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The Impact of Expertise in Archery on the Attentional Biases of Perceptual and Representational Pseudoneglect

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Abstract

Turnbull & McGeorge (1998) asked a group of participants if they had bumped into anything recently and if so, on what side? Results reflected a trend towards bumping on the right. This tendency to bump into objects on the right has since been observed in a naturalistic setting (Nicholls, Loftus, Meyer, & Mattingley, 2007). But rather than an interesting quirk of statistics these studies, and many others have captured a phenomenon called pseudoneglect (Bowers and Heilman, 1980). It represents a subtle yet consistent bias in our spatial attention towards the left half of space and away from the right which results in the pattern of bumping or other lateralised errors seen in the spatial attention literature (See Jewell & McCourt, 2000). Furthermore, this bias does not just impact the perceptual sphere; it also crosses into the representational, impacting our memory for visual information (Bisiach & Luzatti, 1987). But whether this is consistent in individuals who are trained in an accuracy based sport remains unknown. The current research sought to examine perceptual and representational pseudoneglect effects in a group of expert archers compared to neurologically healthy controls. Results suggest that the attainment of expert level in archery is associated with reduced perceptual pseudoneglect. Archers showed a trend towards reduced representational pseudoneglect but this was non-significant. Results are discussed in line with theoretical frameworks of visual attention, pseudoneglect and expertise.

Chapter 1

General Introduction

1. Visual Attention

1.1 Theories of attention

There are two subdivisions of attention; selective (focused) attention, and divided attention. Selective attention involves the selection of a salient stimulus and the focusing on that relative to other stimuli in the environment. An example of this is reading a book. In order to effectively comprehend the subject matter attention must be exclusively devoted to the processing of the visual information on the page (Odegaard, Wozny & Shams, 2016). Divided attention is what we use when performing simultaneous tasks; the devoting of resources to more than one stimulus at a time (Spelke, Hirst, & Neisser, 1976); for example, listening to music while reading.

Visual attention has been suggested to operate in multiple ways; like a spotlight, or a zoom lens, or, more recently, multiple spotlights. The spotlight model suggests that our visual attention has a very sharp focus at its centre (like the circle illuminated directly by a spotlight) and that our attention diminishes the further out from this centre point we look, in the same way that the light illuminates less and less the further away from it one travels. However, is has been argued that this model is too rigid (see Eriksen & St James, 1968) and that attention is more like a zoom lens; we can consciously increase or decrease the area of focal attention. This was supported by LaBerge (1983) who found that when attention was narrow participants categorised the middle letter of his word stimuli, but when it was broad, they categorised the whole word (see also Muller, 2003 for a study examining this model in terms of brain activation). The zoom lens model is exemplified in the course of driving; we increase the focal area during normal driving but if we spot a hazard we focus our attention on that, thereby decreasing the area of our attention (Müller, Bartelt, Donner, Vilringer & Brandt, 2003). More recently, even more flexibility has been attributed to this process (Awh & Pashler 2000) who suggested that attention can take the form of multiple spotlights. This means we can split attention between two spatial locations that are not necessarily adjacent to each other. Morawetz and colleagues (2007) presented letters and digits on screen in five locations simultaneously and asked participants to focus on two locations (depending on the condition) and ignore the rest. They found an increased in neural activity in occipital areas related to those locations but the intervening space was ignored (characterised by no increase in neural activity), consistent with this model (see also Cave et al., 2010 for more support of the flexibility of this model). The current research will focus on selective attention, specifically visual-spatial attention; therefore this type of attention shall now be discussed in more depth.

1.2 Visual-spatial/Selective Attention

Visual-spatial attention, from this point referred to as spatial attention, allows us to selectively bias our visual processing towards specific locations in the visual field, thereby allowing faster and more effective processing of stimuli in that location, relative to those around it (Awe & Jonides, 2001). It also allows us to navigate our surroundings and avoid obstacles in the world around us (Nicholls et al., 2007). Spatial attention is based on far-reaching and diverse networks in the brain involving cortical and subcortical structures, predominantly concentrated in the right parietal cortex. Much of the evidence for the localisation of spatial attention to these areas comes from the study of patients with localised brain damage that exhibit deficits in this capacity, in large part by research into unilateral spatial neglect (USN), also referred to as visual neglect (VN). Early case studies in humans suffering from this condition and ablation studies conducted in monkeys suggested the premotor cortex, cingulate gyrus, thalamus (Cambier et al., 1980) as well as the striatum, the superior colliciulus and pulvinar thalamic nuclei to be the underlying brain areas involved in VN (and therefore, potentially visuo-spatial attention; (Mesulam, 1999). Considerable research has produced the emergent view in recent times that there is no single area responsible, but rather a disparate collection of cortical and subcortical areas and the connections between them. The right tempo-parietal junction (Heilman, et al., 1983; Vallar, 2001), frontal eye fields, (Gitelman et al., 1999) superior colliculi (Mesulam, 1999; Ogourtsove et al., 2010), pulvinar thalamic nuclei (Mesulam, 1999), cingulate gyrus (Gitelman et al., 1999), and basal ganglia (Karnath et al., 2002) have all been implicated using various methods (MRI, fMRI, rTMS). Connections between these modular areas have also been identified as important for the manifestation of neglect. The arcuate (Doricchi et al, 2008), superior longitudinal (Shinoura et al, 2009), inferior and superior occipitofrontal fasciculi (Karnath et al, 2009) as well as the extreme capsule (Karnath et al, 2010) are some of these connections. However, it is not a perfect system and often we can find ourselves bumping into objects or people. This can be caused by an imbalance in our spatial attentional processing known as pseudoneglect.

2. Visual Neglect

2.1 Unilateral Spatial Neglect

Unilateral Spatial Neglect (USN; see also spatial neglect, visuo-spatial neglect, visual neglect and hemi-neglect) is a failure to report, respond or orient to objects in the contralesional visual field. Importantly, this deficit must not be attributable to a primary sensory or motor deficit (Bowers & Heilman 1980). This deficit is seen after stroke, however, the incidence rate is highly variable (33-85%) (Stone, Wilson, Wroot, Halligan, Lange, Marshall & Greenwood, 1991). Left neglect is common after right hemisphere damage; however, right neglect is comparatively rare even after left hemisphere damage (Balint's syndrome; Mesulam et al., 1981; Heilman et al., 1985; Weintraub & Mesulam, 1987; Spiers et al., 1990). It can have highly debilitating consequences as the contralesional visual field is rendered invisible. This can lead patients to omit stimuli on the affected side when completing clinical tests. However, it can have real world implications; patients may only eat one side of a meal or shave or apply make up to one side of their face. It also affects mobility and independence as patients who are otherwise physically capable of walking and navigating through their environment are unable to do so due to the risk of falling or injury.

2.2 Pseudoneglect

When Turnbull and McGeorge (1998) asked 383 participants whether they had bumped into anything recently and if so, on what side, there was a non-significant tendency towards bumping on the right. This demonstrates a trend which is most likely due to a phenomenon called pseudoneglect (Bowers and Heilman, 1980). Pseudoneglect is the failure to report, respond or orient to objects in the right visual field. It is comparable in etiology to USN, however, the degree of the attentional bias is far smaller and typically occurs for the opposite side (i.e. USN typically affects the left hemifield, pseudoneglect the right). USN and pseudoneglect are typically discussed as related manifestations due to an underlying attentional/hemispheric asymmetry. However, there remains no common quantitative theory to support this.

A key test used in the quantification of pseudoneglect is the line bisection task (see Chapter 2), which requires participants to bisect horizontal lines of varying lengths as close to the objective centre as they can. The most comprehensive meta-analysis of pseudoneglect (Jewell & McCourt, 2000) examined 79 studies including a total of 2191 neurologically-healthy participants. Results reflected significant leftward deviations in line and tactile rod bisection tasks and authors concluded that the leftward bias was robust and consistent (Jewell & McCourt, 2000).

More recently, pseudoneglect has been taken out of the laboratory to allow for more real world examination of this phenomenon. Nicholls and colleagues (2007) devised a doorway task to allow pseudoneglect to be observed in a real world situation (walking through a narrow space). Participants were required to walk through a doorway consisting of two poles, the distance between which had been set at 2 mm wider than each participant (measured across their widest part). The most typical finding was that participants navigated the doorway without bumping, which lead authors to conclude that humans are adept at fitting through small spaces. However, when bumping did occur it was significantly more to the right compared to the left (Nicholls, Loftus, Meyer & Mattingley, 2007). A link between performance in line bisection tasks and this more real-world activity of walking through a narrow space was made by Nicholls and colleagues (2008). This research required participants to both complete a line bisection task and then text on a mobile phone while walking through a doorway. Both tasks showed the effects of pseudoneglect and authors assert that this was the first research linking the more clinical pen-and-paper tasks to the real-world doorway task (Nicholls, Loftus, Orr, & Barr, 2008).

2.2.1 Demographic effects on Pseudoneglect

There has been a volume of research into the impact of demographic factors such as age, sex and handedness on pseudoneglect performance. However, the majority of these have used the line bisection task as their only test measure as it is so widely used and well validated. In fact, extensive literature search of three scientific databases (Science Direct, Scopus, and PubMed) returned no demographic studies on the cancellation task or pseudoneglect in general.

Therefore, the demographic variables in the following section will be discussed in the context of the line bisection task.

Age-related decline has an impact on numerous aspects of cognitive function including memory (West, Crook, & Barron, 1992), task switching (Karanyadis et al., 2015), and speed of processing (Eckhert et al., 2010). However, while these effects are largely accepted and consistent there is a lack of agreement in the pseudoneglect literature. Fujii and colleagues (1995) found that elderly participants bisected lines significantly further to the right compared to middle aged or young participants and reported no difference between the latter groups' performance level (Fujii, Fukatsu, Yamadori, & Kimura, 1995). Similar results were reported by Varnava and Halligan (2007). All participants in the current research will be between 18 and 50 years old and therefore age–related decline is deemed not to be an influential factor in our experiments.

Similar to age effects, there is some disagreement on the impact of sex on pseudoneglect. Some studies found that males bisect more to the left than females (Roig & Cicero 1994), others have found that men bisect lines further to the right (Wolfe, 1923). The majority of studies report no significant effects of sex on pseudoneglect (Bradshaw et al., 1995; Brodie & Pettigrew, 1996, Chokron & Imbert, 1993, Luh, 2995, Milner et al., 1992, Scarisbrick et al., 1987; Shuren et al., 1994). Another issue is that many studies use either mixed sex groups or don't report subject sex at all (Jewell & McCourt, 2000). Due to the lack of consistency or agreement and the majority null effects of sex, this will not be considered as an influential factor in the current research.

Handedness is the most common indicator of the lateralisation of cerebral dominance; however, very few studies have examined handedness in the line bisection task. When handedness is examined, all participants appear to bisect lines to the left of veridical centre; however right handed subjects err to a greater degree than left-handed subjects (Luh, 1995;

Scarsbrick et al., 1987). However, the majority of studies limit samples to right-handed participants (Brodie & Pettigrew, 1996; Chokron et al., 1998; Chokron & Imbert, 1993; Fischer, 1994; Fukatsu et al., 1995; Halligan & Marshall, 1993; Jeannerod & Biguer, 1987 and Kageyama et al., 1994) and many studies fail to report handedness at all (e.g Berti et al., 1995; Birch et al., 1960; Bisiach et al., 1985; Butter et al., 1989, Fujii et al., 1991 Hjaltason et al., 1997). The sample in the current research used mainly right-handed participants, therefore handedness effects were not controlled for.

3. Theories of Pseudoneglect

3.1 Hemispheric Specialisation Hypothesis

A large body of research has examined the plausibility of hemispheric specialisation; that each side of the brain is geared towards a particular type of process. The outcome of this has been the generally accepted view that (in right-handed people) the left hemisphere is dominant for language and the right hemisphere for visual spatial processing (Mesulam, 1981; Heilman et al., 1985). Much of the evidence for this right hemisphere specialisation came from the study of visual neglect (VN) and the finding that left neglect is common after right hemisphere damage; however, the opposite is rare (See Mesulam et al., 1981; Weintraub & Mesulam, 1987 for an example). This asymmetry has also been studied in neurologically-healthy participants in two main ways; transient 'lesions' using Transcranial Magnetic Stimulation (TMS) and using functional imaging to examine normal functioning. Using fMRI, Gitelman and colleagues (1999) examined activation as participants completed a task requiring discrimination of a target from a distractor stimulus as quickly as possible. They found a greater area of activation in the right hemisphere (parietal cortex) compared to the left hemisphere in all participants (Gitelman, Nobre, Parrish et al., 1999).

3.1.1 Inhibition Theory

According to the inhibition theory, visual attention is dependent on the balance of inhibition between the two posterior parietal cortices (left and right) (Kinsbourne, 1977; Muri et al., 2002; Batelli et al., 2009). Put simply, there is competition between the left and right brain areas involved in attention, with each trying to suppress the activation of the other. This constant struggle for dominance results in our relatively balanced attentional system. However, this theory can only readily be examined in the case of disrupted function, as it is difficult to directly observe this inhibition in neurologically-healthy controls (Plow, Cattaneo, Carlson, Alvarez, Pascual-Leone, & Batelli, 2014). Behaviourally, in the case of patients with brain lesions affecting the aforementioned cortical and subcortical structures, the inhibition in the impaired hemisphere results in disinhibition of the structures in the unimpaired hemisphere. This can then lead to phenomena such as visual extinction, an inability to perceive a target stimulus on the side opposite the brain damage when there is competing information presented on the same side as the damage (Vallar, 1994). This disinhibition can be difficult to measure in patients suffering from brain damage because lesion location is not uniform and its influence is frequently widespread and unpredictable (Pascual-Leone et al., 2005).

3.2 The activation-orientation hypothesis

The activation-orientation hypothesis is based on the well supported theory of hemispheric specialisation; that the left hemisphere is specialised for verbal processing and the right hemisphere for visuo-spatial processing (Hellige & Michimata, 1989). This model suggests that spatial attention is biased in the direction of the hemisphere that is most active (Kinsbourne 1970; 1987, 1993; Reuter-Lorenz, Kinsbourne & Moscovitch, 1990). Increased right hemisphere activity could cause a stronger leftward attentional bias. This would in turn increase object salience on the left and cause objects on the right to be partially ignored (Nicholls et al., 2007). Therefore, in tasks of a visuo-spatial nature, such as those used to examine pseudoneglect , higher levels of activation should be seen in the right hemisphere with a resultant bias in spatial attention towards the left. Specifically in the line bisection, this activation would lead to overestimation of the left side of the line and therefore the associated bisection errors (McGeorge et al., 2007). However, outside of the laboratory, barring any sort of primary visual impairment, visuo-spatial attention is persistently active. The activation-orientation hypothesis thus helps to explain why this low level bias appears to be consistent and reliable; it is always present due to the fact that as long as we are perceiving visual information, our right hemisphere is consistently active.

More direct evidence for this account has been provided by a recent study conducted by Loftus and Nicholls (2012). Using transcranial direct current stimulation (tDCS) in 30 neurologically-healthy participants, authors examined if stimulation over the left or right posterior parietal cortex (PPC) would have an impact on pseudoneglect. Participants received anodal, cathodal and sham tDCS both before and after pseudoneglect measurement using the greyscales task. This task requires a forced choice between two mirror-reversed luminance gradients requiring participants to indicate which was darker. Before stimulation, all groups showed normal levels of pseudoneglect effects. In the left PPC stimulation group, this effect was significantly reduced by anodal tDCS but not by cathodal or sham tDCS. Stimulation over the right PPC had no effect on task performance (and therefore, on pseudoneglect). Anodal tDCS is an excitatory type of stimulation and authors suggest it may have overcome the lower levels of left PPC activation, thereby reducing the left attentional bias and decreasing pseudoneglect. Authors concluded that the lack of effect of stimulation over the right PPC and the amelioration effect of the anodal left PPC stimulation lead authors support the activation orientation hypothesis (Loftus & Nicholls, 2012).

Behaviourally, this can be seen in spatial tasks with a unimanual activity component. Unimanual activity effects on pseudoneglect were first documented by McCourt and colleagues (2001). They reported that the use of the left or right hand differentially impacted spatial attention and pseudoneglect; left hand use exacerbated the bias while right hand use ameliorated it. Nicholls and colleagues (2007) examined the effects of this as participants navigated through a doorway while firing a toy gun at a target. Participants used the left hand, right hand or both hands to shoot the gun and experimenters examined any differences in their doorway navigation (using bumps to the left and right as the metric). Results indicated that participants exhibited higher levels of bumping in the left hand use condition and lower levels in the right hand use condition, consistent with the unimanual activity effect (Nicholls et al., 2007). Right hand use leads to increased activity in the right hemisphere, according to the activation-orientation hypothesis which would therefore bias attention towards that side of space and decrease the attentional bias of pseudoneglect. This is reflected by the above results.

3.3 Representational Pseudoneglect

Pseudoneglect appears to not only affect the perceptual sphere, i.e. what we can see and process visually. There are numerous studies indicating that this lateralised bias exists for remembered information too. One of the most famous studies examining this is the experiment conducted by Bisiach and Luzatti (1987). This research involved two patients suffering from visual neglect, who were asked to recall a scene that they were familiar with (the Piazza del Duomo in Milan) from two opposing locations. Results showed that most of the remembered scene items were on the right side of space, regardless of viewing angle; illustrating the rightward attentional bias of unilateral neglect.

McGeorge and colleages (2007) conducted a similar experiment in pseudoneglect with a larger sample size of neurologically-healthy individuals. The authors examined attentional bias in mental imagery by asking one hundred healthy participants to imagine the same scene as that used by Bisiach and Luzatti (1987), again from two opposing viewpoints; half were asked to describe the scene facing towards the front of the cathedral and the other half facing away from it. Authors reported that regardless of vantage point, more items were reported from the left side of the image than the right and coined the term 'representational pseudoneglect.' (McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007). Bourlon and colleagues (2010) found a similar bias when they asked participants to reproduce topographical markers in France from memory (Bourlon, Duret, Pradhat-Diehl, et al., 2010) and similar has recently been reported for Canada (Friedman et al., 2012).This asymmetry in visuospatial memory can also exist in what is called 'back-space'(the space behind an individual). Cochini and colleagues (2007) designed a virtual reality experiment to examine this and found that the back space to the right was perceived as being smaller than that to the left (Cochini, Watling, Della Sala & Jansari, 2007).

More recently, representational pseudoneglect has been shown to exist in memory for novel materials. These include natural scenes (Dickinson & Intraub, 2009) and information about the colour, location and identity of objects (Della Sala, Darling & Logie, 2010). In both cases, more information and detail were recalled more readily from the left compared to the right. Darling and colleagues (2012) assessed both perceptual and representational pseudoneglect and found a typical bisection errors consistent with pseudoneglect in the perceptual condition. In this study nineteen neurologically-healthy participants were required to indicate the centre point of a series of horizontal lines of various lengths, both when they were presented visually and also from memory (Darling, Logie & Dela Salla, 2012). Results also reflected a clear leftward bisection bias when participants bisected lines from memory.

