ($M = -.486$ mm, $SD = .814$) [$t(21) = 2.799, p = .011$, $Cohen's\ d = 1.222$] and experimenter-right ($M = -.458$ mm, $SD = .908$) [$t(21) = 2.364, p = .028$, $Cohen's\ d = 1.032$] seating conditions.

To test whether a left distractor increased pseudogneglect and a right distractor decreased pseudoneglect participant's PSEs were submitted to a repeated measures ANOVA with seating position (left, alone, right) as within-subjects factors. The main effect for seating position was not significant [$F(2, 42) = .063, p = .939$, $partial\ \eta^2 = .003$] suggesting that the experimenter-present conditions did not influence pseudoneglect (see Figure 5.2).

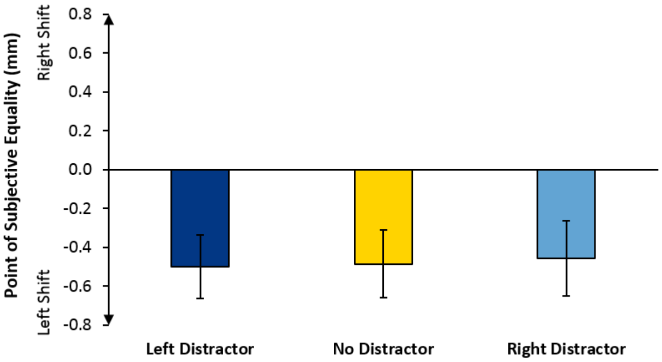


Figure 5.2: Bar graph showing the point of subjective equality for three social conditions. The x-axis displays the left distractor, no distractor and right distractor conditions. The y-axis the point of subjective equality (PSE) where negative values represent a leftward shift and positive values represent a rightward shift of the perceived midpoint. Standard error bars are included.

5.2.4 Discussion

This experiment tested whether a social distractor can influence pseudoneglect on a perceptual Landmark task. I predicted that attention may be drawn towards the social distractor. Furthermore, I predicted that a left distractor will increase pseudoneglect and a right distractor would decrease pseudoneglect. Contrary to these predictions, I did not observe any differences between social-present and social-absent conditions, nor did I measure any differences in pseudoneglect. Based on this null finding it is difficult to draw valid conclusions. There are some key differences between this experiment and Garza et al.'s (2008) study that may have impacted on the results.

In Garza et al.'s (2008) study participants used a laser to bisect lines through a normal or reversed feedback paradigm. Participants underwent three experimental conditions with the experimenter (social distractor) to the left or the right of the computer monitor, or was absent. Garza and colleagues only found evidence for feedback-dependent errors, which the authors concluded represents a perceptual bias only and that attention was drawn towards the social distractor. Taking into account these conclusions, the current study sought to test the social distractor effect using a perceptual Landmark task that does not rely heavily on fine motor skills like Garza et al.'s (2008) laser paradigm. Results showed that Experiment 1 favoured the null hypothesis. Although both tasks measure perceptual biases, the line bisection and Landmark tasks have different task demands which may lead to slight changes in how pseudoneglect is represented (Learmonth et al., 2015). It is possible that the perceptual effect is too weak to be observable in the Landmark task. Alternatively, the presence of the experiment in participants responding space could have nulled out any perceptual effects. For example, if the presence of the experimenter drew attention towards their side but participants felt less inclined to respond by making motor movements into the experimenter's space then this may have led to null findings. But, it is difficult to draw conclusions from null findings especially if perceptual and motor biases have not been clearly separated.

Another key difference between the study by Garza et al. (2008) and the present experiment is the position of the social distractor. In Garza and colleague's study, the experimenter stood next to the left and right sides of the line stimuli and as a result may have introduced gaze cues. Gaze cues have been known to influence attentional orienting (Bayliss et al., 2004; Langton, Watt, & Bruce, 2000; Pfeiffer et al., 2012). In order to eliminate gaze cueing in the current experiment the social distractor was positioned next to the participant. Because Experiment 1 did not demonstrate a social distractor effect, one could argue that the social distractor used in this experiment was perhaps not as salient as the social distractor with gaze cues used in Garza et al.'s (2008) study.

In Garza et al.'s (2008) study, the authors observed attention shifting towards the social distractors. In my experiment I used a similar paradigm and was not able to replicate these findings. Instead Experiment 1 produced null findings. In principle no valid conclusions can be drawn from null findings, however, it is important to acknowledge that there were some minor differences in these two experiments that could have led to different results. These differences are the type of spatial line task employed and the salience of the social distractor. Accordingly, the next experiments aimed to systematically explore how these differences may have impacted on the results.

5.3 Experiment 2: social distractor on a line bisection task

5.3.1 Introduction

The previous study did not observe effects of social distractibility on pseudoneglect in a Landmark task. Although it is difficult to determine what led to non-significant data, there were two main differences in the previous experiment: the task and the position of the distractor. At this point, it is unclear why either of these two differences would impact on the social distractor effect. In an effort to systematically explore these differences, one variable was change at a time starting with the spatial task.

To explore whether the spatial task was important for measuring the social distractor effect, a line bisection task analogous to Garza et al.'s (2008) study was chosen for this experiment. If a line bisection task is sensitive to measuring the social distractor effect then I should observe a cueing effect similar to Garza and colleagues study. Importantly, the social distractor was kept in the same position as Experiment 1. Keeping the distractor next to the participant would also help to identify if the position of the distractor made a difference on the social effect.

Changing the task in this manner may lead to a few possible outcomes. If the line bisection task is sensitive for measuring the social distractor effect then it should not matter where the social distractor is positioned, and a cueing effect should be observed in Experiment 2. If, however, the social effect is contingent on the distractor being positioned in front of the participant then no social effects should be observed in the current experiment.

5.3.2 METHOD

SUBJECTS

Twenty-five ($m = 7$; $f = 18$) university students participated in the experiment in exchange for $10. Ages ranged between 19–42 years of age ($M = 23.36$) and every participants was right-handed (Oldfield, 1971). All participants have normal or normal-to-corrected vision acuity, which is necessary for this study. The experimenter that carried out this study was female. Participants gave informed consent prior to the start of the experiment, and were unaware of the exact purpose of the study. One participant's (f) data was excluded from this experiment as they struggled to complete this task.

STIMULI

Stimuli were based on those used by McCourt and Olafson (1997) and consisted of horizontal lines of two different lengths 180mm and 220mm. While the vertical position of the lines on the page was kept constant (vertical centre), the horizontal position was jittered 5 mm to the left or 5 mm to the

(a) Experimenter absent.   **(b)** Experimenter present.

Figure 5.3: An illustration of the experimental setup used in Experiment 2. Participants completed a line bisection task where the experimenter sat to the left, to the right or was absent. In the alone condition, participants completed the line bisection and turned the pages upside down in front of them. In the social conditions, participants turned the pages upside down to the side of the experimenter.

right. These 'jittered' lines prevented subjects from using strategies, such as using an external marker on or around the page, to assist their decision. Factorial combination of length (long, short), jittering position (5 mm left, 5 mm right) and response hand (left, right) resulted in 32 stimuli.

PROCEDURE

The experiment consisted of 96 trials, 32 trials in each block, where half of the trials were completed with the left and the other half with the right hand. Trials were presented to each participant in a randomised order. Similar to Experiment 1, the seating position of the experimenter was manipulated between blocks, where the participants made line bisections: (1) with the experimenter sitting to their left, (2) alone where the experimenter was outside the testing room or (3) with the experimenter sitting to their right (see Figure 5.3). The order in which the blocks were administered was balanced between subjects.

Each block began with the experimenter handing participants their lines, and giving instructions on which hand to use and where they should turn the pages once a trial is completed. During experimenter-absent blocks, the experimenter started a stopwatch and walked out the room. During experimenter-present blocks, the experimenter sat next to participants then started a stopwatch. The participant and experimenter sat in demarcated locations so that the distance from the midsagittal plane of the participant to the midsagittal plane of experimenter was approximately 450mm. When the experimenter was present, participants were instructed to use their free-hand (non-bisecting hand) to turn completed pages over to the experimenter's side, where completed trials lay face-down in front of the experimenter. When the experimenter was absent, participants were instructed to turn over the completed pages in front of them. Once bisections were completed for one hand, the experimenter stopped the stopwatch, handed participants a new set of lines for their other hand and then started the stopwatch again. Between the two blocks participants were given the Edinburgh handedness questionnaire (Oldfield, 1971) and a filler task with incomplete sentences.

5.3.3 RESULTS

For each participant, lines were measured (in mm) and deviations from the veridical midpoint were calculated.

VARIABILITY These shifts from the midpoint were used to determine the standard deviations of each individual for each seating condition. Standard deviations were calculated to identify if motor performance was more variable in certain blocks due to hand dexterity or social effects. One participant's data was excluded from further analysis, as the variability in his data was 2 standard deviation above the mean cut-off. Excluding his data did not impact on the significance of the following ANOVA. A 3×2 ANOVA was submitted with seating position (left, alone and right), and response hand (left hand and right hand) as within-subjects factors. When submitted to an ANOVA, variability for the left ($M = 3.062$, $SD = .652$), baseline ($M = 2.845$, $SD = .643$) and right ($M = 2.948$, $SD = .748$) seating conditions were not significantly different [$F(2, 44) = 1.503$, $p = .234$, $partial\ \eta^2 = .064$], nor was response hand [$F(1, 22) = .142$, $p = .710$, $partial\ \eta^2 = .006$], nor was the interaction between seating condition and response hand [$F(2, 44) = .093$, $p = .912$, $partial\ \eta^2 = .004$].

SHIFTS FROM THE LINE MIDPOINT Deviation scores from the true midpoint (in mm) were submitted to a 3 × 2 ANOVA with seating position (left, alone & right), and response hand (left & right) as within-subjects factors. There was a main effect for seating position [$F(2, 44) = 4.499$, $p = .017$, *partial* $\eta^2 = .170$], response hand [$F(1, 22) = 4.467$, $p = .046$, *partial* $\eta^2 = .169$], and a significant interaction between seating position and response hand [$F(2, 44) = 9.882$, $p < .001$, *partial* $\eta^2 = .310$] (see Figure 5.4). Post-hoc comparisons were made using Bonferroni adjusted t-tests (significant $p < .05$). Comparisons between the no-distractor-left-response-hand condition was significantly more leftward than the no-distractor-right-response-hand condition [$t(22) = 3.131$, $p < .05$]. Performance differences between the left and right response hands in the baseline (no distractor) condition was expected because of motor biases that have been shown before on a line bisection task. The left-distractor-left-response-hand condition shifted attention significantly rightward compared to the no-distractor-left-response-hand condition [$t(22) = 3.597$, $p < .05$]. Moreover, the left-distractor-left-response-hand condition was significantly more rightward than the right-distractor-left-response-hand condition [$t(22) = 3.181$, $p < .05$]. None of the other Bonferroni adjusted comparisons fell within the significance level of $p < .05$.

DIFFERENCE SCORES In order to examine this relationship more closely between the seating condition and response hand, difference scores were calculated. A 2×2 ANOVA was submitted with difference scores for the seating conditions. There was no main effect for the difference scores for left and right seating conditions [$F(1, 22) = .054$, $p = .819$, *partial* $\eta^2 = .002$], but there was a main effect for response hand [$F(1, 22) = 6.254$, $p = .020$, *partial* $\eta^2 = .221$] and the interaction was also significant [$F(1, 22) = 14.765$, $p = .001$, *partial* $\eta^2 = .402$] (see Figure 5.5). Bonferroni adjusted comparisons showed that only the left-distractor-left-response-hand condition shifted significantly away from the social distractor compared to the left-distractor-right-response-hand condition [$t(22) = 5.200$, $p < .01$]. One sample t-tests showed that the left-distractor-left-response-hand con-

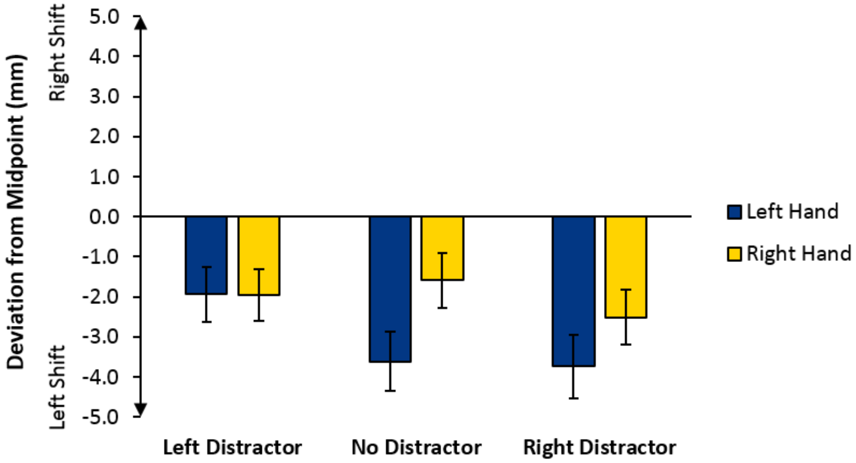


Figure 5.4: Bar graph showing the interaction between social condition and response hand. The x-axis displays the three social conditions: left-distractor, no distractor and right-distractor. The y-axis displays the point of subjective equality (PSE) where negative values represent a leftward shift and positive values represent a rightwards shift. The coloured bars show the left and right response hands. Standard error bars are included in the graph.

dition ($M = -1.667, SD = 2.225$) [$t(22) = 3.597, p = .002$, $Cohen's\ \ d = 1.534$] and ($M = -.915$, $SD = 2.104$) [$t(22) = 2.094, p = .048$, $Cohen's\ \ d = .893$] right-distractor-right-hand conditions shifted away from the social distractor and were significantly different from zero (no bias).

5.3.4 Discussion

The aim of this experiment was to investigate whether a social distractor sitting next to participants could attract attention in a similar manner to the study of Garza et al. (2008). Although Garza and colleague's study positioned the social distractor in front of participants, the current experiment sought to examine the effects of a social distractor that was not in participant's direct line of sight. The current experiment did not replicate the social effects found in Garza et al.'s (2008) study where attention was drawn towards the social distractor (attentional attraction). Instead, I observed attention moving away from the social distractor (attentional withdrawal).

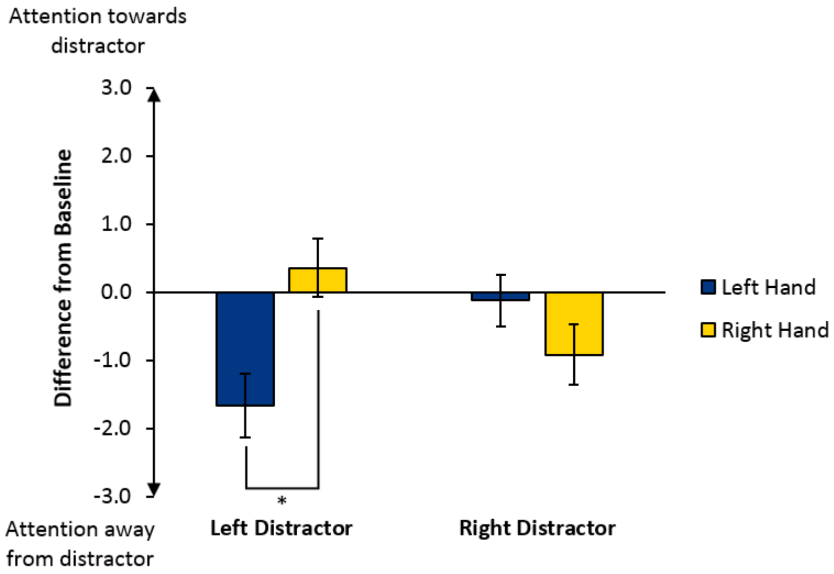


Figure 5.5: Bar graph showing the differences between the left and right distractor conditions for each response hand. The difference scores represent the social conditions subtracted from the baseline (no distractor). The x-axis displays the two conditions where the experimenter was present: left distractor and right distractor. The y-axis displays the difference scores where positive values represent attention moving towards the social distractor and negative values represent attention moving away from the social distractor. Standard error bars are shown.

The attentional withdrawal that we observed in this experiment was opposite to the predicted pattern. However, my hypothesis was guided by limited attention literature. An attentional attraction was predicted because Garza et al. (2008) found this pattern in a line bisection task when the experimenter stood on the left and right sides of the line stimulus. Garza et al.'s (2008) findings are consistent with line bisection literature which has examined the effects of distractors and has shown that attention moves towards the side of the distractor-target (Bultitude & Aimola-Davies, 2006; Milner et al., 1992) even when there are few visual fixations on the distractor (see eye-tracking study by: N. A. Thomas et al., 2015). The results of the current experiment are intriguing as the two main findings suggest that a social distractor may be processed differently to a typical distractor. Firstly, a strong social effect is observed when the social distractor is not directly in front of participants. And secondly, an attentional withdrawal effect was observed, where attention is moving away from the social distractor—which is opposite to typical distractor effects.

An old paper published as a methodological note by Terry and Lower (1979) found a similar effect of perceptual withdrawal to Experiment 2. Terry and Lower (1979) explored the effects of a personal space invasion on attention with an array task. In the authors' study, the experimenter sat laterally to participants and an array of figures was presented to participants. When Terry and Lower (1979) asked participants to point out the figure that first attracted their attention, the authors consistently found that participants pointed to figures distal to the experimenter. Interestingly, this distal bias strengthened as the distance between the participant and the experimenter decreased. Terry and Lower (1979) hypothesised that participants withdrew their attention away from the experimenter to reduce the uneasiness of the personal space invasion. Terry and Lower's observations may explain the findings of the current experiment. Because the social-distractor was positioned within the participant's personal space, the attentional withdrawal observed in the current experiment may relate to social research showing that sitting in close proximity to a stranger can induce feelings of discomfort (see Aiello, 1987, for a review).

An alternative explanation is that the close proximity of the social distractor may have acted as a 'social barrier' that impacted on the mobility of the response hand. This explanation may account for the social condition and response hand interaction found in the current experiment. A recent study by Nicholls et al. (2014) investigated the effects of close objects, such as a barrier, on line bisection performance. The authors positioned the barrier to the left and right sides of the participant and did not find that a close barrier impacted on line bisection performance. Nicholls et al. (2014) barrier study had a very similar set-up to the current experiment, except the barrier was even closer to the participant (260 mm from the centre of the screen to the barrier) than the social distractor in my experiment. The authors did not find an effect of barrier on pseudoneglect in the line bisection task. Based on these data from Nicholls et al. (2014) study, there is little or no evidence to suggest that a 'social barrier' may have impacted on line bisection performance. Furthermore, I did not observe any effects to suggest that a social distractor influenced the motor variability in the line bisection task. Taking all these findings into account it is unlikely that the social distractor affected the mobility of a participant's response hand.

While it is tempting to draw conclusions from the significant data observed in this experiment, this data pattern is contrary to the predicted hypothesis. Because the findings of the current experiment are unusual, I plan to follow-up this study by replicating these findings with a different spatial task. Perhaps following this study up with a spatial task that does not rely on motor performance may give insight into how social distractors are processed.

5.4 Experiment 3: social distractor on a Greyscales task

5.4.1 Introduction

In Experiment 2 there was an effect of social distractors on pseudoneglect, where attention withdrew away from the social distractor. The primary aim of the current experiment is to replicate these effects using another spatial task that is also sensitive in measuring pseudoneglect and relies less on motoric performance. Studies in the attention literature have reported that the line bisection task has a known motor component that increases pseudoneglect (Milner et al., 1992; Jewell & McCourt, 2000). If the current study employs another spatial task that does not rely on motor performance, such as the Greyscales task, then attentional effects that are unique to social distractibility may be discernible.

The Greyscales task is a well-used task that reliably measures pseudoneglect. Furthermore, this task has also been used to measure cueing effects on pseudoneglect. Similar to Landmark and line bisection tasks, cueing effects on Greyscale stimuli also produce attentional attraction towards the distractor (Nicholls & Roberts, 2002). Importantly, the Greyscales task requires participant's to choose of two options that are orthogonal to the attentional bias and do not require a left or right response. Rather the Greyscales require participant's to choose a proximal or distal stimulus from a stimulus pair.

Learmonth et al. (2015) argue that pseudoneglect is multi-faceted and that the Greyscales task induces different task demands to the perceptual Landmark task. Despite both the Landmark and Greyscales tasks using a forced two-choice response paradigm that limits motor involvement, the different task demands in the Greyscales task may be sensitive enough to capture perceptual effects that the Landmark task could not. Moreover, a replication of the effect observed in Experiment 2 (line bisection task) may give insight into the mechanisms behind social attentional withdrawal.

5.4.2 METHOD

SUBJECTS

Twenty-two ($m = 8; f = 14$) university students participated in the experiment in exchange for $10. Ages ranged between 18–45 years of age ($M = 23.62$, $SD = 6.98$) and every participants was right-handed (Oldfield, 1971). All participants had normal or normal-to-corrected vision acuity, which is necessary for this study. Participants gave informed consent prior to the start of the experiment, and were unaware of the exact purpose of the study.

STIMULI

Stimuli were based on those used by Nicholls et al. (1999) which consist of 40 unique horizontal pairs, where the horizontal and radial midlines of the stimulus pairs are aligned with the centre of the page. Within stimulus pair, the centre of the distal stimulus was placed 25 mm above the middle of the page, and the centre of the proximal stimulus was placed 25 mm below the middle of the page. The stimuli consist of two different lengths: 115 mm (long) and 95 mm (short), and two different orientations: distal stimulus dark on the right and proximal stimulus dark on the left, and distal stimulus dark on the left and proximal stimulus dark on the right. Distal and proximal stimuli within a pair were arranged to be left-right reversals and equiluminant to one another (refer to Figure 3.4).

PROCEDURE

The experiment consisted of 120 trials, 40 trials in each block, where half of the trials were completed with the left and the other half with the right hand. Trials were presented to each participant in a randomised order.

The procedure for this experiment was kept identical to Experiment 2. The only difference were the task instructions, which required participants to select the darkest bar in each stimulus pair. Participants responded by drawing a circle around the stimulus bar they perceived as darker.

5.4.3 RESULTS

Participants' responses of luminance judgements were recorded according to which direction (left or right) the darkest region was facing. These data were transformed into a response bias for each participant by subtracting leftward responses from total trials and dividing by total trials then multiplying by

100 to get scores between -100 to +100. Negative scores reflect a leftward bias whereas positive scores reflect a rightward bias.

To determine whether the seating position of the experimenter influenced participant's performance, response bias scores were submitted to a 3x2 ANOVA with seating position (left, alone & right), and response hand (left & right) as within-subjects factors. There was no main effect for seating position $F(2, 42) = 1.321$, $p = .278$, *partial* $\eta^2 = .059$, but there was a significant shift towards the response hand $F(1, 21) = 6.700$, $p = .017$, *partial* $\eta^2 = .242$, and no significant interaction between seating position and response hand $F(2, 42) = .231$, $p = .795$, *partial* $\eta^2 = .011$ (see Figure 5.6).

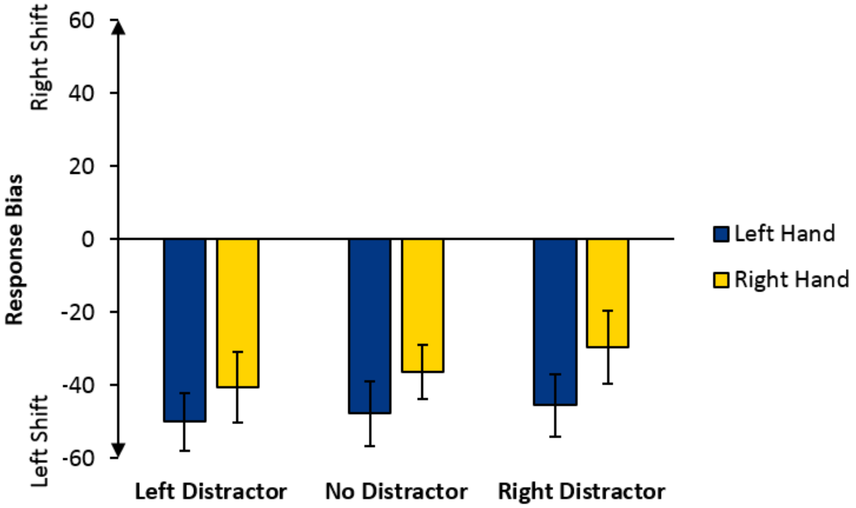


Figure 5.6: Bar graph showing no effect of social distractors in the Greyscales task. The x-axis displays the three social conditions: left-distractor, no distractor and right-distractor. The y-axis displays the response bias where negative values represent as leftward shift and positive values represent a rightward shift. The coloured bars show the left (blue) and right (yellow) response hands. Standard error bars are included.

There was also no effect for the 2×2 ANOVA using difference scores for the side of social distractor $[F(1, 21) = .027, p = .871$, *partial* $\eta^2 = .001]$, response hand $[F(1, 21) = .397, p = .535$, *partial* $\eta^2 = .012]$ and no interaction $[F(1, 21) = .030, p = .865$, *partial* $\eta^2 = .001]$.

5.4.4 Discussion

The aim of this experiment was to replicate the attentional withdrawal observed in Experiment 2. The Greyscales task was chosen for this experiment because it uses a two-choice forced response paradigm to measure pseudoneglect. Perhaps most importantly, responses are orthogonal to the distractor side which was necessary for this study as the line bisection task has a known motor component (McCourt & Olafson, 1997; Milner et al., 1992). It was predicted that attention could either be drawn towards the social distractor, similar to cueing paradigms or away from the social distractor similar to the results found in Experiment 2. Neither of these predictions were observed, as the data favoured the null hypothesis.

Experiments 1, 2 and 3 have tried to replicate the effects found by (Garza et al., 2008), but with a social distractor placed next to the participant. Experiments 1 and 3 did not yield significant data. Experiment 2 showed a different pattern of results where attention was shifted in the opposite direction of the social distractor. It was hypothesised that the social distractor, in close proximity to the participant, may have induced social discomfort that lead to attention being shifted in the opposite direction. Support for this hypothesis comes from a methodological note, where the experimenter gave participants an array and asked them to choose which figure first attracted their attention. Participants consistently reported figures distal to the experimenter. It is therefore possible that both Experiment 2 and Terry and Lower's (1979) experiment found an attentional withdrawal because participants wanted to increase the perceived distances between themselves and the experimenter.

All of these experiments have tried to measure the influence of social distractors on spatial attention by using the experimenter as a social distractor. It is possible that the role of the experimenter as a 'passive-observer' may have led to a series of inconsistent findings. Recent studies that have investigated the effects of other people on spatial attention in stimulus-response paradigms, have included participant pairs or a confederate (Atmaca, Sebanz, Prinz, & Knoblich, 2008; Hommel, Colzato, &

van den Wildenberg, 2009; Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011; Sebanz et al., 2003; Tsai, Kuo, Hung, & Tzeng, 2008). In these studies the social-distractor was also engaged in the task. It is plausible that a social-distractor that engages in the task is more salient compared to an experimenter that acts in a passive role. Experiment 4 explored this possibility further by recruiting a confederate that engaged in the task alongside the participant.

5.5 Experiment 4: social distractor on a visual search task

5.5.1 Introduction

The theme of this chapter is to investigate the effects of social distractors on pseudoneglect. In preceding experiments, I employed three of the most commonly used spatial tasks in the pseudoneglect literature and only found a significant effect using the line bisection task. Although data from these experiments suggests that social distractors may be processed differently to typical spatial distractors, these data have been seemingly inconsistent across three experiments.

A more consistent finding in the social psychology literature is that social presence can facilitate/impair performance tasks that measure cognitive load and response conflict (Baron, 1978; Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011; Huguet, Galvaing, Monteil, & Dumas, 1999; Klauer, Herfordt, & Voss, 2008). These studies argue for the distraction-conflict hypothesis that suggests another person can attract important attentional resources away from the task so that the participant is unable to focus their full attention on task-relevant information. Baron (1986) proposed that simple and complex tasks may lead to facilitated or impaired performance depending on cognitive load. Simple tasks allow participants to direct their attention to task relevant information and filter out task-irrelevant information. In contrast, complex tasks results in decreased performance because participants neglect task-relevant information.

Perhaps a better understanding of how other people can influence spatial attention can be developed if both cognitive load and shifts in attention are taken into consideration. A visual search task is capable of measuring both facilitation/interference effects and hemispheric asymmetries. Array-like tasks, such as the Bells task, are frequently used to measure visual asymmetries in neglect patients (see Chapter Two for details). Furthermore, simple feature search tasks are executed more efficiently by the right hemisphere in healthy participants (Poynter & Roberts, 2012). Employing an array task would also be more similar to Terry and Lower's (1979) experiment in which they found a distal bias from the social distractor.

For Experiment 4, a visual search task was employed with a confederate on the left or right sides of the participant or with the confederate absent. A confederate was used in this task because preceding experiments in this chapter used the experimenter as a social distractor and found inconsistent results. It was hypothesised that inconsistent results across experiments were due to the experimenter not engaging in the task and participants perceiving the experimenter as an observer. If the experimenter is perceived as a 'passive-observer' rather than an 'active-participant', then according to the cognitive load theory participants may have viewed the experimenter as task-irrelevant. If the experimenter is perceived as task-irrelevant, than participants may have filtered out this information and inherently reduced the impact of the social distractor on their task performance. It was hypothesised that if the confederate engaged in the task with the participant then the confederate would be perceived as an 'active-participant' and also task-relevant. Furthermore, if the confederate was perceived as more task-relevant than the experimenter in the previous experiments, then it was predicted that the confederate will elicit a social attention effect.

The search task used in this experiment consisted of a rectangle array where participants searched for a target (inverted triangle) amongst distractors (upright triangles). Participants completed three blocks: with the confederate on the left, on the right or was absent. It was hypothesised that if the confederate produces a cueing effect then facilitation would occur and targets that are on the same side as the confederate would yield faster responses. But, if the confederate produced attentional withdrawal like in Terry and Lower's (1979) experiment, then it was hypothesised that impaired performance would be reflected by slower responses to targets on the same side as the confederate. Both facilitation and impairment have been observed in the social psychology literature with spatial-compatibility paradigms (Atmaca et al., 2008; Baron, 1986; Hommel et al., 2009; Klauer et al., 2008; Knoblich et al., 2011).

5.5.2 METHOD

PARTICIPANTS

Twenty-two ($m = 5$; $f = 17$) university students participated in the experiment in exchange for \$15. Ages ranged between 18–29 years of age ($M = 22.73$; $SD = 3.55$). All participants were right-handed (Oldfield, 1971) and had normal or normal-to-corrected visual acuity. Participants gave informed consent prior to the start of the experiment, and were unaware of the exact purpose of the study.

APPARATUS

The apparatus was identical to Experiment 1.

STIMULI

The visual search stimuli consisted of 60 equilateral triangles randomly placed in a 250 × 65 mm array. Triangles were 8mm on each side and spaced 5mm apart. There were two variations of the array: target-present and target-absent. In target-present trials, one of the triangles along the array was randomly selected and inverted (see Figure 5.7). Of all the target-present trials, the inverted triangle appeared once along each location in the array. In target-absent trials, the inverted triangle did not appear.

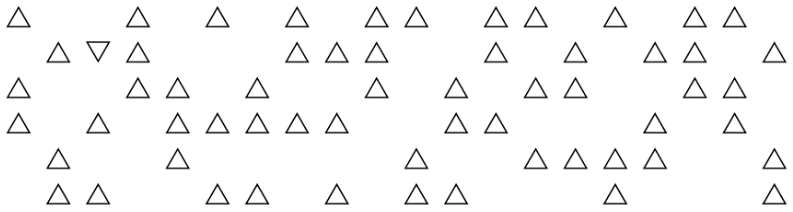


Figure 5.7: An example of the visual search task array. The target (i.e. upside-down triangle) is in the third column on the left side of the array.

Procedure

A confederate was recruited to fulfil the role of a second participant. While the participant was located centrally to the screen, the confederate sat either to the left or right sides of the participant. Each participant completed three blocks of trials. Seating position was manipulated between blocks so that the participants responded to the array while sitting directly in front of the display either: (1) with the confederate sitting to their left, (2) alone (baseline) or (3) with the confederate sitting to their right (see Figure 5.7). Chin-rests were provided in each of the three seating positions to maintain the exact distance between participants and confederate, and to control for distance to the screen. Participants were seated 600 mm directly in front of the screen with a visual angle of 2.8°degrees. The centre of the confederate's chinrest was positioned 450 mm to the left and right of the centre of the participant's chinrest, and viewed the centre of the screen at an angle of 37°degrees. The order in which the blocks were administered was balanced between participants.

Each block consisted of 144 trials in total, where 120 trials were target-present and 24 trials were target-absent. Trials were presented in a randomised order for each participant. Every trial began with a blank white screen for 500 ms, followed by the stimulus presentation for 4000 ms or until both participant and confederate responded. For each trial, the participants and confederate indicated whether the target was present or absent in the array. Two response boxes were placed horizontally—one in front of the participant and another in front of the confederate, and were positioned parallel to their midsagittal planes. Participants responded by pressing keys marked yes or no to indicate whether they saw a target (inverted triangle) or did not see a target (no inverted triangle). If a participant failed to respond within a 4000 ms time period, the trial was rejected and repeated at a later stage in the block. In addition, an error message was displayed prompting the participants to respond more quickly. The lateral position of the response buttons was counterbalanced between participants, as half of the participants had the yes button on the left and the no button on the right, and the other remaining participants had the yes button on the right and the no button on the left. To prevent participants from copying or being distracted from the hand movements of the confederate, the hands of both the participant and confederate were covered using black cloth. Prior to commencing the experimental trials, participants completed six practice trials.

The experimenter started the stimuli presentation software for each block and left the testing room for the duration of that condition. A small camera positioned in the room was used to ensure that participants focused on the task and did not talk. Participants were instructed to signal to the camera when they completed all trials within a condition. During the baseline condition, the confederate left the room. Between the first and second blocks the participant and confederate filled out the Edinburgh Handedness questionnaire (Oldfield, 1971), and between the second and third blocks they both completed a filler task with incomplete sentences.

5.5.3 Results

ERRORS. Three participants had errors that were two standard deviations below the mean for one of the three conditions and were excluded from further analysis leaving $n = 19$. Errors for the left ($M = 7.588$, $SD = 17.170$), right ($M = 5.351$, $SD = 15.169$) and alone ($M = 6.667$, $SD = 16.599$) conditions were submitted to a repeated measures 3 (left, right and no confederate condition) × 2 (left

& right target) ANOVA. Main effects for social condition [$F(2, 36) = 1.043$, $p = .363$, *partial* $\eta^2 = .055$], target [$F(1, 18) = .526$, $p = .478$, *partial* $\eta^2 = .028$], and interaction [$F(2, 36) = 1.470$, $p = .243$, *partial* $\eta^2 = .075$] were not significant.

REACTION TIMES. All trials* were submitted to a 3 × 2 ANOVA with social condition (left, right and no confederate condition) and target side (left & right) as within-subjects factors. There was no main effects of social condition [$F(2, 36) = .115$, $p = .892$, *partial* $\eta^2 = .006$], nor target side [$F(1, 18) = 2.781$, $p = .113$, *partial* $\eta^2 = .134$], but there was a significant interaction [$F(2, 36) = 4.951$, $p = .013$, *partial* $\eta^2 = .266$]. When this same factorial analysis was run for correct responses only the main effect for social condition [$F(2, 36) = .201$, $p = .819$, *partial* $\eta^2 = .011$] was not significant, target side [$F(1, 18) = 4.924$, $p = .040$, *partial* $\eta^2 = .215$] was weakly significant, and the interaction [$F(2, 36) = 2.113$, $p = .136$, *partial* $\eta^2 = .105$] was no longer significant. None of the Bonferroni adjusted post-hoc comparisons were significant [$t(18) < .495$, $p > .05$].

INVERSE EFFICIENCY. As a result of the data significance changing depending on whether the reaction times for all trials or correct trials were used, an inverse efficiency score was calculated that incorporated both accuracy and reaction time data. Inverse efficiency is calculated by dividing mean reaction times by the percentage of accuracy. Inverse efficiency has been used successfully by many researchers (Nicholls, Loveless, Thomas, Loetscher, & Churches, 2015; Rach, Diederich, & Colonius, 2011; Shore, Barnes, & Spence, 2006). I reran the 3 × 2 ANOVA with inverse efficiency scores and found a significant interaction with social condition and target side [$F(2, 36) = 3.549$, $p = .039$, *partial* $\eta^2 = .165$]. There were no main effects for social condition [$F(2, 36) = .034$, $p = .996$, *partial* $\eta^2 = .002$] and target side [$F(1, 18) = 2.901$, $p = .106$, *partial* $\eta^2 = .139$].

---

[*] This included reaction times for both correct and incorrect trials.

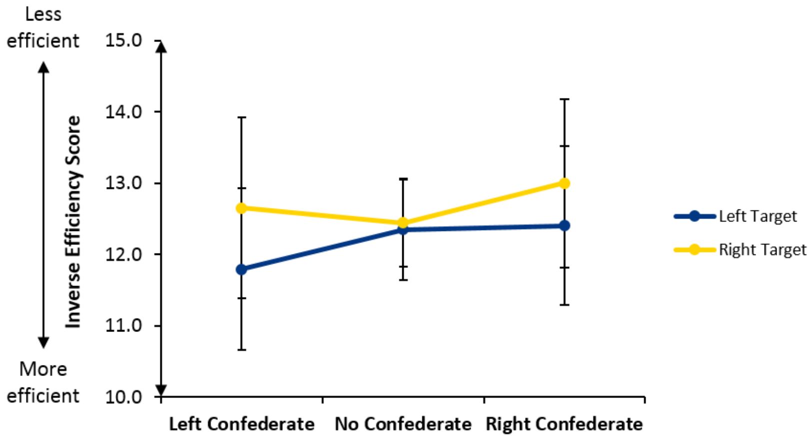


Figure 5.8: Graph demonstrating an interaction between social condition (left, right and no confederate) and target side (left & right) for mean inverse efficiency scores. Lower values suggest greater efficiency and higher values suggest lesser efficiency. Standard error bars are shown.

5.5.4 Discussion

The aim of this social visual search task was to investigate whether a confederate is perceived as a distractor. I hypothesised that the presence of a confederate would facilitate/impair performance so that participants would respond faster/slower to targets that are congruent with the side of the confederate. Results showed that there was an interaction between the social condition and target side, but I did not observe a consistent pattern showing that the targets congruent with the position of the confederate were faster/slower. Instead the data showed variable patterns and a weak interaction between social condition and target side. Because the interaction is weak and different to the predicted direction, it is difficult to determine the meaning behind this interaction. Moreover, these data provided little clarity on the underlying mechanisms of processing social distractors.