Visual processing, be it perceptual or remembered, does not appear to be necessary for representational pseudoneglect to be evident. It can also be seen when participants are asked to explore and describe a stimulus without visual input, i.e. by touch alone (Brooks, Della Sala, & Logie, 2011). This study required participants to bisect a wooden rod using touch alone. Participants used their index finger to explore the horizontal rod and then point to where they believed the centre of the rod to be, without direct visual input. Results reflected the left lateralised attentional bias characteristic of pseudoneglect (Brooks, Della Sala, & Logie, 2011). This bias has also been shown in individuals who are congenitally blind (Catteneo, Fantino, Tiniti & Vecchi, 2011), with blind participants showing a similar bias to that of pseudoneglect using the tactile rod bisection task. Research conducted by Darling and colleagues (2012) used a similar paradigm to the one employed in the current research. They required participants to bisect lines both perceptually (i.e. when they were visible) and from memory, after they had disappeared from the screen. Researchers reported no attentional bias in the perceptual condition but a clear leftward bias in the representational condition.

4. Expertise, Plasticity and Cognition

4.1 Neural plasticity and Expertise

Throughout much of the 20th century, scientific consensus was that the structure of the brain was stable and fixed after the critical period in early childhood had passed. Hubel & Wiesel (1970) showed that ocular dominance in the primary visual area (V1) was fixed after this period had elapsed and similar findings have been reported with respect to language (Lennenberg, 1967). However, this concrete view and the notion of critical periods does not appear to be the case. Our brains are capable of growing new functional neurons and forging novel connections between existing neurons. This can occur in response to brain injury, the ‘internal milieu’ (direct effects on the cortex and their resultant outcomes) or in response to normal learning and external sensory inputs (termed ‘external milieu’; Jacobsen, 1991). In order to remain within the scope of the current research – which encompasses expertise and neurologically-healthy individuals - the focus will be on the external type of plasticity.

Neural plasticity can take two main forms; functional cell plasticity or the changing of existing pathways, and neuroanatomical plasticity or the formation of new connections (see Rakic, 2002a for a review). Karni and colleagues (1995) examined plasticity in the human motor cortex by asking participants to perform a particular sequence of movements (touching finger to thumb) with one hand for several minutes each day. Behaviourally, their accuracy at this finger-thumb touching sequence improved. Researchers then compared performance on this sequence compared to an untrained sequences using functional Magnetic Resonance Imaging (fMRI). The trained sequence produced greater changes in blood flow in the corresponding motor cortex compared to the untrained sequences (Karni, Meyer, Jezzard, Adams, Turner & Ungerleider, 1995). Elbert and colleagues (1995) examined sensory representations in violinists using electroencephalography (EEG). Stimulating the string fingers revealed larger responses in the appropriate brain areas compared to the same stimulation in non-musicians. The size of this effect also correlated with the age at which they started their musical training; larger responses in those who had been training longer from a younger age (Elbert et al., 1995).

Further research in this area was conducted in pianists by Pascual-Leone and colleagues (1995). This study used TMS to map cortical motor areas of the finger flexor and extensor muscles over five days, two hours per day as participants learned and practiced a one handed five-finger exercise. They found enlarging of the related cortical areas and their activation threshold increased compared to a control group that received TMS mapping but did not take part in the practice. Importantly, these changes were only seen in the cortical areas related to the hand used, not of the other hand (Pascual-Leone, Nguyet, Cohen, Brasil-Neto, Cammarota, & Hallett, 1995). In one of the more well-known studies, Maguire and colleagues (1997; 2000; 2011) examined and documented changes in the brains of London taxi drivers. The hippocampal regions of these drivers changed in response to increasing knowledge of the layout of the city of London (Maguire, Frackowiak, & Frith, 1997; Maguire, Gadian, Johnswood et al., 2000; Maguire &Wollett, 2011).

4.2 Expert Performance and Cognition

Expertise was originally purported to be the result of innate ability or inborn talent (Galton 1896). Researchers including Galton concluded this based on associations between performance level with heritable differences in neural system and in the size and structure of the brain (Ericsson, et al., 2006). Much of the research in the field of expertise argued against this point, reporting that superior performance or 'expertise' in various disciplines, including sports, music and the arts, came about only after extensive deliberate practice (Ericsson, 2006; Ericsson et al., 1993; Platz. et al., 2014; McNamara et al., 2014). Adaptations and plasticity are everyday biological/physiological responses and changes that occur in response to habitual usage. For example, running builds the muscles of the legs (Gruber, Jansen, Marienhagen, & Altenmueller, 2010) and singing increases total lung capacity (Gould, 1977). This is not only true for physiological characteristics such as strength, speed or dexterity, but also for neural processes (as the aforementioned and wide-ranging literature on neural plasticity can attest to). Deliberate practice involves performing a specific type of activity, the sole aim of which is to improve that activity; for example, practicing putting in golf for the goal of improving that activity. This practice then results in cognitive, motor, physiological and neural adaptations (Ericsson et al., 1993). The shot routine in archery is split into three phases (stance, draw and aim) all of which involve a stable and fluid sequence of movements

(Ertan et al., 2003). As archery requires repeated practice of this shot routine and its elements in order to achieve expert form, it follows from the above research on plasticity that this would lead to plastic effects in the associated brain areas. Of particular interest here is the final step, the aiming step where the archer focuses on the target and locates the centre. Repeated practice of this aiming step and resulting improvements in accuracy could suggest plastic changes in areas associated with spatial attention and pseudoneglect, similar to the transient changes induces using tDCS (see Loftus & Nicholls, 2012).

One the most frequently-used approaches in examining expertise (and the approach that will be used in the current research) is a comparison between novices and experts in a particular domain (Gruber et al., 2010). In order to achieve this, the control participants must have no experience with the domain being examined, and experts must be able to be defined as such using relevant criteria. However, this definition of ‘expertise’ can be highly challenging (Gruber et al., 2010). In sporting domains such as running and swimming this is less nebulous as performance can be measured objectively (time taken to complete a distance; Ericsson, Roring & Nandagopal, 2006).

Seminal work in the area of expertise and cognition was conducted by De Groot (1965; 1966) and Chase and Simon (1973) examining short-term memory in expert versus novice chess players. De Groot reported no gross differences in chess-related thought processes between these two groups; the number of considered moves, the search heuristics used and the depth of search engaged in were similar. However, he did find differences in short-term memory (masters could replicate a chess position almost perfectly despite only viewing it for five seconds). This ability decreased sharply in players below masters level. De Groot suggested that master chess players have a special form of short-term memory specifically related to the ‘meaningful’ chess positions, rather than a superior global short term memory. This was supported by his finding of comparable performance between masters and novices in reconstructing random positions on the board. De Groot suggested this was due to a difference in encoding of short-term memory; that masters level players encoded the information on the board in chunks of 4 or 5 pieces that were organised in a relational structure (de Groot, 1965; 1966).

Chase and Simon (1973) continued in this vein by examining the chunks in more depth. They used a perceptual and a memory task. In the perceptual task, players re-constructed a chess position that was visible to them. Experimenters used the successive glances they made at the sample board as an index of chunking. The memory experiment was similar to de Groot's; re-constructing a position from memory after a short exposure. Experimenters used timing as the index of chunking here (i.e. which pieces went down together in close proximity). Results confirmed that player level impacts the amount of information that can be extracted within a short window (masters extract significantly more than novices) and reflected that higher level players encode the information in larger chunks, each consisting of familiar arrangements of pieces and that these chess chunks are bound by mutual characteristics (defense, attack, proximity, colour). Authors also found that the number of chunks retained in short-term memory was similar to that seen by Miller (1956) for common words (Chase & Simon , 1973).

Eye movements and visual processing are some of the most studied processes within expertise. Chase and Simon (1973) used eye movements as one of their metrics in the study of 'chunking' in expertise and Goulet and colleagues (1989) showed that levels of expertise were systematically related to eye-movements that preceded decisions within the field of expertise. In tennis, the eye movements of expert players mainly focus on the trunk and shoulders of their opponents in order to read an upcoming shot and make a decision on their response whereas controls tend to focus on their opponent's head for this information (Goulet et al., 1989). Experts in this situation have more visual information available compared to controls (Gruber et al., 2010). Experiments conducted in judo (Paillard, Costes-Salon, Lafont & Dupuis, 2002) and soccer (Helsen & Starkes, 1999) support this finding.

Behaviourally, expertise in the area of attention has been examined in various expert participant groups. The role of attentional expertise on multiple target tracking has been examined in radar operators (experts) compared to undergraduate students (novices; Allen, McGeorge, Pearson, & Milne, 2004). Participants were required to track targets and respond to a probe in one condition and perform the same task while simultaneously compeleting a digit categorisation task. Results showed that experts performed better in both conditions and that attentional resources contributed to the tracking of targets in both novices and experts (Allen, McGeorge, Pearson, & Milne, 2004). Greenfield and colleagues (1994) compared divided attentional performance (using reaction time, RT, as a metric), between video gamers as participants responded to targets that appeared in either high probability, low probability or neutral/equal probability locations on screen. In the first experiment participants were categorised as expert or novice and results suggested that both groups showed an attentional benefit at the high probability locations (faster RT) but that the expert gamers did not show the attentional cost (slower RT) at the low probability locations seen in the novices. Experts also showed significantly faster RTs in the low and high probability trials but not in the neutral trials. The second experiment had an un-stratified group of participants on a continuous skill level (from lower skill to higher skill) and showed that five hours of practice on the study game resulted in a significant decrease in response time for the low probability location. The authors concluded that experience with playing the video game resulted in an improvement in divided attention strategies (Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994)

Neuroimaging studies have also informed the area of expertise by highlighting and examining cortical activity patterns associated with this process and comparing patterns of activation between control participants and experts in a wide variety of domains. In archery, Chang and colleagues (2011) compared the activation maps of elite archers and non-archer controls using fMRI as they performed mental rehearsal of archery shooting. They found an economy of activation in the experts compared to the controls. Activation of the premotor and supplementary motor areas as well as the inferior frontal region, basal ganglia and cerebellum was noted in controls whereas in expert archers the primary activation was confined to the supplementary motor areas. Authors conclude that this more streamlined activation pattern seen in experts could contribute to greater consistency in performance (Chang, Jae-Jun, Jee, Hye, Hui-Jun et al., 2011). Yang-Tae and colleagues examined the effects of archery expertise on the mirror neuron system (see footnote[1]) as expert and novices watched a video of archery. They found hyperactivation of the premotor and inferior parietal cortex in the experts relative to controls and concluded that the human mirror neuron system may contain and expand representations of the motor repertoire. They also reported increased activation in brain regions associated with episodic memory (cingulate cortex, retrosplinial cortex, and parahippocampal gyrus) in expert archers relative to controls. This is suggested to be related to mental rehearsal of their own shot routine which would be more readily accessible in the experts compared to controls (in line with plasticity effects of practice). This streamlining and differential degrees of cortical activity is characteristic of neural plasticity as are the changes in the structure and connectivity associated with achievement of expertise.

4.3 Recurve Archery

Archery is a sport for everyone; young or old, physically fit or with a physical impairment (Needham, 2006). It is a comparatively static sport that requires strength and

[1] Mirror neurons are neurons that fire both in response to performance of an action or observation of that action by another. They were first observed in monkeys by di Pellegrino and colleagues (1992) who found activation in particular neurons in the premotor cortex both when monkeys reached for a nut and when the experimenters did the same (di Pellegrino, et al., 1992). Evidence of these neurons have also been found in humans (see Rizzolatti & Craighero 2004 for a review).

endurance of the upper body, in particular the forearm and shoulder girdle (Mann & Littke, 1989). At its heart it involves the shooting of arrows from a bow towards a target at various distances (depending on the competition type). This core visual and accuracy component is the main rational for this choice of experimental group. Archery can involve arrows being fired at numerous fixed distances, depending on the competition type; therefore archers have to be able to achieve accuracy at distances between 18m and 90m away. This sport requires strength, balance, co-ordination and accuracy in order to excel. The authors suggest that this accuracy is in part mediated by a more balanced or efficient spatial attention system, less influenced by pseudoneglect. This efficiency and 'streamlining' of cortical activity was demonstrated in a sample of archers examined by Kim and colleagues (2008) who reported that controls exhibited a more diffuse pattern of global cortical activity compared to experienced archers. They also reported that during the aiming step activation was seen in the occipital and temporal areas for experts but more frontal areas for the novice controls. This research did not examine pseudoneglect directly, however, from the patterns of activation seen it could be inferred that the experts were employing brain areas related to spatial attention (and therefore potentially to pseudoneglect) whereas the novices were not (Kim, Lee, Kim, Park, Kim Moon, Woo & Tennant, 2008).

5. The current research

The current thesis reports two experiments which explore the phenomenon of pseudoneglect in healthy normal participants; for both studies, the performance of normal controls will be compared with that of a group of expert archers., the archers are predicted to exhibit enhanced spatial processing and reduced susceptibility to pseudoneglect than their counterparts due to their achievement of expertise in a sport that activates brain areas associated with spatial attention (see Kim et al, 2008) and the plastic changes associated with practice and repetitious neural activation (e.g. Karni et al, 1995). Experiment 1 compares the groups on standard measures of pseudoneglect including laboratory-based tasks and the real-world Doorway task of Nicholls and colleagues (2007). In Experiment 2, perceptual and representational pseudoneglect are compared in these groups using a variant of the paradigm used by Darling and colleagues (2012). Again, performance differences were predicted in the expert (archers) group relative to controls, with archers performing better then controls.

Chapter 2

General Methods

2.1 Participants & Recruitment Process

Recruitment involved two groups – controls and experienced archers. All participants were neurologically healthy individuals recruited on a convenience basis. Ethical approval was granted for this research by the Maynooth University ethics committee. All experiments were conducted in accordance with the declaration of Helsinki.

2.1.1 Controls

Controls were defined as individuals from the general population with no archery training or experience. Inclusion criteria for controls were as follows: over 18 years of age; no history of neurological or psychological impairment; no history of drug or alcohol abuse; English as a first language. Exclusion criteria for controls included: severe head trauma resulting in unconsciousness; history of neurological or psychological impairment; drug and alcohol abuse; dyslexia; currently on anti-depressants or psychoactive medication. Control participants were recruited through a mixture of word-of-mouth and flyers posted on the Maynooth University campus, in local shops and in community centres; Londis Maynooth, Spar, Maynooth and Maynooth Community Council.

2.1.2 Experienced Archers

Experienced archers were identified based on two criteria; involvement in the sport for 3+ years and achievement of the Master Bowman classification (taken from the Grand National

Archery Society (GNAS) in the United Kingdom. This requires the achievement of three separate scores of at least 1,191 points in a record status event (as recognised by World Archery). In this type of competition the maximum score achievable is out of a max of 1,440 points in tournaments at the county level and above. To improve homogeneity of the sample all archers that took part in the research shot the Recurve style of archery (see below).

Inclusion criteria for archers were the same as those for controls plus the achievement of the 'Master Bowman' qualification. Exclusion for archers again included the same list plus non-achievement of the 'Bowman' qualification. Archers were recruited from clubs across the Republic of Ireland and Northern Ireland. They were recruited through word-of-mouth and flyers sent to individual clubs (Athboy archery club, Banbridge Archers club, Blackheath Archers, City of Belfast Archers club, Dublin Archers, Dundrum Archers, Liffey Archers and Wicklow Archers) and handed out at competitions.

2.2 Equipment and Materials:

2.2.1 Recurve Archery

Bow set-up consists of a central riser or handle made of wood, metal or carbon upon which two limbs are mounted. The limbs extend vertically from the riser and provide the force which propels the arrow forward. Projecting from the front is a long rod or stabiliser (which extends forward from the riser) and typically two side rods that extend backwards, one to each side. The function of these three elements is to provide stability to the bow. They prevent muscle tremor and unintentional arm movements from negatively affecting the arrow's flight. Mounted to the riser above the stabiliser and side rods is the sight. This is an aiming aid that assists the recurve archer in locating the centre of the target at whatever distance he/she is shooting. This affords higher levels of accuracy to the shot. The final part of the bow set-up is the string which connects the two limbs (See Figure 2.1 for a diagram of archery equipment set up).

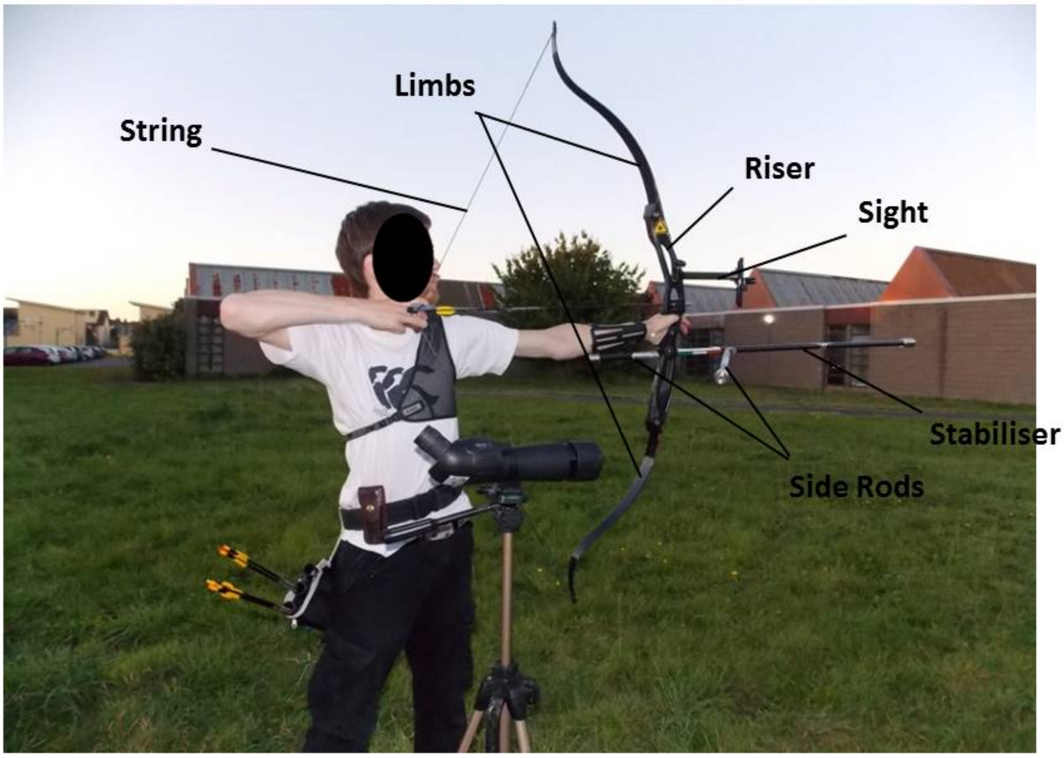

Figure 2.1: Recurve archery equipment set-up.

2.2.2 Cognitive Testing

A cognitive test battery was administered in all stages of the research. Following the initial briefing - which involved the explanation of the inclusion and exclusion criteria and the recording of handedness, vision (normal or corrected to normal) and eye dominance - participants were asked to sign a consent form (see Appendix 1). In order to examine general cognitive functioning, participants were initially required to complete the National Adult Reading Test (NART; Nelson, 1982), the Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982) and the Trail Making Task (TMT; Partington & Lieter, 1949). These tests were used to yield a general estimate of cognitive ability for each participant for comparison purposes so that any observed differences in experimental task performance could not be considered attributable to differences in general cognitive functioning.

The National Adult Reading Test (NART; Nelson, 1982)

The NART was developed to provide a reliable estimate of pre-morbid intellectual ability (Nelson & O'Connell, 1978). It was developed after assessment of patients who had suffered a decline in intelligence revealed that despite varying degrees of neural damage, their ability to read aloud was relatively preserved (Nelson & McKenna, 1975; Blair & Spreen, 2007). The literature reflects the view that the IQ estimation ability of the NART is relatively unaffected by neurological impairment (Crawford & Besson, 1988; O'Carroll & Gilleard, 1986). Crawford and colleagues (1988) reported that NART IQ score correlates significantly with education and social class (Crawford, Stewart, Garthwaite et al., 1988). Neither sex (Crawford et al., 1998; Schlosser & Ivison, 1989) nor age (Crawford et al., 1988; Starr et al., 1992; Crawford et al., 2001) appear to have any effect on NART performance.

Fundamentally, the NART provides an estimate of vocabulary size (Lezak, 2004). It is a reading test of 50 words with irregular grapheme-phoneme correspondences (Coltheart, et al., 1987), which reduces the chance that an educated guess will provide the correct pronunciation (see Appendix 2). The rationale for using this task as an indicator of premorbid IQ is that there is a high correlation between reading ability and intelligence (Carver, 1990; Crawford et al., 1989a) and pronunciation accuracy (O'Carroll, 1995) in the normal population, and word reading tests give a fairly accurate picture of pre-injury IQ (Moss & Dowd, 1991). Furthermore, mildly impaired individuals typically retain their capacity to pronounce irregular words (Crawford et al., 1989a; Fromm et al., 1991). The NART is unsuitable for those suffering from aphasia or other language deficits (Spreen & Strauss, 1998), or those suffering from executive dysfunction who fail to mentally check and correct errors before speaking (Patterson, Graham & Hodges, 1994). However, while it can be sensitive to such neurological damage, evidence suggests it is less so than other measures (Maddrey et al., 1996). In order to extract useable data from the NART, error scores are converted into the three WAIS-R IQ categories Verbal IQ (VIQ), Performance IQ (PIQ) and Full Scale IQ (FSIQ) using the conversion tables found in the accompanying test booklet for the NART (O'Carroll, 1995; see Appendix 2).

A factor analytic study found a high level of construct validity for the NART as a measure of general intelligence, indicated by a high loading (.85) on factor 1 extracted by principal components analysis (Crawford et al., 1989). Factor 1 (*g*) is regarded as representing general intelligence (Spreen & Strauss, 1998). Test re-test reliability of.98 and inter-rater reliability above .88 have also been reported (Crawford et al., 1989; O'Carroll, 1987). The NART was re-standardised in 1991 and the estimated IQ range increased from 131-69, but the original list of words were unchanged (Nelson & Willison, 1991).

The Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald, & Parkes, 1982)

The Cognitive Failures Questionnaire (CFQ; see Appendix 3) is a self-report measure of failures in perception, memory and motor function (Broadbent, Cooper, FitzGerald, & Parkes, 1982). The questionnaire contains 25 items related to everyday 'mishaps' such as 'Do you fail to see what you want in a supermarket (although it's there)?' and 'Do you find you forget why you went from one part of the house to the other?' Participants must rate the frequency of each of these items in their daily lives within the last six months on a five-point rating scale; 0 = Never, 1 = Very Rarely, 2 = Occasionally, 3 = Quite Often, 4 = Very Often (Broadbent et al., 1982). All questions are worded in the same way; rather than selectively positive or negative. Authors found minimal differences when mixed wording was tried and there was evidence that participants could be misreading the scale on some items in this format (Broadbent et al., 1982). The CFQ initially had five lie scale questions taken from the Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975) but these were omitted after initial testing and because some participants objected to the items themselves. The authors reported that the CFQ measures general cognitive failures in the three identified areas only in their validity scale (Broadbent et al., 1982); however, other researchers argue that there are more factors involved including physical clumsiness and absentmindedness (Matthews, 1990). Pollina and colleagues (1992) even suggested that the CFQ measured five different factors; distractibility, misdirected actions, spatial memory, interpersonal intelligence and memory for names. The CFQ appears to contain too few items to measure more than two factors; a general cognitive failures factor and a specific one related to remembering names (Matthews, 1990). Similar factors were reported by Larson and colleagues (1997) who suggested three factors; the first and second reflected those proposed by Matthews, while the final one was ill-defined and explained too little of the variance to be considered meaningful (Matthews et al., 2000).

The Trail Making Task (Partington & Lieter, 1983; Reitan, 1958)

The Trail Making Task (TMT; See Appendix 4) was originally constructed in 1938 as an easily administered test of visuo-motor scanning, divided attention and cognitive flexibility, given in two parts (Lezak et al., 2004). Part A involves the connection of twenty-five encircled numbers arranged randomly on a page, in ascending order, and part B involves the connection of alternating numbers and letters, again in ascending order (Spreen & Strauss, 1998). In its original form any errors went uncorrected by the experimenter.

Performance is affected by age and education but not by gender (Tombaugh, 2004). Stuss and colleagues (1987) reported significant practice effects if the test was repeated after just one week but Lezak and colleagues (1982) found that practice effects existed for Part A but not B. There is high inter-rater reliability for both parts of the TMT; A (.94), B (.90). Part A and B correlate only .49% with each other, suggesting that they both measure slightly different functions (Heilbronner et al., 1991). Typically Part B takes longer to complete. One potential explanation for this, aside from the fact that number-letter switching has a higher cognitive load than number sequencing, is the layout of the test itself. The actual distances between the circles are bigger and there is more visual interference present; in Part A there are 11 items within a 3cm distance from the lines to be drawn; this number rises to 28 in Part B. Therefore, Part B requires more visual processing ability than A (Woodruff, et al., 1995). Gaudino and colleagues reported that if both parts were number-letter switching conditions Part A took an average of eleven seconds longer to complete, while part B took 13.5 seconds longer, compared to number sequencing alone (Gaudino et al., 1995).

Scoring is expressed in terms of time taken (in seconds) to complete Parts A and B, and an overall score calculated by subtracting time taken on A from time taken on Part B. This scoring method was devised by Reitan (1958) and remains the most commonly used today. However, it has been argued that this method results in decreased reliability because time taken also includes the reaction time of the experimenter in spotting errors and pointing them out, and the time taken for the participant to comprehend and correct the error (Lezak, 2004). Lezak (1995) recommends using the overall score (Part B - Part A) when calculating results as this decreases the variability introduced by errors and the subsequent interruptions and correction time.

2.2.3 Spatial Processing Tasks

To examine spatial functioning participants were required to complete Cancellation tasks, a Line Bisection task, a Doorway task and one of two computer-based tasks. In Experiment 1a this task was a visual search. In experiment 1b it was a computer based line bisection with perceptual and memory conditions.

Cancellation Tasks

Cancellation tasks assess an individual's capacity for sustained attention, accuracy of visual scanning and activation and inhibition of responding (Lezak et al. 2004). In routine clinical protocol they are a widely-used and easily-administered measure for the diagnosis of unilateral spatial neglect and the severity of the deficit; spatially biased performance is a strong predictor of neglect severity (Ferber and Karnath, 2001).

Two versions of the cancellation task were used: the Bells Test (Gauthier, Dehaut, & Joanette, 1989) and the Letter Cancellation (Weintraub & Mesulam, 1985). The Bells Test consists of 315 filled symbols; 50 of which are bells, scattered seemingly randomly across an A4 sheet. However, the symbols are actually arranged in seven columns, with five bells in each column (see Figure 2.2 and Appendix 6).

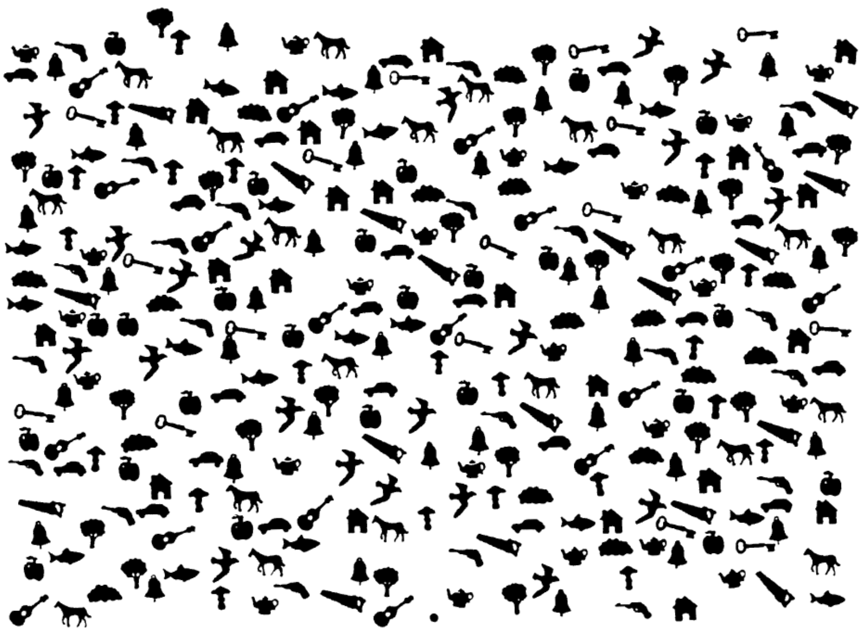

Figure 2.2: Bell cancellation (Gauthier, et al., 1989).

The Letter Cancellation task consists of 60 target stimuli (in this case, the letter 'A), interspersed among distractor letters, all in capitals, again in a random array (Weintraub & Mesulam, 1985; see Figure 2.3 and Appendix 6).

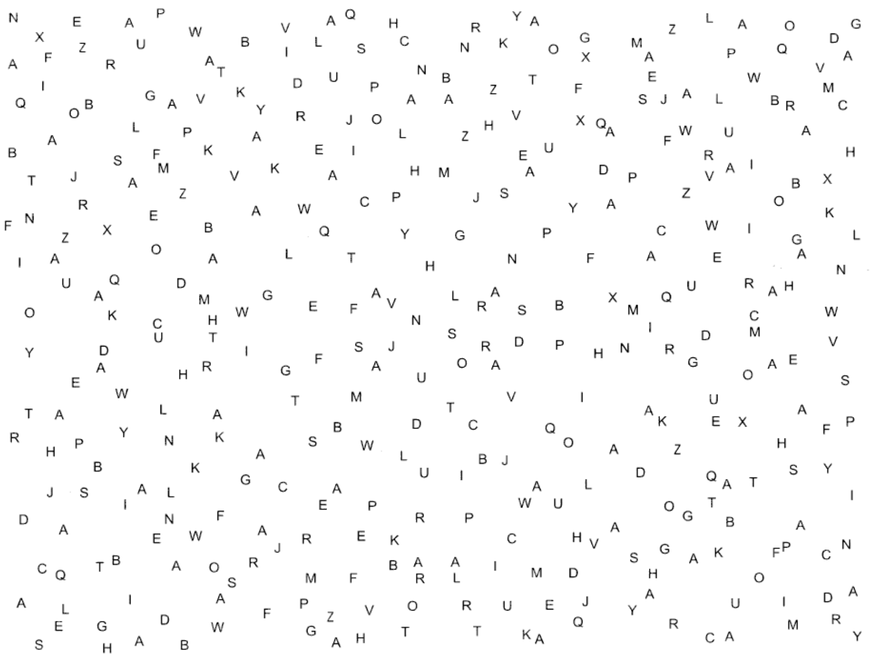

Figure 2.3: Letter cancellation (Weintraub & Mesulam, 1985).

The cancellation task requires individuals to cancel out or delete the prescribed symbols within the allotted time. If the participant stops deleting symbols before the time limit is reached, they should be given a reminder to check if all of the symbols have been deleted. The current research used a time limit of 30 seconds. The standard time limit is 1-5 minutes (Lezak, 2004), however this is the time limit used for measuring neglect after brain injury. When this method was used in pilot testing no omissions were made; therefore it was decided to reduce the time limit down to 30 seconds.

Despite its popularity as a clinical measure, interpretation of the cancellation task is quite arbitrary; it is often used in a binary capacity to classify neglect as either present or absent. To derive a continuous measure from the test it has been suggested that simply summing all omissions will provide a measure of neglect severity, i.e. the Behavioural Inattention Test (BIT, Wilson et al., 1987). However, this method fails to distinguish between spatially-biased performance and a more global inattentive performance. If, for example, one patient omits all the target stimuli on the left side and another patient omits the same number but spread randomly across the test sheet, they would receive the same omission score, despite one being neglect-present and the other neglect-absent (Rorden & Karnath, 2010). In order to combat this Halligan and colleagues (1991) proposed using a lateralisation index (Friedman, 1992) which would give a ratio of the number of targets cancelled on the left side of the test sheet divided by the number detected overall. However, despite being more nuanced, this might not be a reliable measure of severe neglect. Chaterjee and colleagues (1992) suggested using power functions, subsequently analysed using logistic regression. The regression in this case attempts to model target detection probability across a continuous variable using sigmoid functions. In theory when dealing with a single variable one can find the 50% crossing point; however the figure returned may be unintuitive and the analyses is too complicated and sophisticated for daily clinical usage (Rorden & Karnath, 2010).

Mark and Monson (1997) proposed calculating the geographical centre of all neglected stimuli relative to actual page centre as a measure of neglect severity. This ‘neglect-centre’ is reported in the form of co-ordinates to reflect its distance from the page centre in a particular direction. However, authors acknowledge that this is a measure of direction changes in neglect, rather than a measure of neglect severity in itself (Mark & Monson, 1997). A similar method, the Center of Cancellation (CoC) was proposed by Binder and colleagues (1992), involving the mean horizontal location of target items. The CoC score is calculated by summing the horizontal position of each target detected and dividing this by the sum of targets detected (Binder et al., 1992; Rorden, & Karnath, 2010). Therefore, this measure takes into account both the number and location of omissions which is an important indicator of the severity of neglect. Consider two hypothetical participants who each only find one item on the left half of the page: the participant with less severe neglect sees all items on the right half of the page and has a score near 0.5 (mean for targets on the right half), whereas the more severe patient who misses all other targets on the left 3/4 of the page will receive a score near 0.75 (mean for targets on the right 1/4) (Rorden & Karnath, 2010). Therefore, the CoC score reveals the severity of the neglect, rather than just the presence/absence of neglect as other measures do, making it highly practical and useful, both for research and clinical purposes. This method was not widely adopted however, which could be due to the complicated processes required to calculate the CoC by hand. Rorden and Karnath (2010) devised a computer programme where the targets found or omitted can be highlighted and the CoC automatically generated based on this input. In order to do this the required task type is loaded into the programme which automatically place grey squares over the targets. This indicates that none of the targets have been found and is the blank slate from which the CoC score is generated. In order to get this score the experimenter must toggle the squares over the targets that the participant has successfully cancelled, from grey (missed targets) to green (found targets). This is achieved by examining the scoring sheet and matching found targets on this with their counterparts on the screen. This makes it an efficacious and quick analysis method for the cancellation task.

The Line Bisection Task (Schenkenberg, Bradford, & Ajax, 1980)

The line bisection task is a robust indicator of pseudoneglect and unilateral spatial neglect. In the Line Bisection task, participants are required to draw a vertical line through each of these horizontal lines as close to the centre as possible. Experimenters must be vigilant in making sure that the non-drawing hand is kept off the table and that no lines are skipped or bisected more than once and that the centre line of the task sheet is aligned with the midline of the participant on the table (Lezak, 2004). Designed by the researchers for the current projects, participants must bisect ten lines where they believe the centre of each line to be. In test order, the lengths of the lines were 10cm, 14cm, 12cm, 6cm, 12cm, 8cm, 4cm, 14cm and 18cm.

Line length has varying degrees of effect on bisection accuracy; short lines are less likely to result in deviation errors compared to longer lines, and the longer the line, the greater the deviation (Pasquier, et al., 1989). However, controls are far less affected by line length than USN patients (Vallar, Daini & Antonucci, 2000). Normal subjects tend to mark horizontal lines slightly to the left of centre, usually deviating by approximately 1-2mm (Scarisbrick et al., 1987) which would be consistent with pseudoneglect (Nicholls et al., 2007). Handedness as an influence on bisection performance has been the subject of mixed reports; some indicate that right-handed neurologically normal participants bisect lines to the left of centre (Bowers & Heilman, 1980). However, other studies report no effect of handedness on bisection performance (Levander et al., 1993) and it is questionable whether or not this bisection error is truly an effect of hand rather than due to pseudoneglect. Another issue in the handedness research is that a lot of studies only use right-handed participants (Brodie & Pettigrew, 1996; Butter et al., 1988; Chokron & Imbert, 1995; Halligan & Marshall, 1993; Harvey et al., 1995) or fail to report and discuss handedness at all (Berti et al., 1995; Bisiach et al., 1990; Reuter-Lorenz et al., 1990). Based on reviews of the literature and the relatively small percentage of left-handed versus right-handed in the sample population for the current research, the authors did not explore handedness as an influential factor.

Sex appears to have no impact when participants use their preferred hand (Bradshaw, Nettleton, Nathan & Wilson, 1985; Chokron & Imbert, 1993; Hausman, Ergun, Yazgan & Güntürkün, 2001; Milner, Brechmann & Pagliarini, 1992; Speedie, Wertman, et al., 2002).

Roig and Cicero (1994) reported that men exhibited a significantly greater bisection error than women but did not give enough information on effect strengths (Hausman, et al., 2001), therefore sex was not controlled for in the research. Reading direction may influence attention used when performing the line bisection task with left to right readers bisecting more to the right and vice versa. McConkie and Rayner (1976) found an asymmetry in attention during reading; left to right reading participants attended to four characters to the left of their current position and 14 to the right. Right to left readers (e.g. of Hebrew) display the opposite tendency (Pollatsek et al., 1981). However, this directional bias fails to fully account for the hemispheric asymmetries in USN; USN is typically worse in right versus left hemisphere lesions (Speedie et al., 2002; Weinberg et al., 1977). The majority of research into VN and line bisection errors has been with a left to right reading population, which reflects all participants in the current research. Therefore it will not constitute a potential influence on performance in this case.