This study sought to replicate a similar effect to Experiment 2 where the side of the social distractor impacted on pseudoneglect. A visual search task was chosen to measure this effect for two main reasons: search tasks have been previously used to measure visual asymmetries (Poynter & Roberts, 2012) and a search task is similar to Terry and Lower (1979) study where they found attentional withdrawal on an array task. Examining the data showed a mixed pattern of results where an interaction between social condition and target was significant, but only when both correct and incorrect responses were included. When only correct trials were examined this interaction disappeared. As a result of this outcome, inverse efficiency scores were calculated that included both accuracy and reaction times as a measure of performance. With inverse efficiency scores the interaction between social condition and side of the target was significant. But, this interaction did not reflect the predicted hypotheses. Inverse efficiency scores showed that in the social conditions efficiency for the left targets increased and right targets decreased, whereas in the no confederate block efficiency was the same for both targets. Based on this data it is unclear why this pattern of results would occur. It is possible that the task sharing between participants was too weak to influence the outcome of the experiment. Although both the participants and the confederate were instructed to respond within 2 seconds for each trial, coordinating one's responses in this manner may not have allowed for a high level of task sharing. A turn-based paradigm might have increased the level of interdependency between participants and yielded stronger effects.

5.6 General discussion

A series of four experiments were conducted to determine if a social distractor affects task performance in a similar or different way to a typical distractor. Two out the four experiments showed atypical effects that are not supported by well-established findings on cues and distractors. These atypical effects may suggest that social distractors are processed differently, however, the data to support this hypothesis is underwhelming.

The basis for the research in this chapter comes from a plethora of studies that show social distractors can affect attention (Sebanz et al., 2003; Atmaca, Sebanz, & Knoblich, 2011; Atmaca et al., 2008; Huguet et al., 1999; Klauer et al., 2008; Heed et al., 2010). These studies primarily focused on spatial compatibility effects and load processing, however, two studies by Barrett et al. (2000) and Garza et al. (2008) showed that social distractors can also affect orienting of attention. Barrett et al. (2000) and Garza et al. (2008) showed that in a clinical and non-clinical sample attention was drawn towards the social distractor. Moreover, Garza showed that with a left social distractor pseudoneglect increased and with a right social distractor pseudoneglect decreased. This finding is consistent with attentional cueing studies that demonstrate a similar pattern of results (Bultitude & Aimola-Davies, 2006; Milner et al., 1992). Garza and colleagues suggested that this effect was perceptual in nature, as this distractor effect was dependent on visual feedback. This hypothesis was tested with a perceptual Landmark task in Experiment 1. This study was unsuccessful as the data was in favour of the null hypothesis.

Similar to the original methodology used by Garza et al. (2008), Experiment 2 employed a line bisection task to determine if positioning the social distractor next to the participant in Experiment 1 led to the non-significant results. Experiment 2 showed an attentional withdrawal away from the social distractor, which suggests that the social distractor does not have to be in front of the participant for an effect to be observed. Although the effect of attentional withdrawal is intriguing, it is opposite to the effect observed in both Barrett and Garza's studies. A study that is consistent with Experiment 2 is a methodological study by Terry and Lower (1979). In Terry and Lower's study, the experimenter sat laterally to participants and handed participant's an array of figures. Participants were asked to point out the figure that first attracted their attention. The authors found that participants consistently pointed to figures distal to the experimenter. Importantly, this distal bias strengthened as the distance between the participant and the experimenter decreased. Terry and Lower (1979) hypothesised that participants withdrew their attention away from the experimenter to reduce the uneasiness of a personal space invasion. This hypothesis is interesting because it implies that participant's may have tried to decrease their social discomfort by increasing the perceived distance between themselves and the experimenter. It may have been informative to include a non-social distractor condition in the experiment to serve as a comparison with the social distractor condition. If a non-social distractor such as a mannequin was included, then it would have been possible to determine if the attentional withdrawal effect is unique to social distractors. Time constraints precluded the incorporation of additional conditions into the methodology of Experiment 2. Adding non-social distractor conditions may be useful for future experiments that aim to differentiate between social distractors and non-social distractors.

Experiment 3 sought to replicate this attentional withdrawal effect using a Greyscales task. It was argued that because Experiment 2 found an interaction between social condition and response hand, that attentional withdrawal could be a result of a motor bias. For example, participants may be less inclined to deviate their arm movements towards the experimenter side to ensure they would not bump into the experimenter. Although Nicholls et al. (2014) did not find an effect of a close barrier on line bisection performance, I decided to be conservative and selected the Greyscales task for Experiment 3. The Greyscales is a perceptual task that requires forced-choice discrimination between two alternatives and does not rely on motor accuracy to carry out the task. In addition, the Greyscales task was also orthogonal to the left-right social distractor and did not require gross arm movements towards the side of the experimenter. Experiment 3 did not replicate the attentional withdrawal effect in Experiment 2 and did not show any cueing effects similar to Garza et al. (2008). It was hypothesised that perhaps Experiments 1 to 3 displayed inconsistent results because the experimenter was a 'passive-observer' and was not a part of the task. This hypothesis stemmed from an observation of social spatial-compatibility studies where a confederate or another participant usually engaged in the task with the participant.

Experiment 4 attempted to find an effect of social distractor on pseudoneglect by including a confederate who actively engaged in the task with the participant. I hypothesised that if the experimenter was perceived as a 'passive-observer' then participants may have regarded the experimenter as task-irrelevant. In order to make the social distractor more relevant to the search task, Experiment 4 included a confederate that responded to the stimuli alongside the participant. Results from Experiment 4 showed an interaction between the social condition and target side, but did not conform to the predicted hypothesis. The predicted hypothesis for Experiment 4 is that participants would response faster to targets that correspond with the position of the confederate. That is, participants would respond faster to left targets when the confederate is sitting on their left, conversely when the confederate is sitting on their right side participants would respond faster to right targets. The results for this experiment were difficult to interpret for numerous reasons. Firstly, reaction time data produced different effects depending on whether correct trials or all trials (both correct and incorrect) were analysed. Due to this peculiar characteristic in the data I decided to analyse both reaction times and accuracy simultaneously through an inverse efficiency measure. Secondly, the inverse efficiency interaction showed that in the confederate absent condition there was no effect of target side, however, when the confederate was present participants were generally faster to respond to left targets and slower to respond to right ones. This interaction was not predicted and it is unclear why this pattern of results would occur. Despite the participants and confederate being instructed to coordinated their responses within a 2 second time period for each trial, it is possible that the level of task sharing in this experiment was not strong enough to influence the outcome of the results. Alternative social paradigms that increase the salience of the relationship between co-actors may yield stronger effects. For example, turn-based or collaborative experimental paradigms that increase the interdependency between co-actors could produce clearer results.

5.7 Concluding remarks

Four experiments were conducted to determine how a social distractor influences pseudoneglect. Based on the combined research from four experiments there is some evidence to suggest that social distractors behave differently from typical distractors. Furthermore, there is also weak evidence to suggest that social distractors can influence pseudoneglect. Although these data are far from conclusive, it would be interesting to see how manipulating different task demands between two acting participants would impact on attention. For example, joint spatial-compatibility paradigms frequently include turn-based responding to increase the salience of the co-actor (Atmaca et al., 2008; Böckler, Knoblich, & Sebanz, 2012; Knoblich et al., 2011; Sebanz et al., 2006, 2003). Incorporating a similar response paradigm in a Landmark task could demonstrate whether increasing co-actor saliency can influence pseudoneglect.

No man is an island,
Entire of itself,
Every man is a piece of the continent,
A part of the main...

John Donne, 1624

6

No man is an island: task interdependency in a joint Landmark study

Preceding experiments in Chapter Five provided weak evidence for social influences on pseudoneglect. Chapter Six seeks to investigate task interdependency in a joint Landmark task. The first two experiments in this chapter were collected at Honours level in 2011, however, these data have been re-analysed, extended and published in *Cognitive Neuroscience*, as part of my PhD in 2015 (Szpak, Nicholls, et al., 2016). Chapter Six is very different from my Honours thesis and has only developed into its current form as a result of subsequent experiments which are presented in this thesis, an appraisal of new literature and two years of careful deliberation during the course of my PhD.

6.1 Publication Abstract

While it is generally acknowledged that another person's presence can influence how we behave within our environment, our understanding of the mechanisms underlying this influence is limited. Three experiments investigated the effect of social presence on the lateral distribution of spatial attention. Shifts in spatial attention were measured using line bisection, while participants sat in each other's personal space. An attentional withdrawal was observed, whereby attention moved away from the other person when the same task was using turn-taking (Experiment 5) and independent responding (Experiment 6) paradigms. When participant pairs engaged in different tasks (Experiment 7), attentional withdrawal was no longer observed. Our results strongly suggest that the influence of interpersonal proximity on attention merits greater consideration than it has received from researchers investigating social effects on cognition.

6.2 Introduction

Humans do not exist in isolation. We are constantly connecting, coordinating, and reciprocating with others in our environment. Recent technological advancements, such as mobile phones, personal computers and iPads, make it possible to draw others into our personal space regardless of physical distance (Wellman, 2001). Yet, within experimental psychology research, social influences are intentionally kept to a minimum. Although this approach has been the benchmark for studying how the mind works, it has important limitations. In particular, experimental psychology has largely ignored the influence that the presence of another person has on how we perceive and behave (Frith, 2012; Knoblich et al., 2011).

The relative proximity of other people has an important impact on our body. When using public transport, commuters show elevated stress levels when positioned near other passengers (Evans &

Wener, 2007), as manifested by increased physiological arousal and galvanic skin responses (Aiello et al., 1977; McBride et al., 1965). These physiological changes are accompanied by varying levels of discomfort (Aiello et al., 1977; Hayduk, 1981, 1983), ranging from mild to extreme, depending on proximity to others and the size of one's personal space (Hayduk, 1981). In addition, interpersonal proximity affects cognition. Using a classroom setting, Paulus, Annis, and Seta (1976) found that performance on a maze task was reduced when in close proximity to students. Similar results were reported by Nagar and Pandey (1987), who found that interpersonal proximity led to deteriorated performance on complex tasks—but not simple tasks.

When confronted with the uneasiness of personal space invasion on public transport, commuters typically distract themselves by reading, playing with smartphones, or listening to headphones. These behaviours likely reflect strategies that let commuters retreat into privatised personal space, allowing them to feel more psychologically comfortable in situations where personal invasion might occur (Hall, 1966; Hirsch & Thompson, 2011). For example, listening to music reduces the size of personal space, thereby allowing social intrusions at close distances to be better tolerated (Tajadura-Jiménez et al., 2011). Therefore, the social influence of another person could be reduced if participants use a strategy that lets them to focus on a unique aspect of a task, allowing them to retreat into personal space.

We aimed to identify how the presence of another person influences spatial attention and whether this effect can be modulated by interdependency. To address these aims, line bisection was employed to measure the influence of social information on the lateral distribution of spatial attention.

Line bisection tasks are sensitive to lateral cues (Bultitude & Aimola-Davies, 2006; Sosa et al., 2011), and have been used extensively within clinical (Bonato et al., 2008; Loetscher et al., 2012) and non-clinical (Jewell & McCourt, 2000) settings. When judging the relative length of two line segments, individuals tested in isolation typically perceive the left segment to be longer than it actually is (Benwell, Harvey, & Thut, 2014). There are many variants of the line bisection task (see Jewell & Mc-

Court, 2000, for a review), but they all show a tendency to overestimate the left side of the line (Fink et al., 2002; Varnava & Halligan, 2009). This has been referred to as pseudoneglect (Bowers & Heilman, 1980), and is thought to reflect dominant right hemisphere activation for spatial attention (Foxe et al., 2003). Using this basic experimental paradigm, participants judged line length on pre-bisected lines alone, or while someone was sitting to their left or right.

The effect of interpersonal proximity on attentional orienting can result in two opposing effects: attentional attraction or attentional withdrawal. There is tangible evidence to support either hypothesis. Evidence from single participant line bisection studies suggests that lateral cues usually attract and bias attention towards their location (Bultitude & Aimola-Davies, 2006; Milner et al., 1992; Nicholls & Roberts, 2002; Sosa et al., 2011). If a similar cueing effect is observed in the current experiment then line segments ipsilateral to the location of the other person will be perceived as being longer.

Alternatively, interpersonal proximity research suggests that attention may withdraw from the other person. Terry and Lower (1979) sat laterally, in close proximity to participants and showed them an array of horizontally arranged figures. When asked to indicate the figure that first attracted their attention, participants consistently chose figures distal to the experimenter. Intriguingly, this distal bias increased as the distance between the participant and the experimenter decreased. Terry and Lower (1979) suggest that participants withdrew their attention from the experimenter to reduce the uneasiness of the personal space invasion. Further support of this finding comes from Szpak, Loetscher, Churches, et al. (2015), who found that social discomfort that lead to increased physiological anxiety also increased attentional withdrawal. If the attentional withdrawal hypothesis is correct, line segments contralateral to the other person will be perceived as longer.

6.3 EXPERIMENT 5: TURN-BASED LANDMARK TASK

This experiment investigated whether spatial attention is affected when two participants share a task when sitting beside one another. Lateral shifts in spatial attention were measured using line bisection (McCourt, 2001). A high level of interdependency between participants was induced by forcing participants to respond using a turn-taking paradigm. After viewing the pre-bisected line, one participant indicated their response, while the other participant withheld their response. The second participant responded after the first had lodged their response. This joint turn-taking design ensured that responses had to be coordinated between the two participants.

6.3.1 Method

Participants

Twelve pairs ($N = 24$) of unacquainted first-year psychology students (15 females) participated in exchange for course credit. Within the pairs, participant sex was not controlled (i.e. pairs could be same or mixed sex). Ages ranged between 18–50 years ($M = 22.58$, $SD = 6.95$) and all participants were right-handed (Oldfield, 1971). One participant was omitted from analyses, because she did not have corrected-to-normal vision. The Flinders University Social and Behavioural Research Ethics Committee granted ethical approval.

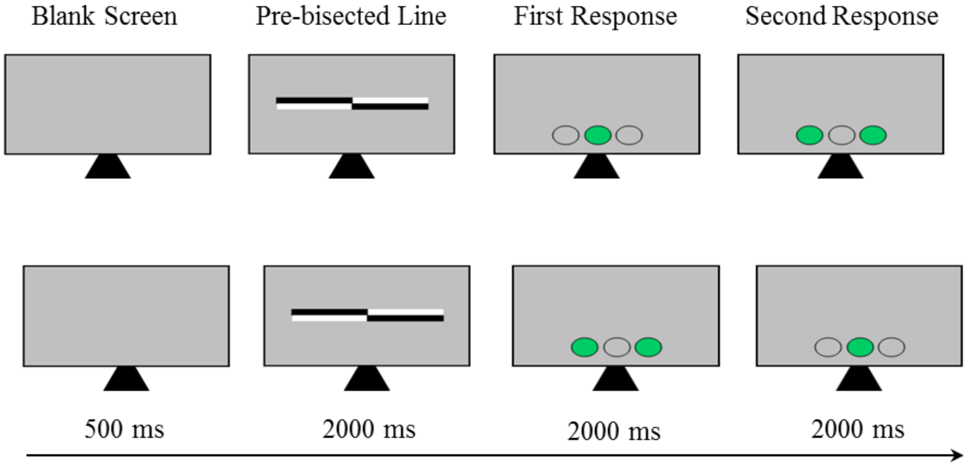
Apparatus

Stimulus presentations were displayed on a LCD screen (550mm diagonally). E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) presented stimuli and ran the experiment. A model 200A PST Serial Response Box recorded responses. A chin rest maintained participant head position and closed-circuit audio-visual surveillance was used to monitor participants.

Stimuli

Stimuli consisted of horizontal lines with a length of 180mm and height of 5mm that subtended a visual angle of 16.7° in length and 0.48° in height (McCourt, 2001; McCourt & Jewell, 1999). Each line was composed of two black and two white bars, arranged in diagonally opposite pairs on a grey

(a) Central-participant responds first.

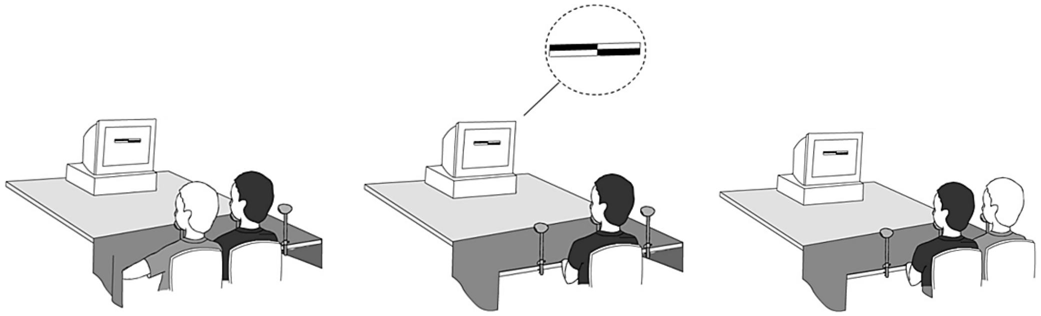


(b) Lateral-participant responds first.

Figure 6.1: Sequence of a line bisection trial: blank screen 500ms, a pre-bisected line trial of 2000ms, and two response screens each presented for 2000ms.

background. Lines were bisected to the left or the right of true centre by 1, 2, or 3mm. Although vertical line location was kept constant in the centre of the screen, horizontal position was jittered 9mm to either the left or right to prevent the use of extrinsic markers (McCourt & Jewell, 1999). The factorial combination of bisection shift (-3, -2, -1, $+1$, $+2$, $+3$), jitter (left, centre, right) and polarity (upper left part black, upper left part white) resulted in 36 unique stimuli. Each stimulus was presented twice times, for a total of 72 trials.

Response screens contained non-directional cues to indicate turn-taking between participants (see Figure 6.1). These cues consisted of three horizontally arranged circles (diameter=18mm which subtended 1.7° in visual angle), presented in the lower portion of the screen, 10mm apart from one another. When the outer two circles were green, the lateral-participant responded first and when the central circle was green, the central-participant responded first.



(a) Lateral-participant on the left of the central-participant. **(b)** Central-participant alone for the baseline condition. **(c)** Lateral-participant on the right of the central-participant.

Figure 6.2: An illustration of the experimental setup. The central-participant is illustrated with dark hair

Procedure

Within each pair, one participant was randomly designated the central-participant, while the other was the lateral-participant. Halfway through the experiment, these roles were swapped. Seating position was manipulated across three blocks of trials so that the central-participant completed line bisection while sitting directly in front of the display: (1) with the lateral-participant sitting to their left, (2) alone with the lateral-participant outside of the room (baseline), and (3) with the lateral-participant sitting to their right (see Figure 6.2). The central-participant was seated 600mm directly in front the screen. The lateral-participant was positioned 450mm to the left or right of centre and viewed the screen at an angle of 37°. The order in which the blocks were administered was counterbalanced amongst participants. Each participant completed five blocks of trials: three as the central-participant and two as the lateral-participant.

Each trial began with a blank grey screen for 500ms, followed by presentation of the pre-bisected line for 2000ms. Two consecutive response screens (i.e. one for each participant) then appeared, for 2000ms each. On each trial, participants indicated whether the left or the right side of the line appeared to be longer. Participants used the leftmost response key to indicate the left side was longer and the rightmost response key to choose the right side. Response keys were placed horizontally in front of participants and parallel with the midsagittal plane. If either participant failed to respond within the 2000ms time window, the trial was rejected and repeated at a later stage. In addition, an error message was displayed prompting participants to respond more quickly. To prevent participants from copying or being distracted by the hand movements of one another, the hands of both participants were covered using black cloth. Participants completed four practice trials prior to commencing the experiment.

The experimenter started the stimuli presentation software for each block and left the testing room for the duration of the condition. A camera was used to ensure that participants remained focused on the task and did not speak to one another. During the baseline condition, the lateral-participant left the room and completed the Edinburgh Handedness Inventory (Oldfield, 1971).

6.3.2 RESULTS AND DISCUSSION

Only data from the central-participant conditions were analysed, as the lateral conditions produced visual eccentricities known to cause asymmetrical effects (Chokron & Imbert, 1993; McCourt, Garlinghouse, & Slater, 2000). The point of subjective equality (PSE) was calculated for each of the seating conditions (left, baseline, right) by fitting a cumulative Gaussian distribution to the proportion of left-side-longer responses for all bisections ranging from -3 to $+3$. When the proportion of left-side-longer responses reached 0.5 (50%), corresponding with a negative bisection (left segment shorter/right segment longer) on the cumulative distribution, it was considered a leftward bias because the left side was reported to be longer, when, in fact, the right side was objectively longer. The PSE indicates the subjective centre (in mm) where an individual perceives the left and right sides of the line to be of equal length. Using a 2SD cut off, 3 participants with wide psychometric functions were considered outliers on the basis of the median absolute deviation rule for outlier detection (Benwell et al., 2014; Leys, Ley, Klein, Bernard, & Licata, 2013), leaving 20 participants.

One-sample t-tests indicated that the PSE for the left ($M = -.57$, $SD = 1.05$; .05° or .32% of the line) [$t(19) = 2.45$, $p = .02$, $Cohen's\ d = 1.123$], baseline ($M = -.62$, $SD = .903$; .06° or .34% of the line) [$t(19) = 3.06$, $p < .01$, $Cohen's\ d = 1.41$] and right ($M = -1.01$, $SD = .82$; .10° or .56% of the line) [$t(19) = 5.47$, $p < .01$, $Cohen's\ d = 2.51$] seating conditions was significantly biased towards the left. Leftward biases (i.e. pseudoneglect) are a signature finding on line bisection tasks and indicate a small imbalance in attentional orienting favouring the left side (Jewell & McCourt, 2000). The replication of this bias was important in validating the use of line bisection in the current paradigm.

The PSE data contains two key pieces of information: the direction of attentional bias (left or right) and the direction in which attention moves in relation to the other person. For the left, baseline, and right seating conditions, a negative PSE is a leftward bias and a positive PSE is a rightward bias. Importantly, the significance of these negative and positive PSEs differs for the left and right seating conditions. In the left seating condition, a PSE greater than the baseline PSE represents a withdrawal of attention and a PSE smaller than the baseline represents an attentional attraction. The converse is true for the right seating condition, where a smaller PSE reflects a withdrawal of attention, and a greater PSE reflects an attraction. To allow for directional consistency, PSE scores were transformed to create social influence scores, which were defined as follows:

$$social\ influence_{left} = \begin{cases} -|PSE_{baseline} - PSE_{left}|, & \text{if } PSE_{baseline} < PSE_{left} \\ |PSE_{baseline} - PSE_{left}|, & \text{otherwise,} \end{cases}$$

and

$$social\ influence_{right} = \begin{cases} -|PSE_{baseline} - PSE_{right}|, & \text{if } PSE_{baseline} > PSE_{right} \\ |PSE_{baseline} - PSE_{right}|, & \text{otherwise,} \end{cases}$$

This ensured that attentional withdrawal was always represented as a negative score and attentional attraction was represented as a positive score (see Figure 6.3). A paired-samples t-test compared social influence$_{\text{left}}$ and social influence$_{\text{right}}$ scores to establish whether attentional biases differed between the left and right seating conditions [$t(19) = 1.86, p = .08$, $Cohen's\ d = .88$]. As there were no reliable differences between the left and right conditions, an overall social influence score was computed as follows:

$$overall\ social\ influence = \frac{social\ influence_{left} + social\ influence_{right}}{2}.$$

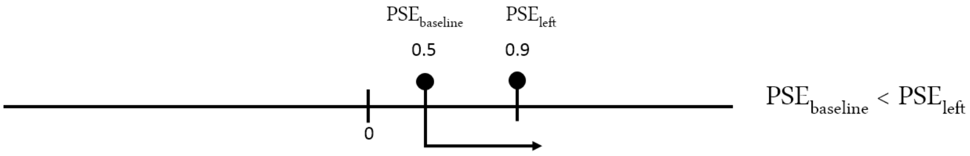
Social influence scores were submitted to a one-sample t-test, allowing for social attraction or withdrawal to be tested directly. The social influence score ($M = -.22$, $SD = .43$) was significantly different from zero [$t(19) = 2.26, p = .036$, $Cohen's\ d = 1.04$] indicating a significant withdrawal of attention from the other person (see Figure 6.4).

The data demonstrate that a person sitting next to you does not attract attention in the same way as common attentional cues (Bultitude & Aimola-Davies, 2006; Milner et al., 1992). Instead, the results show a much more interesting cueing effect, where attention is moved away from the lateral-participant. Attentional withdrawal may relate to social research showing that sitting close to a stranger induces discomfort (see Aiello, 1987, for review) and that people try to increase the distance between themselves and others to reduce this discomfort (Evans & Wener, 2007; Patterson et al., 1971). In the current experiment, participants were not able to physically move away from the 'stranger'. A compensatory reaction could be to shift attention away in order to increase their perceived distance from the other person.

6.4 Experiment 6: independent responding in a joint Landmark task

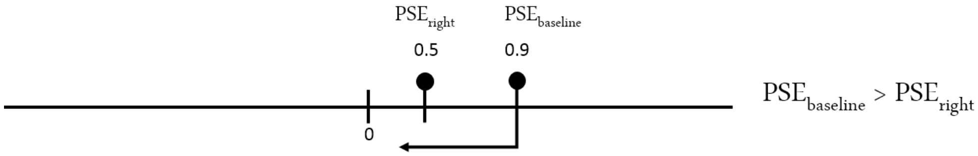
The interdependency brought about by the turn-taking paradigm used in Experiment 5 required a high level of attention towards the actions and intentions of others (Ruys & Aarts, 2010; Sebanz et al., 2006; Tomasello & Carpenter, 2007). This high level of interdependency was possibly a key factor in

(a) Attention has moved rightward (away from the person sitting on the left, i.e., withdrawal) PSE$_{\text{baseline}}$ subtract PSE$_{\text{left}}$ will lead to a negative value



(b) Attention has moved rightward (away from the person sitting on the left, i.e., withdrawal) PSE$_{\text{baseline}}$ subtract PSE$_{\text{left}}$ will lead to a negative value

(c) Attention has moved leftward (away from the person sitting to the right, i.e., withdrawal) and PSE$_{\text{baseline}}$ subtract PSE$_{\text{right}}$ will lead to a positive value.



(d) Attention has moved leftward (away from the person sitting to the right, i.e., withdrawal) and PSE$_{\text{baseline}}$ subtract PSE$_{\text{right}}$ will lead to a positive value.

Figure 6.3: An illustration showing all scenarios of attentional withdrawal for both the left and right seating conditions (relative to the baseline). Negative PSEs reflect a leftward bias, whereas positive PSEs show a rightward bias. Importantly, the significance of these PSE values in relation to the baseline is different for the left and right seating conditions. To reduce the possibility of statistical errors it is necessary to derive a social influence score that takes into account both the direction of the attentional bias and the direction in which attention moves in relation to the other person.

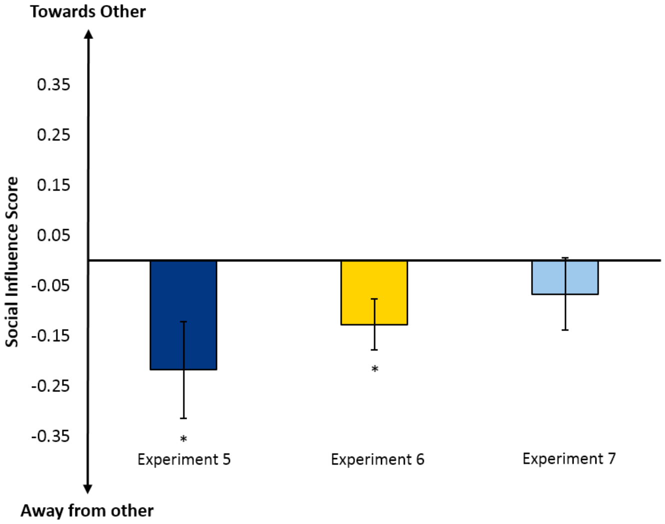


Figure 6.4: Social influence scores for Experiments 5, 6 and 7 with standard error bars. Negative values on the y-axis indicate attention *moving away* and positive values on the y-axis indicate attention *moving towards*.

the emergence of attentional withdrawal. This possibility was investigated here by reducing the dependency between participants. Participants in Experiment 6 responded independently and therefore did not need to coordinate their actions. If interdependency between participants was the central factor in the emergence of attentional withdrawal, this effect should not be observed when turn-taking is eliminated. If an attentional withdrawal effect is observed, then interdependency can be excluded as a driving factor.

6.4.1 Method

Participants

Twelve pairs ($N = 24$) of unacquainted first-year psychology students (17 females) participated in exchange for course credit. Ages ranged between 17–34 years ($M = 21.83$, $SD = 5.74$) and all participants were right-handed (Oldfield, 1971). One participant was omitted from analyses, as he did not have corrected-to-normal vision. The Flinders University Social and Behavioural Research Ethics

Committee granted ethical approval.

APPARATUS, STIMULI AND PROCEDURE

The apparatus and stimuli were identical to Experiment 5. The procedure was similar to Experiment 5; however the turn-taking response paradigm was removed. Each trial began with a blank screen for 500ms, followed by the pre-bisected line for 2000ms. A blank screen then appeared and both participants had 2000ms to indicate their response.

6.4.2 RESULTS AND DISCUSSION

Three participants with wide psychometric functions were considered outliers and from omitted from further analyses. One-sample t-tests indicated that PSE values for the left ($M = -.60, SD = .69$; .06° or .33% of the line) [$t(19) = 3.89, p < .01$, *Cohen's d* $= 1.79$], baseline ($M = -.66, SD = 1.01$; .06° or .37% of the line) [$t(19) = 2.90, p < .01$, *Cohen's d* $= 1.41$], and right ($M = -.84, SD = .79$; .08° or .47% of the line) [$t(19) = 4.73, p < .01$, *Cohen's d* $= 2.17$] seating conditions were significantly biased to the left.

Social influence scores were calculated for PSE data. A one-sample t-test was used to identify whether an attentional attraction or withdrawal effect occurred. Social influence scores ($M = -.12$, $SD = .22$) demonstrated attentional withdrawal [$t(19) = 2.41, p = .026$, *Cohen's d* $= 1.11$]. A paired-samples t-test was also conducted using the social influence$_{\text{left}}$ and social influence$_{\text{right}}$ scores to establish whether attentional biases differed between the left and right seating conditions [$t(19) = .48$, $p = .64$, *Cohen's d* $= .22$].

Experiment 6 replicated the attentional withdrawal effect found in Experiment 5. Reducing the level of dependency between participants did not make attentional withdrawal disappear. That is, when the turn-taking paradigm was eliminated, the allocation of attention continued to move away from the other person. This suggests that task interdependency is not driving the attentional withdrawal effect.

6.5 Experiment 7: joint Landmark with different tasks

Attentional withdrawal was shown in Experiments 5 and 6, which is consistent with previous research showing that during personal space invasion an attempt to increase the distance between oneself and others occurs (Evans & Wener, 2007; Felipe & Sommer, 1966; Patterson et al., 1971). Compensatory strategies are developed, which allow people to retreat into privatised space and feel more comfortable, when physical distance cannot be increased (Hall, 1966; Hirsch & Thompson, 2011). Based on this idea, Experiment 7 investigated whether the social influence of another person could be reduced if participants were given a strategy that allowed them to focus on one aspect of the task that was unique to them. Researchers have shown that when people are able to focus on distinct aspects of a task, they start to feel more independent and in control of the situation because their perceived discomfort is also reduced (Duke & Mullens, 1973; Heckel & Hiers, 1977).

The effect of task was investigated by giving each participant within the dyad a different task. If attentional withdrawal emerges when participants are performing different tasks, it suggests task sharing does not underlie the spatial attention shifts associated social unease. If the social effect is weakened or disappears, it implies that conceptually distancing oneself from another person (i.e. by performing a different task) could help to reduce the social discomfort elicited by the presence of others, thereby making situations more tolerable.

6.5.1 Method

Participants

Eleven pairs ($N = 22$) of unacquainted students (17 females) participated in exchange for $30 (AUD). Ages ranged between 18–34 ($M = 21.59$, $SD = 3.75$) and all participants were right-handed (Oldfield,

1971) and had normal or corrected-to-normal vision. The Flinders University Social and Behavioural Research Ethics Committee granted ethical approval.

Apparatus, stimuli and procedure

The apparatus and stimuli were identical to Experiment 5. A slight procedural change was made as the central- and lateral-participants completed different tasks. The turn-taking paradigm from Experiment 5 was reintroduced, with the central-participant again performing the standard line bisection task. Crucially, the task and instructions for the central-participant remained unchanged from Experiment 5. The lateral-participant completed a memory task where they remembered the relative position of the black and white bars (i.e. the polarity) within the line stimulus. Participants pressed a 'yes' button if the polarity of the previous line was the same as the current line, and a 'no' button if the polarity was different.

Instructions were given in the presence of both individuals—thus, both were aware of the task being carried out by the other person and also knew they would complete the other task halfway through the experiment. After both tasks were explained, instructions on how to respond using the turn-taking paradigm were given.

6.5.2 Results and discussion

Two participants with wide psychometric functions were considered outliers and omitted from further analyses. One-sample t-tests indicated that the PSE for the left ($M = -.52$, $SD = .91$; .05° or .29% of the line) [$t(19) = 2.57, p = .02$, $Cohen's\ d = 1.18$], baseline ($M = -.65$, $SD = .89$; .06° or .36% of the line) [$t(19) = 3.27, p < .01$, $Cohen's\ = 1.50$], and right ($M = -.66$, $SD = .81$; .06° or .37%) [$t(19) = 3.64, p < .01$, $Cohen's\ d = 1.67$] seating conditions were significantly biased to the left.

Social influence scores were calculated for PSE data and subjected to a one-sample t-test to identify whether an attentional attraction or withdrawal effect occurred. Social influence scores ($M = -.07$, $SD = .32$) did not differ from zero [$t(19) = .93$, $p = .36$, *Cohen's d* $= .43$]. A paired-samples t-test was also conducted using the social influenceleft and social influenceright scores to establish whether attentional biases differed between the left and right seating conditions [$t(19) = .54, p = .59$, *Cohen's d* $= .26$]. As a final comparison, overall social influence scores for Experiments 5, 6, and 7 were submitted to an ANOVA [$F(2, 57) = 1.04$, $p = .36$, *partial* $\eta^2 = .04$], which illustrated that they were not significantly different from each other.

In contrast to Experiments 5 and 6, attentional withdrawal was not observed. Performing different tasks might have allowed participants to develop coping strategies, wherein they could conceptually distance themselves from the other person. Similar coping strategies have been observed on public transport. Commuters typically lose themselves in reading, playing with smartphones, or listening to music. Such situational withdrawal can be viewed, at least to some extent, as a coping mechanism to reduce the discomfort induced by over-crowded trains and buses (Hall, 1966). This is supported by research showing that listening to music over headphones shrinks the distance at which people start to feel uncomfortable by approaching strangers (Tajadura-Jiménez et al., 2011).

6.6 GENERAL DISCUSSION

Our experiments investigated the influence of social presence on the lateral distribution of spatial attention. Shifts in spatial attention were measured using a standard line bisection task. All three experiments were fundamentally similar, with only subtle changes to task instructions and response dynamics. This manipulation allowed us to determine how the interdependency between two people is related to the distribution of spatial attention in a shared space.

An interesting pattern of results emerged as social presence influenced spatial attention only when both participants were performing the exact same task. In this instance, an attentional withdrawal effect was observed, with attention moving away from the lateral-participant. When interdependency was high, but separate tasks were carried out, the social effect was reduced/disappeared. Importantly, the replication of the results in Experiments 5 and 6 demonstrates that the observed withdrawal effect is reliable.

Manipulating interdependency in this manner shares some similarities to social stimulus-response (S-R) compatibility paradigms (see Social Flanker and Social Simon task Atmaca et al., 2011; Sebanz et al., 2003). In these social S-R studies impaired task performance reflects a conflict between the simultaneous representation of self and other. But, the 'social' nature of these paradigms has been questioned. For example, Dolk, Hommel, Prinz, and Liepelt (2013, 2014) demonstrated that it is possible to mimic a social S-R effect in a go/no-go paradigm without another person. Although the current tasks did not involve S-R mapping, effects of attentional withdrawal when participant pairs perform the same task were still observed. Our data show that social cues behave differently to common attentional cues; however, further research that directly assesses S-R mapping is needed to determine the relationship between social withdrawal and social S-R effects.

The pattern of results is not consistent with common visual cueing paradigms. When presented in conjunction with line bisection, visual cues usually direct attention toward the cued location (see Jewell & McCourt, 2000; Sosa et al., 2011, for a review). The current findings demonstrate that social cues function differently, leading attention to be directed away from 'strangers'. Interestingly, this is consistent with the social discomfort hypothesis (Aiello et al., 1977; McBride et al., 1965; Patterson et al., 1971).

The social discomfort hypothesis posits that stress-related responses are experienced when others invade our personal space. A common reaction to this discomfort is to physically move away. We required two strangers to sit in close proximity (450mm) and prevented the use of coping strategies, such as physically moving away, blocking, or creating barriers. The ability to create a privatised personal space was therefore inhibited. We suggest central-participants shifted their attention away from lateral-participants to increase the perceived distance between them, making the experimental situation more tolerable. This is consistent with Terry and Lower (1979), who proposed that perceptual withdrawal (e.g., moving attention away), provides an alternative compensatory reaction to having one's personal space invaded.

Importantly, the lack of attentional withdrawal in Experiment 7 can be explained by the *social discomfort hypothesis*. When participants were able to conceptually differentiate themselves from one another, no attentional withdrawal emerged. Feelings of independence and control lead individuals to be more comfortable sitting close to strangers, than when they feel dependent on others (Duke & Nowicki, 1972; Heckel & Hiers, 1977). Consequently, a decrease/elimination of attentional withdrawal would be expected in such situations.

The joint line bisection task we developed could be applied to a number of interesting research questions. In particular, this task might be beneficial in re-examining what Aiello (1987) refers to as the 'dead-ends' in a review of the interpersonal proximity literature. For example, researchers disagree on how males and females make use of space in social situations. There is also evidence of a link between interpersonal proximity and personality (Colzato, de Bruijn, & Hommel, 2012; Duke & Nowicki, 1972). Joint line bisection could be used to measure spatial attention, whilst taking sex and personality traits into account, to clarify existing ambiguous findings in this literature, and also to further our understanding of how individual differences influence interpersonal proximity and spatial attention.