The line bisection is rarely standardised unless it is part of a standardised test battery, i.e. there are many versions of this task. This can make it more difficult to consistently measure reliability and validity across versions. A correlational analysis of line bisection and star cancellation performance in 27 stroke patient participants suggests that it is has good construct validity (Marsh & Kersel, 1993). In order to prepare the data for analysis, signed deviations were extracted for each participant in millimetres; rightward deviations from centre were positive and leftward deviations were negative (see Figure 2.4)

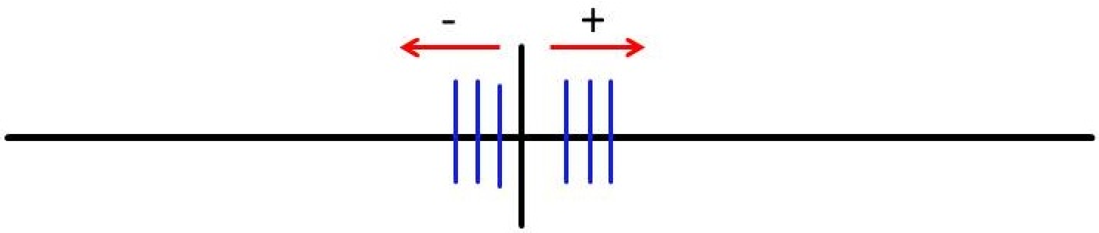

Figure 2.4: Line bisection scoring. Bisections to the left of centre were negative, bisections to the right were positive.

The Doorway Task (Nicholls et al, 2007)

The Doorway Task is a motor task of spatial ability and navigation. It was originally designed by Nicholls and colleagues for their 2007 paper as a way to observe the leftward attentional bias of pseudoneglect in real-world situations, rather than using the typical pen and paper tasks. The task involves walking through a doorway apparatus consisting of two poles, held in position by Velcro, the distance between which has been set at 1cm wider than the participant on each side. This figure is achieved by measuring each participant across their widest part; shoulders or hips, and adding 2cm (Nicholls et al., 2007; see Figure 2.5). Participants walked through the doorway 20 times and the experimenter noted with each pass through the doorway whether there was no bump, a bump to the left or a bump to the right. For a bump to qualify as a true bump the poles had to be set in motion or knocked over. Bumps caused by extraneous clothing were not included and bulky clothing was removed before the experiment started.

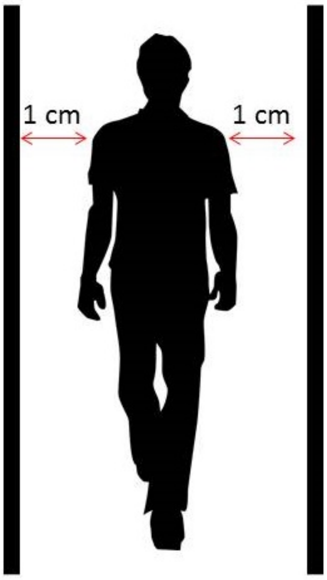

Figure 2.5: Setup of Doorway task. Participants were measured at their widest part and 1cm was added to this figure on each side of the doorway.

The Visual Search Task (Triesman & Gelade, 1980)

Visual search involves a set of complex behaviours that encompass many aspects of human visual and cognitive function. The visual search task has become an important tool in the study of processes such as visual attention, both overt and covert, oculomotor control, integration of visual information and in understanding differences and biases in visual processing (Eckstein, 2011). There are two distinct types of visual search; feature search and conjunction search. In feature search the target stimulus is distinguished from any/all distractors that may be present along one feature dimension (i.e. colour, shape, size, orientation, direction of motion etc.); for example, a red circle target in amongst blue circle distractors, so there is a 'pop-out' effect making it easier to identify targets. Conjunction search is more difficult because targets are defined by the conjunction of features (e.g. colour and shape, such as a blue circle) which are each present in a different subset of distractors (blue squares and red circles). This eliminates the 'pop-out' effect so participants have to perform a more effortful search in order to make a target present/absent judgement (see

Figure 2.6). Reaction times (RTs) also differ depending on the type of visual search employed. In feature (pop-out) search paradigms RTs remain constant and display size (number of disctractors) has minimal bearing on this measure. For conjunction search the RT slope is steep and increases linearly depending on display side (i.e. more distractors means longer RT values) (Trick & Enns, 1998).

According to Feature Integration Theory (FIT; Treisman & Gelade, 1980) this linear increase in RTs is seen because processing and integrating the features associated with each stimulus is a lengthy process. FIT postulates that topographical stimulus features such as shape and colour are initially registered in different cortical areas and must then be pulled from these locations and combined into the perceived stimulus (Treisman & Gelade, 1980). Furthermore, this is a serial process so each stimulus must be processed and integrated individually, thereby increasing RTs in conjunction search tasks (Trick & Enns,1998).

The paradigm in the current research involved searching for a red forward slash (red line pointing diagonally to the right) hidden amongst distractors; blue forward slashes and red and blue backward slashes, horizontal lines and vertical lines (See Figure 2.6 for an example). Participants were asked to make a judgement on the raget being present or absent and indicate this using the mouse (left click for target present, right for target absent). The task consisted of 4 blocks of 30 trials; 15 target present and 15 target absent, that were randomised and separated by a fixation of 1000 ms. Trials were on-screen for 2000 ms or until the participant responded, whichever came first; a lack of response was recorded as incorrect.

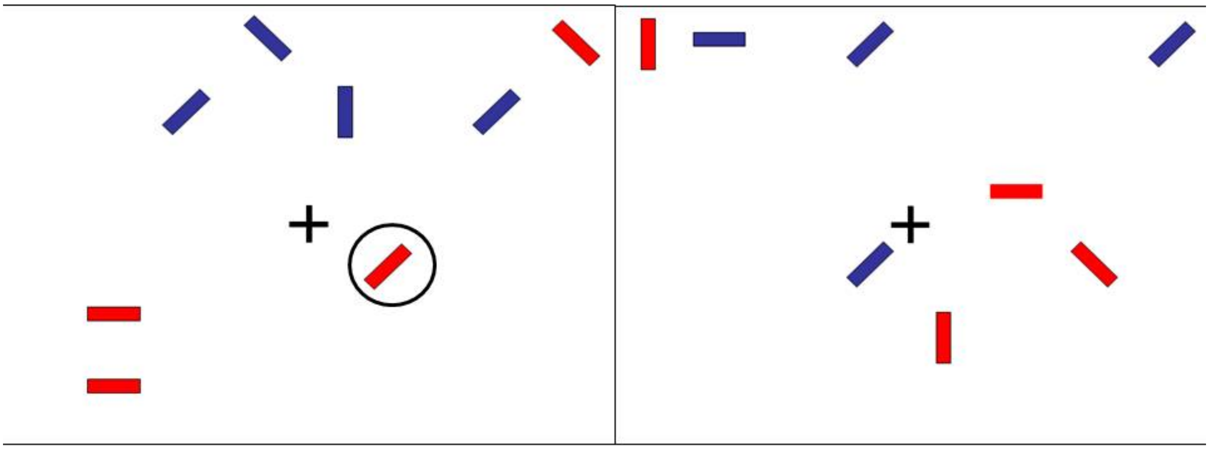

Figure 2.6: An example of a target present (circled in black) and a target absent trial from the Visual Search task in the current research.

The Perceptual and Memory Line Bisection Task (Darling et al., 2014)

Perceptual line bisection tasks such as the pen and paper version (as described above) are a long-standing and well-validated test for spatial attention biases. However, there is evidence to suggest that pseudoneglect exists not only in the perceptual sphere but also in the representational domain (Loftus et al., 2009; Darling et al., 2014).

This computer-based task was designed to assess accuracy and reaction time in three line types; normal (without fins), inward-going fins and outward-going fins (similar to those seen in the Muller-Lyer illusion (Muller-Lyer, 1889). It also covered two input types; perceptual (where subjects made their judgements in real time while looking at the line) and memory (where subjects made their judgements after the line had disappeared from the screen). The task consisted of 60 bisections; 30 perceptual and 30 memory which were counterbalanced across participants. Within these input types there were 10 trials of each line type (no fins, inward-going fins or outward-going fins) which were displayed on screen for 2,000 ms. In each trial vertical lines numbered 1-5 were displayed to indicate potential centre points for the line. Judgement involved choosing which vertical line was the true centre by pressing the corresponding key on the keyboard within a time limit of 2,000 ms. In the perceptual trials the vertical lines were superimposed over the horizontal line and then participants judged the centre. In the memory trials the horizontal line appeared on screen and then disappeared. The vertical lines were then displayed and participants had to choose based on where they remembered the centre of the line being located. The interstimulus interval was a brief fixation of 1,000 ms (see Figure 2.7). The scoring metrics were accuracy and reaction time.

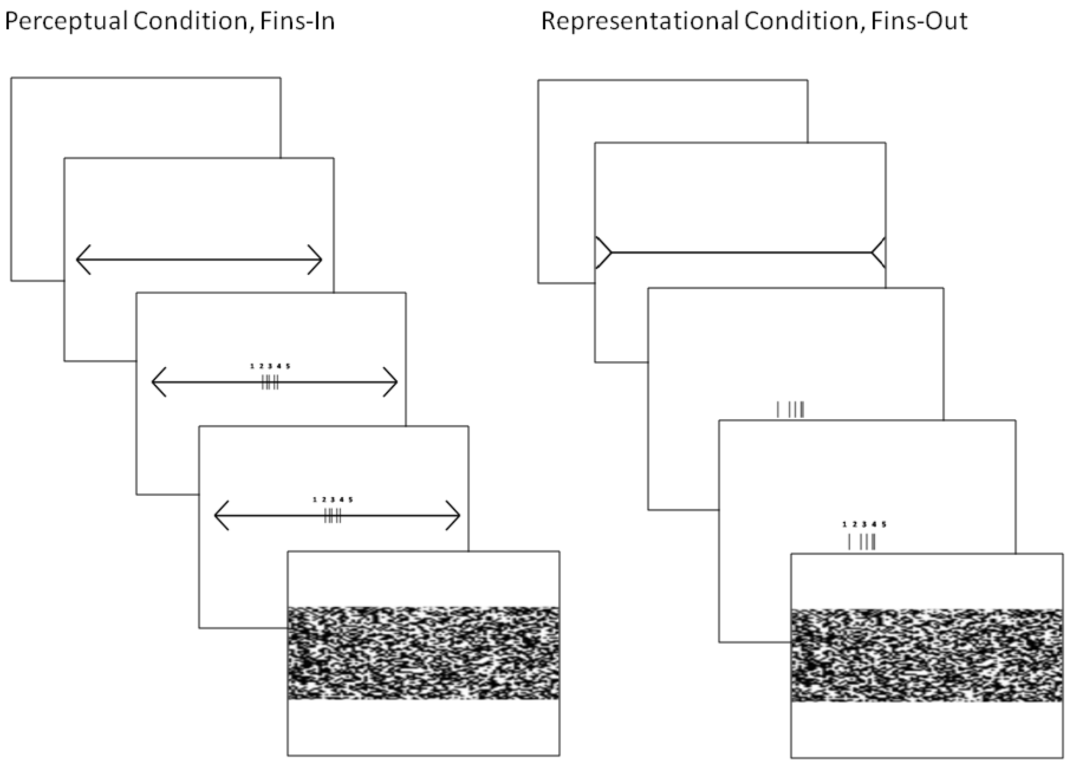

Figure 2.7: Diagram of the perceptual and representational conditions in the Line Bisection Task. A blank screen was displayed for 1,000 ms before each trial. Lines remained on screen for 2,000 ms, then vertical bars appeared followed by numbers after which the participant had 2,000 ms to respond using the appropriate numbered keys. Inter-stimulus interval was a 1,000 ms fixation. After each trial there was a mask lasting 1,000 ms.

2.3 Statistical Analysis

All analysis was conducted using SPSS V8. ANOVAs, MANOVAs, independent and dependent t-tests and non-parametric tests were conducted on behavioural data. Normality was checked using Levene's tests and plots, outliers were screened and post hoc Bonferroni and Greenhouse-Geisser corrections were performed. If necessary to further explore significant results, the file was split to conduct t-tests and the p-value was re-calculated accordingly.

2.3.1 NART

NART performance was converted into the three IQ types (FSIQ, VIQ and PIQ) using the standard NART conversion table (see Appendix 2). A MANOVA will be conducted with group (control or archer) as the Independent Variable (IV) and these IQ types as the Dependent Variable (DV).

2.3.2 CFQ

Results of the CFQ will be analysed using an independent t-test with group as the IV and CFQ scores as the DV.

2.3.3 TMT

Completion time (in seconds) will be measured across Trial A and Trial B and the difference calculated (B-A). A MANOVA will be conducted with group as the IV and these completion times as the DV.

2.3.4 Cancellation Tasks

The CoC will be calculated for each participant in the letter and bell cancellation. A MANOVA will then be conducted for each task type with group as the IV and CoC as the

DV. Follow up independent and dependent t-tests will be conducted on any significant results.

2.3.5 Line Bisection

Signed deviations will be calculated for each participant and a MANOVA conducted with group as the IV and bisection side (right or left) as the DV. Follow up independent and dependent t-tests will be conducted on any significant results.

2.3.6 Doorway Task

Bumps to the left, right and trials where participants did not bump (no bumps) will be recorded and analysed using a MANOVA with group as the IV and Bump Side as the DV. Follow up independent and dependent t-tests will be conducted on any significant results.

2.3.7 Visual Search

Accuracy and Reaction Time (RT – in milliseconds), will be calculated for each participant and analysed using MANOVAs with group as the IV for both. In the accuracy analysis accuracy will be the DV; in RT analysis, RT will be the DV. Follow up independent and dependent t-tests will be conducted on any significant results.

2.3.8 Representational Line Bisection

Accuracy will be calculated for each participant and analysed using a 2x2x3 ANOVA with group (2 levels; control and archer) x condition (2 levels; perceptual and memory) x line type (3 levels; no fins, fins in and fins out). Follow up independent and dependent t-tests will be conducted on any significant effects.

Chapter 3

Perceptual Pseudoneglect in Archers

1. Abstract

Pseudoneglect is a subtle yet consistent bias towards the left in spatial attention exhibited by the normal population (Bowers & Heilman, 1980). Archery is a target sport where accuracy is of high importance; training to the expert level requires up to 10 years of practice to achieve, and results in a higher level of accuracy. This chapter examines whether this accuracy is related to changes in spatial attention; we hypothesised decreased pseudoneglect in archers compared to controls. This hypothesis was largely supported by the results of a spatial battery (Cancellation tasks, Line Bisection, a Doorway task and Visual Search). Archers appeared to be less affected by the spatial attentional bias characteristic of pseudoneglect in both laboratory tests (Bell cancellation and Line Bisection) and the more real-world scenario of the Doorway task.

2. Introduction

Pseudoneglect is a common phenomenon characterised by a subtle yet consistent bias in spatial attention that is exhibited by the normal population (Bowers & Heilman, 1980). This imbalance is similar in theory to that characteristic of visual neglect (or left unilateral spatial neglect, USN; see Chapter 1), whereby the left portion of the visual field is ignored or neglected. However, there are three notable differences: firstly, in pseudoneglect the attentional bias is in the opposite direction i.e. to the left, not the right, meaning that the right side of the visual world is neglected; secondly pseudoneglect is far less severe in magnitude than USN; finally, pseudoneglect is exhibited by the normal population whereas visual neglect presents after unilateral brain damage, typically to the right inferior parietal area or temporo-parietal regions (Critchley, 1966, Mesulam, 1981). This deficit is most typically associated with stroke (Danckert & Ferber, 2006) (see Chapter 1: General Introduction for more information).

Pseudoneglect can be identified through the use of standard pen and paper tests of spatial performance such as the Cancellation task (Gauthier 1989); however, it is more observable in real-world or naturalistic situations. One example of a more naturalistic test is the Doorway task (Nicholls et al., 2007). This task comprises a set of mobile poles that act as a doorway for participants to walk through (See Chapter 2: General Methods for more information). Pseudoneglect is examined by counting the number of bumps to the left and right side of the doorway. In order to take advantage of the real world effects of pseudoneglect, a protocol composed of pen and paper, computer-based and real-world tasks was devised for the current research. It was theorised that this would provide a more comprehensive means of detecting the presence and magnitude of this spatial bias in our samples of interest.

The current study used a version of the Doorway paradigm first demonstrated by Nicholls and colleagues (2007). This experiment involved participants walking through a doorway while firing a toy gun at a target. The width of the doorway was set at 10mm wider than each individual participant measured across their widest part. As they walked through the experimenter noted any contact made with the sides of the doorway. Their results suggested that the majority of the time participants did not bump into the doorway, which is to be expected for something as subtle as this phenomenon, and demonstrated the adeptness of people to fit through small gaps. They concluded that bumping was not random but followed a consistent pattern, attributed to pseudoneglect (Nicholls, et al., 2007).

Recurve archery is a sport involving the propulsion of arrows from a bow comprised of limbs, riser, string, stabilisers, longrod and sight. It is a target discipline with archers firing arrows to distances of between eighteen and ninety metres (depending on competition type). Standard Olympic recurve archery, one of the more recognisable forms of competition, takes place at seventy metres. This sport requires strength, balance, co-ordination and accuracy in order to excel. The authors suggest that this accuracy is in part mediated by a more balanced or efficient spatial attention system, less influenced by pseudoneglect. This is likely the result of neural plasticity effects whereby the consistent practice (both physical and mental) leads to neurogenesis and the growth of new connections in the related areas (see Chapter 1 for more information on the discipline and Chapter 2 for more information on the equipment and set-up).

The neurological underpinnings of the archery shot routine have been examined and compared between expert archers and novice controls (Kim, Lee, Kim, Park, Kim Moon, Woo & Tennant, 2008). This gives clues to the streamlining of cortical activity that occurs as expertise is achieved. As discussed previously there was also a differential pattern of activation between the two groups; the expert archers showed activation in the occipital and temporal areas while the activation pattern in controls was largely in the frontal areas. While this study did not directly examine pseudoneglect, these areas of activation seen in the archers are heavily involved in spatial attention (and therefore potentially in pseudoneglect). One possible reason is that the long training and experience of the experts allowed them to aim using only the occipital and temporal areas without needing to recruit other areas of the brain like the novice controls did; i.e. there was little or no ancillary or unnecessary activation in the experts. From this study it could be inferred that repeated activation of these circuits in the expert archers has lead to plastic effects; removing the necessity for recruitment of other brain areas and strengthening areas associated with spatial attention which could potentially have an impact in pseudoneglect effects. However, as this study didn't examine pseudoneglect directly further work is necessary to clarify if this is the case. . To the best of our knowledge no previous research on the impact of perceptual pseudoneglect in archery has been carried out. Coudereau and colleagues (2006) have conducted research into representational pseudoneglect in visually impaired arches but this will be discussed in the context of experiment 2 which examines this type of pseudoneglect. Other research has examined golfers (Roberts & Turnbull, 2010) and the impact of pseudoneglect on putting and their results suggested that putting is influenced by pseudoneglect effects; they found the characteristic leftward attentional bias in their sample of golfers in all pseudoneglect indices (Roberts & Turnbull, 2010). However, there are intrinsic differences between golf and archery. Firstly, when putting a golfer does not stand directly facing the target, thereby shifting the golfer's frame of reference. Secondly, if the golfer is right handed, all the information regarding the location of the hole (based on how they stand) is on the left (Roberts & Turnbull, 2010). This would lead to increased right hemisphere activation potentially exacerbating the attentional bias. This is demonstrated in tasks than have a unimanual activity component, i.e. the use of one hand or the other during task completion. Left hand use leads to increased right hemisphere activation, which would therefore worsen the leftward attentional bias and right hand use would have the opposite effect (Nicholls et al, 2007). Archers typically stand along the centre line of the target. This position can be shifted slightly if there is more than one archer aiming at the same target, but the degree of this shift is far less marked that that seen in golfers. This also eliminates the effect of target location being misaligned with their body position that is seen in golfers (Roberts & Turnbull, 2010). Accuracy is highly important in target sports and the current research will endeavour to examine if the presence of such elevated accuracy in experienced archers will translate into everyday life.

Overall, we predict that archers will show lower levels of pseudoneglect in all tasks that examine spatial attention (Cancellation, Line Bisection, Doorway task and Visual Search). In the doorway task we predict that the most frequent outcome will be that all participants pass through the doorway without bumping as pseudoneglect is a very subtle phenomenon and humans are generally quite adept at navigating small spaces (Nicholls et al., 2007). However, we hypothesise that archers will show lower levels of rightward bumping than control participants.

3. Method

3.1 Participants

A total of 59 participants were divided into two groups; controls (n=30) and archers (n=29). Controls were recruited from the student population of Maynooth University and the population of the wider Maynooth and Dublin city area; 22 were male and eight female, with the mean age of participants being 25.6 years (range 18-45). Twenty-six were right handed and four were left handed; 24 were right eye dominant (RED) and six were left eye dominant (LED). In addition, 29 experienced archers were recruited from clubs across the Republic of Ireland and Northern Ireland (See Chapter 2 for a list of clubs involved). Twenty-five were male with four female, and the mean age was 27.03 years (range 18-47). Twenty-five were right handed and four left handed, 24 were RED and five LED.

All participants reported normal or corrected-to-normal vision. Testing of all controls and the majority of the archery sample took place in the Department of Psychology, Maynooth University. However, due to distance complications it was necessary to test some archers in their own clubs. In all cases testing was conducted in quiet, private rooms of comparable size to allow consistency, privacy and accuracy of measurements and performance to be maintained across participants. Ethical approval was granted for this research by the ethics committee of Maynooth University. Participants gave informed consent prior to taking part in the research, which they were told was examining spatial attention and navigation in general. They were assured that they had the right to suspend or withdraw participation at any time and they could withdraw their data at any time up to publishing. Upon completion of the protocol they were fully debriefed and all questions were answered.

3.2 Materials and Apparatus

A complete list of the apparatus, materials, tests and stimuli used in this experiment can be found in Chapter 2.

3.3 Procedure

Participants were initially welcomed by the researcher and given the information sheet and informed Consent Form (see Appendix 1) to read and sign. The researcher explained the basic premise of the research and any questions they had were addressed. Eye dominance was assessed through self report but also using the eye dominance test. This involved extending the arms forward, palms facing outwards and crossing over the fingers to form a small triangle. Then, participants were asked to centre this triangle on an object or spot on the opposite wall and keep it within the triangles boundaries as they brought their hands back towards their face. In order to keep the chosen object in the triangle's centre, the hands naturally gravitate to the left or right and when they finally reach the face one eye will be covered while the other will be looking directly through the triangle. This is the dominant eye. Participants were then presented with the cognitive battery in the following order; the National Adult Reading Test (NART) the Cognitive Failures Questionnaire (CFQ) and the Trail Making Task (TMT) Part A and Part B. Participants were then given the spatial battery.

Tasks were presented in the following order; Cancellation tasks (letter and bell), Line Bisection, Doorway task (Nicholls et al., 2007) and the Visual Search (Triesman & Gelade, 1980). The Cancellation tasks had a completion time limit of 30 seconds (see Chapter 2: General Methods for more information on individual tasks).

Data Analysis

Data from these tasks were analysed using SPSS V. For control measures, one-way MANOVAs and independent t-tests were carried out to tests for differences between groups. For spatial battery tasks, mixed ANOVAs were conducted, with Group (2 levels; Archers and Controls) as the between groups factor and Condition (e.g. Target Present and Target Absent for Visual Search accuracy) as within subjects factors. Follow-up paired samples and independent t-tests and post hoc Tukey and Bonferroni tests were also carried out, where appropriate. Signal detection (‘d’) was also used to examine accuracy in the Visual Search task. This calculation involves calculating hits and false alarms as a proportion of the total number of trials before calculating the ‘d’ score. The highest possible ‘d’ (greatest sensitivity) is 6.93 and the effective limit (with 0.99 hits and 0.1 false alarms) is 4.65 therefore, the closer the d value is to 4.65 the more accurate the archers were in our case.

4. Results

4.1 Control measures

Mean scores for each of the NARTs predicted IQ subscales were calculated for Controls, (FSIQ; 111.6, VIQ; 109.77, PIQ; 110.83) and Archers, (FSIQ; 110.76,VIQ; 109.07, PIQ; 110.1). A one-way MANOVA was used to compare these scores between groups for all three NART categories [Wilks’ Lambda = .98; FSIQ; F (1,58) = .14, p = .71; partial eta squared = .001, VIQ; F (1,58) = .12, p = .73, partial eta squared = .001, PIQ; F (1,58) = .13, p

= .71, partial eta squared = .01] with no significant differences noted. Mean CFQ scores were also calculated for Controls (M = 38.4 , SD = 9.49) and Archers (M = 34.48, SD = 7.16). An independent samples t-test was conducted to compare means between groups with no significant difference found (t (57) = 1.83 and p. = .07).

Mean completion times (in seconds) for the three conditions in the TMT (Trial A, Trial B, and B-A) were calculated for the Control and Archer groups. A one-way MANOVA was conducted to compare performance of the two groups across the three conditions and revealed no significant differences between groups [Wilks' Lambda = .77; TMT-A; F (1,58) = .08, p = .77; partial eta squared = .00, TMT-B; F (1,58) = .01, p = .94, partial eta squared = .001, TMT Overall; F (1,58) = .11, p = .74, partial eta squared = .001 (means and standard deviations for Archers and Controls for all control measures are shown in Table 3.1).

Table 3.1: Means and SDs for Controls (n=30) and Archers (n=29) for the NART, CFQ and TMT.

Task		Control Group	Archer Group	Significant
NART				
	Full Scale IQ	111.6 (8.08)	110.76 (8.99)	NS
	Verbal IQ	109.77 (7.31)	109.07 (8.09)	NS
	Performance IQ	110.83 (7.20)	110.1 (7.56)	NS
CFQ		38.4 (9.49)	34.48 (7.16)	NS
TMT				
	Trial A	23.74 (6.64)	23.28 (5.68)	NS
	Trial B	40.61 (11.63)	40.42 (9.49)	NS
	Trial (B-A)	16.89 (10.77)	17.29 (9.48)	NS

NS = non-significant

4.2 Spatial Tasks

4.2.1 Cancellation Task

A Centre of Cancelation (CoC) score was calculated for each participant based on how many items were cancelled on the left and right of centre (See Chapter 2: General Methods for more information on how this was calculated). A negative CoC indicated more cancellations to the left of centre while a positive CoC indicated more to the right. Mean CoC in all trials was calculated for Controls and Archers. An independent samples t-test was performed to compare CoC scores between groups, returning a non-significant difference between Controls for the Letter Cancellation [t (59) = -.67, p. = .51] but a significant difference between groups in the Bell Cancellation [t (59) = -2.48, p. = .04] (See Figure 3.1a). Means and Standard Deviations for all spatial battery tasks are shown in Table 3.2.

Table 3.2: Means and SDs for Archers (n=29) and Controls (n=30) for the Cancellation, Line Bisection, Doorway and Visual Search (accuracy and RT) tasks.

Task	Control Group	Archer Group	Significant
Cancellation			
Letter Cancellation	-0.08 (0.36)	-0.03 (0.12)	NS
Bell Cancellation	-0.15 (0.39)	0.00 (0.07)	*
Line Bisection			
Mean Deviation Left	-1.76 (1.21)	0.26 (0.17)	**
Mean Deviation Right	0.47 (0.66)	0.04 (0.07)	**
Doorway Task			
No Bump Passes	18.43 (1.04)	19.55 (0.63)	**
Left Bumps	0.23 (0.43)	0.07 (0.26)	NS
Right Bumps	1.33 (0.96)	0.38 (0.56)	**
Visual Search Accuracy			
Target Present	27.2 (1.8)	28.8 (0.7)	**
Target Absent	28.86 (1.11)	29.55 (0.83)	**
Visual Search RT (ms)			
Present Correct	963.52 (315.57)	911.2 (220.37)	NS
Present Error	519.78 (203.62)	747.82 (245.97)	**
Absent Correct	1116.38 (354.08)	1118.18 (340.05)	NS
Absent Error	306.21 (183.97)	173.21 (212.8)	*

NS = non-significant; * = p<0.05; ** = p<0.01. All the above results were significantly different from 0 (p <0.001) with the exception of the Bell cancellation (p = 0.056).

4.2.2 Line Bisection

Mean Deviations Left (MDL) and Mean Deviations Right (MDR) were calculated for Controls and Archers. A one-way MANOVA was conducted to compare the performance between the two groups for leftward and rightward deviations. This analysis returned a significant main effect of Group for leftward [Wilks' Lambda = .5; $F(1, 58) = 43.39$, $p = .0001$; partial eta squared = .43] and rightward deviations [$F(1, 58) = 11.96$, $p = .001$; partial eta squared = .17]. Archers showed a lower level of both leftward and rightward errors compared to Controls (See Figure 3.1b).

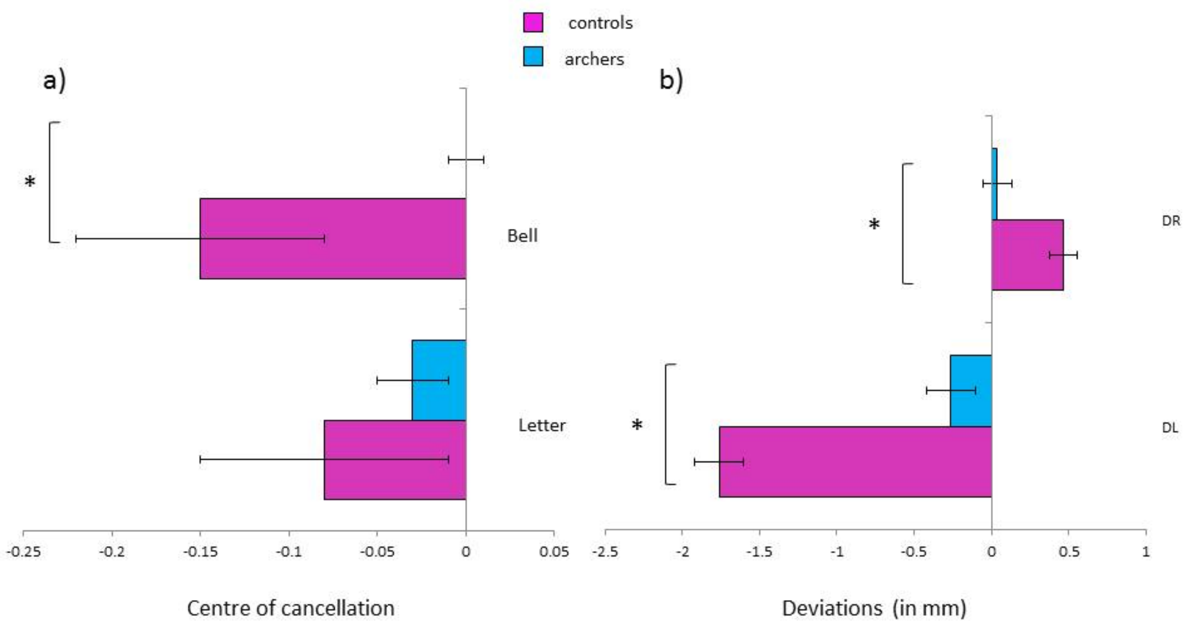

Figure 3.1: Mean scores and standard errors for a) the Cancellation tasks (Letter and Bell) and b) the Line Bisection task. Significant differences were found between groups in the bell cancellation and both deviations right (DR) and deviations left (DL) in the line bisection task.
* = p<0.05

4.2.3 Doorway Task

Number of bumps to the left (BL) and right (BR) and the number of passes without bumps (NB) were recorded for each participant in both groups. A one-way MANOVA was used to compare the effect of Group on bumping and yielded a significant difference between Controls and Archers in the No Bumps and Right Bump conditions [Wilks' Lambda = .7; NB; F (1, 58) = 24.71, p. = .0001; partial eta squared = .3; RB; F (1, 58) = 21.55, p. = .0001, partial eta squared = .27]. The difference level in the Left Bump condition approached significance but failed to achieve significance [F (1, 58) = 3.14, p. = .08, partial eta squared = .05; see Figure 3.2 for means and standard errors for this task].

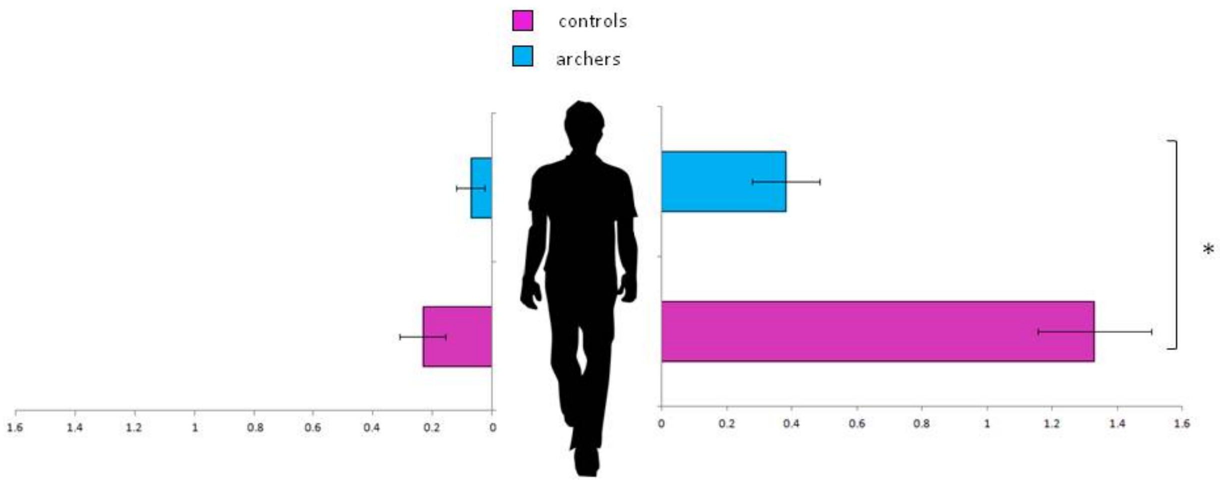

Figure 3.2: Means and standard errors for both groups in the Doorway task. Bumps to the right are on the right and reflect a significant difference between groups with archers showing lower bumping levels and bumps to the left are on the left.

4.2.4 Visual Search

Mean accuracy for the Visual Search task was calculated for both groups across Target Present (TP) and Target Absent (TA) trials. A one-way MANOVA was used to compare the effect of Group on accuracy in TP and TA trials. Results showed a significant between groups difference in the both TP and TA trial types [Wilks' Lambda = .677; TP; F (1, 58) = 20.54, p. < .0001, partial eta squared = .27; TA; F (1, 58) = 7.3, p. = .009, partial eta squared

= .11], with archers showing significantly higher accuracy overall (regardless of trial type)

Signal detection was then conducted in order to examine accuracy with a more direct index of discriminability using the ‘d’ calculation. Controls retuned a ‘d’ of 3.09 and archers returned a ‘d’ of 4.08. Therefore, archers were closer to the effective limit (4.65) and therefore more accurate than controls in this task,

Reaction times for Target Present Correct (TPC), Target Present Error (TPE) and Target Absent Correct (TAC) and Error (TAE) were averaged for all participants across the four blocks. This division across response types (error and correct) was done to allow for a closer examination of RTs in these two conditions and to clarify if a particular group had a higher or lower reaction time to be correct or incorrect in both TP and TA trials. A one-way MANOVA yielded a significant difference in reaction time between Controls and Archers in both Error conditions [Wilks’ Lambda = .553; TPE; F (1, 58) = 15.09, p. < .0001; partial eta squared = .21; TAE; F (1, 58) = 6.61, p. = .01, partial eta squared = .1]. No significant difference was found between groups in the Correct conditions [Wilks’ Lambda = .553; TPC; F (1, 58) = .54, p. = .47, partial eta squared = .01; TAC; F(1, 58) = .001, p. = .98, partial eta squared .00] (See Figure 3.3 for results of both the accuracy and RT metrics for this task).