6.7 Concluding remarks

Three experiments were carried out in Chapter Six to identify whether social proximity can influence lateral shifts in spatial attention. Participant pairs were positioned next to each other in close proximity whilst they completed a Landmark task. Interdependency between pairs was manipulated to ascertain whether participant's relationship within the Landmark task influenced spatial attention. Attentional withdrawal was observed when pairs completed the same task in a turn-taking (Experiment 5) and independent responding (Experiment 6) paradigms. But, when participant pairs were given different tasks (Experiment 7) attentional withdrawal was reduced/disappeared. Importantly, Experiments 5 and 6 replicated the attentional withdrawal effect observed in the previous chapter suggesting that attentional withdrawal is a reliable effect that exists under certain social conditions. It was hypothesised that participants shifted their attention away to increase the perceived distance between themselves and the other person in order to compensate for feelings of social discomfort. Chapter Seven will examine the influence of cooperation and competition on attentional withdrawal.

When we survey our lives and endeavors we soon observe that almost the whole of our actions and desires are bound up with the existence of other human beings.

Albert Einstein, 1949

7

Competition and Cooperation

The previous chapter examined the effects of close interpersonal proximity on spatial attention. Attentional withdrawal emerged showing that attention moved away from the other person, but only when participant pairs were engaged in the same task. When participants were given a different task from their experimental partner, attentional withdrawal was no longer observable. Results from the previous chapter suggest that the level of attentional withdrawal may depend on the relationship between participants. Hence, it is plausible that manipulating the relationship between participants, so that participant pairs are either cooperating or competing with one another, may give insight into the social processes involved in attention withdrawal.

7.1 INTRODUCTION

Personal space is an important region of space surrounding the body, where one can choose to allow or disallow others access (Evans & Howard, 1973; Felipe & Sommer, 1966; Hall, 1966; Hayduk, 1981). Personal space plays an important role in both positive (Knoblich et al., 2011; Manera, Becchio, Cavallo, Sartori, & Castiello, 2011) and negative (Aiello et al., 1977; McBride et al., 1965; Tirachini et al., 2013) social interactions. Crowding is often described as a negative social interaction that most people try to avoid (Evans & Wener, 2007; Hayduk, 1981; Hirsch & Thompson, 2011), whereas cooperation between people is a positive social interaction that is essential for the survival of both the individual and species (Adolphs, 2003a). Both these examples of positive and negative social interactions demonstrate remarkably different effects on personal space when they occur in close interpersonal proximity.

Peripersonal space has been shown to contract or expand under different social situations (Heed et al., 2010; Maister et al., 2015; Teneggi et al., 2013). Negative personal encounters have been shown to contract peripersonal space (Maister et al., 2015; Szpak, Loetscher, Churches, et al., 2015; Szpak, Nicholls, et al., 2016), whereas positive social experiences expand peripersonal space (Heed et al., 2010; Teneggi et al., 2013). A study by Teneggi et al. (2013) measured the size of participant's peripersonal space before and after an economic game. The authors recruited two groups of participants, one group played a competitive economic game and the other group played a cooperative economic game. They found that peripersonal spaces of both participants were distinguishable during the competitive game, but merged when participants played the cooperative game. Merging peripersonal space boundaries during a cooperative task may provide the common perceptual space necessary to coordinate actions when working together to achieve a mutual goal (Knoblich et al., 2011; Sartori et al., 2013; Sebanz et al., 2006).

Given that the competitive/cooperative relationship between participants could play an important role in the attentional withdrawal effect observed in the previous chapter, the present experiment explicitly manipulated levels of cooperation. The present experiment was similar to Experiment 1 in the previous chapter, except that pairs were randomly assigned to two different relationship groups. Half of the participant dyads were required to cooperate in order to achieve a common goal, whereas the other dyads competed against each other. A social withdrawal effect was predicted for the pairs in the competitive group, but a reduced/no effect for the pairs in the cooperative group. This prediction is in line with previous research showing that participants prefer to distance themselves from another person in situations in which they feel stressed, tense and in competition—compared to situations that are friendly and cooperative in nature (Aiello, 1987; Tedesco & Fromme, 1974). Moreover, this prediction also fits with the findings of Teneggi et al.'s (2013) study that showed participant's peripersonal space merge during a cooperative task. If participant's peripersonal spaces merge in this study, I predict that attentional withdrawal would disappear during a cooperative relationship.

7.2 Experiment 8: competitive and cooperative Landmark task

7.2.1 Method

Participants

Twenty-four pairs ($m = 11; f = 13$) of unacquainted first-year psychology students participated in Experiment 4, in exchange for course credit. Ages ranged between 18–50 years of age ($M = 22.62$) with forty-seven right-handed participants, and one (f) left-handed participant (Oldfield, 1971) whose data were not used. Another participant's data were omitted because he did not follow instructions. All remaining participants had normal-to-corrected vision.

Apparatus

Stimulus presentations were displayed on an LCD screen (550 diagonally). E-prime 2.0 software was used to present stimuli to run the experiment. A model 200A PST Serial Response Box recorded participant's responses. A chin rest was used to ensure that participants maintained the same head position throughout the experiment. Closed-circuit audio-visual surveillance was used to monitor participants when the experimenter was outside the testing room.

Stimuli

Stimuli were based on the Landmark lines used by McCourt and Olafson (1997). Lines were 180 mm ($VA = 16.7°$) and 5 mm thick ($VA = 0.48°$), which comprised of two black and white bars arranged as diagonally opposite pairs presented on a grey background. Lines were pre-transected to the left and right of the true centre by 1, 2, and 3 mms. The lines were jittered horizontally 9 mm ($VA = 0.86°$) to the left and right of the screen centre to prevent participants from using external markers as a part of their bisection strategy. 36 unique stimuli resulted from a combination of bisection shift ($-3, -2, -1, +1, +2, +3$ mm), jitter (left, centre and right), and polarity (upper left portion black, upper left portion white). Each unique stimulus was presented twice leading to a total of 72 trials.

Turn-taking response cues contained three-horizontally arranged circles ($diameter = 18$ mm or $VA = 1.72°$) presented in the lower portion of the screen and were separated by 10 mm ($VA = 0.95°$). When it was the central-participant's turn to respond first the centre circle was coloured green, and when it was the lateral-participant's turn the two outer circles were coloured green.

Questionnaire

A questionnaire was used to measure participants' feelings of competition or cooperation. The first half of the questionnaire was a word-completion task consisting of twenty-four word fragments embedded with nine word fragments, which can be used to measure implicit feelings of competition (Kay, Wheeler, Bargh, & Ross, 2004). The nine word fragments gave participants an opportunity to fill the blank spaces with competition-relevant words. For example, _ower (power) or co_pe__tive (competitive). The amount of competition-relevant words indicated by participants, showed how competitive they felt. The second half of the questionnaire was used to measure feelings of competition and cooperation more explicitly using four Likert scales. These Likert scales were based on Iani et al. (2011) where participants rated the experimental situation on a scale of 1 to 7, and were given four dichotomous scales: easy-difficult (1 = *easy*, 7 = *difficult*), pleasant-unpleasant (1 = *pleasant*, 7 = *unpleasant*), positive-negative (1 = *positive*, 7 = *negative*) and cooperative-competitive (1 = *cooperative*, 7 = *competitive*).

Procedure

The procedure was the same as Experiment 1 in the previous chapter except that the pairs were randomly assigned to either a 'competitive' or a 'cooperative' condition.

In the competitive condition, twelve pairs of participants were informed that they would be competing with the other member within the pair. They were informed that, if they achieved a better score than the other participant, they would receive a food reward. To make the reward all the more salient, participants selected the reward (chocolates/biscuits/chips etc.) that they would like prior to starting the experimental trials. Between each seating position, the experimenter told the participants that one of them was doing really well and both participants were encouraged to continue so that one of them could win their reward.

In the cooperative condition, twelve pairs of participants were informed that they would be cooperating with the other member within the pair. They were told that, if their combined accuracy reached a threshold of 80%, they would both receive a reward. Like the competitive condition, participants chose their rewards at the beginning of the experiment. Between each seating position, the experimenter told the participants that they were both doing really well and if they kept on doing well they would both receive their prizes.

7.2.2 Results and discussion

Conforming to the experiments in the previous chapter, only data from the central-participant were analysed. PSEs were calculated for the seating conditions (left, central and right) by fitting a cumulative Gaussian distribution to each individual's data. The PSE indicates a point (in mm) on the Landmark line where the participant perceives the left and right sides to be equally long (subjective centre). Using a ±2SD cut off, three participant's data had wide psychometric curves that were considered outliers. Outliers were identified in accordance with the median absolute deviation rule for outlier detection (Benwell et al., 2014; Leys et al., 2013), leaving 43 participants ($m = 16; f = 27$).

One-sample t-tests indicated that the PSE for the left ($M = -.573$, $SD = .688$; $VA = .055°$) [$t(42) = 5.459, p < .001$, $Cohen's\ d = 1.685$], baseline ($M = -.759$, $SD = .821$; $VA = .078°$) [$t(42) = 6.059, p < .001$, $Cohen's\ d = 1.870$], and right ($M = -.795$, $SD = .704$; $VA = .067°$) [$t(42) = 7.400, p < .001$, $Cohen's\ d = 2.284$] conditions were significantly biased to the left side—pseudoneglect.

In line with the experiments in the previous chapter, a social influence score was also calculated by subtracting the baseline (see previous chapter for further details on the social influence score). Negative social influence scores represent attention moving away from the other person and positive values represent attention moving towards the other. Social influence scores were submitted to a one-sample t-test to directly test for attentional attraction or withdrawal. The overall social influence score was ($M = -.111$, $SD = .285$; $VA = .011°$) and was significantly different from zero [$t(42) = 2.560$, $p = .014$, $Cohen's\ d = .790$]. Attentional withdrawal observed in this experiment was similar to the social effects observed in the previous chapter.

An independent sample t-test was also conducted using group relationship (cooperative, competitive) to determine if there was a difference of social influence between the two groups in this experiment. The mean difference between the competitive ($M = -.108$, $SD = .279$; $VA = .010°$) and cooperative ($M = -.114$, $SD = .295$; $VA = .011°$) groups was not significantly different [$t(41) = .059$, $p = .953$, $Cohen's\ d = .019$] (see Figure 7.1).

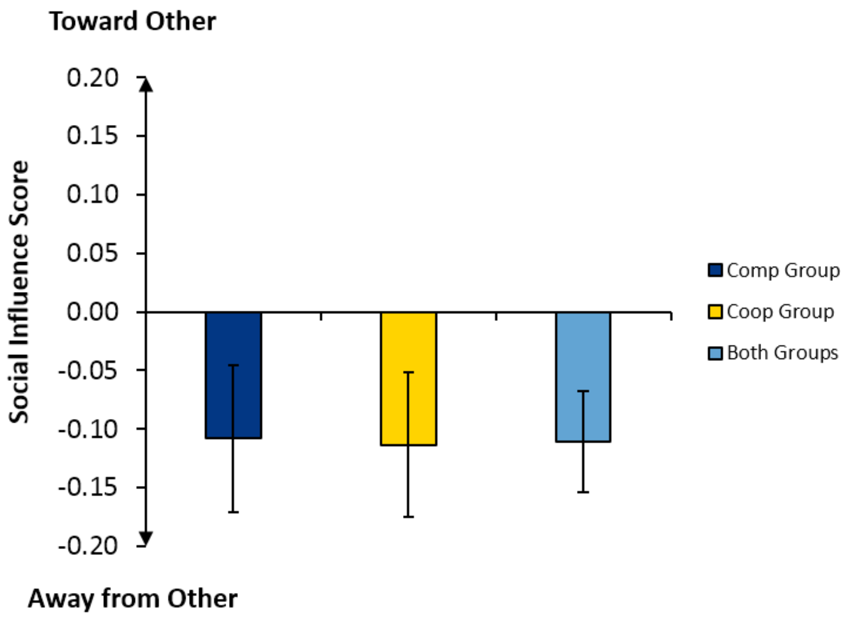


Figure 7.1: Mean social influence score calculated as difference score from the alone condition. Negative values on the y-axis display a withdrawal of attention and positive values on the y-axis display an attentional attraction towards the other.

Thus, contrary to expectation, attentional withdrawal was not moderated by cooperation and competition. This lack of effect may be related to an unsuccessful manipulation of cooperation and competition. To test the efficacy of our manipulation, implicit measures of competitiveness were compared between the cooperative and competitive groups. Although the mean competitiveness score for the cooperative group ($mean = 1.61$) was slightly lower than for the competitive group ($mean = 2.3$), this difference failed to reach statistical significance ($t(41) = 1.69$, $p = .099$). It therefore appears that our attempt at encouraging different cooperative and competitive behaviours was unsuccessful in affecting implicit measures of competitiveness.

It is possible that explicit measures of competitiveness provide a more robust measure of between-group differences than the implicit measure. Differences in explicit responses were submitted to a mixed model ANOVA with group dynamic (competitive, co-operative) as a between-subjects factor and perceived situation (competitive, pleasant, easy and positive) as within-subjects factor. There was neither a main effect of group ($F(1, 41) = 0.18, p = .89, partial\ \eta^2 < .01$) nor a significant interaction between group dynamic and perceived situation ($F(3, 123) = 2.500, p = .078, partial\ \eta^2 = .057$) [Greenhouse-Geisser correction]. Because it could be argued that the interaction showed a trend towards significance, independent t-tests, adjusted for multiple comparisons, were carried out. There was no difference in how the competitive and cooperative groups perceived the task situation for any of the 4 assessed factors ($t(41) < 1.91, p > .25$).

Based on the convincing results by Teneggi et al. (2013), it was expected that the competitive group would show stronger attentional withdrawal than the cooperative group. Teneggi et al. (2013) used an economic game in their study and showed that participant's peripersonal space boundaries merged in a cooperative context. I predicted that if peripersonal space merges to achieve a common goal during a cooperative task, then attentional withdrawal would be reduced. Attentional withdrawal was observed in the present experiment, but there was no difference between the cooperative or competitive groups. It is possible that participants in Teneggi et al.'s (2013) study felt more motivated because they were given continuous feedback about how well they were doing throughout the experiment, and therefore were constantly reminded of their goal and were more driven to do well. The current study did not give participants constant feedback about their progress which could have diminished their drive to do well. Perhaps this oversight might explain why participants did not feel more competitive and why there was no difference in performance between the group dynamics.

The social subscales demonstrated that the between group manipulation of cooperation/competition was not successful. The procedure used to manipulate group dynamics was very similar to a procedure successfully used by Iani et al. (2011). Explicit and implicit measures to determine participant's level of cooperativeness or competitiveness did not yield convincing effects. The main difference between the procedures was the amount and type of reward. In the current experiment, participants were rewarded with food (chocolates, biscuits, chips), worth $3.50 less than the monetary reward used in the Iani et al. study. It is therefore possible that monetary reward played a role in motivating participants to do well. Alternatively, the turn-taking response paradigm and the lack of emphasis on speeded responses might have induced a level of cooperation between participants that could not be overcome by manipulations of reward.

7.3 Concluding remarks

This chapter investigated whether the relationship between participants may affect spatial attention. It was predicted that a competitive participant relationship would elicit an attentional withdrawal, whereas cooperation would induce a weak or no attentional withdrawal effect. The primary aim was to clarify the mechanisms driving the attentional withdrawal effect observed in previous experiments. Importantly, the present study was able to replicate the attentional withdrawal observed in the previous chapter, which further validates this methodology in measuring social effects. But, the between-group manipulation was unsuccessful and there was no difference between competitive and cooperative participant relationships. Taking a physiological measure of social discomfort and correlating physiological discomfort with attentional withdrawal would provide further support for the attentional withdrawal hypothesis. The next chapters will explore social effects on attention further by developing a new spatial attention methodology that will shed light on the underlying factors driving attentional withdrawal. Chapter Nine develops a new methodology that may increase social discomfort and can measure attentional withdrawal. Research showing that front space is more sensitive to personal space invasions inspired the design of this new methodology (Hayduk, 1983). This new methodology sought to increase social discomfort by asking participants to stand across from one another in close personal space. A radial Landmark task was used to capture shifts in attention moving towards or away from the other participant. Because this new methodology had not been tested before in a single participant paradigm, it was unclear how this new setup would affect shifts in attention. I address this knowledge gap in Chapter Eight. Chapter Eight seeks to measure attentional shifts in a single-participant radial Landmark task to test hemispheric asymmetries in the perception of space close to the body.

When we focus consciously on an object—and create a mental image for example—it's not because the brain pattern is a copy or neural representation of the perceived object, but because the brain experiences a special kind of interaction with that object, preparing the brain to deal with it.

Roger Wolcott Sperry, 1987

8

Visual asymmetries in perceived depth

This chapter discusses the hemispheric asymmetries in perceived depth in single-participant paradigms. Topics addressed in this chapter may seem somewhat divergent from material on social attention previously covered. Nevertheless, the main purpose of the experiments in this chapter was to develop a new methodology for testing participant pairs. Experiment 9 was published in *Experimental Brain Research* and Experiment 10 was published in *Brain and Cognition* (Szpak, Thomas, & Nicholls, 2016; Szpak, Loetscher, Bastian, et al., 2015).

In previous chapters, it was hypothesised that participants shift their spatial attention away from another person in order to increase their perceived distance between themselves and the other person. I wanted to build upon this hypothesis by developing a spatial task where participant pairs could complete whilst standing opposite each other. The reasoning behind this new methodology was based on several studies which suggest that frontal space is more sensitive to personal space invasions (Hayduk, 1981). Furthermore, frontal space is socially relevant because this is the area in which most conversations occur (Sommer, 1962). My idea was to give participant pairs a radial Landmark task that they could complete whilst standing across from one another. Radial line bisection tasks have been studied before, but the literature detailing how this type of task affects hemispheric asymmetries in perceived depth is limited. Because of this limitation I thought it would be sensible to test my new proposed methodology on single-participants first. In addition to piloting a new methodology, I thought it would be beneficial to the attention community to expand my proposed study to specifically test for asymmetries in perceived depth.

A second experiment was developed from the findings of Experiment 9 where asymmetries in perceived depth were directly tested using three-dimensional stimuli. The goal of Experiment 10 was primarily to augment the research of Experiment 9 by empirically expanding on the theory behind perceived asymmetries in depth.

8.1 Experiment 9: radial Landmark task

8.1.1 Publication abstract

Research suggests that the left cerebral hemisphere is predisposed for processing stimuli in ‘near’ space whereas the right hemisphere is specialised for processing stimuli in ‘far’ space. This hypothesis was tested directly by asking 25 undergraduates to carry out a landmark radial line bisection task. To test the effect of hemispheric differences in processing, the lines were placed to the left, right or centre within the transverse plane. Consistent with predictions, lines in all three conditions were bisected distal to the true centre. More importantly, there was an asymmetry whereby the distal bias was stronger for lines presented in the left hemispace compared to the right hemispace. The results demonstrate

that the perception of depth is affected by left/right placement along the lateral axis and highlight the cognitive/neural interplay between the radial and lateral axes.

8.1.2 INTRODUCTION

Because we are immersed in a rich three-dimensional environment, our neurophysiology has adapted to process visual information along a three-dimensional space: horizontal, vertical and radial. While there are links between the dimensions, it also appears that the brain has developed separate neural maps for processing information along the three axes (Halligan et al., 2003; Nicholls et al., 2004; Szpak, Loetscher, Bastian, et al., 2015; N. A. Thomas & Elias, 2012).

In relation to radial space, the brain has been shown to activate distinct neural pathways for spatiotopic (near-far) dimensions (Committeri et al., 2007; Heber et al., 2010; Shelton et al., 1990; Weiss et al., 2000). Drawing from near-far dissociations in neglect studies, lesion location is known to influence the direction of neglect on radial line bisection tasks. Parietal injuries can cause neglect of proximal space (Butter, Evans, Kirsch, & Kewman, 1989; Gold, Shuren, & Heilman, 1994; Mennemeier et al., 1992; Rapcsak et al., 1988), whereas temporal-occipital injuries have resulted in neglect of distal space (Adair et al., 1995; Shelton et al., 1990). Shelton et al. (1990) argue for modality-specific attentional biases where attention is preferentially biased away from the body for visual exploration, but distributed near the body for tactile exploration. If this is the case, then distal biases on a radial line bisection task are most likely related to a spatiotopic processing scheme (Chieffi, Iavarone, & Carlomagno, 2008).

The neural processing of radial (near/far) space may be lateralised within the brain. Research conducted by Weiss et al. (2000) recorded brain activity using Position Emission Tomography while participants bisected horizontal lines and pointed to dots in near and far spaces. Stimuli in near space elicited preferential neural activation of areas in the left hemisphere such as the dorsal occipital cortex, intraparietal cortex, ventral premotor cortex and the thalamus. Stimuli in far space bilaterally activated the ventral occipital cortex and the right medial temporal cortex. Neurophysiological support for the cerebral asymmetry model in the healthy population is also consistent with the findings of near-far dissociations in patients with clinical neglect (Adair et al., 1995; Shelton et al., 1990; Vuilleumier, Valenza, Mayer, Reverdin, & Landis, 1998).

There is also tangential behavioural evidence for a cerebral asymmetry in processing near and far space. Heilman et al. (1995) asked participants to judge which line is longer for radially presented lines in the left and right hemispaces. Surprisingly, participants perceived the line in the left hemispace to be shorter than the lines on the right. Heilman et al. (1995) explained these results in terms of a model of functional cerebral asymmetry which argued that the left hemisphere is specialised for local attention near the body whereas the right hemisphere is specialised for global attention away from the body. Heilman et al. (1995) suggested that the ends of the line contracted towards the centre when presented in the left hemispace (right hemisphere), but when lines were presented in the right hemispace (left hemisphere), the ends of the line expanded away from the centre. Accordingly, lines on the left appeared shorter than lines in the right hemispace.

Additional behavioural evidence has been collected by Roth et al. (2002). They asked participants to bisect radial lines whilst occluding one eye. Lines were viewed monocularly by using an eye patch, which activated attentional areas in the contralateral hemisphere. Hence, viewing lines with the left eye activated the far attentional pathways in the right hemisphere leading to misbisections distal to the true midpoint. In contrast, viewing lines with the right eye lead to misbisections closer to the body, presumably because of activating the near attentional areas. These findings are also consistent with the cerebral asymmetries model for near-far processing (Heilman et al., 1995; Shelton et al., 1990). Viewing eye has also been shown to effect the magnitude of perceptual biases in a line bisection task (McCourt & Garlinghouse, 2000). These perceptual biases towards one side of space during a spatial task occur because of functional imbalances between the hemispheres (Benwell et al., 2014; Foxe et al., 2003; McCourt, 2001). A study by McCourt, Freeman, and Tahmahkera-Stevens (2001) found that the strongest attentional biases occurred for lines viewed by the left eye, followed by binocular and then the right eye. This pattern is consistent with the opponent-process hypothesis, where the extent of hemispheric activation determines the strength of attention allocated to the contralateral hemispace (Kinsbourne, 1970). In a subsequent study, Kinsbourne (1972) found that when participants gazed to the left, the right hemisphere was activated and when they gazed to the right, the left hemisphere was activated. Although, distal-proximal attentional networks may be activated for radial stimuli, stimuli in the left and right hemispaces may have had an additive effect on the contralateral hemisphere modulating the level of attention allocated to the opposite hemispace.

In an attempt to test behavioural asymmetries for processing near and far space more directly, Szpak, Loetscher, Bastian, et al. (2015) induced an impression of depth using anaglyph stimuli. Anaglyph 3D is created by taking two pictures of a scene from slightly offset viewpoints and encoding an image for each eye using red or cyan filters. When these two images are viewed with a matching pair of anaglyph glasses, the visual cortex fuses the two viewpoints into one three-dimensional image. In Szpak, Loetscher, Bastian, et al.'s (2015) study, participants made forced-choice closer/further judgements about the relative location of two 3D spheres located in the left and right hemispaces. Results showed a significant bias towards judging the right sphere to be closer than the left sphere. These results are consistent with the idea that the left hemisphere (right hemispace) is specialised for near processing whereas the right hemisphere (left hemispace) is specialised for far processing.

While the study by Szpak, Loetscher, Bastian, et al. (2015) demonstrated an asymmetry for the processing of near and far space, it involved relatively complex anaglyph stimuli presented within an artificial 3D environment. The current study sought to examine asymmetries for processing near and far space using much simpler stimuli that do not require image fusion in a synthetic scene. To this end, a radial Landmark line task was employed. This task is well-known and has been frequently used to test functional asymmetries for horizontal and vertical axes (Çiçek et al., 2009; Fink et al., 2001; Foxe et al., 2003; McCourt & Jewell, 1999; McCourt & Olafson, 1997; Nicholls et al., 2012). Surprisingly, a radial Landmark task has not been used before to measure left/right asymmetries in processing near and far space. Given the simplicity of the task, it should provide a clear picture of how 'near' and 'far' are processed by the left and right cerebral hemispheres.

In the current study, radial lines were presented to the left, right and central spaces and participants made judgements about the relative length of the proximal and distal portions of the lines. The perceived midpoint was then inferred from these decisions by fitting a cumulative Gaussian distribution and calculating the point of subjective equality. In line with a body of research examining proximal/distal differences in radial line bisection, the length of the distal portion of the line was expected to be over-estimated – leading to a shift of the perceived midpoint distal to the true centre (Geldmacher & Heilman, 1994). In addition, an asymmetry was predicted between the left and right hemispaces. For lines presented in the left hemispace, the perceived midpoint should be shifted distal compared to the central condition – reflecting the right hemisphere's predisposition for processing far space. Conversely, for lines presented in the right hemispace, the perceived midpoint should be shifted proximal compared to the central condition.

8.1.3 METHODS

PARTICIPANTS

Twenty-five Flinders university students ($m = 7; f = 18$) participated in the experiment in exchange for $10.00AUD. Their ages ranged between 18–35 years old ($M = 21.72$, $SD = 3.87$) and all had normal or corrected-to-normal visual acuity. Twenty-four participants were right-handed according to criterion set out in the FLANDERS handedness survey (Nicholls, Thomas, Loetscher, & Grimshaw, 2013). Participant's heights ranged between 1.60–1.90.5m ($M = 1.72m$, $SD = 8.41$), which was important to calculate individual visual angles of the stimuli. Participants gave informed consent prior to beginning the experiment. This study was approved by the Human Research Ethics Committee at Flinders University and adhered to the principles of the Declaration of Helsinki.

APPARATUS

Stimuli were displayed on a LCD screen (2921 mm long and 5182 mm wide), that was mounted in a tabletop so that the screen was facing upwards (see Figure 8.1). The table was 790 mm high, 1200 mm long, and 600 mm wide. E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used to run the experiment and record responses. Participants responded using button presses on a numeric keypad. Closed-circuit audio/visual surveillance was used to monitor participants when the experimenter was outside the testing room.

Figure 8.1: An illustration of the experimental setup. A computer screen was inserted into a table allowing participants to view stimuli on the transverse plane. The illustration shows a radial line to the participant's right

STIMULI

The Landmark stimuli were based on those used by McCourt and Jewell (1999). Each radial line was composed of two black and white bars, which were arranged as diagonally opposite pairs on a grey background. Line stimuli ran radially along the participants' midsagittal axis. The distance from the start of the participant's body (edge of the table) to the centre of the computer screen was 310 mm. As participants differed in height, stimuli were viewed from slightly different visual angles (VA). Mean VAs of the stimuli were calculated across all participants using participants mean eye level to the height of the tabletop $M = 830$ mm (i.e. eye level height $M = 1.62$ m – table height 790 mm). Lines were 180 mm ($mean\ VA = 12.24°$) long and 5 mm ($mean\ VA = 0.35°$) wide. Lines were pre-transected by 1, 2, 3, or 4 mm on either the proximal or distal side of the true middle. They were also jittered on the radial axis by 5 mm proximally, at 0 mm and 5 mm distally. Line stimuli were presented at 3 transverse locations: in the true centre of the screen, and at 150 mm ($mean\ VA = 10.24°$) toward either the left or the right side of the screen. Four repetitions of the basic factorial combinations: 2 (longer side: proximal, distal) × 4 (transection: 1 mm (0.069°), 2 mm (0.138°), 3 mm (0.207°), 4 mm (0.276°)), × 3 (jitter: -5 mm, 0 mm, +5 mm), × 3 (space: left, centre, right) × 2 (polarity: black, white) led to a total of 576 trials.

PROCEDURE

Participants were asked to stand upright, with their thighs touching the experimental table and to retain this posture throughout the experiment. This arrangement ensured all participants stood in the exact same position during the experiment. Participants were allowed to freely move their heads. They completed 4 blocks of 144 randomised trials.

Each trial began with a blank grey screen for 500 ms, followed by the pre-transected line for 2000 ms. While the line was visible, participants were asked to indicate whether the proximal or the distal line segment was longer. Responses were made using a two-button response panel, which was aligned with their mid sagittal axis. Participants pressed the nearest buttons to indicate that the proximal segment was longer, and the furthest button to indicate that the distal segment was longer. This intuitive response mapping was maintained throughout the experiment, though hand mapping was counterbalanced. Half of the participants used their left-hand to push the distal button and their right-hand to push to proximal button. The other half used the opposite hand mapping. If participants failed to respond within 2000 ms, the trial was rejected and repeated at a later stage. An error message appeared directly after all missed trials, prompting participants to respond more quickly. The average number of missed trials was 0.392%.

Participants completed 12 practice trials before starting the experimental trials. After the practice trials were finished, the experimenter started the experimental block and left the testing room. A small camera was used to ensure that participants focused on the task in the experimenter's absence. Participants took small breaks between each block. In the first break, the FLANDERS handedness questionnaire was administered. In the second break, height was measured, and in the final break, participants sat down for approximately 2 min.

8.1.4 Results

Errors. Percentage of errors were calculated for left ($M = 25.091$, $SD = 6.285$), centre ($M = 24.276$, $SD = 5.875$) and right ($M = 23.211$, $SD = 7.199$) lines did not differ significantly $F(2, 44) = 1.916$, $p = .159$, $partial\ \eta^2 = .080$.

Point of Subjective Equality To obtain a measure of the perceived midpoint of the Landmark stimuli, it is standard practice to calculate the point of subjective equality (PSE) (Benwell et al., 2014; Foxe et al., 2003; McCourt, 2001). Individual PSEs were calculated by fitting a cumulative Gaussian distribution to the proportion of distal-side-longer responses. By taking the point at which distal and proximal decisions were equiprobable, the perceived midpoint of the radial line could be inferred. Two participants were excluded because their data failed to conform to a cumulative function. Goodness of fit between the curve and the actual data was measured using R^2, generating a mean of .937 (range = .725 to .995). Individual PSEs were pooled to identify a sample mean PSE (in mm) that was used in subsequent analyses. Negative PSE values indicate that the perceived midpoint was distal to the true centre whereas positive PSE values indicate a proximal bias.

One-sample t-tests were used to examine whether mean PSE values showed significant biases, compared to zero (i.e., no directional bias). Mean PSE values for the left ($M = -2.096mm$, $SD = 0.912$; $VA = 0.145°$) [$t(22) = 11.019, p < .001$, $Cohen's\ d = 4.699$], centre ($M = -1.680mm$, $SD = 0.906$; $VA = 0.116°$) [$t(22) = -8.899, p < .001$, $Cohen's\ d = 3.795$] and right ($M = -1.644mm$, $SD = 0.936$; $VA = 0.114°$) [$t(22) = -8.42, p < .001$, $Cohen's\ d = 3.590$] conditions were all distal to the true centre of the line.

A within-participants analysis of variance (ANOVA), with one factor (line space: left, centre, right) demonstrated that line placement had a significant effect on PSE values, $F(2, 44) = 5.039$, $p = .011$, $partial\ \eta^2 = .186$ (see Figure 8.2). Pairwise comparisons using t-tests (significant at $p < .05$) showed that the midpoint was shifted distally for lines presented on the left compared to lines presented in either the centre [$t(22) = 2.730$, $p = .037$, $Cohen's\ d = 1.192$], or on the right side [$t(22) = 2.681$, $p = .041$, $Cohen's\ d = 1.170$]. Lines that were presented in the centre or on the right side did not differ significantly [$t(22) = .236, p > .05$, $Cohen's\ d = .103$].

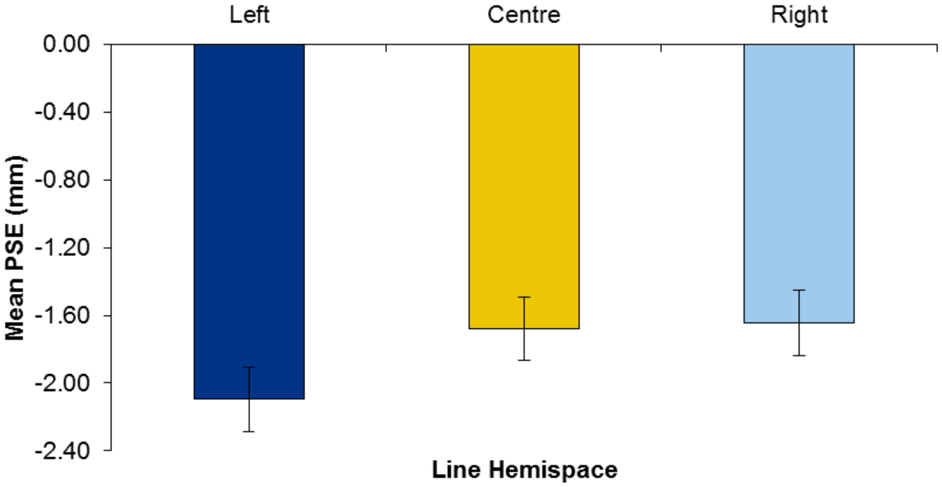


Figure 8.2: Mean point of subjective equality (PSE) for left, centre and right lines with standard errors. Negative values indicate that the perceived centre is distal to the true centre of the line.

8.1.5 Discussion

The current study investigated asymmetries for processing near and far space using a simple radial Landmark task. Previous behavioural research in this field has often investigated this issue indirectly. For example, the study by Heilman et al. (1995) found that lines presented to the left appeared shorter overall and then invoked a local/global mechanism to explain the relative contraction and expansion of the line. Similarly, Roth et al. found that forcing participants to use their left eye caused a distal bias for radial line bisection. A model of unilateral hemisphere activation caused by eye patching was invoked to explain the asymmetry in radial line bisection.

A more direct approach was taken by Szpak, Loetscher, Bastian, et al. (2015). In this case, participants viewed anaglyph 3D spheres presented in the left and right hemispace and made judgements of relative distance. Results demonstrated that participants judged the sphere located on the right to be closer than the sphere on the left. While the study by Szpak, Loetscher, Bastian, et al. (2015) provided direct evidence of a functional asymmetry for processing near and far space, it involved relatively complex stimuli within an artificial 3D environment. To get around this issue, the current study used a very simple radial line bisection task that did not require synthetic depth cues. The line bisection task is well validated and has been used extensively to measure shifts in attention (McCourt & Garlinghouse, 2000; McCourt & Jewell, 1999; N. A. Thomas & Elias, 2012; Vossel et al., 2010). Radial lines were presented in the left, right and central spaces. Overall, participants perceived the centre of the line to be distal to the true centre in all three conditions. This overestimation of the distal segment of the line is consistent with a body of research showing distal biases in radial line bisection (Geldmacher & Heilman, 1994; Halligan & Marshall, 1993). This distal bias may reflect the operation of asymmetric eye-scanning from far to near (Halligan & Marshall, 1993), a 'magnification' of far objects to compensate for a known reduction in size for distant objects (Barrett et al., 2002) or an attentional bias towards far space (Shelton et al., 1990).

Importantly for the current hypotheses, there was an asymmetry in the relative size of the distal overestimation. For lines presented in the left hemispace, the distal bias was increased relative to the central condition. The distal bias was also larger for lines presented in the left hemispace compared to the right hemispace. This asymmetry is consistent with the research carried out by Szpak, Loetscher, Bastian, et al. (2015) and suggests that the right hemisphere, which processes stimuli in the left hemispace, is specialised for processing stimuli in far space.

While an asymmetry was observed between lines presented in the left and central spaces, there was no asymmetry between lines presented in the right and central spaces. In this case, it was expected that the perceived midpoint for right lines would be shifted proximal relative to the central condition. While this lack of asymmetry was unexpected, it may reflect the default mode of processing for a task such as this. That is, the radial line bisection task was carried out with lines located within reach and therefore within peripersonal space. As a result, lines in the central position may not have been truly neutral in relation to near/far processing – but were biased towards near processing.

Our findings thus far have been interpreted using a spatiotopic reference frame wherein the body of the participant serves as the origin and objects in space are perceived as proximal-distal; however, there is an alternative explanation based on a retinotopic reference frame. Although we presented radial lines to participants, the lines were viewed from above and may have projected as vertical lines onto the retina. Along the vertical axis objects would be perceived as up-down rather than distal-proximal. Moreover, if radial lines are interpreted with a retinotopic reference frame, then size distortions in perceived depth might also influence where the midpoint of the line is thought to be.

A study by Suavansri et al. (2012) discusses common retinotopic projections for vertical lines at eye-level and radial lines below eye-level. The authors investigated attentional asymmetries in the vertical dimension by presenting participants with a line bisection task on the coronal plane in three locations: 350mm to the left, right and centre of the midsagittal axis. They found an upward bisection error in all three line locations with lines in the left space producing the largest upward bias and right lines yielding a downward shift. It is interesting that an analogous interaction may occur for vertically oriented lines compared to the radial lines presented below eye-level in the present study. Previc (1998) suggested that the upper visual field was specialised for the processing of far space and involved the ventral visual processing stream. In contrast, the lower visual field is specialised for the processing of near space and involves activation of the dorsal visual processing stream. In support of this dissociation, Szpak, Loetscher, Bastian, et al. (2015) found that anaglyph spheres presented in the lower hemispace were judged to be closer compared to similar spheres presented in the upper hemispace. Thus, the upper hemispace is associated with far space and the lower hemispace is associated with near space.