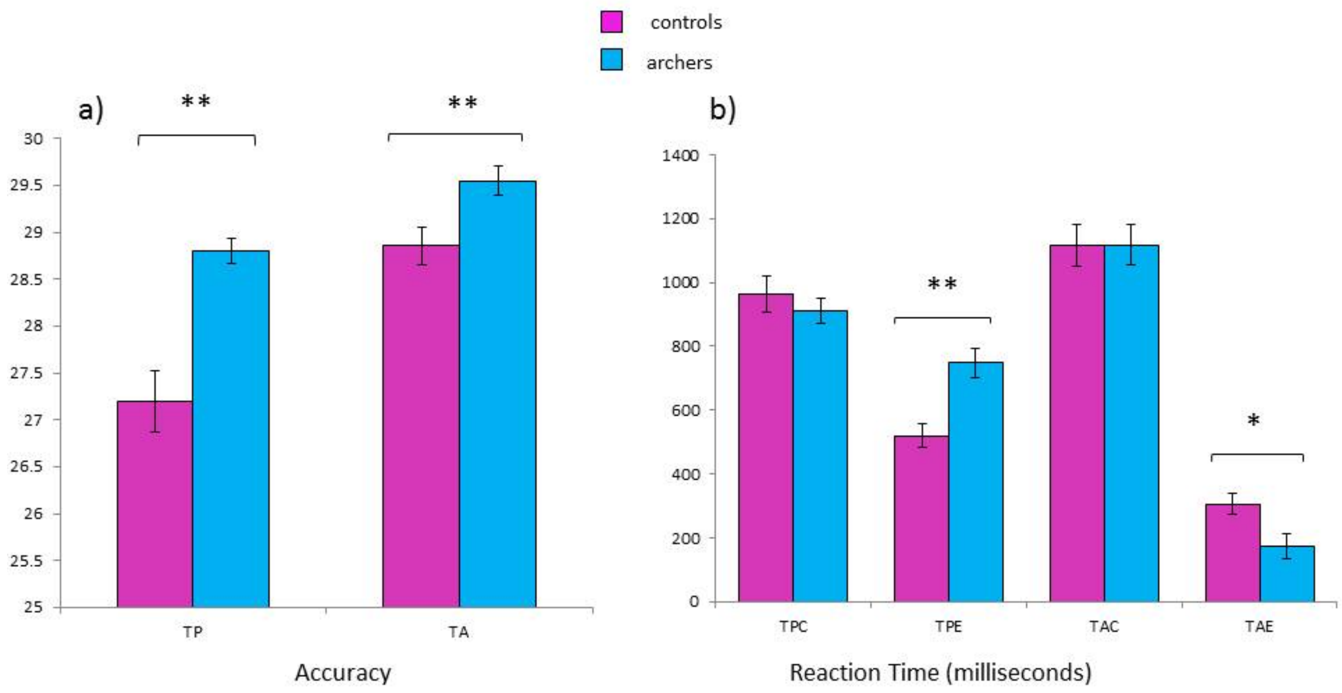

Figure 3.3: a) Accuracy and b) Reaction Time data for both groups in the conjunction Visual Search task. TP = Target present; TA = Target absent; TPC = Target present correct; TPE = Target present error; TAC = Target absent correct; TAE = Target absent error. Significant differences in accuracy were found between controls and archers; with archers showing a higher level of accuracy than controls in both target present and absent conditions. Reaction time differences were only significant for the error conditions; controls were faster to make errors when the target was present and archers when the target was absent.

5. Discussion

The aim of this experiment was to investigate the effects of archery expertise on pseudoneglect. This was achieved through the use of standard pen and paper tasks used to measure pseudoneglect and unilateral spatial neglect (Cancellation task and Line Bisection task), the real world Doorway task and a computer-based Visual Search task.

There were no between groups differences in any of the baseline cognitive measures (NART, CFQ or TMT). This suggests that participants were matched across neuropsychological variables such as IQ, working memory and general absentmindedness.

5.1 Cancellation tasks

Results showed no significant difference in the Letter version of the Cancellation task but a significant difference in the Bell version. One potential explanation for this lack of difference in the Letter Cancellation is that the visual scanning methods used by both groups may have been similar to those employed in reading. Letters are an easily recognisable and comfortable stimulus for participants but they could also potentially cause confounds based on how we normally deal with them (i.e reading them). This response to letters would mean that groups would perform more similarly due to a higher proportion of participants completing the test in a similar way. The significant difference seen in the Bells test could suggest it is less susceptible to these reading direction effects than the letter task. Therefore, it could be providing a more accurate account of spatial performance in participants as they search for the required stimuli (See Jewell & McCourt, 2001 for a review of reading direction effects in line bisection task). The difference in the bell cancellation was not to the degree that was expected. A potential explanation for why the differences in this test are not to the same degree as the other spatial tests is one of sensitivity. Cancellation tasks are capable of picking up post-stroke unilateral visual neglect but they may not be precise enough to pin down the subtle biases seen in pseudoneglect. The CoC measure (Rorden & Karnath, 2010) lends a great deal of precision to these tests but it may be that they lack the capability to accurately capture pseudoneglect. A further limitation is that of sample size. The current sample was limited due to a lack of qualified archers to meet inclusion criteria which would also have impacted the results of these tasks. However, similarly small effects or lack of effects would have been expected in the other tests in the spatial battery had this been the only contributing factor.

5.2 Line Bisection

The analysis of the line bisection task showed a significant difference in performance between control participants and experienced archers for both types of bisection errors (left and right). This would suggest that archers have more balanced spatial attention than controls. The significant difference in leftward bisection errors would, more specifically, suggest that the attentional bias towards the left visual field characteristic of pseudoneglect is less prevalent in archers compared to control participants. Kim and colleagues (2008) examined the neural correlates of the archery shot routine and gave indications into the cortical activity patterns seen during this activity. However, authors did not examine pseudoneglect directly in their experiment, so there is no way to know if the novice controls exhibited more pseudoneglect effects due to their heightened brain activity or whether this brain activity had a bearing on spatial attention at all. Therefore, more research that examines pseudoneglect directly is necessary. As an experimental measure, the Line Bisection task has been well researched and its validity and reliability well documented (See Jewell & McCourt, 2000 for a comprehensive review of the literature). It is also suggested to be a highly sensitive test of pseudoneglect (McCourt & Jewell, 1998) and this appears to be reflected in the results of the current analysis.

5.3 The Doorway Task

The Doorway task was originally developed to examine the impact of pseudoneglect outside of the laboratory, in the real world. It allowed researchers to lend support to the findings of Turnbull & McGeorge (1998) in real time rather than via self-report measures of pseudoneglect. The results of this task in the current research reflects that found by Nicholls and colleagues original paper (2008); that most of the time participants did not bump the poles as they walked through the doorway. This highlights the subtlety of pseudoneglect and the fact that humans are quite adept at judging and fitting through small spaces (Nicholls et al., 2008). Results of the current research supported this; the majority of the time participants passed through the poles of the doorway they did so without touching the poles. Results also showed that archers had lower levels of bumping in both Left Bump and Right Bump conditions. As bumping (specifically rightward bumping) is the metric for measuring pseudoneglect in this task this would suggest that archers exhibited less attentional bias than controls. The use of the doorway task allowed us to examine the decreased pseudoneglect effect in archers that was noted in the Line Bisection (a standard clinical test) as real world behaviour, a replication of similar findings reported by Nicholls, Loftus, Orr & Barre (2008).

5.4 Visual Search

The Visual Search was analysed using two metrics; accuracy and reaction time (RT). There were two trial types in this task; target present (TP) and target absent (TA). Results showed that archers were significantly more accurate than controls in both TP and TA trials. This would suggest that their attention was more balanced as they looked at the screen and searched for the target (or concluded the lack of target). Differences in RT were noted between groups in both error trials (target present error – TPE and target absent error – TAE) with controls showing faster error RTs when the target was present and archers showing faster error RTs when the target was absent. Simply put, controls were faster to make an error when the target was present, archers when the target was absent. The differences in the correct trials were non-significant, both for target present and absent. Interestingly, archers were more accurate compared to controls despite showing a similar response time. This would suggest that they potentially use ‘chunking’ to and examine the array; they process the displayed screen in chunks of multiple stimuli and search each of these for the characteristics of the target stimulus (red colour and forward slash shape), rather than trying to individually process each stimulus on screen while searching for the target, which is suggested to be the strategy employed by the controls (see Chapter 1: General Introduction, deGroot 1965; 1966 & Chase & Simon 1973, for further information on chunking).

6. Conclusion

Spatial attention, allows us to selectively bias our visual processing towards specific locations in the visual field, thereby allowing faster and more effective processing of stimuli in that location, relative to those around it (Awe & Jonides, 2001). Pseudoneglect is a bias in spatial attention that can result in reduced visual accuracy on the right side of space. The results of the current experiment suggest that experienced archers are less affected by the spatial attentive bias of perceptual pseudoneglect that control participants. Overall, archers exhibited better performance than controls on the majority of spatial battery tasks, despite being matched on control measures. This suggests that the visual attentional training to which experienced archers are exposed as part of attaining expertise in their sport may result in a reduction of the leftward attentional bias characteristic of pseudoneglect. This is contrary to existing research into expertise that suggests that deliberate practice and the attainment of expertise only results in improvements in the particular skill being practiced (See Ericsson, 2006; Ericsson et al., 1993). However, this research offers the possibility that domain specific skills honed through deliberate practice and training may generalise – at least partially – to other tasks. In this case, the accuracy achieved through training to the expert level in archery generalises to other tasks requiring accuracy and attentional processing. As the current research only examined archers that were already at the expert level further research is necessary to ascertain if archery training is the causal factor at play or if these participants were already spatially skilled before they took up the sport. Furthermore as this was purely behavioural research, further research is necessary to examine this effect and to reveal potential underlying reasons such as neural plasticity or changes in patterns of activation such as those observed by Chang and colleagues (2011).

In the next chapter, representational pseudoneglect is examined in these groups to investigate whether these effects extend beyond the perceptual domain.

Chapter 4

Representational Pseudoneglect in Archers

Abstract

Pseudoneglect can be seen for memories of visual information as well as our perception (See McGeorge et al, 2007; Brooks et al, 2014). The similarities between the two modes of pseudoneglect would suggest that the representational type has the same underlying mechanisms as the perceptual. The current study examined a sample of controls and archers to compare performance in a representational line bisection task, based on that used by Darling and colleagues (2012). Given the reported similarities between perceptual and representational pseudoneglect it was hypothesised that archers would show similarly higher levels of performance compared to controls in the representational paradigm as was shown in the perceptual paradigm in Experiment 1 (see Chapter 3: Experiment 1). Results of the current study largely supported this, with some exceptions. This chapter also explored the effect on the Muller-Lyer illusion (Muller-Lyer, 1889) on both groups; hypothesising that Archers would be less effected by the illusion than Controls. Results suggested that there were no overall differences between groups in this illusion but that Archers showed a significant difference between the fins in condition (which makes the line appear shorter) and the fins out condition (which makes the lines appear longer).

4.1 Introduction

Pseudoneglect, as it is most often studied, is seen as a perceptual phenomenon. However, there is a large body of research that supports the idea that it exists in the representational sphere as well; that our mental representations can be affected by the attentional bias (See Brooks, Della Sala & Darling, 2014 for a review). A seminal study conducted by McGeorge and colleages (2007) examined attentional bias in mental imagery by asking one hundred neurologically healthy participants to imagine a scene they knew well (the Piazza del Duomo in Milan). They were asked to imagine it from two opposing viewpoints; half were asked to describe the scene facing towards the front of the cathedral and the other half facing away from it. Authors reported that more items were reported from the left side of the image than the right, regardless of vantage point (McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007). This type of pseudoneglect can also be seen when participants are asked to explore and describe a stimulus without visual input, i.e. by touch alone (Bowers & Heilman, 1980).

Research in unilateral spatial neglect (USN) has also lent some support to this idea with USN patients reported to perform poorly with the bisection of mental number lines (Zorzi et al, 2000; Priftis et al, 2006). As visual neglect and pseudoneglect are suggested to be similar in terms of their underlying neurology and processes, this would seem to suggest that neglect in both its broad forms can exist for representational space. Research conducted by Darling and colleagues (2012) used a similar paradigm to the one employed in the current experiment. They required participants to bisect lines both perceptually (i.e. when they were visible) and from memory (i.e. after they had disappeared from the screen). They reported no attentional bias in the perceptual condition but a clear leftward bias in the memory (or representational) condition (Darling, Logie, & Della Sala, 2012). However, these bisections were done in extrapersonal space (beyond arms' reach); stimuli were presented on a projector and responses were made using a keyboard placed in the participants lap. Research would suggest the effects of pseudoneglect are different in different spatial reference frames (Keller, Schindler, Kerkhoff, von Rosen, & Golz, 2005; Aimola, Schindler, Simone, & Venneri, 2012).

Perhaps the clearest evidence for this representational bias comes from studies conducted in visually impaired and congenitally blind participants. Cattaneo and colleagues (2011) compared performance in a tactile wooden rod bisection in congenitally blind and blindfolded sighted individuals. All participants exhibited the leftward attentional bias consistent with pseudoneglect. The authors concluded that visual experience was not therefore necessary for pseudoneglect to manifest (Cattaneo, Fantino, Tinti, Pascual-Leone, Silvanto, & Vecchi, 2011). Furthermore, similar results to those found by Loftus and colleagues (2008; 2009) in the bisection of mental number lines has been found in blind individuals (Cattaneo, Fantino, Silvanto, Tinti, & Vecchi, 2011).

There has been some suggestion that this representational neglect is not a separate phenomenon to its perceptual counterpart (Darling et al, 2012). Rather than a distortion purely in memory, it may be brought about by the characteristic lateralised bias of pseudoneglect that then decays further in memory. However, clarifying which of these possibilities is the underlying cause is difficult given that most tasks used to examine this phenomenon evoke visual perception (Dellatolas, Vanluchene & Coutin, 1996; Nicholls, Bradshaw & Mattingley, 1999). Darling and colleagues' (2012) experiment examined this and found a left lateralised attentional bias for representational information but not for perceptual. This is at odds with the general bias of perceptual pseudoneglect but was supportive of the idea that visual memory is affected by its own bias (Darling, et al., 2012).

4.1.1 Line length & the Muller-Lyer Illusion

There are numerous factors that can influence our perception of line length judgement (see Jewell & McCourt, 2000, for a review). One of the more prominent factors is line length. Longer lines are more influenced by pseudoneglect compared to shorter lines and the bisection errors have been found to cross from left to right as lines get shorter (Halligan & Marshall, 1988; McCourt & Jewell, 1999; Rueckert et al, 2002). A novel method of examining the impact of line length on pseudoneglect is using the Muller-Lyer illusion. The Muller-Lyer illusion is named for its original investigator FC Muller-Lyer (1889). In its usual form the illusion consists of 2 horizontal lines of the same length, one with inward going fins at either end, similar to an arrow, and the other with outward going fins, similar to arrow feathers. The horizontal lines are the same length but the fins alter how the length is perceived with inward going fins making the line appear shorter and outward going fins making the line appear longer (see Coren, 1970; Coren & Girgus, 1978). The current experiment will use lines like these in order to examine any effect the fins may have on both perceptual judgements and representational judgements of veridical centre, interspersed with control lines with no fins. This is similar to a study conducted by Vallar and colleagues (2000) in patients with visual neglect. We hypothesise that inward going fins will produce more accurate bisection choices compared to control lines and outward going fins will have the opposite effect. In terms of between groups differences, we hypothesise that archers will show a higher level of performance, i.e. bisections closer to true centre across all line types and response modes (perceptual and representational). The rationale for this is that their proposed spatial expertise would lessen the impact of the illusion created by the fins due to the practice related plastic changes discussed earlier.

4.1.2 Rationale

Extensive literature search reveals only one previous study examining archery and representational pseudoneglect. Coudereau and colleagues (2006) examined two groups of visually impaired individuals; one group of archery experts and the other group who did not take part in any sport. In order to ensure blindness was homogenous, all participants were required to wear blackout goggles and to bisect 10 wooden rods using their index fingers. Results suggested that, in fact, the control group performed better than the archers in the bisection task. This was contrary to expectations, as the authors had hypothesised that regular training in a precision sport such as archery would result in a higher level of performance in that group. They concluded that the attention that archers must devote to the position of their left hand in space promotes a ‘negligence’ of the right side of space and therefore lead to this result (Coudereau, Gueguen, Pratte, & Sampaio, 2006). However, in normally sighted individuals, recurve archery uses a sight to aid in the aiming step of the shot. This sight is typically to the right of the bow (as most archers are right eye dominant) which would mean that the focus of attention is less concentrated on the spatial position of the left arm holding the bow. In effect, therefore, the tactics that the visually impaired archers in the above study have to rely on in order to shoot are less salient for sighted recurve archers. Therefore, such results must be interpreted with caution in light of the current research.

Archery does not require visualisation or even necessarily accurate visual recall of the scene related to each shot due to the fact that in competition archers may need to shoot as far as 90 metres. Recall tends to be more focused on the sensations and biomechanical inputs and outputs of each shot, comparing and examining arrow flight based on these movements and noting any changes caused by inaccuracies or slips in form. However, as perceptual pseudoneglect appears to be decreased in archers (see Chapter 3) it was hypothesised that a decrease in representational pseudoneglect would be noticed in archers compared to controls.

4.2 Method

4.2.1 Participants

Participants were divided into two groups; controls and archers. 30 controls were recruited from the student population of Maynooth University and the population of the wider Maynooth and Dublin city area. 19 were male and 11 female and the mean age of participants was 24 (range 18-47). 27 were right handed and 3 were left handed, 28 were right eye dominant (RED) and 2 were left eye dominant (LED). Due to constraints on the number of archers that met the inclusion criteria for the current research, the same group from experiment 1a took part in the current research (See Chapter 3 for demographic information for this group). All participants reported normal or corrected to normal vision. Testing of all controls and the majority of the archery sample took place in the Department of Psychology, Maynooth University. However, due to distance complications it was necessary to test some archers in their own clubs. In all cases testing was conducted in quiet, private rooms of comparable size to allow consistency, privacy and accuracy of measurements and performance to be maintained across participants.

4.2.2 Materials and Apparatus

Control and Spatial Battery

NART, CFQ, TMT, Letter and Bell Cancellation, Line Bisection and Doorway task. See Chapter 2: General Methods for theoretical background for these tasks and Chapter 3 Experiment 1 for administration and scoring methodology.

The Perceptual and Memory Line Bisection Task (Darling, et al 2014)

Perceptual line bisection tasks such as the pen and paper version (as described in Chapters 2 and 3) are a long-standing and well-validated test for spatial attention biases. However, there is evidence to suggest that pseudoneglect exists not only in the perceptual sphere but also in the representational domain (Loftus et al 2009; Darling, et al 2014). This computer-based task was designed to assess accuracy and reaction time in three line types; normal (without fins), inward-going fins and outward-going fins (similar to those seen in the Muller-Lyer illusion; Muller-Lyer 1889). It also covered two input types; perceptual (where subjects made their judgements in real time while looking at the line) and representational (where subjects made their judgements from memory after the line had disappeared from the screen). The task consisted of 60 bisections; 30 perceptual and 30 representational. Within these input types there were 10 trials of each line type (no fins, inward-going fins or outward-going fins). The lines were black and superimposed on a white background. In all trials the lines were displayed on the screen for 2,000 milliseconds at 13.12 degrees of visual angle. Vertical bars numbered 1-5 were displayed to indicate potential centre points for the line. Judgement involved choosing which vertical bar was the true centre by pressing the corresponding key on the keyboard. In the perceptual trials the vertical bars were superimposed over the horizontal line and then participants judged the centre. This was done by pressing the corresponding number either 1,2,3,4 or 5, on the numeric keypad of the laptop within 2000ms of the numbers appearing above each vertical bar. In the memory trials the horizontal line appeared on screen and then disappeared. The vertical bars were then displayed and participants had to choose based on where they remembered the centre of the line being within 2,000 milliseconds of the numbered bars appearing on the screen. The inter-stimulus interval consisted of a 1,000 millisecond fixation. The scoring metrics were accuracy and reaction time (See Chapter 2, Figure 2.7 for a schematic of this task).

4.2.3 Procedure

Participants were initially welcomed by the researcher and given the Information Sheet and informed Consent Form to read and sign. The researcher explained the basic premise of the research and any questions participants had were addressed. Eye dominance was assessed through self-report but also using the ‘hand triangle’ technique whereby participants are asked to stand and extend both hands in front of them, palms facing out and one on top of the other so that the space between them at the widest part is approximately the width of a €2 coin. Participants were then asked to keep both eyes open, pick a spot on the opposite wall and keep that in the centre of this hole between their hands. They were then asked to bring their hands in towards their face, keeping that spot visible through the space. Using this technique participants naturally travel towards the dominant eye in order to keep the chosen spot visible. Therefore, when participants’ hands touched their faces one eye would be covered (the non-dominant eye) while the other (the dominant eye) would still be looking through the space between their hands.

Participants completed the cognitive and spatial batteries, with the exception of the computer-based Visual Search task (see Chapter 3 for more detail). Upon completion of all of the pen and paper tasks and the Doorway task, participants moved on to the computer-based line bisection task. The task was presented on a Dell Latitude D531 laptop with a 12” screen. Participants sat on a fixed chair 0.5 metres from the screen and used the number keys to provide responses using their dominant hand. The experimenter explained the protocol for the task using printed laminated sheets illustrating each trial and line type. Instructions were as follows:

> *“In this task you will be required to indicate the centre of each line, in a similar way to the earlier pen and paper version. You will see horizontal lines appear on the screen in front of you; some will have inward going fins,*

some will have outward going fins and some will be just plain lines. But rather than making the choice yourself you will have to choose between one of five vertical lines that will then appear onscreen. Sometimes these vertical lines will appear over the horizontal line (so you can judge by looking), other times the horizontal line will disappear before these vertical lines appear so you will have to remember where the centre was and make your choice from memory."

(see Appendix 8 for sample trial and line type sheets used).

Participants read the on-screen instructions with the experimenter present to answer any questions. When they were ready to begin the experimenter left the room to allow for a distraction-free environment. Upon completion of this task participants were fully debriefed as to the specific nature of the study and any questions they had were answered. They were then thanked for their time and participation and escorted from the department or testing location.

4.2.4 Design and Data Analysis

A 2 x 2 x 3 mixed factorial design was used in this experiment with three IVs; group (2 levels; control and archer), mode (2 levels; perceptual and representational) and line type (3 levels; control – no fins, inward going fins and outward going fins). The DV was accuracy. Analysis was carried out using SPSS V and statistical tests conducted included MANOVAs, repeated measures ANOVAs, independent and dependent t-tests and follow up post-hoc comparisons.

4.3 Results

4.3.1 Cognitive and Spatial Battery

The cognitive and spatial batteries were assessed using the same methods as Experiment 1. No significant differences were noted in any of the cognitive tasks (NART - Wilks' Lambda = .974, p. = .69, partial eta squared = .26;CFQ - or TMT; Wilks' Lambda = .979, p. = .76, partial eta squared = .03;Analysis of the Cancellation tasks using independent tests revealed a significant difference between groups in both the Letter [t (59) = -2.00, p = .05] and Bell tasks [t (59) = 2.7, p = .01]. MANOVA analysis of the Line Bisection revealed significant differences between controls and archers in both deviations left [Wilks' Lambda = 36.06, F (1, 58) = 5.84, p. = < .005, partial eta squared = .39] and deviations right [Wilks' Lambda = 2.61, F (1, 58) = 11.53, p. < .001, partial eta squared = .17]. MANOVA analysis of the doorway task (Wilks' Lambda = .69) returned a non-significant different between groups in the left bump condition [F (1, 58) = 4.25, p. = .04, partial eta squared = .06], but a significant difference between controls and archers in the no bump [F (1, 58) = 25.58, p. < .005, partial eta squared = .31] and right bump condition [F (1, 58) = 21.7, p. < .005, partial eta squared = .28]. see Table 4.1 for means and standard deviations for these tasks).

Table 4.1: Means and standard deviations across both groups for all cognitive and spatial tasks

Task		Control Group	Archer Group	Significant
NART				
	FSIQ	111.27 (7.69)	110.76 (8.99)	NS
	VIQ	109.5 (7.02)	109.07 (8.09)	NS
	PIQ	110.6 (6.78)	110.1 (7.56)	NS
CFQ		38.4 (9.49)	34.48 (7.16)	NS
TMT				
	TMTA	22.99 (1.03)	23.28 (5.68)	NS
	TMTB	40.31 (1.83)	40.42 (9.49)	NS
	TMTB-A	17.30 (1.67)	17.29 (9.48)	NS
Cancellation				
	Letter Cancellation	-0.17 (0.37)	-0.03 (0.12)	*
	Bell Cancellation	-.19 (0.38)	0.00 (0.07)	*
Line Bisection				
	Mean Deviation Left	-1.79 (1.36)	-0.26 (1.65)	**
	Mean Deviation Right	0.46 (0.66)	0.04 (0.07)	**
Doorway Task				
	No Bump Passes	18.37 (1.1)	19.55 (0.63)	**
	Left Bumps	0.27 (0.45)	0.07 (0.26)	NS
	Right Bumps	1.37 (1.0)	0.38 (0.56)	**

NS = non-significant; * = $p<0.05$; ** = $p<0.01$.

4.3.2 Representational Line Bisection Task

Accuracy in this task was operationalised as mean deviation to left or right of the true centre of the chosen vertical bar for each trial within each modality (Perceptual or Representational/Memory) and line type (control/no fins, fins in or fins out). Line length was not examined as a factor as the lines were all the same length. Mean scores for all trial types (Control Perceptual – CP; Control Memory – CM; Fins In Perceptual – FIP, Fins In Memory – FIM , Fins Out Perceptual – FOP and Fins Out Memory – FOM) were calculated for controls and archers (See Table 4.2 for means and standard deviation scores

Table 4.2: Means and Standard Deviations for both groups across all trial types

Task		Archer Group	Control Group	Significant
Perceptual				
	No Fins	-7.2 (9.5)	-1.45 (6.17)	NS
	Fins In	-6.07 (7.79)	-.07 (5.76)	NS
	Fins Out	-4.7 (13.18)	-3.41 (6.88)	NS
Representational				
	No Fins	-5.13 (11.09)	-3.28 (5.01)	NS
	Fins In	-3.27 (11.49)	-1.62 (7.92)	NS
	Fins Out	-5.17 (14.91)	-4.69 (9.23)	NS

NS = non-significant

A 2 x 2 x 3 mixed factorial ANOVA (group – 2 levels; condition – 2 levels and line type – 3 levels) was conducted to assess between and within groups differences across the 6 trials types. No main effect of group was reported; [Wilks' Lambda = 0.89, $F(1, 58) = 2.64$, p. = .11, partial eta squared = .04]. A significant interaction effect was returned for

Condition x Group (Wilks' Lambda = .91, F (1, 58) = 5.84, p. = .019, partial eta squared = 0.09. There were no significant main effects found for Condition (perceptual or memory); Wilks' Lambda = 1, F (1, 58) = .005, p. = .946 or Line Type (although this approached significance); Wilks' Lambda = .903, F (1, 58) = 3.01. p. = .06. There were no significant interaction effects between Line Type x Group (Wilks' Lambda = .98, F (1, 58) = .59, p. = .56); Condition x Line Type (Wilks' Lambda = .979, F (1, 58) = .59, p. = .56); or Condition x Line Type x Group (Wilks' Lambda = .97, F (1, 58) = .97, p. = .39; See Figure 4.1 for a visual representation of performance differences across conditions)

The file was then split by group and two 2 x 3 repeated measures ANOVAs were conducted to examine conditions and line types separately for each group. For controls no significant results were returned; Condition [Wilks' Lambda = .95, F (1, 29) = 1.56, p. = .221]; Line Type [Wilks' Lambda = .93, F (1, 58) = 1.1, p. = .35]; Condition x Line Type (Wilks' Lambda = .93, F (1, 58) = 1.02, p. = .38). Archers showed a main effect of Condition (Wilks' Lambda = .617, F (1, 58) = 17.38), p. = .0005, partial eta squared = 0.38) but no main effect of Line Type (Wilks' Lambda = .83, F (1, 58) = 2.86, p. = .08) or interaction effect of Condition x Line Type (Wilks' Lambda = 1, F (1, 58) = .11, p. = .88 (see Figure 4.1).

With the file still split paired samples t-tests were conducted to compare all three line types (control, fins in and fins out) within condition (perceptual or representational). Controls returned no significant differences for either perceptual or memory conditions. Archers returned non-significant differences in the Memory Condition for all Line Types. In the Perceptual Condition a significant difference was returned for Fins Out compared to Fins In; t (1, 58) = 2.77 p. = .03; See Figure 4.1).

Finally, split file was then turned off and a follow up t-test was conducted to compare Groups across Conditions in the Control Line Type (no fins). This returned a significant difference between Controls and Archers in the Perceptual Condition [t (2, 57) = -2.75, p. = .01] but not in the Memory Condition [t (2, 57) = -.82, p. = .41; see Figure 4.1].

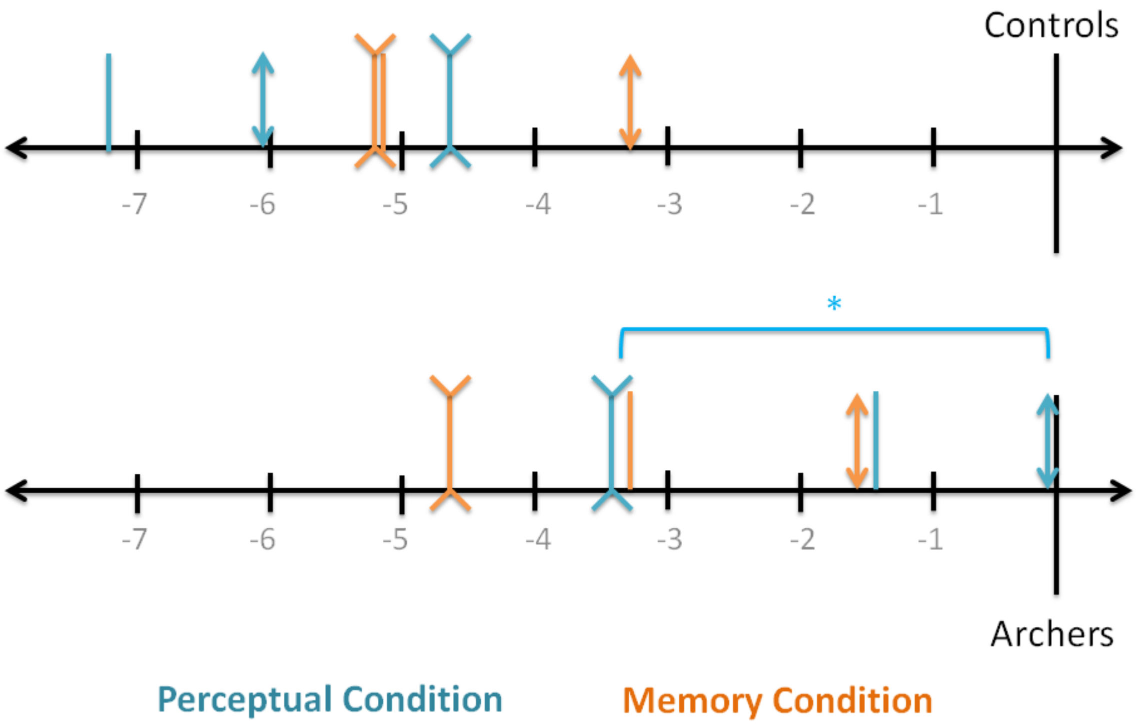

Figure 4.1: Result for controls and archers in the Representational Line Bisection Paradigm. Bisections are all leftward of centre and therefore are negative. Blue represents the perceptual condition and orange the memory condition. Line types are displayed with examples of each; control line (no fins), fins in and fins out with the position of these indicating mean performance values achieved in their corresponding Line Type across conditions and groups.

4.4 Discussion

The aim of the current study was to investigate the relationship between archery expertise and both perceptual and representational types of pseudoneglect and the susceptibility of each to the Muller-Lyer illusion. This was achieved using a battery of tasks designed to examine perceptual pseudoneglect (Letter and Bell Cancellation, Line Bisection, Doorway task) and a computer-based line bisection with both perceptual and representational pseudoneglect featuring Muller-Lyer fins.

4.4.1 Cognitive and Spatial Batteries

As in Experiment 1, results of the cognitive battery suggested that both groups were matched in terms of general cognitive functioning. This assured that any differences found in other tasks were not due to differences in processes such as executive functioning, memory, or IQ. Results of the Cancellation tasks were more in line with the original hypothesis for the current study; that there would be a difference between groups, with archers performing better than controls. In the previous experiment, the Letter Cancellation showed a smaller degree of difference between the groups in terms of performance. This was repeated here; however, archers were seen to perform significantly better than controls (although the size of the effect was small). Again, these results are suggested to be due to the scanning method employed by participants. All participants in the previous and current experiments are native English readers and writers, which entails reading left to right. As concluded previously, this could have an impact on the scanning methods employed to complete this task (Chokron & Imbert, 1993). The consistency of this finding across both experiments supports this claim.

4.4.2 Representational Line Bisection & the Muller-Lyer effect

In the representational line bisection paradigm, in general, Archers seemed less affected by pseudoneglect compared to controls, as they seemed to bisect closer to the true centre than controls (see Figure 4.1 above). In general, ignoring line type, perceptual trials were bisected further to the left for controls participants compared to archers.

Archers showed a similar pattern of performance as found by Darling and colleagues (2012). Like their participants, our Archers showed the same exaggerated effect for Memory compared to Perceptual conditions; overall in the current experiment (ignoring fins) memory trials were bisected further left than perceptual trials. However, unlike their participants (who were all neurologically healthy controls); our controls didn’t exhibit this stark difference. This lack of effect in our control participants could be due to an inherent difference between the two experimental paradigms; their experiment was conducted on lines in extrapersonal space (beyond arms reach) and ours in peripersonal space (within reaching space). There is some evidence to suggest that pseudoneglect is different in these two spatial reference frames and therefore these effects could explain why this difference was not observed. However, this does not answer the question of why the Archers were affected as they bisected the lines in peripersonal space also and therefore should have had a similar response to controls. Instead, they behaved like Darling and colleagues’ (2012) controls had with lines in extrapersonal space. This could potentially suggest a different method of processing for remembered visual information used by the archers due to their training and expertise; they process this representational information (or potentially just representational information with an accuracy component) as if they were viewing it in extrapersonal space (like they would process remembered visual information relating to a target).

Regarding the illusory component of the experiment, all participants were affected by the Muller-Lyer illusion as expected; inward fins reduced pseudoneglect and outward increasing it, relative to the control lines. However, these were mainly non-significant trends with one exception; control participants in the perceptual condition. This is similar to the findings of Vallar and colleagues (2000) in neglect patients.

Results of the current study are at odds with those reported by Coudereau and colleagues (2006) in visually impaired archers, which suggested that the bias in representational pseudoneglect was stronger for the archers compared to the controls. However, this could potentially be due to the different mechanisms employed by these two different types of archers. Visually impaired archers typically rely on positional awareness; focusing on the spatial position of their left arm in order to ensure the accuracy of the shot (as seen in the aforementioned research). Sighted archers (as in this study) do devote attention to body position in order to 'feel the shot' and ensure their body is in correct alignment to achieve proper form, however, they use visual cues for most of their input on aiming.

The results of the Representational Line Bisection Task largely reflected results of other perceptual tasks. Archers performed better in the perceptual conditions compared to controls, consistent with the results of previous tasks; they were less affected by pseudoneglect compared to the control group. The lack of difference in the fins out condition could be the result of various factors. Firstly, sample size and the inherent difficulty with achieving clarity and consistency when working with a small sample group. However, if this was the only factor in play there would be less consistency in other results. Another potential causality is that participants found the task quite difficult; many participants reported finding the time constraint stressful and this put excessive pressure on them. As the fins out condition in the Muller-Lyer illusion makes the line look longer this could mean that participants had to spend a longer time scanning it and trying to work out the centre point but could not do this successfully due to the time constraint. A final suggestion is that archers were more influenced by the illusion in the fins out condition. No basis for this exists in the literature as there are very few studies conducted using a similar paradigm with a population of similarly skilled experts however, it warrants further investigation to clarify if this is a real phenomenon or just a result of small sample size. No difference was found between groups in the representational conditions. This lack of difference could be due to the small sample size discussed above. However, it could also be due to an inherent difference between perceptual and representational expertise.

However, it must be restated that the archers that took part in this part of the study were the same group who participated in Experiment 1. This was necessary due to the low number of archers within Ireland that met the stringent inclusion criteria for the current research. Therefore, while conclusions drawn from the perceptual results in the current experiment lend support to the previous study they must be taken with this in mind. As there are very few other studies examining pseudoneglect in sport, (and none in archers to the best of our knowledge), further research into perceptual pseudoneglect in expert archers and sportspeople in general is necessary before major conclusions can be drawn.

A further limitation was the style of bisection employed. Rather than active bisection which is achieved by reaching or pointing or drawing or otherwise interacting with the stimulus to provide the bisection, this was passive bisection; a key press. While no previous studies could be found examining this specifically, or even tangentially, these two different styles of bisection could have slightly different underlying mechanisms which could help to further explain the differences noted in the current experiment.

Chapter 5

General Discussion

5.1 The Current Research

The hypothesis of the current research was that we would see improvements in spatial attentional performance in experienced archers compared to controls on a variety of spatial tasks which probe the phenomenon of pseudoneglect. We examined this in both the perceptual and representational abilities of a group of 29 archers and two groups of 30 controls (one for each experiment). Archers were recruited from archery clubs across the Republic and the North of Ireland by word of mouth and flyers handed out at competitions and emailed directly to club secretaries. Archers were classified as experienced if they had been involved in the sport for three years or more and had achieved the Master Bowman classification as outlined by the Grand National Archery Society (GNAS) in the United Kingdom. Neurologically healthy controls were recruited from Maynooth University and the surrounding town and counties using work of mouth and flyers posted in community centres and local shops (See Chapter 2 for more recruitment information including inclusion and exclusion criteria for both groups).

In Experiment 1 we sought to examine if there would be a difference in pseudoneglect effects between the groups on several perceptual tasks. Pseudoneglect is typically measured from the perceptual perspective, using stimuli that can be visually processed. Results suggested two things. Firstly, the evidence of the lateralised bumping in the Doorway task and the mis-bisection of lines in the Line Bisection tasks seen in control participants further supports the phenomenon of pseudoneglect, both in the more clinical pen-and-paper tasks and in the observable behaviour of the Doorway task. Secondly, results supported the original hypothesis of the research; that perceptual pseudoneglect would be reduced in the archery group compared to the controls.