If the radial lines in the current experiment are perceived as vertical within a retinotopic reference frame then size distortions might affect the perception of depth. A study by Girgus and Coren (1975) attributed vertical bisection errors to size distortions in perceived depth which they refer to as constancy scaling (Gregory, 1963; Künnapas, 1957). They argue that vertical lines are perceived as receding in depth, so that the top portion of the line is perceived as further away than the lower half. Because of constancy scaling, the top portion of the line, which is perceived as more distant, will also be perceived as longer. The lower portion of the line will be perceived as being closer and shorter than the top portion. This will lead to bisections being placed above the true midpoint of a vertical line. The constancy scaling interpretation is also consistent with the separate visual pathway hypothesis that suggests the upper hemispace is directed by the ventral stream and the lower hemispace is directed by the dorsal stream (Goodale & Milner, 1992; Previc, 1990). Research in support of this hypothesis shows that the constancy scaling illusion occurs for perceptual judgments directed by the ventral stream, but disappears when the dorsal stream is loaded with visuomotor actions (Pitzalis, Di Russo, Spinelli, & Zoccolotti, 2001; Servos, Carnahan, & Fedwick, 2000). If in the current experiment, the lines were perceived as vertical with the top portion receding in depth like in Girgus and Coren (1975), then presenting lines in the left and right sides of the screen may have activated the contralateral hemispheres as well as the ventral stream.

The present study shows that processing differences along one dimension can influence perceptions along another dimension. These inter-dimensional influences are particularly important for the perception of depth in the three-dimensional world that we live in. The association between the radial and lateral axes and between the radial and vertical axes both rely on a cognitive/neurological link. In the case of the former association, it is related to cerebral functional specialisation whereas the latter association is related to functional specialisation of the ventral and dorsal visual streams. It would be interesting to explore these links further to determine how processing differences in one dimension can distort judgements along another dimension.

8.2 Experiment 10: three-dimensional task

8.2.1 Publication abstract

Our ability to process information about an object's location in depth varies along the horizontal and vertical axes. These variations reflect functional specialisation of the cerebral hemispheres as well as the ventral/dorsal visual streams for processing stimuli located in near and far space. Prior research has demonstrated visual field superiorities for processing near space in the lower and right hemispaces and for far space in the upper and left hemispaces. No research, however, has directly tested whether the functional specialisation of the visual fields actually makes objects look closer when presented in the lower or right visual fields. To measure biases in the perception of depth, we employed anaglyph stimuli where participants made closer/further judgements about the relative location of two spheres in a three-dimensional virtual space. We observed clear processing differences in this task where participants perceived the right and lower spheres to be closer and the left and upper spheres to be further away. Furthermore, no relationship between the horizontal and vertical dimensions was observed suggesting separate cognitive/neural mechanisms. Not only does this methodology clearly demonstrate differences in perceived depth across the visual field, it also opens up many possibilities for studying

functional asymmetries in three-dimensional space.

8.2.2 INTRODUCTION

A variety of mechanisms contribute to our ability to perceive our visual world in three dimensions. Monocular cues such as perspective, relative size, shading and occlusion all play a role in the perceived distance of an object (Howard & Rogers, 2012). For animals with binocular vision, such as humans, stereopsis and convergence can provide particularly accurate information about an object's distance from the observer (Howard & Rogers, 2012). Precise depth perception is critical to survival fitness and continues to play a particularly important role for those who work in complex multidimensional spaces – such as pilots, surgeons, and athletes. Given the importance of accurately judging depth in the environment that surrounds us, it is surprising to learn that asymmetries exist in the processing of near and far space along the horizontal and vertical axes.

In relation to the horizontal axis, asymmetries for processing near and far stimuli have been observed by Heilman et al. (1995). Under free-viewing conditions, they presented radial lines to the left and right hemispaces and asked participants to judge which of the two lines appeared longer. Analyses demonstrated that lines presented to the left hemispace were judged to be shorter compared to those presented to the right hemispace. To explain these results, Heilman et al. (1995) referred to a model of functional cerebral asymmetry. They argued that the left hemisphere is specialised for tasks involving local attention (see: Barrett et al., 1998; I. H. Robertson, Mattingley, Rorden, & Driver, 1998) and for peripersonal spatial tasks such as reading and writing. In contrast, the right hemisphere was believed to be specialised for global attention (see: Barrett et al., 1998; L. C. Robertson et al., 1988) and for extrapersonal spatial tasks such as face/emotion recognition and navigation. The left hemisphere therefore directs attention towards the body whereas the right hemisphere directs attention away from the body. With this cerebral asymmetry in mind, Heilman et al. (1995) suggested that the ends of the lines retracted towards the middle when they fell to the left hemispace – causing them to appear shorter. Conversely, the endpoints of the lines expanded away from the middle when they fell on the right hemispace – causing them to appear longer.

Neurological research supports a left/right asymmetry for processing near and far space. Weiss et al. (2000) asked participants to bisect lines or point towards dots located in either near or far space. Positon Emission Tomography (PET) was used to record activity of the brain as they carried out the tasks. For tasks located in near space, results showed preferential activation of centres located in the left hemisphere, including the dorsal occipital cortex, the intraparietal cortex, the ventral premotor cortex and the thalamus. For tasks located in far space, there was bilateral activation of ventral occipital cortex and the right medial temporal cortex. The PET research complements clinical research showing dissociations in neglect between peripersonal and extrapersonal space for patients with unilateral lesions to the left or right hemispheres (Vuilleumier et al., 1998; Williamson et al., 2014).

Asymmetries have also been reported for processing near and far space along the vertical axis. Geldmacher and Heilman (1994) presented stimuli above and below fixation and demonstrated that visual attention in the upper portions of a visual scene is biased towards more distant points in space. Previc, Breitmeyer, and Weinstein (1995) presented random dot stereograms in the upper-left, upper-right, lower-left, lower-right quadrants of a display. Participants were asked to detect a shape within the anaglyph image as quickly as possible. Results showed that, while there was no upper/lower difference for near targets, far targets were identified more readily in the upper visual field. There was also an unexpected advantage for detecting far targets in the upper-left quadrant, which is consistent with the left/right asymmetry discussed above.

The effect of position along the vertical axis are in line with an evolutionary model of upper/lower visual field specialisation developed by Previc (1998). Previc proposed that human spatial behaviours, such as grasping objects or searching, have evolved in relation to the expected location of these objects in space. For the upper visual field, Previc suggested there was an advantage for visual search behaviours for objects typically found in far space. Conversely, Previc suggested that we have an advantage for visuomotor manipulatory behaviours (such as grasping) in the lower visual field because these objects are typically found in near space (see Chewning et al., 1998; Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010). The specialisation of the upper and lower visual fields is thought to reflect asymmetries in the activation of ventral and dorsal visual streams, respectively (Previc, 1998). Specialisation of the ventral and dorsal visual streams for processing stimuli in near and far space is borne out by fMRI research. Chen, Weidner, Vossel, Weiss, and Fink (2012) asked participants to perform allocentric/egocentric judgements on objects located in near or far space within a virtual 3D environment. Results demonstrated two dissociable streams of processing within the brain. Processing in far space loaded on the ventral stream whereas near processing loaded on the dorsal stream.

From the research reviewed thus far, it appears that asymmetries exist within the horizontal and vertical axes in the way near and far space are processed. The right and lower dimensions are specialised for processing near space, whereas the left and upper dimensions are specialised for far space. While research has investigated the comparative specialisation of the visual fields, to our knowledge, no research has directly tested whether this specialisation actually affects the perception of depth in both the horizontal and vertical dimensions. That is, does the specialisation of the left hemisphere/right hemispace for 'near' processing make objects appear closer on the right compared to the left? Similarly, does the specialisation of the dorsal stream/lower hemispace for processing near objects make objects appear closer in the lower hemispace compared to the upper hemispace? Besides being interesting from a theoretical viewpoint, systematic biases in the perceived depth of an object could be important from an applied perspective when making fine judgements of relative depth. For example, relative depth precision is essential for everyday tasks such as driving and specialised tasks such as surgery.

To investigate asymmetries in the perceived distance of an object, we used anaglyph images to induce a perception of an object located at different depths. Anaglyph images contain pictures taken from slightly different viewpoints coded in either red or cyan. When offset slightly in relation to one another and viewed through a pair of anaglyph glasses, the binocular disparity gives rise to an impression of an object located in three-dimensional space. Stereoscopic 3D are an ideal means of exploring asymmetries in depth perception along the horizontal and vertical axes – but have not been used before. We presented spheres along the horizontal and vertical axes offset slightly from one another in perceived 3D space. Participants made forced-choice discriminations of 'nearer' or 'further'. If the right and lower hemispaces are predisposed for processing objects in near space, we predicted that participants would be biased towards reporting that these spheres were closer compared to similar spheres presented in the left and upper hemispaces. Because eye dominance could affect the left/right asymmetry for anaglyph images, this was used as a between groups variable in the horizontal analysis. Finally, to investigate whether the horizontal and vertical asymmetries are the result of separate cognitive/neurological mechanisms, a correlation analysis was performed.

8.2.3 METHOD

PARTICIPANTS

Fifty-eight ($m = 15$; $f = 43$) university students participated in the experiment in exchange for $10AUD. Ages ranged between 18–62 years of age ($M = 24.862$, $SD = 7.321$) and every participant was right-handed according to the FLANDERS handedness test (Nicholls et al., 2013). All participants had normal or corrected-to-normal vision acuity, and out of the fifty-eight participants thirty-one were right-eye dominant (Coren, Porac, & Duncan, 1979). Participants gave informed consent prior to the start of the experiment. This study was approved by the Human Research Ethics Committee at Flinders University and adhered to the principles outlined in the Declaration of Helsinki.

APPARATUS

Stimulus presentations were displayed on a LCD screen (500mm diagonally). Stimuli were created using OpenGL, and red-cyan anaglyph glasses were used to view the 3D stimuli. E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used to run the experiment and an E-Prime Serial response box was used to record participants' responses. Participants' heads were kept still using a chin-rest (Richmond Products; model # 6100R) placed 600mm in front of the computer screen. Closed-circuit audio/visual surveillance was used to monitor participants when the experimenter was outside of the testing room.

STIMULI AND VIEWING CONDITIONS

Rendering stereo images involves defining a collection of surfaces with reflectance properties, light sources and camera to model the projection of the surfaces onto the virtual imaging plane. The projection is controlled by the camera's focal length and optical centre which collectively define the convergence of the virtual optical rays onto the imaging plane. We generated a set of stereo images by defining cameras in a virtual scene that represent the participant's eyes in the real world. Essentially, we modelled the computer screen in the virtual space as the imaging plane with the participant's eyes as the optical centres for each of the two cameras. This process requires knowing the distance of the participant's eyes from the computer screen. Accordingly, the diameter of the spheres and their distance in front of the screen are defined in millimetres, and in order for the apparent parallax to be consistent with the appearance of a specific sized spheres at a defined distance from the participant, the projection from the virtual world onto the real world screen must be accurately modelled.

THE THREE DIMENSIONAL VIRTUAL SCENE. The 3D scene consisted of a pair of greyscale spheres, the virtual imaging plane (at screen depth) and a background plane. The spheres were assigned a Lambertian shader and the light-source in the scene was position directly in front of the spheres. The spheres had a diameter of 30mm ($VA = 2.86°$) and were separated from each other by 65mm ($VA = 6°$) (centre-to-centre). There were ten different depth displacements, five at negative parallax and five at positive parallax. The ten displacements were coupled to produce five pairs of spheres, which stepped out progressively from the perceived depth midpoint (0.75mm, 1mm, 2mm, 3mm and 4mm). The background plane was rendered -80mm behind the virtual imaging plane and was textured with non-repeating white noise. The purpose of the background plane was to provide another point of reference for comparing the depth of the two spheres. The 3D scene was modelled with respect to an observer with interocular distance of 65mm located 600mm from a computer screen with a resolution 1920 × 1080 square pixel aspect ratio and a 550mm diagonal length.

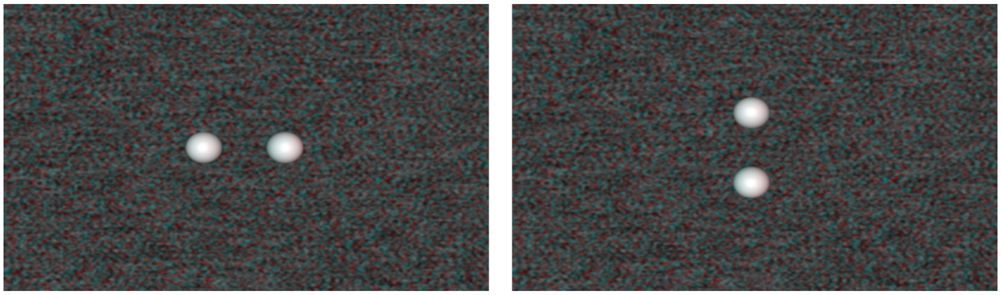


Figure 8.3: Example anaglyph stimuli from the horizontal and vertical blocks, respectively.

Depth perception from stereo requires each eye to see a slightly different viewpoint of a scene. We used the anaglyph approach to achieve stereovision by encoding these viewpoints into a different colour sub-space for each eye. When viewed through anaglyph glasses, this process allowed participant's left and right eyes to each perceive a left and right offset of the virtual scene. The brain fuses these left and right offsets and perceives them as one three dimensional image. A set of stereo images was generated by rendering a grey-scale image for each eye using virtual cameras. A composite anaglyph image was created by rendering a grey-scale image of the virtual scene for each eye, where the image for the left eye is encoded in the red channel and the image for the right eye is encoded in the green and blue (cyan) channels. These images were also rendered with sub-pixel accuracy to avoid image artefacts due to aliasing (see Figure 8.4). Both of these steps were performed using custom software written in OpenGL/C++.

The spheres were arranged in one of two different orientations. In the horizontal condition, the

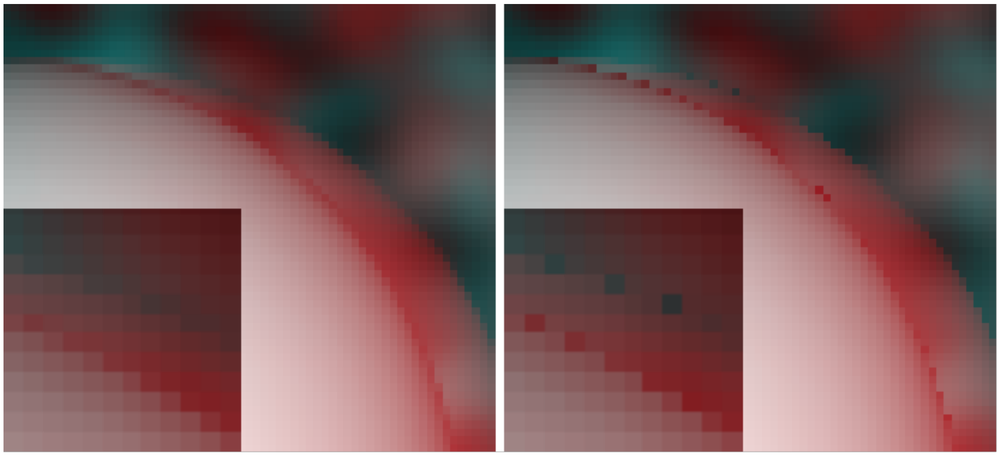


Figure 8.4: Example stimuli from the horizontal and vertical blocks, respectively.

spheres were arranged along the vertical centre of the screen. In the vertical condition, the spheres were arranged around the horizontal centre of the screen (see Figure 8.3). In both conditions, the spheres were presented so that one appeared closer than the other (with position balanced). The spheres were presented in five orthogonal pairs with relative distances of 0.75mm, 1mm, 2mm, 3mm and 4mm (see Figure 8.5).

PROCEDURE

The horizontal and vertical arrangements of the 3D spheres were administered within separate blocks, which contained 200 trials each. The order in which the blocks were administered was balanced between participants. Within each block, the factors of relative displacement (0.75mm, 1mm, 2mm, 3mm & 4mm) and position (top/left closer or top/left further) were equally represented and their order was randomised.

Each trial began with a background of non-repeating white noise perceived 80mm behind screen depth for 500ms. A set of spheres was then presented for 2000ms, after which the screen reverted back to the noise background. Participants responded to the spheres on a two-button response panel,

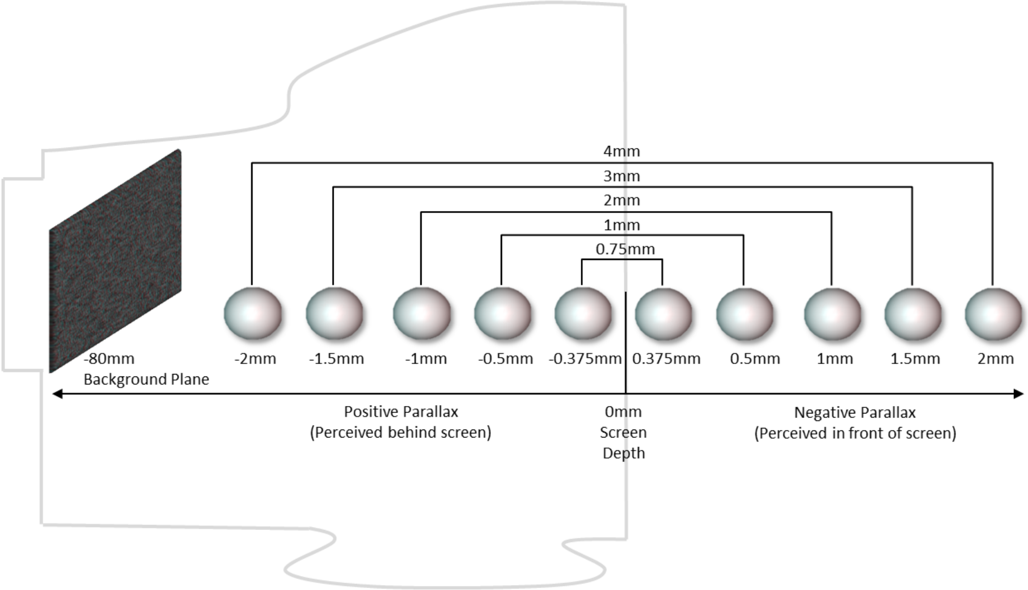


Figure 8.5: An illustration showing how the background plane, spheres and virtual imaging plane (at screen depth) were represented in relation to one another in the 3D scene. The background plane was situated 80mm behind the virtual imaging plane. Five spheres with positive parallax were generated to be perceived behind the virtual imaging plane and five spheres with negative parallax were generated to be perceived in front of the virtual imaging plane.

which was aligned with their mid sagittal plane. Once a response was made the spheres disappeared and the start of the next trial began.

For the horizontal block, participants pushed the left/right buttons to indicate that the left/right sphere was closer. For the vertical block, the response panel was rotated by 90 degrees so that the top/bottoms buttons were used to indicate whether the top/bottom sphere was closer. To control for a simple motoric response bias, half of the participants indicated which sphere was closer while the other half indicated which sphere was further. If a participant failed to respond within 2000ms, the trial was rejected and repeated at a later stage. In addition, a reminder was displayed prompting participants to respond more quickly for subsequent trials.

Prior to commencing the experimental trials, participants completed six practice trials. Practice trials were repeated once more if participants felt their eyes had not fully adjusted to the anaglyph stimuli. If participants were still unable to see the difference in depth between the two spheres, their participation was discontinued.

Analysis

Response bias. To convert all decisions to 'closer' responses, the data for participants who responded 'further' were inverted to 'closer' responses. A response bias score was then calculated using a difference score. For the horizontal trials, the number of left-closer responses was subtracted from the number of right-closer responses and then converted into a percentage of the total number of trials in that condition. Scores therefore range from -100 (the left sphere always appears closer) to $+100$ (the right sphere always appears closer). For the vertical trials, the number of upper-closer responses was subtracted from the number of lower-closer responses and then converted into a percentage of the total number of trials in that condition. Scores therefore range from -100 (the lower sphere always appears closer) to +100 (the upper sphere always appears closer).

8.2.4 RESULTS

ERROR. A simple measure of error was calculated by summing the numbers of errors within a condition and converting it to a percentage of the total numbers of trials within that condition. Any subject who had an error worse than chance for any of the two conditions was excluded from analysis. Based on this criterion, three participants were excluded and the remaining fifty-five participant's ($m = 15$; $f = 40$) data were analysed. A repeated measures ANOVA with orientation (horizontal, vertical) and relative displacement (0.75mm, 1mm, 2mm, 3mm, 4mm) as within-participants factors, showed that fewer errors were made for the horizontal ($M = 31.100$, $SD = 8.714$) stimuli compared to the vertical ($M = 38.155$, $SD = 6.919$) stimuli $F(1, 54) = 40.298, p < .001$, $partial\ \eta^2 = .427$. There was also an effect of displacement $F(4, 216) = 85.437, p < .001$, $partial\ \eta^2 = .613$ where participants made more errors for smaller relative displacements. Finally, there was an interaction between orientation and relative displacements $F(4, 216) = 4.224, p = .003$, $partial\ \eta^2 = .073$ (see Figure 8.6). This interaction was examined by post-hoc ANOVAs on the horizontal and vertical data in isolation. The analyses showed that the F value was much larger for the horizontal $F(4, 216) = 75.442, p < .001$, $partial\ \eta^2 = .585$ condition compared to the vertical $F(4, 216) = 31.541, p < .001$, $partial\ \eta^2 = .369$ condition —reflecting a stronger effect of displacement in the former condition.

HORIZONTAL TRIALS RESPONSE BIAS. The number of 'closer' responses for horizontal trials across the different relative displacements is shown in Figure 8.7. The data show a skew towards more 'closer' responses towards the right. To test whether there were more right closer responses (i.e more positive response bias scores) a one-sample t-test was conducted on participants' mean response bias scores. The t-test displayed a rightward bias ($M = 10.748$, $SD = 22.662$) which was significantly different from zero $t(54) = 3.518, p = .001$, $Cohen's\ d = .957$. An independent t-test showed no effect of sex differences $t(53) = .066, p = .948$, $Cohen's\ d = .260$, $BF = 4.67$. To test whether the rightward bias was affected by eye dominance, an independent samples t-test was conducted on the data with

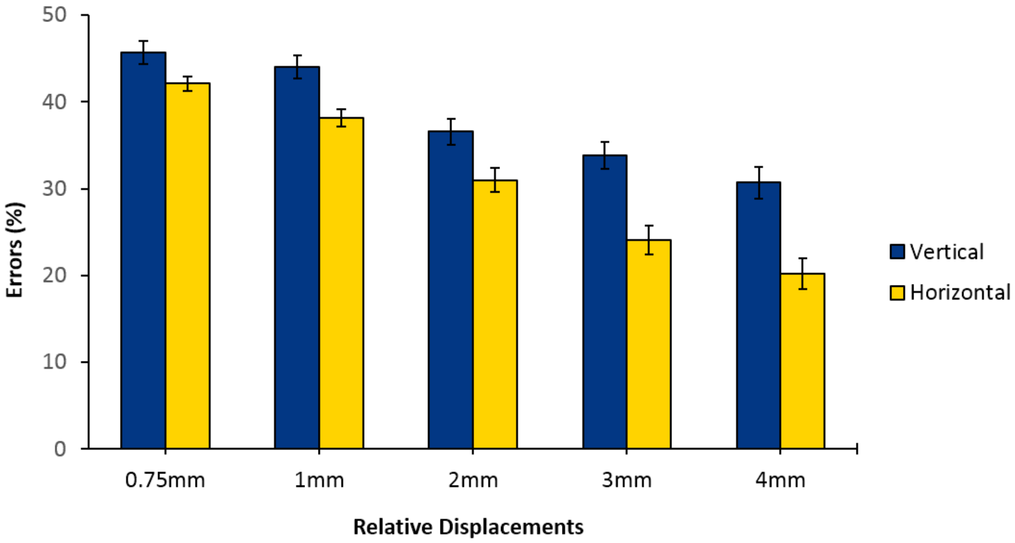


Figure 8.6: Graph showing the mean percentage error rate and error bars for horizontal and vertical trials across the different relative displacements.

response bias as the dependent variable and eye dominance (left/right) as the independent variable. This analysis showed no effect of eye dominance $t(53) = .937, p = .353$, *Cohen's* $d = .257$. Bayesian analysis confirms support for the null hypothesis Bayes Factor $(BF) = 4.720$, $H0 = .825$, $H1 = .175$. Bayes Factor values above 1 provide support for the null hypothesis and values below 1 provide support for the alternative hypothesis (see Campbell & Thompson, 2012).

VERTICAL TRIALS RESPONSE BIAS. The number of 'closer' responses across the different relative displacements for vertical trials is shown in Figure 8.8. The data show a skew towards more 'closer' responses for lower trials. To test whether there were more lower closer responses (i.e more negative response bias scores) a one-sample t-test was conducted on participants' mean response bias scores. This test showed that participants displayed a bias toward more 'closer' responses for lower spheres $(M = -8.709, SD = 26.575)$ which was significantly different from zero $t(54) = 2.431, p = .018$, *Cohen's* $d = .662$. An independent t-test showed no effect of sex differences $t(53) = 1.053, p = .297$,

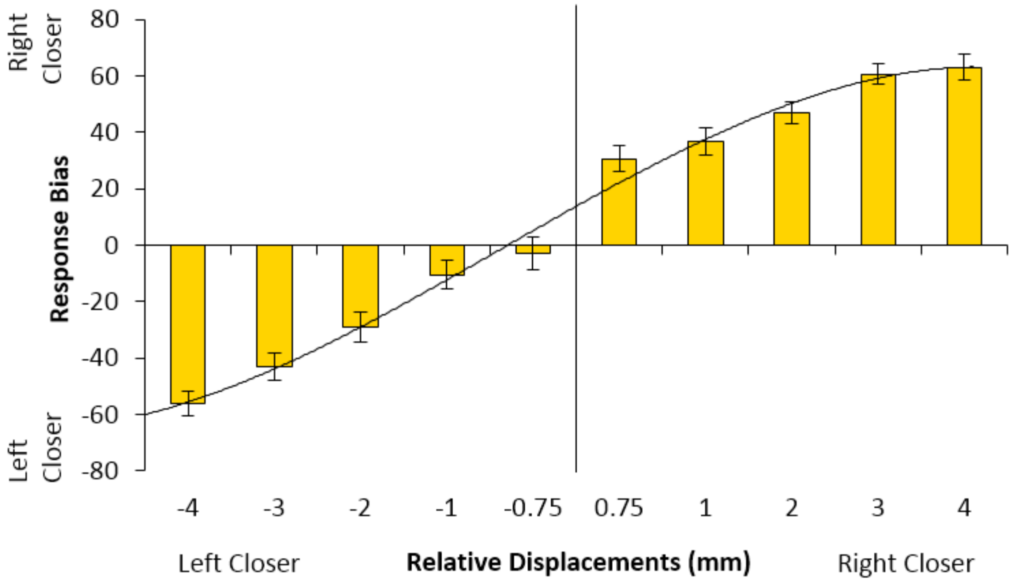


Figure 8.7: Graph showing response biases and error bars for the different relative displacements of the spheres. Negative response biases show that participants perceived the left sphere to be closer, whereas positive biases show that participants perceived the right sphere to be closer.

Cohen's d $=$ .289, *BF* $=$ 4.197.

POINT OF SUBJECTIVE EQUALITY. Points of subjective equality (PSEs) provide useful information about the magnitude of spatial bias in our 3D task by identifying the point at which an individual cannot distinguish the difference in depth between the spheres i.e. the point at which the spheres are perceived to be at the same depth. Because some participants had very wide curves, cumulative Gaussian distributions could not be fitted to everyone's individual data. Instead, these curves were fitted to the data averaged over participants. For horizontal trials, an overall PSE was calculated by fitting a cumulative Gaussian distribution to the proportion of right-sphere-closer responses across the 10 different relative displacements. The point at which right and left responses were equiprobable was then estimated to give a PSE. Overall, participants perceived the right sphere to be .499mm ($SE =$ .101) closer compared to the left. For vertical trials, a similar analysis demonstrated that participants

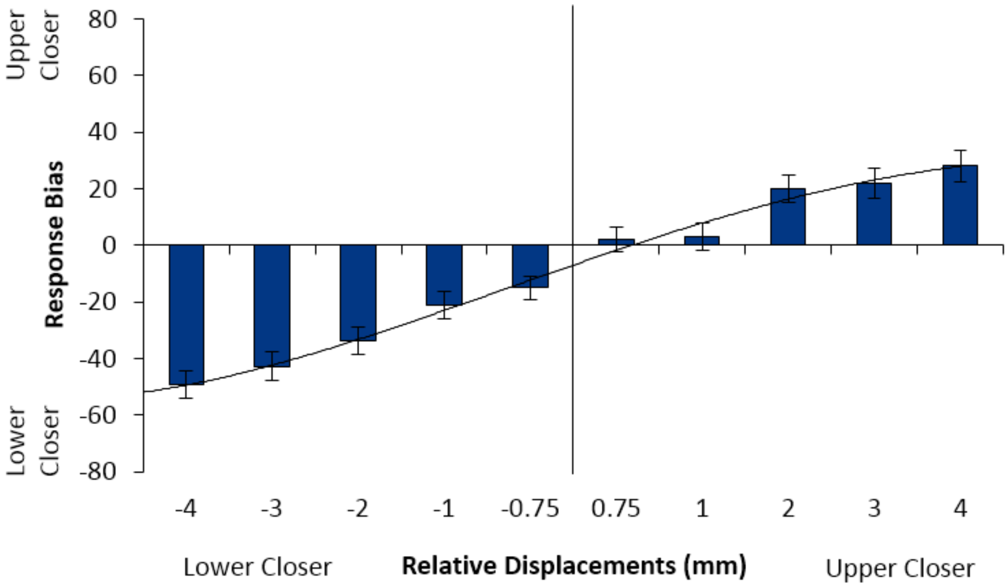


Figure 8.8: Graph showing response biases and error bars for the different relative displacements of the spheres. Negative response biases show that participants perceived the lower sphere to be closer, whereas positive biases show that participants perceived the upper sphere to be closer.

perceived the lower sphere to be .573mm ($SE = .159$) closer than the upper sphere.

Correlation. Mean response bias scores were calculated for the horizontal and vertical conditions and subjected to a Pearson correlation. The analysis demonstrated that there was no association between the biases shown for the horizontal and vertical axes $n = 55$, $r = .137$, $p = .318$.

8.2.5 Discussion

The current study investigated asymmetries within the horizontal and vertical dimensions for judgements of relative depth. Analysis of error rate revealed an unexpected effect whereby errors were substantially lower for detecting relative depth along the horizontal axis compared to vertical axis. This difference in error rate was less evident for more difficult trials with smaller relative displacements —possible due to a floor effect. It therefore appears that, despite the fact that the conditions were essentially identically except for a 90°rotation, participants found the horizontal condition considerably easier than the vertical condition. A similar effect, which may be analogous, has been reported by Wenderoth (1994). He demonstrated that, when detecting patterns of symmetry, people are faster and more accurate at making side-by-side discriminations compared to up-down discriminations. He suggested that this attentional disposition reflected the operation of scanning or attentional strategies (Julesz, 1971; Wenderoth, 1994). Furthermore, the advantage for processing horizontally aligned displays is compatible with the idea that focused attention has an elliptical shape where attention is distributed broadly along the horizontal plane and narrowly along the vertical plane (Andersen & Kramer, 1993; Feng, Jiang, & He, 2007; Hüttermann & Memmert, 2014; Hüttermann, Memmert, & Simons, 2014; Hüttermann, Memmert, Simons, & Bock, 2013; Künnapas, 1957; Pan & Eriksen, 1993; Pype, Lin, Murray, & Boynton, 2010).

Analysis of response bias along the horizontal axis revealed that participants perceived the sphere on the right to be closer than the sphere on the left. This asymmetry was not affected by eye dominance and therefore cannot be attributed to an imbalance in the way the anaglyph images were inspected. The results are consistent with a mechanism related to cerebral asymmetry. This asymmetry has been demonstrated by Williamson et al. (2014) using patients with unilateral cerebral lesions. For patients with left hemisphere lesions, rightward neglect was observed for lines placed in proximal space – but performance was normal for lines placed in distal space. Patients with lesions to the right hemisphere showed a different pattern. In this case, the patients exhibited leftward neglect for lines placed in distal space – but performance was normal for lines placed in proximal space. The results are also consistent with research conducted on non-clinical patients. For example, Roth et al. (2002) investigated the effect of monocular viewing on radial lines placed in either the left or right hemispaces. They found that monocular viewing caused activation of the attentional systems in the contralateral hemisphere. Thus, viewing lines with the left eye causes activation of the far attentional network in the right hemisphere and causes participants to bisect lines distal to them.

While the experiments reviewed in the paragraph above demonstrate asymmetries in the processing of depth, none have directly compared the perception of depth between the left and right sides. That is, the studies have presented stimuli to either the left or right sides or have manipulated function of either the left or right cerebral hemispheres. The current study is unique because it compares preference for depth within the one trial. We are therefore able to demonstrate that, for our task, the sphere on the right is judged to be .471mm closer than the sphere on the left. Because response was controlled (nearer/further) between participants, this asymmetry cannot be due to a simple response bias.

What links cerebral asymmetries in processing depth (Heilman et al., 1995) with the behaviour observed in the current study is a matter for speculation. It is possible however, that the preference of each hemisphere for processing near/far space affects the saliency of objects located in different depths. Thus, because the left hemisphere is predisposed for processing stimuli in proximal space, it causes a shift in attention towards proximal space on the right side. This shift in attention then increases the saliency of the stimulus features favouring a ‘near’ response. Similarly, for the right hemisphere, the predisposition for processing stimuli in distal space leads to enhancement of features favouring a ‘far’ response on the left side.

Analysis of response bias along the vertical axis revealed that spheres presented in the lower hemispace were judged to be .571mm closer compared to comparable spheres presented in the upper hemispace. The results are consistent with Previc (1998) model of upper and lower visual field presentation. Previous research has demonstrated that the upper visual field is quicker to process random dot stereograms (Previc et al., 1995). The current study extends this research by showing that, not only is the upper hemispace better suited to processing objects located in far space, but also that objects appear to be further away when presented in the upper hemispace.

Previc (1990) interpreted upper/lower visual field differences in terms of the specialisation of the ventral and dorsal visual streams, respectively. Functional scanning of the brain supports the proposition that the ventral stream is specialised for the processing of far space whereas the dorsal stream is specialised for the processing of objects located in near space (Chen et al., 2012). Evolutionary arguments are made to support this dissociation such that actionable objects that are within reach are usually located in the lower hemispace whereas distant objects are normally located in the upper hemispace (Goodale & Milner, 1992).

The effect of vertical location on judgements of distance can also be explained in relation to the shape of the vertical horopter. The horopter is a set of points in space, which yield single vision and produce images on corresponding points in the two retinas (Cooper, Burge, & Banks, 2011). The empirical vertical horopter, which describes the points that appear to lie in the same direction from each eye is a vertical line tilted backwards from the observer (J. M. Harris, Chopin, Zeiner, & Hibbard, 2012). Once again, adaptive reasons have been put forward to explain the backwards slope of the vertical horopter related to gravity and our orientation with respect to the ground (Cooper et al., 2011). The slope of the horopter can also explain the current results. In this case, increased uncrossed disparity in the upper field causes anaglyph images to appear further away. In contrast, increased crossed disparity in the lower visual field causes anaglyph images to appear closer. While the current study cannot differentiate Previc (1990) account from the one based on the horopter, it can nevertheless be seen that both provide a good account of the current data and are also based on a similar ecological mechanism.

A number of studies investigating horizontal and vertical asymmetries in the same participants have not found any reliable relationship between these two axes (Adair et al., 1995; Nicholls et al., 2004; Pitzalis et al., 2001). In the current study, an examination of the correlation between individual biases in the horizontal and vertical dimensions also revealed no association between these dimensions. One could argue that the lack of association between the dimensions is unsurprising given that different cognitive/neural mechanisms are thought to underlie the processing of depth. Thus, asymmetries in processing depth along the horizontal axis is governed by a cerebral asymmetry (Heilman et al., 1995) whereas asymmetries for processing depth along the vertical axis is governed by differential activation of the ventral/dorsal streams (Previc, 1990) or the backwards slope of the vertical horopter (J. M. Harris et al., 2012). Nevertheless, the current data do cast doubt on explanations related to the order in which the stimuli were inspected and eye movements. For example, Durgin, Doyle, and Egan (2008) reported an upper-left bias in the initial movement of gaze during a visual search task. It is therefore possible that the initial gaze location causes a difference in perceived depth —pushing objects located in the left and upper positions backwards. If this were the case, however, one would expect that this common strategy would cause a relationship between the dimensions —and this was not found.

8.2.6 Conclusion

Our study has shown that the perceived depth of an object varies across the visual field. The pattern of results conforms to well-known asymmetries in the processing of depth along the horizontal and vertical axes. While stereoscopic stimuli have been used extensively in visual science, they have been used less often within the laterality literature. Moreover, although the current study used anaglyph images to investigate asymmetries in 3D attention, other stereo methods such as the Wheatstone stereoscope or frame-interleave stereo projection, which do not necessitate spectral fusion may also provide interesting insights.

8.3 CONCLUDING REMARKS

This chapter sought to test a new methodology in a single-participant paradigm that could be modified in the next chapter to incorporate participant pairs. Experiment 9 achieved this goal by establishing a baseline performance for a radial Landmark task presented below eye-level. In addition to successfully developing a new experimental paradigm, Experiments 9 and 10 also extended theoretical knowledge on the perception of depth. Chapter Nine will continue with the theme of this thesis by examining interpersonal discomfort and spatial attention in a joint radial Landmark task.

A human being is a deciding being.

Viktor Frankl, 1991

9

Individual differences in social discomfort

This chapter consists of two experiments that investigate the effect of individual differences in social discomfort on the distribution of spatial attention. The first experiment in this thesis has been published in a special issue of *Neuropsychologia* on sensorimotor and social aspects of peripersonal space (Szpak, Loetscher, Churches, et al., 2015). The second experiment in this chapter addresses the limitations of the first experiment and replicates important findings.

9.1 EXPERIMENT II: PHYSIOLOGICAL SOCIAL DISCOMFORT IN A JOINT LANDMARK TASK

9.1.1 PUBLICATION ABSTRACT

Being in close social proximity to a stranger is generally perceived to be an uncomfortable experience, which most people seek to avoid. In circumstances where crowding is unavoidable, however, people may seek to withdraw their attention from the other person. This study examined whether social discomfort, as indexed by electrodermal activity, is related to a withdrawal of attention in 28 (m=8, f=20) university students. Students performed a radial line bisection task while alone or together with a stranger facing them. Physiological arousal was indexed by a wrist monitor, which recorded electrodermal activity. Correlational analyses showed that individuals who displayed physiological discomfort when together showed a withdrawal of the perceived midpoint of the line towards them (and away from the stranger). Conversely, individuals who showed no discomfort exhibited an expansion of the perceived midpoint away from them. We propose that participants shift their attention away from the stranger to increase interpersonal distance and reduce anxiety/arousal.

9.1.2 INTRODUCTION

Being in close proximity to a stranger is generally perceived as an uncomfortable experience, which many people seek to avoid. As a result, when commuting to work in public transport, passengers opt to stand instead of sitting between two other people (Fried & DeFazio, 1974). Similarly, when standing in an elevator, people arrange themselves so that they are as far away from each other as possible (Lockard, Mcvittie, & Isaac, 1977).

Exposure to crowding and personal space invasion triggers a number of physiological reactions. Commuters on public transport, for example, show elevated self-report stress levels, increased salivary cortisol and performance aftereffects when sitting in close proximity to other commuters (Evans & Wener, 2007). McBride et al. (1965) measured electrodermal activity while interpersonal proximity and orientation was manipulated in a laboratory setting. Electrodermal activity (EDA) is a reliable physiological indicator of heightened arousal and distress (Boucsein, 2012) and is related to other indices of stress, such as salivary cortisol (Reinhardt, Schmahl, Wüst, & Bohus, 2012). McBride et al. (1965) observed elevated levels of EDA when participants stood 300mm or 900mm apart face-to-face compared to when they stood 2700mm apart. The EDA response to proximity was greatest when participants stood face-to-face, was reduced when they stood to side-to-side, and was the least when participants stood front-to-back. It therefore appears that standing face-to-face in close proximity with someone else is more arousing and therefore less comfortable than other orientations.

The physiological response to anxiety is mediated via the sympathetic nervous system and efferent input from brain structures such as the hypothalamus and the amygdala. The amygdala, in particular, appears to play an important role in personal space regulation. Kennedy et al. (2009) examined the personal space of a woman with bilateral amygdala damage. When asked to approach the experimenter until a point at which she felt uncomfortable, they found that her preferred chin-to-chin distance was substantially smaller compared to controls. When she rated her comfort when a confederate stood very close front-on, she rated the experience as comfortable whereas the confederate found it unpleasant. The role of the amygdala in personal space regulation was confirmed in an fMRI study, which showed that activation of the amygdala increased when the participant knew the experimenter was closer (Kennedy et al., 2009).

Individual differences in social discomfort can affect the physiological response to crowding. For example, Aiello et al. (1977) determined the distance at which a number of healthy participants started to feel uncomfortable. Participants were then classified as preferring either ‘far interpersonal’ or ‘close interpersonal’ distances. When exposed to a situation in which participants were in close proximity to strangers, the participants with a far interpersonal distance preference showed a marked elevation of EDA (i.e. distress) compared to the participants with a close interpersonal preference. In an EEG study, (Perry, Rubinsten, Peled, & Shamay-Tsoory, 2013) found that individuals that prefer far interpersonal distances also rated higher on the Liebowitz Social Anxiety Scale (LSAS). Moreover, they found that socially anxious individuals showed a decline in early N1 ERPs suggesting that less attentional resources are allocated to social stimuli. Perry et al. (2013) therefore argued that socially anxious individuals experience social discomfort earlier than others and, as a consequence, direct their attention away from social information.

Individual differences in social discomfort also affect cognition in crowded situations. Individuals who report that they feel uncomfortable in crowded environments perform worse on tests of creativity after they have been exposed to a crowded situation (Aiello et al., 1977). Similarly, Rawls et al. (1972) found that psychomotor performance deteriorated in close interpersonal situations for individuals who reported that they preferred to interact with others at a distance. The performance of participants who reported that they felt comfortable when interacting at close range, however, was relatively unaffected by manipulations of interpersonal distance (Rawls et al., 1972). While the above studies support the idea of individual differences in responses to crowding, it is important to note that the reported effects were small and in some instances ambiguous (Exp.2, Rawls et al., 1972).

Unpleasant as it might be, sometimes close social proximity cannot be avoided—especially on public transport. In order to cope with these situations, individuals employ strategies to feel more comfortable when confronted with the uneasiness of a personal space invasion. On public transport, such strategies might involve engaging in activities such as reading, playing with smartphones or listening to music over headphones (Evans & Wener, 2007; Hirsch & Thompson, 2011; Lloyd et al., 2009; Tajadura-Jiménez et al., 2011). A common strategy to deal with social proximity is therefore to withdraw attention to the wider outside environment and retreat into an attentional space confined to peripersonal space.

While withdrawing attention from the outside world using devices such as a smartphone is a strategic response, there is also evidence which suggests that withdrawal is a product of physiological arousal itself. (Tracy et al., 2000) manipulated arousal while participants performed a letter discrimination task where the targets were presented centrally or peripherally. Brain activity was measured using fMRI and arousal was measured using EDA. The results demonstrated that arousal was associated with a narrowed attentional focus, reflected in heightened thalamic activity, which may act as a gate to peripheral visual input. A narrowed focus of attention may also reflect the effect of cognitive load (Mackworth, 1965; Wood, 2006). For example Pomplun, Reingold, and Shen (2001) demonstrated that visual span, as indexed by a visual search task, was substantially reduced with increasing task difficulty (see also: Callaway & Dembo, 1958; Weltman, Smith, & Egstrom, 1971). Therefore, for individuals who feel anxious in a situation of close social proximity, increased arousal and/or high cognitive load may lead to a withdrawal of their attentional space.

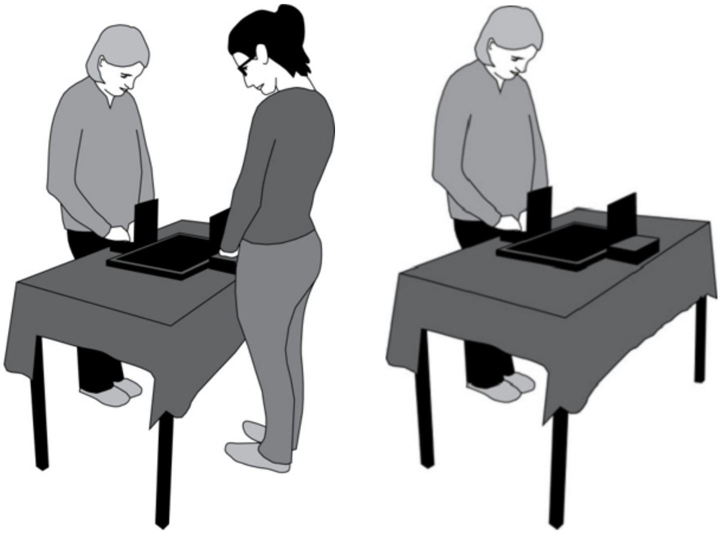
Individual differences in the effect of social proximity could have important implications for how we perceive and attend to the space that surrounds us. To explore this issue, we measured attention and arousal in an experiment which manipulated social proximity. Attention in radial space was measured using a perceptual line bisection task. Line bisection tasks are frequently used in clinical (Bonato et al., 2008; Loetscher et al., 2012) and non-clinical (Hach & Schütz-Bosbach, 2012; McCourt et al., 2001; McCourt & Garlinghouse, 2000) settings and provide a reliable index of shifts in spatial attention (McCourt, 2001). For lines that extend radially from proximal to distal space, a distal bisection bias is typically observed (Barrett et al., 1998; Heilman et al., 1995). Arousal was measured using EDA, which is a reliable index of anxiety and arousal (Boucsein, 2012) and is affected by social proximity (McBride et al., 1965).

Spatial attention and arousal were measured while participants completed a line bisection task while standing: (a) alone or, (b) together so that they faced one another at an uncomfortably close distance. Given that close proximity with a stranger may cause anxiety and participants will want to withdraw from this situation, higher levels of EDA and a withdrawal of the subjective midpoint might be predicted for the ‘together’ condition. It is well known, however, that individual differences in reactions to social proximity exist (Aiello, 1987; Aiello et al., 1977; Rawls et al., 1972). These individual differences are bi-directional and can range from particularly negative reactions to close social proximity (Aiello et al., 1977; Rawls et al., 1972) to people who actually seek out and enjoy crowded situations where they identify with others (Novelli, Drury, Reicher, & Stott, 2013). Individual differences also exist in the way spatial attention is distributed and are affected by central dopaminergic function in normal individuals (Slagter, Davidson, & Tomer, 2010) and levels of mid/frontal activation of the right hemisphere (Simon-Dack, Holtgraves, Marsh, & Fogle, 2013). These differences have the potential to override any overall difference between the conditions. To incorporate individual differences into the analysis, a correlational analysis examining the relation between individual differences in arousal and shifts in attention may be more revealing. For individuals who found close proximity unpleasant, as indexed by an increase in EDA in the together condition, the perceived midpoint of the line was expected to withdraw towards them. In contrast, for individuals who found close proximity pleasant, as indexed by a fall in EDA in the together condition, the perceived midpoint of the line was expected to expand towards the other person.

9.1.3 METHOD

PARTICIPANTS

Sixteen pairs of unacquainted university students ($m = 10, f = 22$) participated in the experiment in exchange for $10 (AUD). Their ages ranged between 18–38 years old ($M = 23.97$) and all had normal or corrected-to-normal visual acuity. Thirty-one participants were right-handed according to criterion set out in the FLANDERS handedness survey (Nicholls et al., 2013). Participants gave informed consent prior to the start of the experiment and the study was approved by the Human Research Ethics Committee at Flinders University. Two participants' data were excluded from the analysis because the participants did not follow the instruction requiring them to use one hand on each button (they used one hand for both buttons). Another participant was excluded because the



(a) Participants performing task together.

(b) Participant performing task alone.

Figure 9.1: Illustration of the experimental setup when participants performed the task: (a) together and (b) alone.

electro-dermal sensors temporarily malfunctioned and no data were recorded. This left 29 participants in the sample ($m = 8, f = 21$). All participants were questioned about their relationship at the end of the experiment to ensure that participant pairs did not know each other.

APPARATUS

Stimulus presentations were controlled with a PC running Windows XP and displayed on a LCD screen (2921mm long and 5182mm wide). The LCD screen was mounted in a tabletop so that the screen was facing upwards (see Figure 9.1). The table was 790mm high, 1200mm long and 600mm wide. E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used to run the experiment and record responses. Each participant responded using a numeric keypad, which was placed within a black cardboard box to obscure their responses from the other participant. Electro-dermal activity (EDA) was monitored using the Affectiva Q-sensor. Closed-circuit audio/visual surveillance was used to oversee participants when the experimenter was outside the testing room.

STIMULI

Line bisection stimuli were based on those used by McCourt and Garlinghouse (2000). The lines ran radially along the participants' mid sagittal axis and were 180mm long and 5mm wide. Each radial line was composed of two black and white bars, which were arranged as diagonally opposite pairs on a grey background (see Figure 9.2). The lines were transected by 1, 2, or 3mm to either side of the true middle. To avoid marks, such as a bit of dust on the screen, being used to assist bisections, the position of the lines was jittered by 9mm to either side of the true radial middle of the screen. A green or blue circle (diameter 18mm) was presented in the centre of the screen to indicate which participant should respond.

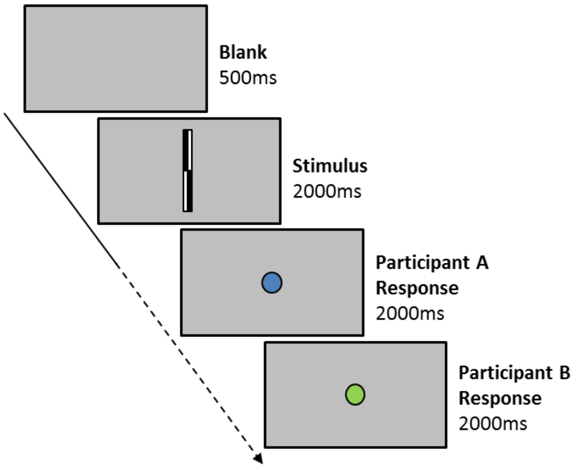


Figure 9.2: Illustration of the trial sequence of four screens presented in succession during each trial. A blank screen of 500ms, a pre-bisected line stimulus of 2000ms, and two response screens for participant's A and B each presented for 2000ms.

PROCEDURE

When pairs of participants entered the laboratory, both were immediately fitted with EDA sensors. This was done to allow time for measurements to stabilise before the experimental trials began. The testing session was composed of three blocks of trials. In one block, participants were tested together in the same room. In the other two blocks, each participant was tested alone. Each participant therefore completed two blocks. The order in which the blocks were administered was controlled between pairs of participants.

In the together session, participants stood to either side of the table, which was 600mm wide (see Figure 9.1). They were asked to stand upright, with their thighs touching the table and to retain this posture throughout the experiment. This arrangement ensured that participants' heads were roughly 600mm apart during the experiment. Each testing block was comprised of 96 trials, which consisted of 2 repetitions of the factorial combinations of turn order (your/other's turn, other's/your turn), bisection shift (-3, -2, -1, $+1$, $+2$, $+3$mm) jitter (-9, $+9$mm) and polarity (black/white). Note that negative and positive measurements indicate proximal and distal shifts, respectively, throughout this experiment. The order in which the different factorial combinations occurred was randomised for each participant.

Each trial began with a blank grey screen for 500ms, followed by the pre-bisected line for 2000ms. The experimental stimulus was then replaced by two consecutive response screens—one for each participant (see Figure 9.2). The response screens consisted of either a blue or green circle placed in the middle of the screen, which indicated who should respond. The order in which the blue and green circles appeared was balanced and appeared in a random order. Participants within a pair were randomly assigned to the blue or green circles. Upon presentation of 'their' colour, participants were asked to indicate which of the proximal or distal line segments was longer. Responses were made using a two-button response panel, which was aligned with their mid sagittal axis. Participants pressed the nearer/further buttons to indicate that the proximal/distal line was longer, respectively. This intuitive response mapping was maintained throughout the experiment. Half of the participants used their left-hand to push the distal button and their right-hand to push to proximal button. The other half used the opposite hand and the order was balanced between participants. The first respondent had a 2000ms window in which to make their response before the second response screen appeared. The second respondent also had a 2000ms response window in which to make their response. If either participant failed to respond to their response screen within 2000ms, the trial was rejected and repeated at a later stage. If a trial was rejected on this basis, an error message appeared which could be read by both participants, prompting them to respond more quickly. This error messaged appeared directly after a participant missed their response screen. Although no direct measure was made of the number of rejections, video observation suggested that the number was less than 2%.

In the alone session, participants were tested in isolation while the other participant waited outside the room for the duration of the session (about 7min) and completed the handedness questionnaire. In the alone condition, participants adopted the same position on the same side of the table that they used (or would use) in the together condition. The presentation of the stimuli was identical to the together condition. Because only one person was present, however, the response procedure was modified slightly. In this case, participants were still assigned to 'their' colour. Even if the other person's response colour appeared first, they were required to wait for 2000ms until their response screen appeared and then make their response.

Before starting the experimental trials, participants completed eight practice trials. Once participants had completed the practice trials, the experimenter started the block and left the testing room for the duration of that condition. At the beginning and end of each block, the EDA data were electronically marked so that the recording could be synchronised with the block. A small camera was positioned in the testing room on the side of participants to ensure that participants focused on the task, did not talk or move away from one another (i.e: step back).

9.1.4 RESULTS

A point of subjective equality (PSE) was calculated for the together and alone conditions by fitting a cumulative Gaussian distribution to the proportion of distal-side-longer responses. By taking the point at which distal and proximal decisions were equiprobable, the perceived middle of the radial line could be deduced. Goodness of fit between the curve and the actual data was measured using R^2 and ranged from .629 to 1 with a mean of .939. Positive values reflect a shift in the perceived middle away from the observer (distal) whereas negative values reflect a shift in the perceived middle towards the observer (proximal).

The mean PSE for the together condition was $+1.851$mm ($SD = 1.003$) and a one-sample t-test revealed that this mean was significantly distal to the true centre [$t(28) = 9.928, p < .001, d = 3.752$]. The PSE for the alone condition ($M = +1.551$mm, $SD = .996$) was also significantly distal to the true centre [$t(28) = 8.391, p < .001$, *Cohen's* $d = 3.171$]. The PSE data were then tested with an ANOVA with sex of the participant (*m* or *f*), sex-pairings (same-sex, opposite-sex) and condition-order (alone-first or together-first) as between-participants factors and alone/together as a within-participant factor. There was no effect of being alone or together [$F(1, 21) = 1.136, p = .299$, *partial* $\eta^2 = .051$]. No other main effects or interactions were significant with the exception of a weak interaction between condition-order and sex-pairings [$F(1, 21) = 4.648, p = .043$, *partial* $\eta^2 = .181$]. As there was no logical reason to expect this interaction and since it did not involve the alone/together condition, it will not be discussed further.

Electro dermal activity was measured as electrical conductance across the skin in units of microsiemens. A low pass filter at 1Hz was applied to these data to remove recording artefacts and the mean EDA for each block was determined. A log transform was applied to these data to normalise the distribution (Boucsein, 2012). The EDA data were analysed using the same ANOVA used for the PSE data. There was no effect of being alone or together [$F(1, 21) = 0.001, p = .991$, *partial* $\eta^2 = .000$]. While all other main effects and interactions failed to reach statistical significance, there was an interaction between being alone/together and condition-order that approached statistical significance [$F(1, 27) = 4.142, p = .055$, *partial* $\eta^2 = .165$]. Post-hoc analyses revealed no effect of condition-order for the alone condition [$t(27) = .377, p = .709$, *Cohen's* $d = .140$]. For the together condition there was a trend $[t(27) = 1.885, p = .070, \textit{Cohen's } d = .739]$ showing that log EDAs were lower when participants performed the together condition first ($M = -1.303$, $SD = 1.111$) compared to when they did this condition second ($M = -.373$, $SD = 1.198$).

To investigate the relationship between physiological arousal and shifts in spatial attention, change scores were calculated for both dependent variables. For spatial attention, the PSE for the alone condition was subtracted from the PSE for the together condition. A negative score indicates that the PSE withdrew towards the observer when they were with another person. Alternatively, a positive score indicates the PSE expanded away from the observer when they were with another person. These PSE change scores were tested for statistical abnormalities by identifying outliers three standard deviation outside of the mean. Accordingly, one female's data was identified as an outlier and was excluded from further analysis n= 28. For skin conductance, the EDA for the alone condition was subtracted from the together condition. A negative score indicates that EDA was lower when the participants were together compared to when they were alone. Alternatively, a positive score indicates that EDA was higher when the participant was with someone else. Change scores for EDA were also tested for outliers using three standard deviations from the mean. No more participants were excluded.

Analysis of the relationship between the differences scores for PSE and EDA revealed a significant negative correlation $[r(27) = -.419, p = .026]$. According to Cohen (1988), $R^2 = .176$ is a medium effect size. Inspection of Figure 9.3 indicates that individuals whose EDA increased when they were with someone else also had a withdrawal of the perceived midpoint towards themselves. Conversely, individuals who showed a drop in their EDA when they were with someone else showed an expansion in the perceived midpoint of the line away from themselves. This correlation was followed up with a between-groups comparison where participants with lower EDA (below zero) or higher EDA (above zero) when together with another person were separated into two groups (both $N = 14$). An independent samples t-test revealed that the lower EDA group showed an expansion of attention ($M = .491$, $SD = .558$) whereas the higher EDA group showed attentional withdrawal ($M = -.090$,

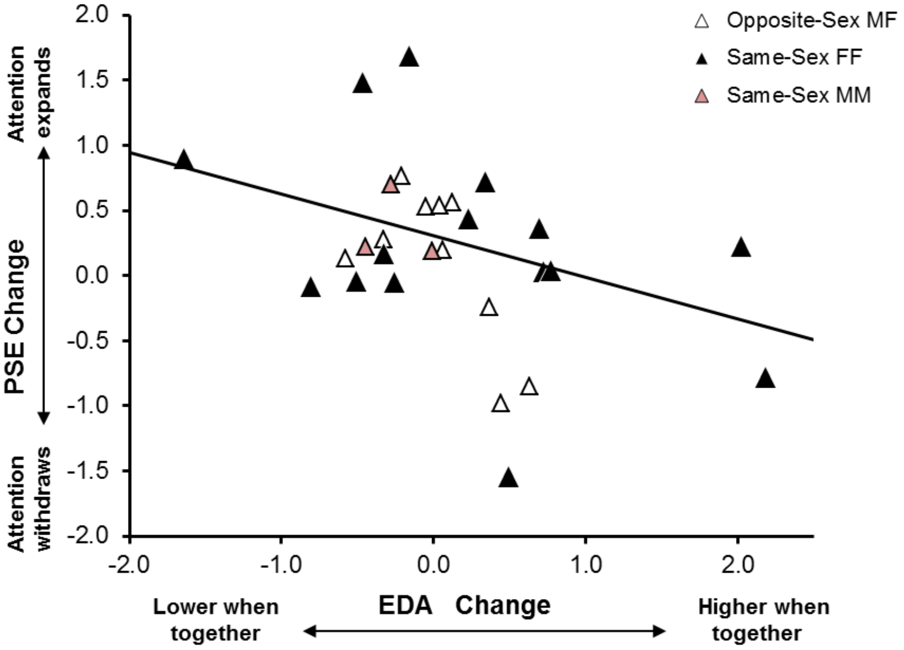


Figure 9.3: Scatterplot showing the relationship between changes in PSE (measured in mm) and log EDA (measured in µS). The best fitting linear regression is shown.

$SD = .687$) [$t(26) = 2.456, p = .021, Cohen's\ d = .928$]. There were no further significant correlations with PSEs and log EDAs in the two conditions.

9.1.5 DISCUSSION

This experiment investigated the effect of individual differences in interpersonal discomfort on the distribution of spatial attention. Shifts in spatial attention were gauged using the perceptual line bisection task, which is a well-validated measure of spatial attention (McCourt, 2001). For both the together and alone conditions, there was distal bias, whereby the perceived midpoint of the line was shifted away from the observer. This distal bias is consistent with other studies in the area and may reflect the operation of a perceptual/attentional mechanism (Barrett et al., 2002; Geldmacher & Heilman, 1994; Graff-Radford et al., 2006; Jeong et al., 2006; Jewell & McCourt, 2000). It has been suggested that the right hemisphere is responsible for directing attention to the distal portion of radial lines (Heilman et al., 1995; Roth et al., 2002). There was no overall effect of being together or alone on the perceived midpoint; this null finding was most likely caused by variations between individuals in the degree to which they find close interpersonal distances unpleasant (McBride et al., 1965).

The physiological reaction to being in close proximity with a stranger was measured using EDA. Skin conductance is a reliable indicator of arousal and activation of the sympathetic nervous system (Bach, Friston, & Dolan, 2010). Like the line bisection data, there was no effect of being together or alone —once again, most likely reflecting individual differences in the degree to which social proximity was unpleasant. It is interesting that some participants showed no signs of anxiety/arousal in the together condition given that face-to-face contact within 900mm is known to increase EDA (McBride et al., 1965). Differences in individual physiological responses to social proximity could reflect sex (McBride et al., 1965), cultural (Remland, Jones, & Brinkman, 1995) and personality (Heckel & Hiers, 1977) variations in response to crowding. The EDA response did interact with the order in which the conditions were administered. Higher EDAs were recorded in the together condition —but only when it followed the alone condition. It is possible that, when participants did the alone condition first, they may have thought of the space around the table as being 'theirs' (see: Lyman & Scott, 1967). Therefore, when the together condition followed the alone condition the presence of another person invading 'their' space may have been especially confronting – causing an increase in arousal and EDA.

To investigate individual differences in the relation between social proximity anxiety and spatial attention, a correlational analysis was conducted. The data demonstrated a significant correlation between changes between the together and alone conditions for perceived midpoint and EDA. Individuals whose anxiety/arousal increased in the together condition showed a shift in the perceived midpoint of the line towards themselves. Conversely, individuals whose anxiety/arousal decreased when they were together with someone else showed a shift in the perceived midpoint away from themselves. It therefore appears that individuals who experience interpersonal discomfort withdraw their attention towards themselves whereas individual who do not experience this discomfort expand their attention towards the other person.

The current results suggest that individuals who found the close proximity of stranger uncomfortable withdrew into their own personal space. These data are therefore relevant to a study by Terry and Lower (1979). Terry and Lower asked participants to identify an item within an array, which first caught their attention. Social proximity was manipulated by having the experimenter sitting to one side of the participant at a moderate distance, or very close. For the close condition, there was a clear bias for the participant to select items on the side contralateral to the experimenter. Terry and Lower concluded that close social proximity caused a 'perceptual withdrawal' similar to turning one's face or eyes away from an intruder. A problem with the study by Terry and Lower, however, is that discomfort was only inferred. It is therefore possible that participants chose targets contralateral to the experimenter because of an attentional bias unrelated to social discomfort. In contrast, our experiment demonstrates a relationship between perceptual withdrawal in a social situation and physiological arousal, and we propose that participants shifted their attention away to increase the perceived distance between themselves and the other person.

The data also suggest that some individuals actually enjoy the experience of having someone else in close proximity. While research investigating the positive aspects of crowding is less common (Novelli et al., 2013), studies have shown that individuals can enjoy crowded situations when a collective experience is felt (Neville & Reicher, 2011). In addition, Ickes et al. (1982) have shown that if a positive relationship develops between individuals, then the individuals tend to chose a smaller interpersonal distance (see also: Evans & Howard, 1973; Willis, 1966). In the together condition, therefore, some individuals may have experienced a certain level of collective experience and camaraderie as they 'played' the task together. This collective experience may explain why some individuals showed decreased EDA in the together condition and also showed an expansion of spatial attention away from themselves.

While the current experiment shows a clear relation between physiological arousal due to social proximity and spatial attention, a few issues remain to be resolved. First, no attempt was made to control sex-pairings (*f*:*f*, *m*:*f* & *m*:*m*). To examine each of these pairings, the number of participants, especially males, would have to be dramatically increased. Research by Argyle and Dean (1965) showed that conversational distances between people vary by gender, where opposite-sexes stand further apart from each other. We did not observe any gender or sex-pairing effects in the social conditions and our correlation does not appear to be driven by extreme values of opposite-sex pairings (see Figure 9.3). While the results of the current study are not invalidated by a lack of gender control, it would be interesting to investigate systematically the effect of gender on arousal caused by social proximity.

Another issue is related to the discomfort experienced by social proximity. Although EDA is thought to be a reliable index of arousal/anxiety caused by social proximity (Boucsein, 2012), it would also be interesting to administer a questionnaire after the experiment to measure states and traits of anxiety to determine if these moderate the relation between arousal and attention. It is also possible that clinical groups with anxiety disorders would show altered attentional boundaries.

9.2 Experiment 12: individual differences in physiological social discomfort in a joint Landmark task

9.2.1 Introduction

Experiment 11 investigated the effect of interpersonal discomfort, as measured by electrodermal activity, on the allocation of spatial attention. Individual differences in interpersonal discomfort was related to shifts in attention. Individuals who exhibited physiological social discomfort when together showed a withdrawal of spatial attention away from the other, whereas individuals that displayed no lower physiological arousal in the together condition showed an expansion of attention towards the other. Because the results of Experiment 11 have not been demonstrated before, Experiment 12 sought to replicate these data using a larger sex-matched sample. Furthermore, personality traits were included to extend the findings of Experiment 11.

A substantial amount of personal space research supports sex differences (see Aiello, 1987; Hayduk, 1981, for a review). Furthermore, various studies show that different sex-pairings require different interpersonal distances (Argyle & Dean, 1965; Bailey, Caffrey, & Hartnett, 1976; Fisher & Byrne, 1975; D. R. Thomas, 1973). Hayduk (1983) review on personal space acknowledges inconsistent findings on sex effects across 27 different studies with stop-approach paradigms, observational data, and seating placement. In Aiello (1987) review, the author makes an intriguing distinction that may explain such inconsistent sex effects. Aiello argues that although females allow other people to approach more closely, when approaching others, females are less inclined to intrude on another's personal space. Taking this argument into account, it would be interesting to determine what physiological and behaviour affects occur when different sex-pairs are already in close interpersonal proximity.

Apart from sex-differences, numerous review papers have implicated the involvement of other factors, such as personality differences, on the regulation of interpersonal distances. Notably, the effects of personality differences and interpersonal discomfort is somewhat mixed. Some researchers show that extroverts prefer smaller interpersonal distances (Patterson & Sechrest, 1970; Cook, 1970), whereas other researchers do not find any extroversion-introversion effects (Williams, 1971; Meisels & Canter, 1970). Moreover, other personality traits such as locus of control (Heckel & Hiers, 1977; Duke & Nowicki, 1972), trait anxiety (Iachini et al., 2015; Perry et al., 2013, 2015), and emotional stability (Iachini et al., 2015) have also been implicated.

Because physiological arousal measures in Experiment 11 only reflected state anxiety it is unclear what effect trait anxiety may have on attentional withdrawal. A study by Perry et al. (2013) found a relationship between preferred social distances and social anxiety traits measured on the Liebowitz Social Anxiety Scale (LSAS). Perry and colleagues found that participants with higher trait social anxiety preferred larger interpersonal distances. In accordance with Perry et al. (2013) study, perhaps individuals with higher trait anxiety could also have increased attentional withdrawal.

Well-known personality measures, such as the LSAS and NEO-FFI-III (Costa & McCrae, 1992) were administered in Experiment 12. The impact of Big Five personality traits on the distribution of spatial attention is unclear, however, there is some evidence to suggest that extroverts prefer closer interpersonal distances. This implies that extroverts may feel more comfortable in the together condition and therefore may show attentional attraction towards their partner. Regarding trait social anxiety, Perry et al. (2013) demonstrated that participants with high trait social anxiety preferred larger interpersonal distances. If this is the case in Experiment 12, then participants with higher trait social anxiety might also have increased attentional withdrawal.

9.2.2 METHODS

PARTICIPANTS

Twenty-seven pairs ($n = 54$) of unacquainted university students ($m = 27, f = 27$) participated in the experiment in exchange for $10 (AUD). Sex-pairing was equally balanced between participants with 18 participants in each of the three pairings: male-male (*M*:*M*), male-female (*M*:*F*), and female-female (*F*:*F*). Their ages ranged between 19-48 years old ($M = 25.259$) and all had normal or corrected-to-normal visual acuity. Fifty-two participants were right-handed according to criterion set out in the FLANDERS handedness survey (Nicholls et al., 2013). Participants gave informed consent prior to the start of the experiment and the study was approved by the Human Research Ethics Committee at Flinders University.

Apparatus, Stimuli, and Procedure

Apparatus, stimuli and procedure were identical to Experiment 11, with one exception that participants were given two computerised personality measures that they completed alone.

The Big Five Personality Inventory (NEO-FFI-3). Participants were administered the NEO-FFI-3 (McCrae & Costa, 1991) between the social and alone blocks. The questionnaire contains sixty items that are divided into five personality subscales that measure neuroticism, extroversion, openness to experience, agreeableness and conscientiousness. Each personality subscale includes twelve items. Example items from each subscale include: "I often feel tense and jittery" (neuroticism), "I really enjoy talking to people" (extroversion), "I am intrigued by the patterns I find in art and nature" (openness), "I generally try to be thoughtful and considerate" (agreeableness), and "I strive for excellence in everything I do" (conscientiousness). Participants are given five response options which include strongly disagree, disagree, neither agree nor disagree, agree and strongly agree. Responses are assigned a score between 0-4 with some items being reverse coded. Response scores within each subscale are summed to provide five personality scores for each personality trait. The NEO-FFI-3 has high test-retest reliability with correlation coefficients ranging from .75 to .90 for all personality subscales (Costa & McCrae, 1992; Murray, Rawlings, Allen, & Trinder, 2003; Robins, Fraley, Roberts, & Trzesniewski, 2001).

THE LIEBOWITZ SOCIAL ANXIETY SCALE (LSAS). The LSAS (Liebowitz, 1987) was always given to participants at the end of the experiment. The LSAS is a well-used and clinically validated assessment of social anxiety (Fresco et al., 2001; Heimberg et al., 1999; Mennin et al., 2002; Weeks et al., 2005). The LSAS consisted of twenty-four items about different social situations. Participants were asked to give a rating between 0–3 on how fearful or avoidant they felt in each of the twenty-four social situations. The twenty-four items were grouped into two social anxiety subscales addressing social interaction (11 items) and social performance (13 items). Example items for each subscale participants rated, include: "meeting strangers" (social interaction) and "giving a report to a group" (social performance). Response scores from each domain of fear, avoidance and the subscales of social interaction and performance are summed to create and overall index of social anxiety.

RESULT

POINT OF SUBJECTIVE EQUALITY. Because the data for this experiment was considerably noisier than for previous experiments the cumulative Gaussian distribution method for estimating a PSE failed to converge in many instances, and could not accurately model the data. We therefore estimated the PSE by using logistic regression, which is an established alternative method (Kingdom & Prins, 2010). The logistic regression method produced much more accurate fits to the data.

The together and alone conditions were individually fitted to the proportion of distal-side-longer responses. By taking the point at which distal and proximal decisions were equiprobable, the perceived middle of the radial line could be deduced. Seven participant's data (12.96 %) did not conform to a cumulative distribution and a PSE could not be reliably calculated from these participant's responses. These seven participant's data was excluded, leaving 47 participants for analysis. Positive values reflect a shift in the perceived middle away from the observer (distal) whereas negative values reflect a shift in the perceived middle towards the observer (proximal).

The mean PSE for the together condition was +1.481 mm ($SD = .833$) and a one-sample t-test revealed that this mean was distal from the true centre [$t(46) = 12.190, p < .001$, *Cohen's d* $= 3.595$]. The PSE for the alone condition was $+1.484$ mm ($SD = .758$) was also significantly distal to the true centre [$t(45) = 13.422, p < .001$, *Cohen's d* $= 3.958$]. The PSE data were then submitted to an ANOVA with sex of the participant (*M* or *F*), sex-pairing (same-sex, opposite-sex) as between subjects-factors and alone/together as a within subjects factor. There was no effect of being alone or together [$F(1, 43) = .029, p = .865$, *partial* $\eta^2 = .001$]. There were also no significant interactions with participant sex [$F(1, 43) = .294, p = .591$, *partial* $\eta^2 = .007$], nor sex-pairing [$F(2, 43) = .613$, $p = .546$, *partial* $\eta^2 = .028$].

ELECTRO DERMAL ACTIVITY (EDA). EDA was measured as electrical conductance across the skin in units of microSiemens (µS). A low pass filter at 1Hz was applied to these data to remove recording artefacts and the mean EDA for each block was determined. A log transform was applied to these data to normalise the distribution (Boucsein, 2012). The EDA data were analysed using the same ANOVA used for the PSE data. There was no effect of EDA in the alone or together blocks [$F(1, 43) = 2.882$, $p = .097$, *partial* $\eta^2 = .063$], and all other main effects and interactions also failed to reach statistical significance.

DIFFERENCE SCORES In accordance with Experiment 11, I wanted to investigate differences in the relation between physiological arousal and shifts in spatial attention. Change scores were calculated for both PSE and EDA, by subtracting the alone condition from the together condition. A negative PSE reflects attentional withdrawal towards the observer when participant pairs were together. In contrast, a positive PSE reflects attention expanding away from the observer when participants were together. For the skin conductance measure, when the alone condition was subtracted from the together condition, positive EDA values indicated higher arousal in the together condition and negative EDA values indicated lower arousal in the together condition.

An analysis of the relationship between the difference scores for the PSE and EDA data showed a

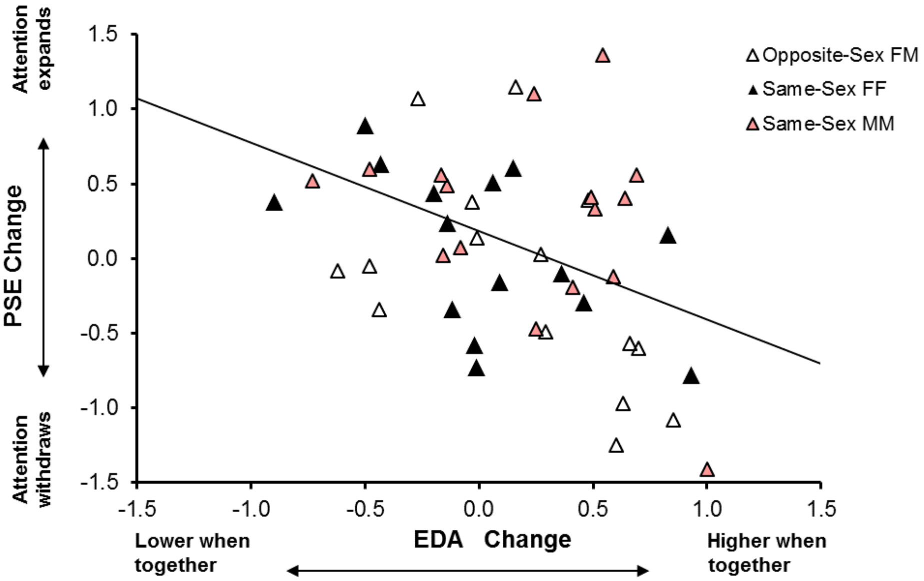


Figure 9.4: Scatterplot showing the relationship between changes in PSE (measured in mm) and log EDA (measured in µS). The best fitting linear regression is shown.

significant negative correlation [$r(46) = -.406, p = .005$] (see Figure 9.4). Consistent with Experiment 11, Experiment shows an identical relationship with PSE and EDA. The relationship shows that individuals whose EDA increased when they were together with another person also had attentional withdrawal where the perceived midpoint shifted proximally. Conversely, individuals who displayed a drop in EDA in the together condition also had an expansion of attention where the perceived midpoint of the line shifted distally. In addition, to test whether opposite- or same-sex pairs felt more anxious if they did the task together first, a simple ANOVA was conducted with EDA difference scores, sex-pairings (same-sex, opposite-sex) and condition-order (alone first, together first), there was no interaction between these three variables [$F(1, 43) = 1.337, p = .254, partial\ \eta^2 = .030$].

PERSONALITY MEASURES. Previous studies have correlated personality factors with preferred social distances, therefore it is possible that personality factors may also influence shifts in attention. None of the Big-Five personality traits predicted performance on the Landmark task [$r(46) < .121, p > .417$], and neither did any of the LSAS subscales (social performance fear, social performance avoidance, social interaction fear, social interaction avoidance) $[r(46) < .068, p > .649]$.

9.2.3 Discussion

Experiment 12 examined the influence of individual differences in interpersonal discomfort on spatial attention. In particular, this experiment aimed to address the limitations of Experiment 11. Experiment 11 found a novel effect of interpersonal discomfort on spatial attention, which demonstrated individuals who had increased arousal in the together condition exhibited attentional withdrawal and individuals with lower arousal in the together condition displayed attentional attraction. These data shows a clear relationship between physiological arousal from close social proximity and spatial attention. Although Experiment 12 also showed individual differences in interpersonal discomfort, these data cannot be explained by personality or sex-pairings.

Even with a larger sample than Experiment 11, Experiment 12 did not find significant effects of sex or sex-pairing. It is possible that either this methodology is not conducive to measuring sex-effects or that sex-effects may be context-dependent. Importantly, Experiment 12 was able to replicate the findings of Experiment 11 suggesting that the relationship between physiological arousal from close interpersonal distances and spatial attention is a reliable effect. This social attentional effect was not related to any of the Big Five personality traits on neuroticism, extroversion, openness, conscientiousness or agreeableness. Moreover, participants with high trait social anxiety did not have greater attentional withdrawal as predicted. Self-report measures such as the Big Five and Liebowitz social anxiety scale have previously been reported in studies that use approaching behaviours rather than the static positioning used in Experiments 11 and 12. The difference in methodologies may explain why Experiment 12 did not find any relationship between self-report measures and attentional withdrawal.

9.3 GENERAL DISCUSSION

Two studies were conducted to determine the effect of close interpersonal distances on spatial attention. Both of these studies were methodologically identical, with the exception of Experiment 12 including personality questionnaires. Experiments 11 and 12 show that the relationship between physiological social discomfort and spatial attention is a replicable finding.

Experiment 11 examined the influence of sex-pairing on the relationship between EDA and shifts in attention, but the sample size did not equally represent the different sex-pairings categories. In Experiment 11 three different sex-pairing categories (*M*:*M*; *F*:*F* & *M*:*M*) was put into the ANOVA as a between-subjects factor. This analysis did not show an interaction between sex-pairing and shifts in attention demonstrating that no one pairing category was driving the effect. But, the sample in Experiment 11 did not evenly represent the different categories, for example in the male-male category only three participant's data was suitable for the analysis. Studies in the personal space literature suggest that sex-paring can influence preferred interpersonal distance (Aiello, 1987; Hall, 1966; Hayduk, 1983). For example, this research shows that male-male pairings require larger interpersonal distances (Bailey, Hartnett, & Gibson JR, 1972; Brady & Walker, 1978). Experiment 12 sought to amend this limitation by obtaining a larger sample so that all categories are evenly recruited. Obtaining a larger sample allowed for a superior analysis demonstrating that individual differences in social discomfort are not related to sex-pairing.

Recent studies have found correlations between stop-approach distances and personality traits, such as dynamism (Iachini et al., 2015) and social anxiety (Perry et al., 2015, 2013). The relationship between dynamism and personal space is analogous to various studies in (Aiello, 1987) review that shows extroverts choose smaller interpersonal distances. Iachini et al. (2015) measured both comfort and reaching distance in a stop-approach task, and took measures of the Big Five personality traits and state-trait anxiety. The author's data show that when the participant approached the confederate extroversion was a stronger predictor variable, but trait anxiety correlated with all conditions for both comfort and reachable distances. These results are comparable with two other recent studies measuring trait social anxiety and preferred interpersonal distances (Perry et al., 2015, 2013). Experiment 12 did not find a relationship between attentional attraction-withdrawal and any of the five personality traits or trait social anxiety. Perhaps the stop-approach paradigm and Experiment 12 obtained different results because the methodologies are relatively dissimilar. In the stop-approach task the participant approaches a confederate, whereas in Experiment 12 participant pairs are positioned at a pre-defined location. Because extroverts have been described as people who enjoy seeking out social stimulation, it is therefore plausible that extroversion is better correlated with interpersonal approaching behaviours measured in the stop-approach task.

9.4 Concluding remarks

While Experiment 12 failed to identify any new individual differences, it nevertheless replicated the social effect found in Experiment 11. Exact replication of new effects is an extremely important part of scientific research that is often neglected in psychological research. Recent papers have remarked on publication biases in psychological research and have suggested registered reports, replication studies and Bayesian statistics as potential solutions (Nosek et al., 2015; Leggett, Thomas, Loetscher, & Nicholls, 2013; Collaboration, 2015). Because Experiment 12 was able to replicate the relationship between physiological social discomfort and spatial attention, which suggests that the social effect is a reliable finding that could be extended by future research.

The important thing is not to stop questioning. Curiosity has its own reason for existing.

Albert Einstein, 1955

10

General Discussion

THE AIM OF THIS thesis was to investigate to what extent close interpersonal distances can shift spatial attention. Experiments presented in the first part of this thesis, examined the effects of social distractors on attentional asymmetries in mere presence situations. Guided by the theoretical and empirical implications of social distractors in single-participant paradigms, subsequent studies presented in this thesis gradually evolved well-known single-participant paradigms to include participant pairs. Joint-participant paradigms were established to identify the underlying mechanisms involved in socially influenced spatial attention.

The interplay between social space and cognition is a relatively new and emerging area of research in cognitive neuroscience. Typically, experimental methodologies in cognitive neuroscience use the ‘minimalist’ approach. This approach requires the experimenter to reduce as many irrelevant experimental variables as possible in order to test only the effects of interest. As a by-product of the minimalist approach, social influences from other people are purposely excluded and individuals are studied in isolation. Because the minimalist approach has been used prolifically in cognitive neuroscience, and become the gold standard for many experimental designs, few studies in this area can provide a cognitive perspective on social space.

Recent studies have sought to address this gap in the cognitive literature by modifying single-participant paradigms to create joint paradigms (see Knoblich et al., 2011; Sebanz et al., 2006, for a review). These modifications have been largely successful and have provided interesting insights on social attention. Examples of single-participant studies that have been modified to create joint versions include the Simon (Sebanz et al., 2003), (Atmaca et al., 2008) SNARC, flanker (Atmaca et al., 2011) and crossmodal integration (Heed et al., 2010) tasks. All of these studies rely on stimulus-response compatibility to show that a co-actor can induce facilitation or interference effects. While these spatial-compatibility studies show how social attention between two co-actors is engaged in a shared environment, these studies do not demonstrate how close interpersonal distances can influence the perception of space.

The studies detailed in this thesis are particularly concerned with the effects of close interpersonal distances on the distribution of attention to space. My research question was borne out of numerous studies in social psychology on personal space. Studies on personal space show that social discomfort can influence how close another person is perceived relative to one’s own body (Hayduk, 1981; Iachini et al., 2015; Kennedy et al., 2009; McBride et al., 1965; Perry et al., 2015). This social effect implies that the close proximity of another person can influence perceptions of distance and body space, which are both highly relevant concepts to cognitive neuroscience. This thesis examined the effect of social distance on the distribution of attention more closely through a series of twelve experiments.

Thus far, the question ‘can social proximity impact on spatial attention?’ has directed the research of this thesis. The experimental chapters have addressed this question, but have also led to more pertinent questions such as: 'how does social discomfort influence attention?', 'can different social contexts modulate effects on spatial attention?', and 'do individual characteristics influence social attention differently?' Addressing these questions has led me to develop a new model of social attention, which will be discussed towards the end of the thesis in accordance with key contributions.

10.1 Can social proximity impact on spatial attention?

The stop-approach methodology was developed to measure the effects of social distances between two people. The stop-approach method requires a participant to walk towards a confederate and to stop at a distance which they consider a comfortable conversational distance (Kennedy et al., 2009; Lloyd et al., 2009; Perry et al., 2015). Recent studies show that the average preferred social distance is about 600 mm (Kennedy et al., 2009; Lloyd et al., 2009; Perry et al., 2015; Tajadura-Jiménez et al., 2011). Research on preferred social distances demonstrate that participants with increased physiological arousal prefer larger social distances than those with lower arousal (Aiello et al., 1977; McBride et al., 1965; Perry et al., 2015). This research supports the idea that physiological responses to social distances can influence how close a social stimulus is perceived to be. This idea is consistent with cognitive studies on narrowed attention showing that an increase in arousal makes objects in near space appear larger and therefore closer (Callaway & Dembo, 1958; Callaway & Thompson, 1953; Wood, 2006).

Arousal is mediated by the sympathetic nervous system and efferent input from the amygdala and hypothalamus (Adolphs, 2003b; Adolphs, Tranel, & Damasio, 1998; Kennedy et al., 2009). The amygdala is particularly important in regulating personal space and shaping appropriate social behaviour (Kennedy & Adolphs, 2014; Kennedy et al., 2009). If areas such as the amygdala are damaged personal space regulation is also effected. When patients with amygdala damaged asked to approach others in a stop-approach paradigm, they choose substantially closer social distances compared to controls (Kennedy et al., 2009). If the amygdala is unable to provide an appropriate physiological response to an approaching stimulus then an appropriate social response cannot be selected. These data on stop-approach methods suggest that arousal acts as an important physiological cue. Systematic increases in arousal are accompanied by closer social distances, which leads to a narrowing of attention and indicates to the individual that another person is approaching their personal space. If the stop-approach method suggests that attention narrows with an approaching social stimulus, how is spatial attention affected if another person is already in close proximity?

Besides spatial effects observed with an approaching social stimulus, an individual's perception of space is also affected when a social stimulus has already approached and remains in close proximity. Five chapters in this thesis demonstrate that another person in close proximity can influence size judgements measured by spatial line tasks. Furthermore, these five methodological chapters reveal that a close social stimulus is processed differently to typical spatial cues/distractors.

Chapter Five consisted of four experiments examining the effects of close social distractors on spatial attention. Based on research from the distractor-cueing literature, the chapter sought to address the hypothesis that mere presence social distractors can shift attention to the same side as the social distractor. Various different tasks were employed to test this hypothesis, such as the Landmark, line bisection, Greyscales and visual search task. Results were inconsistent with only two experiments (Experiments 2 and 4) showing social effects. Experiment 2 utilised the line bisection task and found the opposite pattern to the hypothesis, demonstrating attentional withdrawal away from the social distractor. Experiment 4 utilised the visual search task and demonstrated stronger pseudoneglect in confederate present conditions. I found it difficult to reconcile these different pattern of results, but noticed that in both instances the social distractor influenced spatial attention differently to typical distractors, which have been shown to attract attention. Because the effects were weak and inconsistent across experiments, I thought that perhaps increasing the involvement of the social stimulus may shed light on these unprecedented findings.

Chapter Six contained three studies examining the role of interdependency between participants on spatial attention. These three studies also used a close interpersonal paradigm that was analogous to the previous experiments in Chapter Five. Two out of the three experiments (Experiment 5 and 6) were able to replicate the attentional withdrawal effect first observed in Experiment 2. The attentional withdrawal effect showed that participant's perception of the midpoint of a line shifted away from another person. This midpoint shift away from the other person exhibited two spatial behaviours: participants perceived the portions of the left and right sides of the line to be longer/shorter than they objectively were; and the size of the line portions were perceived differently in the social condition. All three studies used a Landmark task with slight changes to the task that altered the interdependency between participant pairs in nuanced ways.

Experiment 5 found that when participant pairs were given a turn-based version of the Landmark task attention shifted away from the other person. The turn-based response dynamic was introduced to increase the saliency of the other person. In a turn-based dynamic, a participant's response-partner becomes more task-relevant and more attentional resources have to be focused on their partner to identify when it is 'their turn' and 'other's turn'. Experiment 6 also found an attentional withdrawal effect in an independent response paradigm where both participants could respond after the line disappeared. Findings of Experiment 6 suggest that the attentional withdrawal effect is not contingent on a turn-based dynamic. Based on the data from these three experiments (Experiments 2, 5, and 6), it was hypothesised that in order to reduce feelings of social discomfort, participants withdrew their attention in order to increase the perceived distances between themselves and the other person.

Experiment 7 investigated whether there were any differences on the attentional withdrawal effect when participants engages in a solo- or different-task paradigm. The conceptualisation of Experiment 7 was based on crowding research, which observed people engaging in solo activities to reduce feelings of social discomfort associated with crowding (Hall, 1966; Hirsch & Thompson, 2011). It was theorised that people may use solo activities as a way to gain control by conceptually distancing themselves from other people. In light of this hypothesis, Experiment 7 sought to test whether giving participants a 'way out' to deconceptualise themselves from the other person reduced the attentional withdrawal effect. In accordance with this hypothesis, Experiment 7 did not find any significant social effect when participants were given different tasks on the same shared stimuli. Moreover, this hypothesis may explain why the experimenter-present study in Chapter Four showed weak and inconsistent effects. In Chapter Five, the experimenter was not engaged in the same task as the participant and as a result participants may have deconceptualised themselves from the experimenter thereby reducing social discomfort and attentional effects.

Chapter Seven investigated whether a cooperative or competitive task dynamic influenced the attentional withdrawal effect. It was hypothesised that attentional withdrawal would increase in a competitive task and decrease in a cooperative task. This hypothesis was based on research showing a competitive task dynamic is regarded as more unpleasant, hostile and difficult than a cooperative one (Iani et al., 2011; Ruys & Aarts, 2010). If a competitive task is viewed as more unpleasant then participants may choose to increase attentional withdrawal to reduce their social discomfort. The cooperative and competitive Landmark task did not demonstrate differing levels of attention withdrawal. Implicit and explicit measures of competitiveness did not show that participants felt particularly competitive or co-operative in either of the group dynamics. Even though participants were participating for a reward, the lack of evidence from the implicit and explicit measures suggest that the group manipulation did not work. Although the group manipulation did not work in Experiment 8, an overall attentional withdrawal effect was still observed that is consistent with previous experiments.

Chapter Eight developed a new spatial methodology for the social experiments in Chapter Nine. Experiment 9 showed that on a radial Landmark task, participants typically display a distal bias towards the end of the line. Asymmetries in perceived depth are thought to occur because of hemispheric imbalances where the right hemisphere is predisposed to attending to distal information. This theory was supported in Experiment 10 which employed three-dimensional stimuli to measure asymmetries in perceived depth. Subsequent experiments tested whether this inherent bias to attend to distal space could be altered by another person positioned at the end of the line.

Chapter Nine investigated whether attentional withdrawal was related to social discomfort as measured by physiological arousal. Experiments 11 and 12 showed that the inherent distal bias observed in Chapter Eight shifted when another person was introduced into the experimental paradigm. Participants that displayed an increase in physiological arousal in the together condition also had attentional withdrawal away from the other participant. Participants with decreased physiological arousal in the together condition demonstrated attentional attraction towards the other person. Individual differences in perceived discomfort are related to attentional attraction-withdrawal. These individual differences are not related to sex-pairing or the personality measures in Experiment 12. Perhaps individual differences in attentional withdrawal are because of a top-down social modulation on spatial attention.

10.2 Top-down social modulation of spatial attention.

Neurocognitive research shows that the distance of objects is determined by the distance from one's body (Gallivan et al., 2009; Rizzolatti et al., 1997). In order to determine the distance of objects from one's body, the body is used as a perceptual ruler (Proffitt, 2013). The distance of low-level perceptual cues are measured via the possible extension of one's own limbs and action potentialities (Cléry et al., 2015; Gallivan et al., 2009; Rizzolatti et al., 1997, 1981). Likewise, similar perceptual measurements are also made to determine the distance of other people and social interaction potentialities (Cléry et al., 2015; De Vignemont, 2014; Lloyd, 2009; Proffitt, 2013).

Several researchers have shown that the brain maps out the body of the self and others (Brozzoli et al., 2013; Caggiano et al., 2009). Mirror neurons show that when observing the action of another person, similar motor areas are activated as if the observer was performing the same action (Fadiga et al., 1995; Rizzolatti & Fabbri-Destro, 2008). Brozzoli et al. (2013) showed that common regions in the ventral premotor and parietal cortices are activated when an object approaches one's own hand and the hand of another person. This suggests that peripersonal space is mapped out for both the self and other. Perhaps the advantage of mapping out the peripersonal space of the self and other is to establish what social interactions are available under the present context.

Teneggi et al. (2013) demonstrated the benefits for neurologically mapping the peripersonal space of the self and other. In the authors' study, they measured participant's peripersonal space boundaries with irrelevant approaching and receding auditory stimuli and captured participant's responses to a tactile stimulus. After peripersonal space was measured, participants were either seated in front of a mannequin or another person. The authors found that when participants were seated in front of another person their peripersonal space shrunk, but was unaffected for the mannequin condition. Moreover, when Teneggi et al. (2013) gave participants a cooperative task peripersonal space expanded to incorporate the other person. Modulating the size of peripersonal space through social interactions is a salient example of how top-down social processing can affect the perception of sensory information.

Top-down social processing also affected how participants perceived the line tasks in this thesis. In Chapter Six, participant's attentional withdrawal was influenced by the interdependency between participant pairs. When participant pairs both completed a Landmark task in a turn-based paradigm attentional withdrawal was observed, but when participants were given different tasks attentional withdrawal disappeared. Similarly, no attentional withdrawal was observed in Experiment 1 when participants completed a Landmark task with a passive social distractor present. In Experiments 11 and 12 the level of attentional attraction-withdrawal was related to physiological anxiety. This shows that attentional attraction occurred when participants perceived the social situation as comfortable, but attention withdrawal occurred when participants perceived the social situation as uncomfortable.

Preferred social distances have been shown to be related to the level of control one feels in a social situation (Aiello, 1987; Duke & Mullens, 1973; Duke & Nowicki, 1972; Nowicki & Duke, 1974). Crowding research supports the notion that people seek more control by establishing a privatised space that they can consider to be 'my space' (Hall, 1966; Sommer, 2002; Thompson et al., 2012). Often commuters on public transport create a private space by engaging in solo activities such as listening to music, engaging with smartphones or reading a book (Hirsch & Thompson, 2011; Thompson et al., 2012). Interestingly, listening to music through headphones has been shown to reduce the size of personal space by allowing others to approach more closely (Tajadura-Jiménez et al., 2011). This research may suggest why the choice to use music devices is so prevalent in crowded spaces (Bull, 2005; Hirsch & Thompson, 2011; Sommer, 2002; Thompson et al., 2012).

10.3 Model of social attention

This final section develops a new model of social attention by synthesising all theoretical and experimental insights gathered in this thesis. The proposed model of social attention identifies three social stages: an approaching social stimulus, top-down social processing and choosing an appropriate social outcome (see Figure 10.1). Each stage of social engagement hypothesises different effects on attention and behaviour.

At the stage of initial sensory input from a social stimulus, the individual orients attention towards the stimulus (Figure 10.2). A recent study by Perry et al. (2015) measured EEG and physiological anxiety (cortisol) in a stop-approach paradigm. The authors found increased alpha suppression over central and occipital sites for far interpersonal distances. In light of these EEG data, Perry et al. (2015) hypothesised that attention is greatest when a person first enters into a room. Furthermore, they demonstrated that individuals with higher sensory sensitivity show greater alpha suppression for approaching stimuli suggesting that early cortical excitability affects later social behaviours. Moreover, a review by (Lloyd, 2009) proposed that at the stage of initial sensory input from a social stimulus, body and face areas, such as the temporal-occipital junction and the fusiform face area, are likely to be involved in differentiating between human and non-human objects (Downing, Jiang, Shuman, & Kanwisher, 2001). This initial attentional orientation towards the stimulus provides the sensory

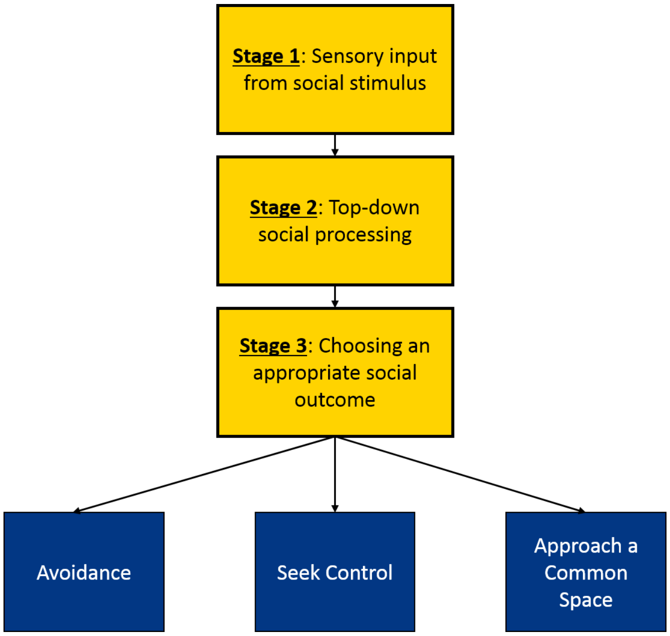


Figure 10.1: Schematic of the proposed model of social attention.

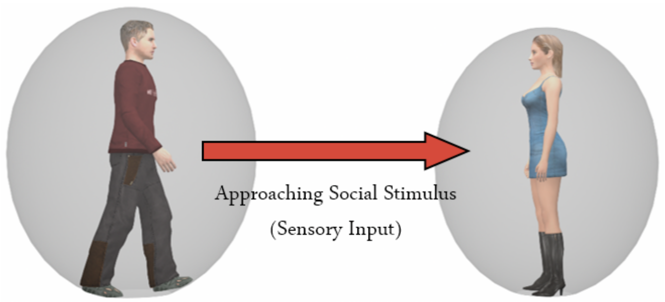
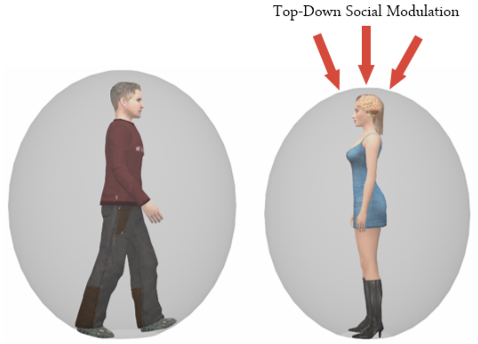


Figure 10.2: Stage 1. An approaching social stimulus. The illustration depicts attention orienting toward the social stimulus. This first stage is a precondition for subsequent social processing. The baseline size of peripersonal space is shown for each human model.



Top-Down Modulators

- How far away is the other person relative to my body?
- Am I comfortable with this social distance?
- Is this social distance appropriate?
- What is the purpose of this social encounter?
- What social behaviour is appropriate in this social context?

Figure 10.3: Stage 2. The illustration shows the second stage of social attention when top-down social processing influences later social behaviours. Top-down social processing shapes how the situation is perceived and informs the selection of appropriate social choice outcomes.

prerequisite necessary for top-down judgements.

Top-down processing directly shapes how the social situation is perceived (see Figure 10.3). Drawing from the research on top-down social processing outlined in the previous subsection, it is hypothesised that during this top-down stage the individual assesses the social situation to determine relative social distance and appropriate behaviour options. Initially, the individual uses low-level perceptual cues to identify the distance of the approaching person relative to their own body (Cléry et al., 2015; Graziano & Cooke, 2006). During assessment of social distance the role of peripersonal space is particularly important. Peripersonal space is a representational guide to identify what social interactions are possible as a social stimulus approaches the space near the individual's body (Coello, Bourgeois, & Iachini, 2012; De Vignemont & Iannetti, 2015; Iachini et al., 2014). As the other person continues to approach the individual, the individual recurrently assesses whether they are comfortable with the interpersonal distance. To make this assessment of social discomfort possible, the brain continues to supply rapid online sensory information.

Although judging the distance of other people relative to oneself feels like an automatic process, it is highly regulated by our beliefs and perceptions about a social encounter (Lloyd, 2009). At the latter

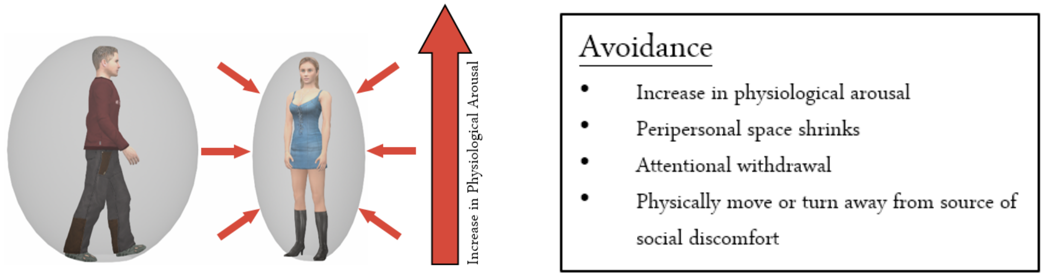


Figure 10.4: Stage 3. Choosing an appropriate social outcome (Option 1: Avoidance). The illustration shows an avoidance choice outcome stemming from stage 2. Avoidance is one of three possible choice behaviours and likely results from a social encounter that is perceived as negative. During the avoidance phase, an individual's physiological arousal increases to indicate when an approaching social stimulus enters one's personal space. Physiological arousal leads to the shrinking of peripersonal space and cues the individual to engage in avoidant behaviours. These avoidant behaviours include: physically moving or turning away, and withdrawing attention away from the other person towards oneself.

end of this stage, more complex assessments are made about the appropriateness of the interpersonal distance, purpose of the social encounter and suitable behavioural options. During these complex assessments other personality, contextual and emotional factors may influence whether the situation is perceived as a negative or positive social encounter (Aiello, 1987; Hayduk, 1983; Iachini et al., 2015; Iani et al., 2011; Perry et al., 2015, 2013). Depending on the outcome of these assessments the perception of the social situation shapes which behaviour the individual chooses to employ next. Based on theoretical and empirical knowledge from the experiments in this thesis, there are three possible choice outcomes: avoidance, seeking control and approaching a common space. These behaviours are not fixed and may change as the social situation naturally develops.

Avoidant behaviours have been thoroughly documented in Hall's (1966) observational research and subsequent studies using the stop-approach methodology (see Aiello, 1987; Hayduk, 1983, for a review). Some avoidant behaviours include physically moving, turning away or averting gaze from the source of social discomfort (Evans & Wener, 2007; Felipe & Sommer, 1966; Hall, 1966; Thompson et al., 2012). Personal space invasions have been shown to trigger an increase in physiological arousal (Aiello et al., 1977; McBride et al., 1965; Szpak, Loetscher, Churches, et al., 2015). It is hypothesised

Seek Control

- Establish 'my space'
- Focus on a solo task
- Size of peripersonal space depends on level of control

Figure 10.5: Stage 3. Choosing an appropriate social outcome (Option 2: Seeking Control). The illustration shows a second possible choice outcome on seeking control. In this case, individuals may try to establish an area that they feel is 'my space'. This area may be established by engaging in solo tasks so that one could feel more independent and control of the situation. The size of one's peripersonal space depends on the level of perceived control.

that systematic increases in arousal act as a physiological cue to indicate when an approaching social stimulus enters one's personal space. Moreover, an increase in physiological arousal is accompanied by shrinking peripersonal space (Perry et al., 2015) and attentional withdrawal away from the other person (Szpak, Loetscher, Churches, et al., 2015; Szpak, Nicholls, et al., 2016) (see Figure 10.4). The experiments in this thesis are the first to demonstrate the relationship between shifts in spatial attention and social discomfort induced by close interpersonal distances. The avoidance outcome is likely a choice behaviour for social situations that are perceived to be negative, such as crowded public spaces.

Seeking control is another choice behaviour that has been suggested to reduce feelings of social discomfort by making social intrusions more tolerable (see Figure 10.5). Preferred social distances have been related to feelings of control in the social situation (Aiello, 1987; Duke & Mullens, 1973; Heckel & Hiers, 1977; Nowicki & Duke, 1974). Research on crowding shows that engaging in solo activities such as listening to music, using smartphones or reading a book is prevalent in crowded situations (Hall, 1966; Hirsch & Thompson, 2011; Thompson et al., 2012). It has been suggested that people engage in solo activities to establish a privatise area that one feels is 'my space' (Lloyd et al., 2009; Thompson et al., 2012).Research on social discomfort and music demonstrates that music can reduce the size of one's personal space thereby allowing others to approach more closely (Tajadura-Jiménez et al., 2011).

Approach a Common Space

- Establish 'our space'
- Focus on a joint task
- Expand/merge peripersonal space
- Attentional attraction towards other

Figure 10.6: Stage 3. Choosing an appropriate social outcome (Option 3: Approach a Common Space). The illustration shows a third choice outcome that likely results from a social experiences that is perceived as positive. In this choice outcome, an individual will feel comfortable enough to approach a shared space where they can focus on a joint activity. It is hypothesised that attentional attraction occurs during this experience.

Experiments 1, 3, and 7 of this thesis reveal that that attentional withdrawal is no longer observed when two people are acting in the same social space and one person is given a different task. In Chapter Six, it was hypothesised that if an individual is given a different task, they could focus on the part of the task that is unique to them and therefore enable them to feel more independent and in control of the situation. In turn, feeling more in control of the situation reduces feelings of social discomfort in close interpersonal proximity. From these data, it is hypothesised that the size of one's peripersonal space depends on the level of perceived control.

Approaching a common space is a positive choice option that is likely reserved for social activities requiring shared goals. Although this thesis has not discussed approaching a common space with as much detail as avoidance and seeking control outcomes, there is also research that demonstrates positive aspects of close interpersonal distances (Neville & Reicher, 2011; Novelli et al., 2013). Ickes et al. (1982) show that if a positive relationship is developed between individuals, they choose a smaller interpersonal distances. Experiments 11 and 12 of this thesis showed that some individuals had lower physiological arousal in the together condition compared to the alone condition. It is possible that these individuals felt that the computer screen, which the Landmark was presented on, was a shared space where they both could 'play' the task together. In Experiments 11 and 12, these comfortable individuals demonstrated attentional attractional towards the other person.

Research on spatial-compatibility tasks show that when individuals engage in a joint activity a common perceptual area is established (see Sebanz et al., 2006, for a review). Teneggi et al. (2013) hypothesised that in a cooperative task peripersonal space expands and merges with the other's peripersonal space to create 'our space'. This hypothesis would be consistent with research showing that in order to carry out successful cooperative actions a high level of attention needs to be allocated towards others intentions and actions (Ruys & Aarts, 2010; Sebanz et al., 2006; Tomasello & Carpenter, 2007). In addition, this hypothesis further provides support for attentional attraction towards the other.

In summary, the model of social attention proposed that sensory information from an approaching social stimulus (stage 1) is assessed via top-down processing (stage 2) in order to select an appropriate social behavioural option (stage 3). Depending on how the social situation is assessed in stage 2, the individual chooses one of three behaviours: avoidance, seeking control and approaching a common space. Importantly, these choice behaviours are not fixed and can change or adapt as the social situation evolves. For example, an individual may choose to engage in a cooperative task with another person, only to discover that their partner is being unpleasant. As a consequence, the individual may then choose to engage in avoidant behaviour.

10.4 FUTURE DIRECTIONS

One particularly interesting research challenge that was not addressed in this thesis is the relationship between the size of peripersonal space and extent of attentional attraction-withdrawal. Although it has been hypothesised in this thesis that an expansion of attention is related to attentional attraction and that a contraction of space is related to attentional withdrawal, it may be particularly useful to identify how closely coupled peripersonal space and spatial attention are. This research question is particularly challenging as it is known to be difficult to accurately and directly measure peripersonal space (Cléry et al., 2015; De Vignemont & Iannetti, 2015). In addition, peripersonal space has been shown to contract and expand under different situations, which poses another difficulty in measuring peripersonal space.

Another interesting area for future research would be identifying the personality and contextual factors that may modulate attentional attraction-withdrawal. In Chapter 9, I tried to relate some personality factors, which had previously been implicated in preferred social distances, to shifts in spatial attention and I was unsuccessful. Even though attempts to find personality factors that modulate shifts in attention were unfruitful, research on preferred social distances have suggested other personality traits that may prove useful. These personality traits include locus of control, sensory sensitivity and dynamism (Heckel & Hiers, 1977; Iachini et al., 2015; Nowicki & Duke, 1974; Perry et al., 2015). Furthermore, studying spatial attention in patients with clinical anxiety could provide unique insights that could improve the proposed model of spatial attention.

10.5 Concluding remarks

This thesis has contributed several key findings that demonstrate another person can influence spatial attention. Firstly, experiments in this thesis demonstrate that another person in close interpersonal proximity can induce attentional withdrawal. Several experiments in this thesis were able to demonstrate attentional withdrawal suggesting that it is a reliable finding that could be an exciting avenue for future studies. Secondly, experiments in this thesis showed that shifts in attention behaved differently under different social contexts which is consistent with top-down modulation of social attention. Lastly, a model of social attention was proposed in this thesis that may provide a basis for future research to build upon.

References

Adair, J. C., Williamson, D. J., Jacobs, D. H., Na, D. L., & Heilman, K. M. (1995). Neglect of radial and vertical space: importance of the retinotopic reference frame. *Journal of Neurology, Neurosurgery & Psychiatry*, *58*(6), 724–728. doi: 10.1136/jnnp.58.6.724

Adolphs, R. (2003a). Cognitive neuroscience of human social behaviour. *Nature Reviews: Neuroscience*, *4*(3), 165–178. doi: 10.1038/nrn1056

Adolphs, R. (2003b). Is the human amygdala specialized for processing social information? *Annals of the New York Academy of Sciences*, *985*(1), 326–340. doi: 10.1111/j.1749-6632.2003.tb07091.x

Adolphs, R., Tranel, D., & Damasio, A. (1998). The human amygdala in social judgment. *Nature*, *393*(6684), 470–474. doi: 10.1038/30982

Aiello, J. R. (1987). Human spatial behavior. *Handbook of Environmental Psychology*, *1*, 389–504.

Aiello, J. R., Derisi, D. T., Epstein, Y. M., & Karlin, R. A. (1977). Crowding and the role of interpersonal distance preference. *Sociometry*, *40*(3), 271–282. doi: 10.2307/3033534

Aiello, J. R., & Douthitt, E. A. (2001). Social facilitation from triplett to electronic performance monitoring. *Group Dynamics: Theory, Research, and Practice*, *5*(3), 163–180. doi: 10.1037/1089-2699.5.3.163

Andersen, G. J., & Kramer, A. F. (1993). Limits of focused attention in three-dimensional space. *Perception & Psychophysics*, *53*(6), 658–667. doi: 10.3758/BF03211742

Argyle, M., & Dean, J. (1965). Eye-contact, distance and affiliation. *Sociometry*, *28*(3), 289–304. doi: 10.2307/2786027

Atmaca, S., Sebanz, N., & Knoblich, G. (2011). The joint flanker effect: sharing tasks with real and imagined co-actors. *Experimental Brain Research*, *211*(3-4), 371–385. doi: 10.1007/s00221-011-2709-9

Atmaca, S., Sebanz, N., Prinz, W., & Knoblich, G. (2008). Action co-representation: the joint snarc effect. *Social Neuroscience*, *3*(3-4), 410–420. doi: 10.1080/17470910801900908

Bach, D. R., Friston, K. J., & Dolan, R. J. (2010). Analytic measures for quantification of arousal from spontaneous skin conductance fluctuations. *International Journal of Psychophysiology*, *76*(1), 52–55. doi: 10.1016/j.ijpsycho.2010.01.011

Bailey, K. G., Caffrey, J. V., & Hartnett, J. J. (1976). Body size as implied threat: Effects on personal-space and person perception. *Perceptual and Motor Skills*, *43*(1), 223–230. doi: 10.2466/pms.1976.43.1.223

Bailey, K. G., Hartnett, J. J., & Gibson JR, F. W. (1972). Implied threat and the territorial factor in personal space. *Psychological Reports*, *30*(1), 263–270.

Baluch, F., & Itti, L. (2011). Mechanisms of top-down attention. *Trends in Neurosciences*, *34*(4), 210–224. doi: 10.1016/j.tins.2011.02.003

Baron, R. S. (1978). Invasions of personal space and helping: Mediating effects of invader's apparent need. *Journal of Experimental Social Psychology*, *14*(3), 304-–312. doi: doi:10.1016/0022-1031(78)90018-5

Baron, R. S. (1986). Distraction-conflict theory: Progress and problems. *Advances in Experimental Social Psychology*, *19*(1986), 1–40. doi: 10.1016/S0065-2601(08)60211-7

Barrett, A. M., Beversdorf, D. Q., Crucian, G. P., & Heilman, K. M. (1998). Neglect after right hemisphere stroke a smaller floodlight for distributed attention. *Neurology*, *51*(4), 972–978. doi: 10.1212/WNL.51.4.972

Barrett, A. M., & Burkholder, S. (2006). Monocular patching in subjects with right-hemisphere stroke affects perceptual-attentional bias. *Journal of Rehabilitation Research and Development*, *43*(3), 337–346. doi: 10.1682/JRRD.2005.01.0015

Barrett, A. M., Buxbaum, L. J., Coslett, H. B., Edwards, E., Heilman, K. M., Hillis, A. E., ... Robertson, I. H. (2006). Cognitive rehabilitation interventions for neglect and related disorders: moving from bench to bedside in stroke patients. *Journal of Cognitive Neuroscience*, *18*(7), 1223–1236. doi: 10.1162/jocn.2006.18.7.1223

Barrett, A. M., Crosson, J. B., Crucian, G. P., & Heilman, K. M. (2002). Far bias on the radial line bisection task: Measuring perceptual-attentional and motor-intentional bias in normal subjects. *Cortex*, *38*(5), 769–778. doi: 10.1016/S0010-9452(08)70043-1

Barrett, A. M., Crucian, G. P., Beversdorf, D. Q., & Heilman, K. M. (2001). Monocular patching may worsen sensory-attentional neglect: A case report. *Archives of Physical Medicine and Rehabilitation*, *82*(4), 516–518.

Barrett, A. M., Schwartz, R. L., Crucian, G. P., Kim, M., & Heilman, K. M. (2000). Attentional grasp in far extrapersonal space after thalamic infarction. *Neuropsychologia*, *38*(6), 778–784. doi: `10.1016/S0028-3932(99)00144-X`

Bartolomeo, P. (2014). *Attention disorders after right brain damage*. London: Springer.

Bartolomeo, P., De Schotten, M. T., & Doricchi, F. (2007). Left unilateral neglect as a disconnection syndrome. *Cerebral Cortex*, *17*(11), 2479–2490. doi: `10.1097/WCO.0b013e32816aa3a3`

Bayliss, A., di Pellegrino, G., & Tipper, S. (2004). Orienting of attention via observed eye gaze is head-centred. *Cognition*, *94*(1), 10. doi: `10.1016/j.cognition.2004.05.002`

Becchio, C., Sartori, L., & Castiello, U. (2010). Toward you: the social side of actions. *Current Directions in Psychological Science*, *19*(3), 183–188. doi: `10.1177/0963721410370131`

Bender, M. B., & Teuber, H.-L. (1948). Spatial organization of visual perception following injury to the brain. *Archives of Neurology & Psychiatry*, *59*(1), 39–62. doi: `10.1001/archneurpsyc.1948.02300360049004.`

Benwell, C. S. Y., Harvey, M., & Thut, G. (2014). On the neural origin of pseudoneglect: Eeg-correlates of shifts in line bisection performance with manipulation of line length. *NeuroImage*, *86*(1), 370–380. doi: `10.1016/j.neuroimage.2013.10.014`

Berti, A., & Frassinetti, F. (2000). When far becomes near: remapping of space by tool use. *Journal of Cognitive Neuroscience*, *12*(3), 415–420. doi: `10.1162/089892900562237`

Bisiach, E., Capitani, E., Colombo, A., & Spinnler, H. (1976). Halving a horizontal segment: A study of hemisphere-damaged patients with cerebral focal lesions. *Schweizer Archiv für Neurologie, Neurochirurgie und Psychiatrie*, *118*(2), 199–206.

Bisiach, E., Geminiani, G., Berti, A., & Rusconi, M. L. (1990). Perceptual and premotor factors of unilateral neglect. *Neurology*, *40*(8), 1278–1278. doi: `10.1212/WNL.40.8.1278`

Bisiach, E., & Luzzatti, C. (1978). Unilateral neglect of representational space. *Cortex*, *14*(1), 129–133.

Bisiach, E., Ricci, R., Lualdi, M., & Colombo, M. R. (1998). Perceptual and response bias in unilateral neglect: two modified versions of the milner landmark task. *Brain and Cognition*, *37*(3), 369–386. doi: 10.1006/brcg.1998.1003

Böckler, A., Knoblich, G., & Sebanz, N. (2012). Effects of a coactor's focus of attention on task performance. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(6), 1404–1415. doi: 10.1037/a0027523

Bonato, M., Priftis, K., Marenzi, R., & Zorzi, M. (2008). Modulation of hemispatial neglect by directional and numerical cues in the line bisection task. *Neuropsychologia*, *46*(2), 426–433. doi: 10.1016/j.neuropsychologia.2007.08.019

Bonnì, S., Mastropasqua, C., Bozzali, M., Caltagirone, C., & Koch, G. (2013). Theta burst stimulation improves visuo-spatial attention in a patient with traumatic brain injury. *Neurological Sciences*, *34*(11), 2053–2056. doi: 10.1007/s10072-013-1412-y

Boucsein, W. (2012). *Electrodermal activity* (2nd ed.). New York: Springer. doi: 10.1007/978-1-4614-1126-0

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: effects of hemispace on a tactile line bisection task. *Neuropsychologia*, *18*(4-5), 491–498. doi: 10.1016/0028-3932(80)90151-7

Brady, A. T., & Walker, M. B. (1978). Interpersonal distance as a function of situationally induced anxiety. *British Journal of Social and Clinical Psychology*, *17*(2), 127–133. doi: 10.1111/j.2044-8260.1978.tb00254.x

Brain, W. R. (1941). Visual disorientation with special reference to lesions of the right cerebral hemisphere. *Brain*, *64*(4), 244–272. doi: 10.1093/brain/64.4.244

Braine, L. G. (1968). Asymmetries of pattern perception observed in israelis. *Neuropsychologia*, *6*(1), 73–88. doi: 10.1016/0028-3932(68)90041-9

Bremmer, F., Schlack, A., Kaminiarz, A., & Hoffmann, K.-P. (2013). Encoding of movement in near extrapersonal space in primate area vip. *Frontiers in Behavioral Neuroscience*, *7*(8). doi: 10.3389/fnbeh.2013.00008

Brian Krupp, D., Robinson, B., & Elias, L. J. (2010). Free viewing perceptual asymmetry for distance judgments: objects in right hemispace are closer than they appear. *The International Journal of Neuroscience*, *120*(8), 580–582. doi: 10.3109/00207451003601201

Brozzoli, C., Gentile, G., Bergouignan, L., & Ehrsson, H. H. (2013). A shared representation of the space near oneself and others in the human premotor cortex. *Current Biology*, *23*(18), 1764–1768. doi: 10.1016/j.cub.2013.07.004

Bryden, M. P., & Rainey, C. A. (1963). Left-right differences in tachistoscopic recognition. *Journal of Experimental Psychology*, *66*(6), 568–571. doi: 10.1037/h0048905

Bull, M. (2005). No dead air! the ipod and the culture of mobile listening. *Leisure Studies*, *24*(4), 343–355. doi: 10.1080/0261436052000330447

Bultitude, J. H., & Aimola-Davies, A. M. (2006). Putting attention on the line: investigating the activation–orientation hypothesis of pseudoneglect. *Neuropsychologia*, *44*(10), 1849–1858. doi: 10.1016/j.neuropsychologia.2006.03.001

Butter, C. M. (1992). Effect of stimuli in right hemispace on left-sided neglect in a line cancellation task. *Neuropsychologia*, *30*(10), 859–864. doi: 10.1016/0028-3932(92)90031-G

Butter, C. M., Evans, J., Kirsch, N., & Kewman, D. (1989). Altitudinal neglect following traumatic brain injury: a case report. *Cortex*, *25*(1), 135–146. doi: 10.1212/WNL.38.2.277

Caggiano, V., Fogassi, L., Rizzolatti, G., Thier, P., & Casile, A. (2009). Mirror neurons differentially encode the peripersonal and extrapersonal space of monkeys. *Science*, *324*(5925), 403–406. doi: 10.1126/science.1166818

Callaway, E., & Dembo, D. (1958). Narrowed attention: A psychological phenomenon that accompanies a certain physiological change. *AMA Archives of Neurology & Psychiatry*, *79*(1), 74–90. doi: 10.1001/archneurpsyc.1958.02340010092008

Callaway, E., & Thompson, S. (1953). Sympathetic activity and perception: An approach to the relationships between autonomic activity and personality. *Psychosomatic Medicine*, *15*(5), 443–455.

Campbell, J. I. D., & Thompson, V. A. (2012). Morepower 6.0 for anova with relational confidence intervals and bayesian analysis. *Behavior Research Methods*, *44*(4), 1255–1265. doi: 10.3758/s13428-012-0186-0

Cardinali, L., Frassinetti, F., Brozzoli, C., Urquizar, C., Roy, A., & Farnè, A. (2009). Tool-use induces morphological updating of the body schema. *Current Biology*, *19*(12), R478–R479. doi: 10.1016/j.cub.2009.05.009

Cavézian, C., Valadao, D., Hurwitz, M., Saoud, M., & Danckert, J. (2012). Finding centre: ocular and fmri investigations of bisection and landmark task performance. *Brain Research*, *1437*(1), 89–103. doi: 10.1016/j.brainres.2011.12.002

Chao, L. L., & Knight, R. T. (1995). Human prefrontal lesions increase distractibility to irrelevant sensory inputs. *NeuroReport*, *6*(12), 1605–1610.

Chen, Q., Weidner, R., Vossel, S., Weiss, P. H., & Fink, G. R. (2012). Neural mechanisms of attentional reorienting in three-dimensional space. *The Journal of Neuroscience : the Official Journal of the Society for Neuroscience*, *32*(39), 13352–13362. doi: 10.1523/jneurosci.1772-12.2012

Chewning, J., Adair, J. C., Heilman, E. B., & Heilman, K. M. (1998). Attentional bias in normal subjects performing visual and tactile radial line bisections. *Neuropsychologia*, *36*(11), 1097–1101. doi: 10.1016/S0028-3932(98)00025-6

Chica, A. B., Bartolomeo, P., & Valero-Cabré, A. (2011). Dorsal and ventral parietal contributions to spatial orienting in the human brain. *The Journal of Neuroscience*, *31*(22), 8143–8149. doi: 10.1523/jneurosci.5463-10.2010

Chica, A. B., de Schotten, M. T., Toba, M., Malhotra, P., Lupiáñez, J., & Bartolomeo, P. (2012). Attention networks and their interactions after right-hemisphere damage. *Cortex*, *48*(6), 654–663. doi: 10.1016/j.cortex.2011.01.009

Chieffi, S., Iavarone, A., & Carlomagno, S. (2008). Effects of spatiotopic factors on bisection of radial lines. *Experimental Brain Research*, *189*(1), 129–132. doi: 10.1007/s00221-008-1458-x

Chokron, S., & Imbert, M. (1993). Egocentric reference and asymmetric perception of space. *Neuropsychologia*, *31*(3), 267–275. doi: 10.1016/0028-3932(93)90091-D

Chow, A., Gozli, D., & Pratt, J. (2014). Examining the locus of the attentional attraction effect. *Attention, Perception, & Psychophysics*, *76*(8), 2389–2397. doi: 10.3758/s13414-014-0724-1

Churches, O., Loetscher, T., Thomas, N., & Nicholls, M. E. R. (2015). Perceptual biases in the horizontal and vertical dimensions are driven by separate cognitive mechanisms. *Quarterly Journal of Experimental Psychology*, *(In press)*.

Çiçek, M., Deouell, L. Y., & Knight, R. T. (2009). Brain activity during landmark and line bisection tasks. *Frontiers in Human Neuroscience*, *3*(7), 1–8. doi: 10.3389/neuro.09.007.2009

Clark, C. R., Geffen, G. M., & Geffen, L. B. (1989). Catecholamines and the covert orientation of attention in humans. *Neuropsychologia*, *27*(2), 131–139. doi: 10.1016/0028-3932(89)90166-8

Cléry, J., Guipponi, O., Wardak, C., & Hamed, S. B. (2015). Neuronal bases of peripersonal and extrapersonal spaces, their plasticity and their dynamics: knowns and unknowns. *Neuropsychologia*, *70*, 313–326. doi: 10.1016/j.neuropsychologia.2014.10.022

Coello, Y., Bourgeois, J., & Iachini, T. (2012). Embodied perception of reachable space: how do we manage threatening objects? *Cognitive Processing*, *13*(1), 131–135. doi: 10.1007/s10339-012-0470-z

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Collaboration, O. S. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716. doi: 10.1126/science.aac4716

Colzato, L. S., de Bruijn, E. R. A., & Hommel, B. (2012). Up to "me" or up to "us"? the impact of self-construal priming on cognitive self-other integration. *Frontiers in Psychology*, *3:341*. doi: 10.3389/fpsyg.2012.00341

Committeri, G., Pitzalis, S., Galati, G., Patria, F., Pelle, G., Sabatini, U., … Pizzamiglio, L. (2007). Neural bases of personal and extrapersonal neglect in humans. *Brain*, *130*(2), 431–441. doi: 10.1093/brain/awl265

Cook, M. (1970). Experiments on orientation and proxemics. *Human Relations*, *23*(1), 61–76. doi: 10.1177/001872677002300107

Cooper, E. A., Burge, J., & Banks, M. S. (2011). The vertical horopter is not adaptable, but it may be adaptive. *Journal of Vision*, *11*(3), 1–19. doi: 10.1167/11.3.20

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201–215. doi: 10.1038/nrn755

Corbetta, M., & Shulman, G. L. (2011). Spatial neglect and attention networks. *Annual Review of Neuroscience*, *34*(1), 569–599. doi: 10.1146/annurev-neuro-061010-113731

Coren, S., Porac, C., & Duncan, P. (1979). A behaviorally validated self-report inventory to assess four types of lateral preference. *Journal of Clinical and Experimental Neuropsychology*, *1*(1), 55–64. doi: 10.1080/01688637908401098

Costa, P. T., & McCrae, R. R. (1992). Normal personality assessment in clinical practice: The neo personality inventory. *Psychological Assessment*, *4*(1), 5–13. doi: `10.1037/1040-3590.4.1.5`

Costantini, M., Ambrosini, E., Tieri, G., Sinigaglia, C., & Committeri, G. (2010). Where does an object trigger an action? an investigation about affordances in space. *Experimental Brain Research*, *207*(1-2), 95–103. doi: `10.1007/s00221-010-2435-8`

Coull, J. T. (1998). Neural correlates of attention and arousal: insights from electrophysiology, functional neuroimaging and psychopharmacology. *Progress in Neurobiology*, *55*(4), 343–361.

Cowey, A., Small, M., & Ellis, S. (1994). Left visuo-spatial neglect can be worse in far than in near space. *Neuropsychologia*, *32*(9), 1059–1066. doi: `10.1016/0028-3932(94)90152-X`

Darling, S., Logie, R., & Della Sala, S. (2012). Representational pseudoneglect in line bisection. *Psychonomic Bulletin & Review*, *19*(5), 879–883. doi: `10.3758/s13423-012-0285-z`

De Schotten, M. T., Dell'Acqua, F., Forkel, S. J., Simmons, A., Vergani, F., Murphy, D. G. M., & Catani, M. (2011). A lateralized brain network for visuospatial attention. *Nature Neuroscience*, *14*(10), 1245–1246. doi: `10.1038/nn.2905`

De Vignemont, F. (2014). Shared body representations and the 'whose'system. *Neuropsychologia*, *55*(1), 128–136. doi: `10.1016/j.neuropsychologia.2013.08.013`

De Vignemont, F., & Iannetti, G. D. (2015). How many peripersonal spaces? *Neuropsychologia*, *70*(SI), 327–334. doi: `10.1016/j.neuropsychologia.2014.11.018`

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2013). The (not so) social simon effect: A referential coding account. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1248–1260. doi: `10.1037/a0031031`

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2014). The joint flanker effect: Less social than previously thought. *Psychonomic Bulletin & Review*, *21*(5), 1224–1230. doi: `10.3758/s13423-014-0583-8`

Doricchi, F., de Schotten, M. T., Tomaiuolo, F., & Bartolomeo, P. (2008). White matter (dis) connections and gray matter (dys) functions in visual neglect: gaining insights into the brain networks of spatial awareness. *Cortex*, *44*(8), 983–995. doi: `10.1016/j.cortex.2008.03.006`

Doricchi, F., & Tomaiuolo, F. (2003). The anatomy of neglect without hemianopia: a key role for parietal–frontal disconnection? *NeuroReport*, *14*(17), 2239–2243.

Downing, P. E., Jiang, Y., Shuman, M., & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science*, *293*(5539), 2470–2473. doi: 10.1126/science.1063414

Drain, M., & Reuter-Lorenz, P. A. (1996). Vertical orienting control: Evidence for attentional bias and" neglect" in the intact brain. *Journal of Experimental Psychology: General*, *125*(2), 139–158. doi: 10.1037/0096-3445.125.2.139

Driver, J., & Mattingley, J. B. (1998). Parietal neglect and visual awareness. *Nature Neuroscience*, *1*(1), 17–22. doi: 10.1038/217

Duecker, F., & Sack, A. T. (2014). The hybrid model of attentional control: New insights into hemispheric asymmetries inferred from tms research. *Neuropsychologia*, *74*(SI), 21–29. doi: 10.1016/j.neuropsychologia.2014.11.023

Duke, M. P., & Mullens, C. (1973). Preferred interpersonal distance as a function of locus of control orientation in chronic schizophrenics, nonschizophrenic patients, and normals. *Journal of Consulting and Clinical Psychology*, *41*(2), 230–234. doi: 10.1037/h0035141

Duke, M. P., & Nowicki, S. (1972). A new measure and social-learning model for interpersonal distance. *Journal of Experimental Research in Personality*, *6*(2-3), 119–132.

Durand, J.-B., Nelissen, K., Joly, O., Wardak, C., Todd, J. T., Norman, J. F., ... Orban, G. A. (2007). Anterior regions of monkey parietal cortex process visual 3d shape. *Neuron*, *55*(3), 493–505. doi: 10.1016/j.neuron.2007.06.040

Durgin, F. H., Doyle, E., & Egan, L. (2008). Upper-left gaze bias reveals competing search strategies in a reverse stroop task. *Acta Psychologica*, *127*(2), 428–448. doi: 10.1016/j.actpsy.2007.08.007

Efran, M. G., & Cheyne, J. A. (1973). Shared space: The co-operative control of spatial areas by two interacting individuals. *Canadian Journal of Behavioural Science*, *5*(3), 201–210. doi: 10.1037/h0082345

Eskes, G. A., Butler, B., McDonald, A., Harrison, E. R., & Phillips, S. J. (2003). Limb activation effects in hemispatial neglect. *Archives of Physical Medicine and Rehabilitation*, *84*(3), 323–328. doi: 10.1053/apmr.2003.50012

Evans, G. W., & Howard, R. B. (1973). Personal space. *Psychological Bulletin*, *80*(4), 334–344. doi: 10.1037/h0034946

Evans, G. W., & Wener, R. E. (2007). Crowding and personal space invasion on the train: Please don't make me sit in the middle. *Journal of Environmental Psychology*, *27*(1), 90–94. doi: 10.1016/j.jenvp.2006.10.002

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: a magnetic stimulation study. *Journal of Neurophysiology*, *73*(6), 2608–2611.

Farnè, A., & Làdavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *NeuroReport*, *11*(8), 1645–1649.

Felipe, N. J., & Sommer, R. (1966). Invasions of personal space. *Social Problems*, *14*(2), 206–214. doi: 10.1525/sp.1966.14.2.03a00080

Feng, C., Jiang, Y., & He, S. (2007). Horizontal and vertical asymmetry in visual spatial crowding effects. *Journal of Vision*, *7*(2), 13. doi: 10.1167/7.2.13

Ferber, S., & Karnath, H. (2001). How to assess spatial neglect-line bisection or cancellation tasks? *Journal of Clinical and Experimental Neuropsychology*, *23*(5), 599–607. doi: 10.1076/jcen.23.5.599.1243

Fernandez-Duque, D., & Posner, M. I. (1997). Relating the mechanisms of orienting and alerting. *Neuropsychologia*, *35*(4), 477–486. doi: 10.1016/S0028-3932(96)00103-0

Ferraro, L., Iani, C., Mariani, M., Milanese, N., & Rubichi, S. (2011). Facilitation and interference components in the joint simon task. *Experimental Brain Research*, *211*(3-4), 337–343. doi: 10.1007/s00221-011-2711-2

Fini, C., Brass, M., & Committeri, G. (2015). Social scaling of extrapersonal space: Target objects are judged as closer when the reference frame is a human agent with available movement potentialities. *Cognition*, *134*(1), 50–56. doi: 10.1016/j.conb.2008.08.001

Fini, C., Costantini, M., & Committeri, G. (2014). Sharing space: the presence of other bodies extends the space judged as near. *PloS One*, *9*(12), e114719. doi: 10.1371/journal.pone.0114719

Fink, G. R., Marshall, J. C., Weiss, P. H., Toni, I., & Zilles, K. (2002). Task instructions influence the cognitive strategies involved in line bisection judgements: evidence from modulated neural mechanisms revealed by fmri. *Neuropsychologia*, *40*(2), 119–130. doi: 10.1016/S0028-3932(01)00087-2

Fink, G. R., Marshall, J. C., Weiss, P. H., & Zilles, K. (2001). The neural basis of vertical and horizontal line bisection judgments: an fmri study of normal volunteers. *NeuroImage*, *14*(1), S59–S67. doi: 10.1006/nimg.2001.0819

Fisher, J. D., & Byrne, D. (1975). Too close for comfort: Sex differences in response to invasions of personal space. *Journal of Personality and Social Psychology*, *32*(1), 15–21. doi: 10.1037/h0076837

Foxe, J. J., McCourt, M. E., & Javitt, D. C. (2003). Right hemisphere control of visuospatial attention: line-bisection judgments evaluated with high-density electrical mapping and source analysis. *NeuroImage*, *19*(3), 710–726. doi: 10.1016/S1053-8119(03)00057-0

Frassinetti, F., Rossi, M., & Ladavas, E. (2001). Passive limb movements improve visual neglect. *Neuropsychologia*, *39*(7), 725–733. doi: 10.1016/S0028-3932(00)00156-1

Fresco, D. M., Coles, M. E., Heimberg, R. G., Liebowitz, M. R., Hami, S., Stein, M. B., & Goetz, D. (2001). The Liebowitz social anxiety scale: a comparison of the psychometric properties of self-report and clinician-administered formats. *Psychological Medicine*, *31*(6), 1025–1035. doi: 10.1017/S0033291701004056

Fried, M. L., & DeFazio, V. J. (1974). Territoriality and boundary conflicts in the subway. *Psychiatry: Journal for the Study of Interpersonal Processes*, *37*(1), 47–59.

Frith, C. D. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *367*(1599), 2213–2223. doi: 10.1098/rstb.2012.0123.

Gallese, V., Keysers, C., & Rizzolatti, G. (2004). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences*, *8*(9), 396–403. doi: 10.1016/j.tics.2004.07.002

Gallivan, J. P., Cavina-Pratesi, C., & Culham, J. C. (2009). Is that within reach? fmri reveals that the human superior parieto-occipital cortex encodes objects reachable by the hand. *The Journal of Neuroscience*, *29*(14), 4381–4391. doi: 10.1523/jneurosci.0377-09.2009

Gamberini, L., Seraglia, B., & Priftis, K. (2008). Processing of peripersonal and extrapersonal space using tools: Evidence from visual line bisection in real and virtual environments. *Neuropsychologia*, *46*(5), 1298–1304. doi: 10.1016/j.neuropsychologia.2007.12.016

Garza, J. P., Eslinger, P. J., & Barrett, A. M. (2008). Perceptual-attentional and motor-intentional bias in near and far space. *Brain and Cognition*, *68*(1), 9–14. doi: 10.1016/j.bandc.2008.02.006

Gauthier, L., Dehaut, F., & Joanette, Y. (1989). The bells test: a quantitative and qualitative test for visual neglect. *International Journal of Clinical Neuropsychology*, *11*(2), 49–54.

Geldmacher, D. S., & Heilman, K. M. (1994). Visual field influence on radial line bisection. *Brain and Cognition*, *26*(1), 65–72. doi: 10.1006/brcg.1994.1042

Girgus, J. S., & Coren, S. (1975). Depth cues and constancy scaling in the horizontal-vertical illusion: The bisection error. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *29*(1), 59–65. doi: 10.1037/h0082021

Gold, M., Shuren, J., & Heilman, K. M. (1994). Proximal intentional neglect: a case study. *Journal of Neurology, Neurosurgery & Psychiatry*, *57*(11), 1395–1400. doi: 10.1136/jnnp.57.11.1395

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, *15*(1), 20–25. doi: 10.1016/0166-2236(92)90344-8

Graff-Radford, J., Crucian, G. P., & Heilman, K. M. (2006). The right arm likes to be close. *Cortex*, *42*(5), 699–704. doi: 10.1016/s0010-9452(08)70407-6

Graziano, M. S. A., & Cooke, D. F. (2006). Parieto-frontal interactions, personal space, and defensive behavior. *Neuropsychologia*, *44*(6), 845–859. doi: 10.1016/j.neuropsychologia.2005.09.009

Gregory, R. L. (1963). Distortion of visual space as inappropriate constancy scaling. *Nature*, *199*(4894), 678–680. doi: 10.1038/199678a0

Grimsen, C., Hildebrandt, H., & Fahle, M. (2008). Dissociation of egocentric and allocentric coding of space in visual search after right middle cerebral artery stroke. *Neuropsychologia*, *46*(3), 902–914.

Gross, C. G., & Graziano, M. S. A. (1995). Review: Multiple representations of space in the brain. *The Neuroscientist*, *1*(1), 43–50. doi: 10.1177/107385849500100107

Guagnano, D., Rusconi, E., & Umiltà, C. A. (2010). Sharing a task or sharing space? on the effect of the confederate in action coding in a detection task. *Cognition*, *114*(3), 348–355. doi: 10.1016/j.cognition.2009.10.008

Hach, S., & Schütz-Bosbach, S. (2012). Touching base: The effect of participant and stimulus modulation factors on a haptic line bisection task. *Laterality: Asymmetries of Body, Brain and Cognition*, *17*(2), 180–201. doi: 10.1080/1357650X.2010.551128

Hall, E. T. (1966). *The hidden dimension*. Garden City, New York: Doubleday.

Halligan, P. W., Fink, G. R., Marshall, J. C., & Vallar, G. (2003). Spatial cognition: evidence from visual neglect. *Trends in Cognitive Sciences*, *7*(3), 125–133. doi: `10.1016/S1364-6613(03)00032-9`

Halligan, P. W., & Marshall, J. C. (1989). Is neglect (only) lateral? a quadrant analysis of line cancellation. *Journal of Clinical and Experimental Neuropsychology*, *11*(6), 793–798. doi: `10.1080/01688638908400936`

Halligan, P. W., & Marshall, J. C. (1993). The bisection of horizontal and radial lines: a case study of normal controls and ten patients with left visuospatial neglect. *International Journal of Neuroscience*, *70*(3-4), 149–167.

Halligan, P. W., & Marshall, J. C. (1995). Lateral and radial neglect as a function of spatial position: a case study. *Neuropsychologia*, *33*(12), 1697–1702. doi: `10.1016/0028-3932(95)00041-0`

Halligan, P. W., & Marshall, J. C. (1998). Neglect of awareness. *Consciousness and Cognition*, *7*(3), 356–380. doi: `10.1006/ccog.1998.0362`

Halsband, U., Gruhn, S., & Ettlinger, G. (1985). Unilateral spatial neglect and defective performance in one half of space. *International Journal of Neuroscience*, *28*(3-4), 173–195. doi: `10.3109/00207458508985388`

Harris, A. J. (1999). Cortical origin of pathological pain. *The Lancet*, *354*(9188), 1464–1466. doi: `10.1016/S0140-6736(99)05003-5`

Harris, J. M., Chopin, A., Zeiner, K., & Hibbard, P. B. (2012). Perception of relative depth interval: systematic biases in perceived depth. *The Quarterly Journal of Experimental Psychology*, *65*(1), 73–91. doi: `10.1080/17470218.2011.589520`

Hartman-Maeir, A., & Katz, N. (1995). Validity of the behavioral inattention test (bit): relationships with functional tasks. *American Journal of Occupational Therapy*, *49*(6), 507–516. doi: `10.5014/ajot.49.6.507`

Harvey, M. (2004). Perceptual and premotor neglect: Is there an ideal task to categorise patients? *Cortex*, *40*(2), 323–328. doi: `10.1016/S0010-9452(08)70127-8`

Hayduk, L. A. (1981). The permeability of personal space. *Canadian Journal of Behavioural Science*, *13*(3), 274–287. doi: `10.1037/h0081182`

Hayduk, L. A. (1983). Personal space: where we now stand? *Psychological Bulletin*, *94*(2), 293–335. doi: 10.1037/0033-2909.94.2.293

Heber, I. A., Siebertz, S., Wolter, M., Kuhlen, T., & Fimm, B. (2010). Horizontal and vertical pseudoneglect in peri-and extrapersonal space. *Brain and Cognition*, *73*(3), 160–166. doi: 10.1016/j.bandc.2010.04.006

Heckel, R. V., & Hiers, J. M. (1977). Social distance and locus of control. *Journal of Clinical Psychology*, *33*(2), 469–471. doi: 10.1002/1097-4679(197704)33:2<469::AID-JCLP2270330229>3.0.CO;2-J

Heed, T., Habets, B., Sebanz, N., & Knoblich, G. (2010). Others' actions reduce crossmodal integration in peripersonal space. *Current Biology*, *20*(15), 1345–1349. doi: 10.1016/j.cub.2010.05.068

Heilman, K. M. (1995). Attentional asymmetries. In K. Hugdahl & R. J. Davidson (Eds.), *Brain asymmetry* (p. 217-234). Cambridge, Massachusetts: The MIT Press.

Heilman, K. M., Bowers, D., Coslett, H. B., Whelan, H., & Watson, R. T. (1985). Directional hypokinesia prolonged reaction times for leftward movements in patients with right hemisphere lesions and neglect. *Neurology*, *35*(6), 855–855. doi: 10.1212/WNL.35.6.855

Heilman, K. M., Chatterjee, A., & Doty, L. C. (1995). Hemispheric asymmetries of near-far spatial attention. *Neuropsychology*, *9*(1), 58–61. doi: 10.1037/0894-4105.9.1.58

Heilman, K. M., & Valenstein, E. (1979). Mechanisms underlying hemispatial neglect. *Annals of Neurology*, *5*(2), 166–170. doi: 10.1002/ana.410050210

Heilman, K. M., & Van Den Abell, T. (1980). Right hemisphere dominance for attention the mechanism underlying hemispheric asymmetries of inattention (neglect). *Neurology*, *30*(3), 327–327. doi: 10.1212/WNL.30.3.327

Heimberg, R. G., Horner, K. J., Juster, H. R., Safren, S. A., Brown, E. J., Schneier, F. R., & Liebowitz, M. R. (1999). Psychometric properties of the Liebowitz social anxiety scale. *Psychological Medicine*, *29*(1), 199–212.

Hirsch, L., & Thompson, K. (2011). I can sit but i'd rather stand: Commuter's experience of crowdedness and fellow passenger behaviour in carriages on australian metropolitan trains. conference paper delivered at the 34th australisian transport research forum (atrf) proceedings held on 28-30 september 2011 in adelaide, australia.

Hommel, B. (1993). The role of attention for the simon effect. *Psychological Research*, *55*(3), 208–222. doi: 10.1007/BF00419608

Hommel, B., Colzato, L., & van den Wildenberg, W. (2009). How social are task representations? *Psychological Science*, *20*(7), 794–798. doi: 10.1111/j.1467-9280.2009.02367.x

Howard, I. P., & Rogers, B. J. (2012). *Perceiving in depth, volume 2: Stereoscopic vision.* New York: Oxford University Press.

Huguet, P., Galvaing, M. P., Monteil, J. M., & Dumas, F. (1999). Social presence effects in the stroop task: further evidence for an attentional view of social facilitation. *Journal of Personality and Social Psychology*, *77*(5), 1011–1025. doi: 10.1037/0022-3514.77.5.1011

Hurwitz, M., Valadao, D., & Danckert, J. (2011). Static versus dynamic judgments of spatial extent. *Experimental Brain Research*, *209*(2), 271–286. doi: 10.1007/s00221-011-2539-9

Hüttermann, S., & Memmert, D. (2014). The influence of motivational and mood states on visual attention: A quantification of systematic differences and casual changes in subjects' focus of attention. *Cognition and Emotion*, *29*(3), 471–483. doi: 10.1080/02699931.2014.920767

Hüttermann, S., Memmert, D., Simons, D., & Bock, O. (2013). Fixation strategy influences the ability to focus attention on two spatially separate objects. *PloS One*, *8*(6), e65673. doi: 10.1371/journal.pone.0065673

Hüttermann, S., Memmert, D., & Simons, D. J. (2014). The size and shape of the attentional "spotlight" varies with differences in sports expertise. *Journal of Experimental Psychology: Applied*, *20*(2), 147–157. doi: 10.1037/xap0000012

Iachini, T., Coello, Y., Frassinetti, F., & Ruggiero, G. (2014). Body space in social interactions: A comparison of reaching and comfort distance in immersive virtual reality. *PLoS One*, *9*(11), e111511. doi: 10.1371/journal.pone.0111511

Iachini, T., Ruggiero, G., Ruotolo, F., di Cola, A. S., & Senese, V. P. (2015). The influence of anxiety and personality factors on comfort and reachability space: a correlational study. *Cognitive Processing*, *16*(1), 255–258. doi: 10.1007/s10339-015-0717-6

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., & Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Experimental Brain Research*, *211*(3-4), 439–445. doi: 10.1007/s00221-011-2651-x

Ickes, W., Patterson, M. L., Rajecki, D. W., & Tanford, S. (1982). Behavioral and cognitive consequences of reciprocal versus compensatory responses to preinteraction expectancies. *Social Cognition*, *1*(2), 160–190. doi: 10.1521/soco.1982.1.2.160

Iriki, A., Tanaka, M., & Iwamura, Y. (1996). Coding of modified body schema during tool use by macaque postcentral neurones. *NeuroReport*, *7*(14), 2325–2330. doi: 10.1097/00001756-199610020-00010

Ishida, H., Nakajima, K., Inase, M., & Murata, A. (2010). Shared mapping of own and others' bodies in visuotactile bimodal area of monkey parietal cortex. *Journal of Cognitive Neuroscience*, *22*(1), 83–96. doi: 10.1162/jocn.2009.21185

Jeong, Y., Drago, V., & Heilman, K. M. (2006). Radial character-line bisection. *Cognitive and Behavioral Neurology*, *19*(2), 105–108. doi: 10.1097/01.wnn.0000210694.97931.1e

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, *38*(1), 93–110. doi: 10.1016/S0028-3932(99)00045-7

Julesz, B. (1971). *Foundations of cyclopean perception* (Vol. xiv). Oxford, England: The University of Chicago Press.

Kaitz, M., Bar-Haim, Y., Lehrer, M., & Grossman, E. (2004). Adult attachment style and interpersonal distance. *Attachment & Human Development*, *6*(3), 285–304. doi: 10.1080/14616730412331281520

Karnath, H.-O. (2001). New insights into the functions of the superior temporal cortex. *Nature Reviews Neuroscience*, *2*(8), 568–576. doi: 10.1038/35086057

Karnath, H.-O., Ferber, S., & Himmelbach, M. (2001). Spatial awareness is a function of the temporal not the posterior parietal lobe. *Nature*, *411*(6840), 950–953. doi: 10.1038/35082075

Karnath, H.-O., Rorden, C., & Ticini, L. F. (2009). Damage to white matter fiber tracts in acute spatial neglect. *Cerebral Cortex*, *19*(10), 2331–2337.

Kay, A. C., Wheeler, S. C., Bargh, J. A., & Ross, L. (2004). Material priming: The influence of mundane physical objects on situational construal and competitive behavioral choice. *Organizational Behavior and Human Decision Processes*, *95*(1), 83–96. doi: 10.1016/j.obhdp.2004.06.003

Kennedy, D. P., & Adolphs, R. (2014). Violations of personal space by individuals with autism spectrum disorder. *PLoS One*, *9*(8), e103369. doi: `10.1371/journal.pone.0103369`

Kennedy, D. P., Gläscher, J., Tyszka, J. M., & Adolphs, R. (2009). Personal space regulation by the human amygdala. *Nature Neuroscience*, *12*(10), 1226–1227. doi: `10.1038/nn.2381`

Kerkhoff, G. (2001). Spatial hemineglect in humans. *Progress in Neurobiology*, *63*(1), 1–27. doi: `10.1016/S0301-0082(00)00028-9`

Kim, H., Kwon, S., Wu, S., & Sohn, K. (2014). Why do passengers choose a specific car of a metro train during the morning peak hours? *Transportation Research Part A: Policy and Practice*, *61*(1), 249–258. doi: `10.1037/h0082345`

Kimura, D. (1961). Cerebral dominance and the perception of verbal stimuli. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *15*(3), 166–171. doi: `10.1037/h0083219`

Kimura, D. (1966). Dual functional asymmetry of the brain in visual perception. *Neuropsychologia*, *4*(3), 275–285. doi: `10.1016/0028-3932(66)90033-9`

Kingdom, F. A. A., & Prins, N. (2010). *Psychophysics: a practical introduction*. London: Academic Press.

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica*, *33*(1), 193–201. doi: `10.1016/0001-6918(70)90132-0`

Kinsbourne, M. (1972). Eye and head turning indicates cerebral lateralization. *Science*, *176*(4034), 539–541. doi: `10.1126/science.176.4034.539`

Kinsbourne, M. (1982). Hemispheric specialization and the growth of human understanding. *American Psychologist*, *37*(4), 411–420. doi: `10.1037/0003-066X.37.4.411`

Klauer, K. C., Herfordt, J., & Voss, A. (2008). Social presence effects on the stroop task: Boundary conditions and an alternative account. *Journal of Experimental Social Psychology*, *44*(2), 469–476. doi: `10.1016/j.jesp.2007.02.009`

Knoblich, G., Butterfill, S., & Sebanz, N. (2011). Psychological research on joint action: theory and data. In B. H. Ross (Ed.), *The psychology of learning and motivation* (pp. 59–101). San Diego: Elsevier. doi: `10.1016/b978-0-12-385527-5.00003-6`

Koch, G., Bonni, S., Giacobbe, V., Bucchi, G., Basile, B., Lupo, F., … Caltagirone, C. (2012). Theta-burst stimulation of the left hemisphere accelerates recovery of hemispatial neglect. *Neurology*, *78*(1), 24–30. doi: 10.1212/WNL.0b013e31823ed08f

Koch, G., Oliveri, M., Cheeran, B., Ruge, D., Gerfo, E. L., Salerno, S., … others (2008). Hyper-excitability of parietal-motor functional connections in the intact left-hemisphere of patients with neglect. *Brain*, *131*(12), 3147–3155. doi: 10.1093/brain/awn273

Kristjánsson, Á., Vuilleumier, P., Malhotra, P., Husain, M., & Driver, J. (2005). Priming of color and position during visual search in unilateral spatial neglect. *Journal of Cognitive Neuroscience*, *17*(6), 859–873. doi: 10.1162/0898929054021148

Künnapas, T. M. (1957). The vertical-horizontal illusion and the visual field. *Journal of Experimental Psychology*, *53*(6), 405–407. doi: 10.1037/h0048637

Làdavas, E., Carletti, M., & Gori, G. (1994). Automatic and voluntary orienting of attention in patients with visual neglect: Horizontal and vertical dimensions. *Neuropsychologia*, *32*(10), 1195–1208. doi: 10.1016/0028-3932(94)90102-3

Langton, S. R., Watt, R. J., & Bruce, I. (2000). Do the eyes have it? cues to the direction of social attention. *Trends in Cognitive Sciences*, *4*(2), 50–59. doi: 10.1016/S1364-6613(99)01436-9

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences*, *9*(2), 75–82. doi: 10.1016/j.tics.2004.12.004

Le, A., Stojanoski, B. B., Khan, S., Keough, M., & Niemeier, M. (2015). A toggle switch of visual awareness? *Cortex*, *64*(1), 169–178. doi: 10.1016/j.cortex.2014.09.015

Learmonth, G., Gallagher, A., Gibson, J., Thut, G., & Harvey, M. (2015). Intra-and inter-task reliability of spatial attention measures in pseudoneglect. *PloS One*, *10*(9), e0138379. doi: 10.1371/journal.pone.0138379

Leggett, N. C., Thomas, N. A., Loetscher, T., & Nicholls, M. E. R. (2013). The life of p:"just significant" results are on the rise. *The Quarterly Journal of Experimental Psychology*, *66*(12), 2303–2309. doi: 10.1080/17470218.2013.863371

Leonards, U., Stone, S., & Mohr, C. (2013). Line bisection by eye and by hand reveal opposite biases. *Experimental Brain Research*, *228*(4), 513–525. doi: 10.1007/s00221-013-3583-4

Levine, B., Fujiwara, E., O'connor, C., Richard, N., Kovacevic, N., Mandic, M., ... others (2006). In vivo characterization of traumatic brain injury neuropathology with structural and functional neuroimaging. *Journal of Neurotrauma*, *23*(10), 1396–1411. doi: `10.1089/neu.2006.23.1396`

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*. doi: `10.1016/j.jesp.2013.03.013`

Liebowitz, M. R. (1987). Social phobia. In D. Klein (Ed.), *Anxiety* (Vol. 22, p. 141–-173). Basel: Karger.

Lloyd, D. M. (2009). The space between us: a neurophilosophical framework for the investigation of human interpersonal space. *Neuroscience and Biobehavioral Reviews*, *33*(3), 297–304. doi: `10.1016/j.neubiorev.2008.09.007`

Lloyd, D. M., Coates, A., Knopp, J., Oram, A., & Rowbotham, S. (2009). Don't stand so close to me:the effect of auditory input on interpersonal space. *Perception*, *38*(4). doi: `10.1068/p6317`

Lockard, J. S., Mcvittie, R. I., & Isaac, L. M. (1977). Functional significance of the affiliative smile. *Bulletin of the Psychonomic Society*, *9*(5), 367–370. doi: `10.3758/BF03337025`

Loetscher, T., Nicholls, M. E. R., Brodtmann, A., Thomas, N. A., & Brugger, P. (2012). Disentangling input and output-related components of spatial neglect. *Frontiers in Human Neuroscience*, *6*(176), 1–11. doi: `10.3389/fnhum.2012.00176`

Loftus, A. M., & Nicholls, M. E. R. (2012). Testing the activation–orientation account of spatial attentional asymmetries using transcranial direct current stimulation. *Neuropsychologia*, *50*(11), 2573–2576. doi: `10.1016/j.neuropsychologia.2012.07.003`

Loftus, A. M., Nicholls, M. E. R., Mattingley, J. B., & Bradshaw, J. L. (2008). Left to right: representational biases for numbers and the effect of visuomotor adaptation. *Cognition*, *107*(3), 1048–1058. doi: `10.1016/j.cognition.2007.09.007`

Longo, M. R., & Lourenco, S. F. (2006). On the nature of near space: Effects of tool use and the transition to far space. *Neuropsychologia*, *44*(6), 977–981. doi: `10.1016/j.neuropsychologia.2005.09.003`

Longo, M. R., & Lourenco, S. F. (2007). Space perception and body morphology: extent of near space scales with arm length. *Experimental Brain Research*, *177*(2), 285–290. doi: `10.1007/s00221-007-0855-x`

Longo, M. R., Trippier, S., Vagnoni, E., & Lourenco, S. F. (2015). Right hemisphere control of visuospatial attention in near space. *Neuropsychologia*, *70*(SI), 350–357. doi: `10.1016/j.neuropsychologia.2014.10.035`

Loughnane, G. M., Shanley, J. P., Lalor, E. C., & O'Connell, R. G. (2015). Behavioral and electrophysiological evidence of opposing lateral visuospatial asymmetries in the upper and lower visual fields. *Cortex*, *63*(1), 220–231. doi: `10.1016/j.cortex.2014.09.003`

Lourenco, S. F., & Longo, M. R. (2009). The plasticity of near space: evidence for contraction. *Cognition*, *112*(3), 451–456. doi: `10.1016/j.cognition.2009.05.011`

Lourenco, S. F., Longo, M. R., & Pathman, T. (2011). Near space and its relation to claustrophobic fear. *Cognition*, *119*(3), 448–453. doi: `10.1016/j.cognition.2011.02.009`

Lyman, S. M., & Scott, M. B. (1967). Territoriality: A neglected sociological dimension. *Social Problems*, *15*(2), 236–249. doi: `10.1525/sp.1967.15.2.03a00090`

Mackworth, N. H. (1965). Visual noise causes tunnel vision. *Psychonomic Science*, *3*(1-12). doi: `10.3758/BF03343023`

Maister, L., Cardini, F., Zamariola, G., Serino, A., & Tsakiris, M. (2015). Your place or mine: Shared sensory experiences elicit a remapping of peripersonal space. *Neuropsychologia*, *70*(1), 455–461. doi: `10.1016/j.cub.2013.01.043`

Malhotra, P. A., Parton, A. D., Greenwood, R., & Husain, M. (2006). Noradrenergic modulation of space exploration in visual neglect. *Annals of Neurology*, *59*(1), 186–190. doi: `10.1002/ana.20701`

Manera, V., Becchio, C., Cavallo, A., Sartori, L., & Castiello, U. (2011). Cooperation or competition? discriminating between social intentions by observing prehensile movements. *Experimental Brain Research*, *211*(3-4), 547–556. doi: `10.1007/s00221-011-2649-4`

Mark, V. W. (2003). Acute versus chronic functional aspects of unilateral spatial neglect. *Frontiers in Bioscience*, *8*, e172–189. doi: `10.2741/973`

Mark, V. W., & Heilman, K. M. (1997). Diagonal neglect on cancellation. *Neuropsychologia*, *35*(11), 1425–1436.

Mark, V. W., & Heilman, K. M. (1998). Diagonal spatial neglect. *Journal of Neurology, Neurosurgery & Psychiatry*, *65*(3), 348–352.

Marois, R., Leung, H.-C., & Gore, J. C. (2000). A stimulus-driven approach to object identity and location processing in the human brain. *Neuron*, *25*(3), 717–728. doi: 10.1016/S0896-6273(00)81073-9

Mattingley, J. B., Bradshaw, J. L., & Bradshaw, J. A. (1995). The effects of unilateral visuospatial neglect on perception of müller-lyer illusory figures. *Perception*, *24*(4), 415–433.

Mattingley, J. B., & Driver, J. (1997). Parietal lobe contributions to the representation of space. In P. Thier & H.-O. Karnath (Eds.), *Experimental brain research series* (pp. 309–338). Berlin, Heidelberg: Springer: Verlag.

McBride, G., King, G. M., & James, J. W. (1965). Social proximity effects on galvanic skin responses in adult humans. *The Journal of Psychology*, *61*(1), 153–157. doi: 10.1080/00223980.1965.10544805

McCourt, M. E. (2001). Performance consistency of normal observers in forced-choice tachistoscopic visual line bisection. *Neuropsychologia*, *39*(10), 1065–1076. doi: 10.1016/S0028-3932(01)00044-6

McCourt, M. E., Freeman, P., & Tahmahkera-Stevens, C. (2001). The influence of unimanual response on pseudoneglect magnitude. *Brain and Cognition*, *45*(1), 52–63. doi: 10.1006/brcg.2000.1255

McCourt, M. E., & Garlinghouse, M. (2000). Asymmetries of visuospatial attention are modulated by viewing distance and visual field elevation: Pseudoneglect in peripersonal and extrapersonal space. *Cortex*, *36*(5), 715–731. doi: 10.1016/s0010-9452(08)70548-3

McCourt, M. E., Garlinghouse, M., & Slater, J. (2000). Centripetal versus centrifugal bias in visual line bisection: Focusing attention on two hypotheses. *Frontiers in Bioscience*, *5*, D58–71.

McCourt, M. E., & Jewell, G. (1999). Visuospatial attention in line bisection: stimulusmodulation of pseudoneglect. *Neuropsychologia*, *37*(7), 843–855. doi: 10.1016/S0028-3932(98)00140-7

McCourt, M. E., & Olafson, C. (1997). Cognitive and perceptual influences on visual line bisection: Psychophysical and chronometric analyses of pseudoneglect. *Neuropsychologia*, *35*(3), 369–380. doi: 10.1016/S0028-3932(96)00143-1

McCrae, R. R., & Costa, P. T. (1991). The neo personality inventory: Using the five-factor modei in counseling. *Journal of Counseling & Development*, *69*(4), 367–372. doi: 10.1002/j.1556-6676.1991.tb01524.x

McGeorge, P., Beschin, N., Colnaghi, A., Rusconi, M. L., & Della Sala, S. (2007). A lateralized bias in mental imagery: Evidence for representational pseudoneglect. *Neuroscience Letters*, *421*(3), 259–263. doi: 10.1016/j.neulet.2007.05.050

McGlinchey-Berroth, R., Milberg, W. P., Verfaellie, M., Alexander, M., & Kilduff, P. T. (1993). Semantic processing in the neglected visual field: Evidence from a lexical decision task. *Cognitive Neuropsychology*, *10*(1), 79–108. doi: 10.1080/02643299308253457

Meisels, M., & Canter, F. M. (1970). Personal space and personality characteristics: A non-confirmation. *Psychological Reports*, *27*(2), 287–290.

Mennemeier, M., Pierce, C., Chatterjee, A., Anderson, B., Jewell, G., Dowler, R., ... Mark, V. (2005). Biases in attentional orientation and magnitude estimation explain crossover: neglect is a disorder of both. *Journal of Cognitive Neuroscience*, *17*(8), 1194–1211. doi: 10.1162/0898929055002454

Mennemeier, M., Wertman, E., & Heilman, K. M. (1992). Neglect of near peripersonal space. *Brain*, *115*(1), 37–50. doi: 10.1093/brain/115.1.37

Mennin, D. S., Fresco, D. M., Heimberg, R. G., Schneier, F. R., Davies, S. O., & Liebowitz, M. R. (2002). Screening for social anxiety disorder in the clinical setting: using the Liebowitz social anxiety scale. *Journal of Anxiety Disorders*, *16*(6), 661–673. doi: 10.1016/S0887-6185(02)00134-2

Mesulam, M.-M. (1981). A cortical network for directed attention and unilateral neglect. *Annals of Neurology*, *10*(4), 309–325. doi: 10.1002/ana.410100402

Mesulam, M.-M. (1999). Spatial attention and neglect: parietal, frontal and cingulate contributions to the mental representation and attentional targeting of salient extrapersonal events. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *354*(1387), 1325–1346. doi: 10.1098/rstb.1999.0482

Milner, A. D., Brechmann, M., & Pagliarini, L. (1992). To halve and to halve not: an analysis of line bisection judgements in normal subjects. *Neuropsychologia*, *30*(6), 515–526. doi: 10.1016/0028-3932(92)90055-Q

Milner, A. D., Harvey, M., Roberts, R. C., & Forster, S. V. (1993). Line bisection errors in visual neglect: Misguided action or size distortion? *Neuropsychologia*, *31*(1), 39–49.

Molenberghs, P., Sale, M. V., & Mattingley, J. B. (2012). Is there a critical lesion site for unilateral spatial neglect? a meta-analysis using activation likelihood estimation. *Frontiers in Human Neuroscience*, *6*(78), 1–10. doi: 10.3389/fnhum.2012.00078

Morris, R., Mickel, S., Brooks, M., Swavely, S., & Heilman, K. M. (1985). Recovery from neglect. In *Journal of clinical and experimental neuropsychology* (Vol. 7, pp. 609–609).

Mulckhuyse, M., & Theeuwes, J. (2010). Unconscious attentional orienting to exogenous cues: A review of the literature. *Acta Psychologica*, *134*(3), 299–309. doi: `10.1016/j.actpsy.2010.03.002`

Munk, H. (1890). Of the visual area of the cerebral cortex, and its relation to eye movements. *Brain*, *13*(1), 45–70. doi: `10.1093/brain/13.1.45`

Murray, G., Rawlings, D., Allen, N., & Trinder, J. (2003). Neo five-factor inventory scores: Psychometric properties in a community sample. *Measurement and Evaluation in Counseling and Development*, *36*(3), 140–149.

Na, D. L., Adair, J. C., Williamson, D. J. G., Schwartz, R. L., Haws, B., & Heilman, K. M. (1998). Dissociation of sensory-attentional from motor-intentional neglect. *Journal of Neurology, Neurosurgery & Psychiatry*, *64*(3), 331–338. doi: `10.1136/jnnp.64.3.331`

Nagar, D., & Pandey, J. (1987). Affect and performance on cognitive task as a function of crowding and noise. *Journal of Applied Social Psychology*, *17*(2), 147-–157.

Neville, F., & Reicher, S. (2011). The experience of collective participation: shared identity, relatedness and emotionality. *Contemporary Social Science*, *6*(3), 377–396. doi: `10.1080/21582041.2012.627277`

Nicholls, M. E. R., Bradshaw, J., & Mattingley, J. B. (1999). Free-viewing perceptual asymmetries for the judgement of brightness, numerosity and size. *Neuropsychologia*, *37*(3), 307–314.

Nicholls, M. E. R., Loetscher, T., & Rademacher, M. (2010). Miss to the right: The effect of attentional asymmetries on goal-kicking. *PloS One*, *5*(8), e12363. doi: `10.1371/journal.pone.0012363`

Nicholls, M. E. R., Loftus, A., Mayer, K., & Mattingley, J. B. (2007). Things that go bump in the right: The effect of unimanual activity on rightward collisions. *Neuropsychologia*, *45*(5), 1122–1126. doi: `10.1016/j.neuropsychologia.2006.07.015`

Nicholls, M. E. R., Loveless, K. M., Thomas, N. A., Loetscher, T., & Churches, O. (2015). Some participants may be better than others: Sustained attention and motivation are higher early in semester. *The Quarterly Journal of Experimental Psychology*, *68*(1), 10–18. doi: `10.1080/17470218.2014.925481`

Nicholls, M. E. R., Mattingley, J. B., Berberovic, N., Smith, A., & Bradshaw, J. L. (2004). An investigation of the relationship between free-viewing perceptual asymmetries for vertical and horizontal stimuli. *Cognitive Brain Research*, *19*(3), 289–301. doi: 10.1016/j.cogbrainres.2003.12.008

Nicholls, M. E. R., & Roberts, G. R. (2002). Can free-viewing perceptual asymmetries be explained by scanning, pre-motor or attentional biases? *Cortex*, *38*(2), 113–136. doi: 10.1016/S0010-9452(08)70645-2

Nicholls, M. E. R., Roden, S., Thomas, N. A., Loetscher, T., Spence, C. J., & Forte, J. D. (2014). Close to me: the effect of asymmetrical environments on spatial attention. *Ergonomics*, *57*(6), 876–885. doi: 10.1080/00140139.2014.899633

Nicholls, M. E. R., Thomas, N. A., Loetscher, T., & Grimshaw, G. M. (2013). The flinders handedness survey (flanders): A brief measure of skilled hand preference. *Cortex*, *49*(10), 2914–2926. doi: 10.1016/j.cortex.2013.02.002

Nicholls, M. E. R., Thomas, N. A., Loetscher, T., Wignall, S., Yates, M. J., Forte, J. D., & Spence, C. J. (2012). The relationship between vertical stimulation and horizontal attentional asymmetries. *The Quarterly Journal of Experimental Psychology*, *65*(12), 2384–2396. doi: 10.1080/17470218.2012.688979

Nico, D. (1996). Detecting directional hypokinesia: the epidiascope technique. *Neuropsychologia*, *34*(5), 471–474. doi: 10.1016/0028-3932(95)00123-9

Nosek, B. A., Alter, G., Banks, G. C., Borsboom, D., Bowman, S. D., Breckler, S. J., … Christensen, G. (2015). Promoting an open research culture: Author guidelines for journals could help to promote transparency, openness, and reproducibility. *Science*, *348*(6242), 1422–1425. doi: 10.1126/science.aab2374.

Novelli, D., Drury, J., Reicher, S., & Stott, C. (2013). Crowdedness mediates the effect of social identification on positive emotion in a crowd: a survey of two crowd events. *PloS One*, *8*(11), e78983. doi: 10.1371/journal.pone.0078983

Nowicki, S., & Duke, M. P. (1974). A locus of control scale for noncollege as well as college adults. *Journal of Personality Assessment*, *38*(2), 136–137. doi: 10.1080/00223891.1974.10119950

Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist*, *56*(9), 717–734. doi: 10.1037/0003-066X.56.9.717

Oldfield, R. C. (1971). The assessment and analysis of handedness: the edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. doi: 10.1016/0028-3932(71)90067-4

Ortigue, S., Megevand, P., Perren, F., Landis, T., & Blanke, O. (2006). Double dissociation between representational personal and extrapersonal neglect. *Neurology*, *66*(9), 1414–1417. doi: 10.1212/01.wnl.0000210440.49932.e7

Pan, K., & Eriksen, C. W. (1993). Attentional distribution in the visual field duringsame-different judgments as assessed by response competition. *Perception & Psychophysics*, *53*(2), 134–144. doi: 10.3758/BF03211723

Parton, A., Malhotra, P., & Husain, M. (2004). Hemispatial neglect. *Journal of Neurology, Neurosurgery & Psychiatry*, *75*(1), 13–21.

Patterson, M. L., Mullens, S., & Romano, J. (1971). Compensatory reactions to spatial intrusion. *Sociometry*, *34*(1), 114–121. doi: 10.2307/2786354

Patterson, M. L., & Sechrest, L. B. (1970). Interpersonal distance and impression formation. *Journal of Personality*, *38*(2), 161–166. doi: 10.1111/j.1467-6494.1970.tb00001.x

Paulus, P. B., Annis, A. B., & Seta, J. J. (1976). Density does affect task performance. *Journal of Personality and Social Psychology*, *34*(2), 248–253. doi: 10.1037//0022-3514.34.2.248

Perry, A., Nichiporuk, N., & Knight, R. T. (2015). Where does one stand: a biological account of preferred interpersonal distance. *Social Cognitive and Affective Neuroscience*, *(in press)*, nsv115. doi: 10.1093/scan/nsv115

Perry, A., Rubinsten, O., Peled, L., & Shamay-Tsoory, S. G. (2013). Don't stand so close to me: A behavioral and erp study of preferred interpersonal distance. *NeuroImage*, *83*(1), 761–769. doi: 10.1016/j.neuroimage.2013.07.042

Pfeiffer, U., Schilbach, L., Jording, M., Timmermans, B., Bente, G., & Vogeley, K. (2012). Eyes on the mind: investigating the influence of gaze dynamics on the perception of others in real-time social interaction. *Frontiers in Psychology*, *3*, 537. doi: 10.3389/fpsyg.2012.00537

Pitzalis, S., Di Russo, F., Spinelli, D., & Zoccolotti, P. (2001). Influence of the radial and vertical dimensions on lateral neglect. *Experimental Brain Research*, *136*(3), 281–294. doi: 10.1007/s002210000580

Pitzalis, S., Spinelli, D., & Zoccolotti, P. (1997). Vertical neglect: Behavioral and electrophysiological data. *Cortex*, *33*(4), 679–688. doi: 10.1016/S0010-9452(08)70725-1

Pomplun, M., Reingold, E. M., & Shen, J. (2001). Investigating the visual span in comparative search: The effects of task difficulty and divided attention. *Cognition*, *81*(2), B57–B67. doi: 10.1016/S0010-0277(01)00123-8

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. doi: 10.1080/00335558008248231

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*(1), 25–42. doi: 10.1146/annurev.ne.13.030190.000325

Poynter, W., & Roberts, C. (2012). Hemispheric asymmetries in visual search. *Laterality: Asymmetries of Body, Brain and Cognition*, *17*(6), 711–726. doi: 10.1080/1357650X.2011.626558

Previc, F. H. (1990). Functional specialization in the lower and upper visual fields in humans: Its ecological origins and neurophysiological implications. *Behavioral and Brain Sciences*, *13*(3), 519–542. doi: 10.1017/S0140525X00080018

Previc, F. H. (1998). The neuropsychology of 3-d space. *Psychological Bulletin*, *124*(2), 123–164.

Previc, F. H., Breitmeyer, B. G., & Weinstein, L. F. (1995). Discriminability of random-dot stereograms in three-dimensional space. *International Journal of Neuroscience*, *80*(1-4), 247–253. doi: 10.3109/00207459508986103

Proffitt, D. R. (2013). An embodied approach to perception by what units are visual perceptions scaled? *Perspectives on Psychological Science*, *8*(4), 474–483. doi: 10.1177/1745691613489837

Pype, A., Lin, J., Murray, S., & Boynton, G. (2010). Individual differences in the shape of visual attention during object tracking. *Journal of Vision*, *10*(7), 315–315. doi: 10.1167/10.7.315

Rach, S., Diederich, A., & Colonius, H. (2011). On quantifying multisensory interaction effects in reaction time and detection rate. *Psychological Research*, *75*(2), 77–94. doi: 10.1007/s00426-010-0289-0

Rapcsak, S. Z., Cimino, C. R., & Heilman, K. M. (1988). Altitudinal neglect. *Neurology*, *38*(2), 277–277. doi: 10.1212/WNL.38.2.277

Rawls, J. R., Trego, R. E., McGaffey, C. N., & Rawls, D. J. (1972). Personal space as a predictor of performance under close working conditions. *The Journal of Social Psychology*, *86*(2), 261–267. doi: 10.1080/00224545.1972.9918627

Reinhardt, T., Schmahl, C., Wüst, S., & Bohus, M. (2012). Salivary cortisol, heart rate, electrodermal activity and subjective stress responses to the mannheim multicomponent stress test (mmst). *Psychiatry Research*, *198*(1), 106–111. doi: 10.1016/j.psychres.2011.12.009

Remland, M. S., Jones, T. S., & Brinkman, H. (1995). Interpersonal distance, body orientation, and touch: Effects of culture, gender, and age. *The Journal of Social Psychology*, *135*(3), 281–297. doi: 10.1080/00224545.1995.9713958

Reuter-Lorenz, P. A., Kinsbourne, M., & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition*, *12*(2), 240–266. doi: 10.1016/0278-2626(90)90018-J

Reuter-Lorenz, P. A., & Posner, M. I. (1990). Components of neglect from right-hemisphere damage: an analysis of line bisection. *Neuropsychologia*.

Ricciardelli, P., Bricolo, E., Aglioti, S. M., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: exploring the tendency to imitate another individual's gaze. *NeuroReport*, *13*(17), 2259–2264.

Riddoch, M. J., & Humphreys, G. W. (1983). The effect of cueing on unilateral neglect. *Neuropsychologia*, *21*(6), 589–599. doi: 10.1016/0028-3932(83)90056-8

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*(1), 169-192. doi: 10.1146/annurev.neuro.27.070203.144230

Rizzolatti, G., & Fabbri-Destro, M. (2008). The mirror system and its role in social cognition. *Current Opinion in Neurobiology*, *18*(2), 179–184. doi: 10.1016/j.conb.2008.08.001

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (1997). The space around us. *Science*, *277*(5323), 190–191. doi: 10.1126/science.277.5323.190

Rizzolatti, G., Riggio, L., & Sheliga, B. M. (1994). *Space and selective attention* (Vol. 15). London, England: The MIT Press.

Rizzolatti, G., Scandolara, C., Matelli, M., & Gentilucci, M. (1981). Afferent properties of periarcuate neurons in macaque monkeys. ii. visual responses. *Behavioural Brain Research*, *2*(2), 147–163. doi: 10.1016/0166-4328(81)90053-X

Ro, T., & Rafal, R. D. (1996). Perception of geometric illusions in hemispatial neglect. *Neuropsychologia*, *34*(10), 973–978. doi: 10.1016/0028-3932(96)00018-8

Roberts, R., & Turnbull, O. H. (2010). Putts that get missed on the right: Investigating lateralized attentional biases and the nature of putting errors in golf. *Journal of Sports Sciences*, *28*(4), 369–374. doi: 10.1080/02640410903536467

Robertson, I. H., & Halligan, P. W. (1999). *Spatial neglect: A clinical handbook for diagnosis and treatment*. East Sussex, UK: Psychology Press.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), 747–758. doi: 10.1016/S0028-3932(97)00015-8

Robertson, I. H., Mattingley, J. B., Rorden, C., & Driver, J. (1998). Phasic alerting of neglect patients overcomes their spatial deficit in visual awareness. *Nature*, *395*(6698), 169–172. doi: 10.1038/25993

Robertson, L. C., Lamb, M. R., & Knight, R. T. (1988). Effects of lesions of temporal-parietal junction on perceptual and attentional processing in humans. *The Journal of Neuroscience*, *8*(10), 3757–3769.

Robins, R. W., Fraley, R. C., Roberts, B. W., & Trzesniewski, K. H. (2001). A longitudinal study of personality change in young adulthood. *Journal of Personality*, *69*(4), 617–640. doi: 10.1111/1467-6494.694157

Roth, H. L., Lora, A. N., & Heilman, K. M. (2002). Effects of monocular viewing and eye dominance on spatial attention. *Brain*, *125*(9), 2023–2035. doi: 10.1093/brain/awf210

Ruys, K. I., & Aarts, H. (2010). When competition merges people's behavior: Interdependency activates shared action representations. *Journal of Experimental Social Psychology*, *46*(6), 1130–1133. doi: 10.1016/j.jesp.2010.05.016

Sarri, M., Greenwood, R., Kalra, L., & Driver, J. (2009). Task-related modulation of visual neglect in cancellation tasks. *Neuropsychologia*, *47*(1), 91–103. doi: 10.1016/j.neuropsychologia.2008.08.020

Sartori, L., Bucchioni, G., & Castiello, U. (2013). When emulation becomes reciprocity. *Social Cognitive and Affective Neuroscience*, *8*(6), 662–669. doi: 10.1093/scan/nss044

Satz, P. (1968). Laterality effects in dichotic listening. *Nature*, *218*(1), 277–278. doi: 10.1038/218277a0

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends in Cognitive Sciences*, *10*(2), 70–76. doi: 10.1016/j.tics.2005.12.009

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: just like one's own? *Cognition*, *88*(3), B11–21. doi: 10.1016/S0010-0277(03)00043-X

Serfaty, C., Soroker, N., Glicksohn, J., Sepkuti, J., & Myslobodsky, M. S. (1995). Does monocular viewing improve target detection in hemispatial neglect? *Restorative Neurology and Neuroscience*, *9*(2), 77–83. doi: 10.3233/RNN-1995-9202

Servos, P., Carnahan, H., & Fedwick, J. (2000). The visuomotor system resists the horizontal-vertical illusion. *Journal of Motor Behavior*, *32*(4), 400–404. doi: 10.1080/00222890009601389

Shelton, P. A., Bowers, D., & Heilman, K. M. (1990). Peripersonal and vertical neglect. *Brain*, *113*(1), 191–205. doi: 10.1093/brain/113.1.191

Shore, D. I., Barnes, M. E., & Spence, C. J. (2006). Temporal aspects of the visuotactile congruency effect. *Neuroscience Letters*, *392*(1), 96–100. doi: 10.1016/j.neulet.2005.09.001

Shulman, G. L., Pope, D. L. W., Astafiev, S. V., McAvoy, M. P., Snyder, A. Z., & Corbetta, M. (2010). Right hemisphere dominance during spatial selective attention and target detection occurs outside the dorsal frontoparietal network. *The Journal of Neuroscience*, *30*(10), 3640–3651. doi: 10.1523/jneurosci.4085-09.2010

Siman-Tov, T., Mendelsohn, A., Schonberg, T., Avidan, G., Podlipsky, I., Pessoa, L., ... Hendler, T. (2007). Bihemispheric leftward bias in a visuospatial attention-related network. *The Journal of Neuroscience*, *27*(42), 11271–11278. doi: 10.1523/jneurosci.0599-07.2007

Simon, J. R., & Rudell, A. P. (1967). Auditory sr compatibility: the effect of an irrelevant cue on information processing. *Journal of Applied Psychology*, *51*(3), 300–304. doi: 10.1037/h0020586

Simon-Dack, S. L., Holtgraves, T., Marsh, L. M., & Fogle, K. L. (2013). Resting electroencephalography correlates of pseudoneglect: an individual differences approach. *NeuroReport*, *24*(15), 827–830. doi: 10.1097/WNR.0b013e328364125b

Slagter, H. A., Davidson, R. J., & Tomer, R. (2010). Eye-blink rate predicts individual differences in pseudoneglect. *Neuropsychologia*, *48*(5), 1265–1268. doi: 10.1016/j.neuropsychologia.2009.12.027

Sommer, R. (1962). The distance for comfortable conversation: A further study. *Sociometry*, *25*(1), 111–116. doi: 10.2307/2786041

Sommer, R. (2002). Personal space in a digital age. In R. Bechtel & A. Churchman (Eds.), *Handbook of environmental psychology* (pp. 647–660). New York: John Wiley & Sons.

Soper, W. B., & Karasik, R. (1977). Use of spatial cues with regard to the invasion of group space. *Psychological Reports*, *40*(3c), 1175–1178. doi: 10.2466/pr0.1977.40.3c.1175

Sosa, Y., Clarke, A. M., & McCourt, M. E. (2011). Hemifield asymmetry in the potency of exogenous auditory and visual cues. *Vision Research*, *51*(11), 1207–1215. doi: 10.1016/j.visres.2011.03.012

Sturm, W., & Willmes, K. (2001). On the functional neuroanatomy of intrinsic and phasic alertness. *NeuroImage*, *14*(1), S76–S84. doi: 10.1006/nimg.2001.0839

Suavansri, K., Falchook, A. D., Williamson, J. B., & Heilman, K. M. (2012). Right up there: Hemispatial and hand asymmetries of altitudinal pseudoneglect. *Brain and Cognition*, *79*(3), 216–220. doi: 10.1016/j.bandc.2012.03.003

Szpak, A., Loetscher, T., Bastian, J., Thomas, N. A., & Nicholls, M. E. R. (2015). Visual asymmetries for relative depth judgments in a three-dimensional space. *Brain and Cognition*, *99*(1), 128–134. doi: 10.1016/j.bandc.2015.08.005

Szpak, A., Loetscher, T., Churches, O., Thomas, N. A., Spence, C. J., & Nicholls, M. E. R. (2015). Keeping your distance: attentional withdrawal in individuals who show physiological signs of social discomfort. *Neuropsychologia*, *70*(SI), 462–467. doi: 10.1016/j.neuropsychologia.2014.10.008

Szpak, A., Nicholls, M. E. R., Thomas, N. A., Laham, S. M., & Loetscher, T. (2016). 'No man is an island': effects of interpersonal proximity on spatial attention. *Cognitive Neuroscience*, *7*(1–4), 45–54. doi: 10.1080/17588928.2015.1048677

Szpak, A., Thomas, N. A., & Nicholls, M. E. R. (2016). Hemispheric asymmetries in perceived depth revealed through a radial line bisection task. *Experimental Brain Research*, *234*(3), 807–813. doi: 10.1007/s00221-015-4504-5

Tajadura-Jiménez, A., Pantelidou, G., Rebacz, P., Västfjäll, D., & Tsakiris, M. (2011). I-space: the effects of emotional valence and source of music on interpersonal distance. *PloS One*, *6*(10), e26083. doi: 10.1371/journal.pone.0026083

Tedesco, J. F., & Fromme, D. K. (1974). Cooperation, competition and personal space. *Sociometry*, *37*(1), 116–121. doi: 10.2307/2786471

Tegner, R., & Levander, M. (1991). The influence of stimulus properties on visual neglect. *Journal of Neurology, Neurosurgery & Psychiatry*, *54*(10), 882–887. doi: 10.1136/jnnp.54.10.882

Teneggi, C., Canzoneri, E., Di Pellegrino, G., & Serino, A. (2013). Social modulation of peripersonal space boundaries. *Current Biology*, *23*(5), 406–411. doi: 10.1016/j.cub.2013.01.043

Terry, R., & Lower, M. (1979). Perceptual withdrawal from an invasion of personal space: A methodological note. *Personality and Social Psychology Bulletin*, *5*(3), 396–397. doi: 10.1177/014616727900500326

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & Psychophysics*, *49*(1), 83–90. doi: 10.3758/BF03211619

Thomas, D. R. (1973). Interaction distances in same-sex and mixed-sex groups. *Perceptual and Motor Skills*, *36*(1), 15–18. doi: 10.2466/pms.1973.36.1.15

Thomas, N. A., Castine, B. R., Loetscher, T., & Nicholls, M. E. R. (2015). Upper visual field distractors preferentially bias attention to the left. *Cortex*, *64*(1), 179–193. doi: 10.1016/j.cortex.2014.10.018

Thomas, N. A., & Elias, L. J. (2012). Perceptual asymmetries in greyscales: Object-based versus space-based influences. *Cortex*, *48*(5), 553–562. doi: 10.1016/j.cortex.2010.11.015

Thompson, K., Hirsch, L., Loose, S. M., Sharma-Brymer, V., Rainbird, S., Titchener, K., ... Dawson, D. (2012). Riding a mile in their shoes: Understanding australian metropolitan rail passenger perceptions and experiences of crowdedness using mixed-methods research. *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice*, *21*(2), 46–59.

Tirachini, A., Hensher, D. A., & Rose, J. M. (2013). Crowding in public transport systems: effects on users, operation and implications for the estimation of demand. *Transportation Research Part A: Policy and Practice*, *53*(1), 36–52. doi: 10.1016/j.tra.2013.06.005

Toba, M.-N., Cavanagh, P., & Bartolomeo, P. (2011). Attention biases the perceived midpoint of horizontal lines. *Neuropsychologia*, *49*(2), 238–246. doi: 10.1016/j.neuropsychologia.2010.11.022

Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*(1), 121–125. doi: 10.1111/j.1467-7687.2007.00573.x

Toraldo, A., Fiori, F., & Vanzan, S. (2010). The geometry of the landmark task. *Behavioural Neurology*, *23*(4), 221. doi: 10.3233/BEN-2010-0300

Tracy, J. I., Mohamed, F., Faro, S., Tiver, R., Pinus, A., Bloomer, C., ... Harvan, J. (2000). The effect of autonomic arousal on attentional focus. *NeuroReport*, *11*(18), 4037–4042. doi: 10.1097/00001756-200012180-00027

Triplett, N. (1898). The dynamogenic factors in pacemaking and competition. *The American Journal of Psychology*, *9*(4), 507–533. doi: 10.2307/1412188

Tsai, C. C., Kuo, W. J., Hung, D. L., & Tzeng, O. J. L. (2008). Action co-representation is tuned to other humans. *Journal of Cognitive Neuroscience*, *20*(11), 2015–2024. doi: 10.1162/jocn.2008.20144

Vaishnavi, S., Calhoun, J., & Chatterjee, A. (2001). Binding personal and peripersonal space: evidence from tactile extinction. *Journal of Cognitive Neuroscience*, *13*(2), 181–189. doi: 10.1162/089892901564243

Vallar, G. (2001). Extrapersonal visual unilateral spatial neglect and its neuroanatomy. *NeuroImage*, *14*(1), S52–S58. doi: 10.1006/nimg.2001.0822

Vallar, G., & Perani, D. (1986). The anatomy of unilateral neglect after right-hemisphere stroke lesions. a clinical/ct-scan correlation study in man. *Neuropsychologia*, *24*(5), 609–622.

Varnava, A., Dervinis, M., & Chambers, C. D. (n.d.). The predictive nature of pseudoneglect for visual neglect: evidence from parietal theta burst stimulation. *Plos One*.

Varnava, A., & Halligan, P. W. (2009). Line bisection: Does introspection inform cognitive strategy? *Neuropsychologia*, *47*(1), 280–283. doi: 10.1016/j.neuropsychologia.2008.08.002

Verdon, V., Schwartz, S., Lovblad, K.-O., Hauert, C.-A., & Vuilleumier, P. (2009). Neuroanatomy of hemispatial neglect and its functional components: a study using voxel-based lesion-symptom mapping. *Brain*, awp305. doi: 10.1093/brain/awp305

Vossel, S., Eschenbeck, P., Weiss, P. H., & Fink, G. R. (2010). The neural basis of perceptual bias and response bias in the landmark task. *Neuropsychologia*, *48*(13), 3949–3954. doi: 10.1016/j.neuropsychologia.2010.09.022

Vossel, S., Geng, J. J., & Fink, G. R. (2014). Dorsal and ventral attention systems distinct neural circuits but collaborative roles. *The Neuroscientist*, *20*(2), 150–159. doi: 10.1177/1073858413494269

Vuilleumier, P. (2002). Perceived gaze direction in faces and spatial attention: a study in patients with parietal damage and unilateral neglect. *Neuropsychologia*, *40*(7), 1013–1026. doi: 10.1016/S0028-3932(01)00153-1

Vuilleumier, P. (2013). Mapping the functional neuroanatomy of spatial neglect and human parietal lobe functions: progress and challenges. *Annals of the New York Academy of Sciences*, *1296*(1), 50–74. doi: 10.1111/nyas.12161

Vuilleumier, P., & Schwartz, S. (2001). Beware and be aware: capture of spatial attention by fear-related stimuli in neglect. *NeuroReport*, *12*(6), 1119–1122.

Vuilleumier, P., Valenza, N., Mayer, E., Reverdin, A., & Landis, T. (1998). Near and far visual space in unilateral neglect. *Annals of Neurology*, *43*(3), 406–410. doi: 10.1002/ana.410430324

Weeks, J. W., Heimberg, R. G., Fresco, D. M., Hart, T. A., Turk, C. L., Schneier, F. R., & Liebowitz, M. R. (2005). Empirical validation and psychometric evaluation of the brief fear of negative evaluation scale in patients with social anxiety disorder. *Psychological Assessment*, *17*(2), 179–190. doi: 10.1037/1040-3590.17.2.179

Weiss, P. H., Marshall, J. C., Wunderlich, G., Tellmann, L., Halligan, P. W., Freund, H. J., … Fink, G. R. (2000). Neural consequences of acting in near versus far space: a physiological basis for clinical dissociations. *Brain*, *123*(12), 2531–2541. doi: 10.1093/brain/123.12.2531

Wellman, B. (2001). Physical place and cyberplace: The rise of personalized networking. *International Journal of Urban and Regional Research*, *25*(2), 227–252. doi: 10.1111/1468-2427.00309

Weltman, G., Smith, J. E., & Egstrom, G. H. (1971). Perceptual narrowing during simulated pressure-chamber exposure. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *13*(2), 99–107. doi: 10.1177/001872087101300202

Wenderoth, P. (1994). The salience of vertical symmetry. *Perception*, *23*(2), 221–236. doi: 10.1068/p230221

Williams, J. L. (1971). Personal space and its relation to extraversion-introversion. *Canadian Journal of Behavioural Science/Revue Canadienne des Sciences du Comportement*, *3*(2), 156-160. doi: 10.1037/h0082257

Williamson, J. B., Haque, S., Burtis, B., Harciarek, M., Lamb, D., Zilli, E., & Heilman, K. M. (2014). The influence of stimulus proximity on judgments of spatial relationships in patients with chronic unilateral right or left hemisphere stroke. *Journal of Clinical and Experimental Neuropsychology*, *36*(8), 787–793. doi: 10.1080/13803395.2014.940855

Willis, F. N. J. (1966). Initial speaking distance as a function of the speakers' relationship. *Psychonomic Science*, *5*(6), 221–222. doi: 10.3758/BF03328362

Wood, J. (2006). Effect of anxiety reduction on children's school performance and social adjustment. *Developmental Psychology*, *42*(2), 345–349. doi: 10.1037/0012-1649.42.2.345

Woods, D. L., & Knight, R. T. (1986). Electrophysiologic evidence of increased distractibility after dorsolateral prefrontal lesions. *Neurology*, *36*(2), 212–216. doi: 10.1212/WNL.36.2.212