This research made no attempt to examine why this difference exists between archers and controls; however, it could be mediated by processes outlined in the Activation Orientation Hypothesis , which suggests that spatial attention is biased in the direction of the hemisphere that is most active (Kinsbourne 1970; 1987, 1993; Reuter-Lorenz, Kinsbourne & Moscovitch, 1990). Increased right hemisphere activity could cause a stronger leftward attentional bias. This would in turn increase object salience on the left and cause objects on the right to be partially ignored (Nicholls et al., 2007; also see Loftus & Nicholls, 2012). However, activity levels and patterns of activation are not the same for everyone. Chang and colleagues (2011) reported that brain activation in expert archers is much more streamlined compared to novice archers, with less extraneous brain activity recorded. Potentially, therefore, the overall level of right hemisphere activation in the experts may have been lower. As a result the exacerbation of the leftward attentional bias normally purported by the Activation Orientation Hypothesis could have been reduced. Further neuroimaging research in line with Chang and colleagues (2011) is necessary to examine the causality of this reduction in pseudoneglect that we found for expert archers. However, any research trying to examine causality would have to be longitudinal as this would allow for conclusions to be drawn based on pre-post expertise measurements or neurophysiological data thus rendering researchers more capable of defining causality.

The purpose of Experiment 2 was to examine representational pseudoneglect and the impact of the Muller-Lyer illusion in expert archers compared to controls. This was achieved by using a line bisection paradigm requiring participants to judge the veridical centre either when the line was on screen (perceptually), or after it had disappeared (representationally). There were also three types of line; control lines (with no fins) and Muller-Lyer illusion style lines (inward- or outward-going fins). Results partially supported the first part of the original hypothesis; that archers would display lower levels of representational pseudoneglect compared to controls; they exhibited reduced bisection errors in two out of three line types (no fins and inward-going fins) in the representational condition. For the Muller-Lyer illusion component of the research it was hypothesised that archers would be less affected by the presence of the fins than control participants as the selective attention necessary to reliably focus on and hit the centre of a target regardless of distance could also generalise to reduce the interference of the illusion caused by the presence of the fins. Results suggested that, overall, the fins had little bearing on the degree of bisection errors when compared to performance on the control lines (no fins). However, archers did show a significant difference between the fins-in and fins-out line types in the perceptual condition, similar to the effect observed by Vallar and colleagues (2001) in patients with unilateral spatial neglect (USN).

Again, no attempt was made to determine causality in this research; merely to investigate the presence or absence of differences. Proposed reasons for the causality of the differences in performance with the control lines are described above. As representational and perceptual neglect are presumed similar in aetiology, processes such as brain activity and areas of activation may therefore be shared (McGeorge et al., 2007; Darling et al., 2012). This would mean that similar effects of archery in perceptual pseudoneglect should transfer to its representational counterpart; we should see a reduction in representational pseudoneglect in archers compared to controls, similar to the reduction in perceptual pseudoneglect. However, this was not what was observed. In perceptual trials archers showed a similarly improved performance in bisection accuracy compared to controls (consistent with Experiment1). In representational trials we did not see this difference; archers performed on a similar level to control participants across all line types. Looking at control lines in isolation- excluding any potential effect of the Muller-Lyer illusion - there were significant differences between groups in perceptual but not representational conditions. This could potentially suggest that representational pseudoneglect is not coded in the brain in the same way as its perceptual counterpart. In terms of the Muller-Lyer illusory component we found the expected direction of effects; fins-in led to smaller degrees of bisection error and fins-out to larger errors; however, these were mainly non-significant trends. There exists no similar research examining this effect in a group of similarly-trained experts. As a result the findings and conclusions are purely speculative, and further research using the same or a similar paradigm to the current research is required to examine this more closely.

5.2 Pseudoneglect

5.2.1 Perceptual Pseudoneglect

Pseudoneglect has been well documented in both clinical tests such as the Line Bisection task (see Jewell & McCourt for a meta-analysis); real world tasks like the Doorway paradigm (Nicholls et al., 2007) and in everyday life (see Turnbull & McGeorge, 1998; Nicholls et al., 2007; 2008). However, even this phenomenon is not standard in all conditions or across all areas of space. There is a large body of evidence to suggest that this disparity in spatial attention is different for near space (within arms-reach) and far space (any region of space outside of this (see McCourt & Garlinghouse, 2000). The general consensus is that the attentional bias towards the left crosses to the other side as one moves from near to far space. Results of the current study support the near space account of pseudoneglect (leftward attentional bias), with both archers (when they made errors) and controls exhibiting more rightward errors in tasks. The current research did not examine far space effects and to the best of our knowledge no direct studies examining this phenomenon in archers exist.

However, there are potential clues in responses to an informal questionnaire and parallels in other research that could inform an hypothesis. As archery is a sport that involves a target at a distance far beyond reaching space, it would seem natural that archers would be influenced by the far space bias during the aiming and release steps of the shot. However, informal questioning of some of the expert archer group during the experimental process could suggest otherwise. They responded that rather than focusing on the distant target they focus instead on the target picture created in the sight that is mounted on the riser (within reaching space; see Chapter 2 for a diagram of archery equipment). As this was informal and non-structured/recorded, no solid conclusions could be drawn from this information. It does, however, suggest that archers may instead remap far space to near space while performing the shot routine, which would mean they would ordinarily be more prone to standard pseudoneglect. This spatial remapping is also well documented in the literature; where the use of a tool to extend reaching space also extends our near space reference frame out to the corresponding distance (Bruce & Goldberg, 1985; Colby, Duhamel & Goldberg, 1996; Berti & Frassinetti, 2000; Longo & Lourenco, 2006). This could also be in play for other similarly structured sports such as golf. Further research is necessary to investigate the above hypotheses regarding the point of aim used by archers (actual target versus target picture) and any remapping of spatial reference frames that may occur because of this.

5.2.2 Representational Pseudoneglect

As discussed previously (See Chapter 4), pseudoneglect appears to extend into the representational sphere as well as the perceptual (Darling, Logie, & Della Sala, 2012) McGeorge et al., 2007). Natural scenes (Dickinson & Intraub, 2009) and information about the colour, location and identity of objects (Della Sala, Darling & Logie, 2010) also seem to be affected by this representational bias. Representational pseudoneglect has also be seen without direct visual input, both in sighted individuals using a tactile rod bisection tasks (Brooks, Della Sala, & Logie, 2011) and in individuals who are congenitally blind (Catteneo, Fantino, Tiniti & Vecchi, 2011). The neurological substrates of representational pseudoneglect are suggested to be the same as those in the perceptual type as evidenced by neuroimaging studies. Behaviourally, this is represented as described above, with our memory for places, objects etc., suffering the same pattern of spatial bias and neglect seen in perceptual pseudoneglect. The inherent similarities between these two modes of pseudoneglect should mean that any improvements brought about in the perceptual mode should also be seen in the representational mode. There has been some suggestion that representational and perceptual are not unitary phenomena (Darling et al, 2012); representational pseudoneglect may just be a result of the perceptual bias when the remembered information was encoded that then decays further in memory, leading to the apparent exacerbation of the attentional bias. Darling and colleagues (2012) findings contradicted this idea, supporting instead the separation of biases for perception and memory and the worsening of the bias in representational tasks. In the current study no significant differences were found between groups in the representational mode, despite significant differences in the perceptual. However, there is a plausible explanation for why this is the case.

Expertise involves deliberate practice of appropriate behaviours in order to attain that level in a particular skill or discipline (Ericsson, 2006). However, there is also an element of mental rehearsal that is integral to the achievement of expert level in a skill or discipline. This has been previously examined in pianists (see Pascual-Leone et al., 1995) and the authors discussed the importance of this type of practice (see also Ericsson, 2006). But this mental practice appears to focus on the mechanical aspects of the particular skill being learned (Pascual-Leone et al., 1995; Maguire et al., 2000). There is evidence of mental rehearsal within archery; however, it could potentially be missing an integral component. On a neurological level, the mental rehearsal of the shot routine involves the physical steps of the archery shout routine (i.e. nock, draw, hold and loose). This is why many of the same corresponding areas can be seen activating during mental rehearsal as are seen in physical rehearsal (See Chang et al., 2011). However, I would suggest that this mental rehearsal potentially skips the aiming step; an integral part of the shot routing that coincides with the draw and hold steps.

While this is a theory based on the results of the current experiments, there is some evidence that could suggest support. Chang and colleagues (2011) reported that the areas of activation found in their fMRI mental rehearsal paradigm were mainly confined to the supplementary motor area. This would suggest that on a neural level the areas of primary activation were only concerned with the physical elements of the shot, rather than the spatial attentive elements of the aim step. Reinforcing the physical steps of the shot routine is a relatively simple rote exercise similar to the reinforcing of a particular shot in tennis or kick in rugby. However, the aiming step may be too complex to create a beneficial true mental representation of; the target in reality is often too far away to get an accurate perceptual image of the centre ring and as discussed previously, archers may alternate between using the physical target and the target picture captured in their sight which may have no impact on perceptual aiming but may make representational aiming difficult. Thus, the physical steps of the correct ‘form’ necessary to hit the centre of the target are trained to the point of being ingrained, rather than the associated spatial attentional system. Alternatively, the spatial attentional system may be employed in this mental rehearsal, however the target picture is too small for this to have any real impact on representational pseudoneglect; i.e. a goalmouth is a wide area for players to imagine kicking the ball into; however, the ten ring on a target at even the shortest competitive distance of 18 metres is significantly smaller. As this is purely speculative, further research is necessary to extend the scope of the current study and examine potential causal factors including those suggested above. A comparison type approach examining representational pseudoneglect in experts in archery and another sport such as penalty kicks in football or rugby where the area of accuracy is significantly larger could provide evidence for or against what has been suggested above. The reason for suggesting penalty kicks is that they are more static in nature and therefore more similar to archery which is a largely static sport. However the difference in pseudoneglect in both modes between static and active sports could also be examined.

The Muller-Lyer effect was found to have little or no bearing on participants' performance in the representational presentation mode. Generally, one would expect inward-going fins to produce a more accurate performance as they serve to reduce the apparent length of the line and outward-going fins a less accurate result as they have the opposite effect. However, this was only partially the case in the current study. Results were similar to those found for the perceptual mode; fins-in lines showed smaller degrees of bisection error and fins-out showed larger deviations, but again, these were non-significant trends across both groups. A potential explanation for this is a technical one; in order to define the response key associated with each vertical bar, numbers appeared above the stimulus. However, these numbers were not aligned directly over their corresponding bar as to do so would have made them illegible due to the close proximity of the bars to each other. This may have resulted in participants having to devote attention away from the line (and therefore the fins) in order to decide which number line to choose

5.3 Implications and Future Directions

5.3.1 Visual Attention

The current research suggests that training in archery may result in lower levels of pseudoneglect compared to controls. The nature of archery as an accuracy based sport involving spatial attention and the nature of practice and resultant plasticity could be the driving force behind these findings. This could have implications for spatial attention in general as this reduction in attentional bias in the expert group suggests a higher level of attentional functioning and a more balanced attentional field. As discussed in Chapter 3, we cannot infer causality directly as it was not possible to ascertain whether or not the archers had always been better spatially before they discovered the sport, or if this spatial attentional improvement came about as a result of archery participation. In order to examine this, a longitudinal paradigm would be needed to examine archers from beginner to expert level.

As suggested above, more research is also necessary to clarify near versus far space differences in archery, and other long range target sports such as golf and shooting. The anecdotal responses suggesting potential remapping could, however, have implications for these studies. For example, archery, golf and rifle shooting (with a sight or scope or other aiming aid within reaching space), could also fall prey to similar remapping effects so a target discipline would have to be selected where no such issue may arise. Also, as a further complication, unimanual activity effects (McCourt, Freeman, Tahmakera-Stevens, & Chausee, 2001) would have an impact on target sports that use a single hand, such as javelin, which satisfies the first condition but would be prone to the effects of the second. However, a suitably designed experiment in an appropriate sport (or other far space spatial skill) could provide a base of evidence for the existence or lack of a near versus far space difference in spatial attention experts.

5.3.2 Expertise

There is an element of mental practice which exists and influences the achievement of expertise that has been examined in numerous different groups (Sackett, 1934; Druckman & Swets, 1988; Driskell, Copper & Moran, 1994). But, this mental practice appears to focus on the mechanical aspects of the particular skill being learned; just like the physical practice of playing the piano involves the movement of the fingers over the keys, so too does the mental practice involve these movements (Chang et al., 2011). In archery, the mental rehearsal of the shot routine involves the physical steps of the shout routine which is why the same corresponding areas can be seen activating during mental rehearsal as are seen in physical rehearsal (Chang et al., 2011). However, we would suggest that aiming is the critical step that may be less focused on, or potentially skipped altogether in mental rehearsal of archery. Reinforcing the physical steps of the shot routine is a relatively simple rote exercise but aiming at a mental representation of a target in the absence of all the external and internal forces; the wind, rain the sun, shadows and muscle fatigue is something that may be too nebulous to feature in the rehearsal.

There is no consensus on how expertise should be examined (Ericsson, 2006). However, the theoretical framework used in the seminal work conducted by deGroot (1978) and Chase and Simon (1973) consists of three basic characteristics. The first is that the focus is on producing and observing outstanding performance under the standardised conditions of the laboratory setting. Secondly, the purpose is to analyse and describe the cognitive processes involved in the outstanding performance. Finally, the cognitive processes are examined and mechanisms are suggested for how they are acquired (Ericsson, 2006). The current research was structured in a similar way, with spatial attention being the skill domain being examined. I selected appropriate spatial attention tasks to try to best capture the participants' performance (outstanding or otherwise), then attempted to describe what cognitive processes may be involved in the improved performance of the archers (namely the activation orientation hypothesis and practice effects). Finally, suggestions were made as to how this was acquired - specifically, deliberate practice effects and neural plasticity.

The current research has implications for the world of expertise in terms of support for existing theories. Expertise research has led to the pervasive belief that deliberate practice only reinforces the skill-set being practiced; practising the piano only improves one's ability to play the piano and not, for example, the violin. So, this suggests that the rehearsed skills do not transfer, even when other associated activities may seem similar (e.g. piano and violin). However, there are some conflicting views that suggest that overall hand dexterity and fine motor control also improves with piano instruction (Costa-Giomi, 2006) and non-musical activities such as strength training (Olafsdottir, Zatsiorsky, & Latash, 2008). This line of reasoning may be supported by the current data. Deliberate practice of the archery shot routine not only results in more accuracy of the shot itself, as evidenced by expert-level performance, but this accuracy would seem to generalise into everyday life (evidenced by the results of both the clinical/laboratory-based and Doorway tasks). This could have implications for the wider generalisability of skills to everyday life and also for future research. Should this prove to be a reliable phenomenon, future research into domains such as spatial attention or dexterity will need to screen participants to avoid including too many participants that may have expertise in areas that impact these as this could confound the results and impact on generalisability.

5.4 Limitations

As has been said throughout the current research, there was no attempt made to determine underlying causality; suggestions were made that training in archery may result in lower levels of pseudoneglect but the structure of the experiments did not allow for more concrete statements. One limitation concerns the choice of a cross-sectional compared to a longitudinal design; existing experts were examined rather than using a pre-post longitudinal method where beginners were tested and then tested again once expert level had been achieved. The cross-sectional approach used gave insights and revealed a performance difference that is worth exploring further but with the current design it was impossible to be certain if archery was the causal factor in improved spatial attention or if these archers had already had an improved spatial attention system prior to engagement with the sport.

A further limitation concerns sample size; due to the small number of archers that met our inclusion criteria it was necessary to use the same sample for both experiments. This reduces the generalisability of the results to the wider population of archers. Further research is necessary therefore to ascertain if the findings represent a true effect and if so, the degree of difference in spatial performance and pseudoneglect between expert archers and controls.

A final limitation is confined to the representational line bisection task. This task used a passive bisection approach; participants did not interact with the stimulus by bisecting it physically or engaging with it directly as they would in active bisection. Instead, they indicated choice using a key press. This lack of physical action could be a potential reason why results were not as expected. As has been discussed, unimanual activity differentially impacts on the degree of the attentional bias of pseudoneglect (see Nicholls et al 2007). Therefore, if no hand or arm movements are taking place there may be a reduction in the observable phenomenon.

5.5 Conclusion

Pseudoneglect affects all of us, young and old, to varying degrees, normally without much impact aside from the occasional bumped elbow. It can be reduced by contralateral hand use or exacerbated by ipsilateral hand use (Nicholls et al, 2007). However, this reduction/exacerbation is only present while the appropriate hand is being used. This research represents the first example of training leading to a global reduction in pseudoneglect outside of the domain of that trained skill. Archery is an accuracy based sport for all, young and old, physically fit or with physical disabilities (Needham, 2006). It is a pleasant thought that an activity pursued for enjoyment, competition and team spirit could have an impact on day to day life off the shooting line.

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Appendix 1 – Information sheet and Consent form

Letter of Informed Consent for Participation in Research at the Department of Psychology, NUI Maynooth

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Your participation is requested in an experimental study taking place in the Department of Psychology at Maynooth University examining spatial ability and ways it could potentially be influenced. During the experiment you will be asked to do a number of different tasks – some will be pen and paper based, some will be on the computer, requiring you to look at the screen and respond using the mouse or keyboard. Another task will require you to walk along a certain path. For the physical task we will ensure you are in no danger of falling over.

The total time for your participation will be a maximum of 1 hour

The specific nature of the study will be explained as soon as you have completed your session. Personal information will not appear on any test sheets or publications and no participant will ever be personally identifiable from any publicly presented publications. Any data collected over the course of the experimental process will be anonymous, identified only by a code number, assigned randomly before commencement of experimentation. Your responses will be combined with others and reported in group form in a scientific paper, your own data will remain anonymous and be available to you at your discretion. You may withdraw from the study at any stage or you may withdraw your data up until the work in published.

Performance on these tasks does not provide any diagnostically relevant information. In the unlikely event that you experience any distress or discomfort as a result of participating you should contact your own GP.

It must be recognized that, in some circumstances, confidentiality of research data and records may be overridden by courts in the event of litigation or in the course of investigation by lawful authority. In such circumstances the University will take all reasonable steps within law to ensure that confidentiality is maintained to the greatest possible extent

Finally, if you suffer from any of the following, you may not be eligible to take part **Please tick if any of the following apply)**:

- severe visual impairments ☐
- history of psychological/neurological impairment ☐
- severe head trauma resulting in unconsciousness ☐
- history of epilepsy ☐
- dementia/moderate to severe aphasia ☐
- currently taking psychoactive medication ☐
- other relevant medical condition ☐
- history of drug/alcohol issues ☐
- acute mobility conditions
- (i.e. lower limb amputation/recent joint replacement) ☐
- any muscular/bone problems that cause spatial ability
- impairments ☐
- dyslexia ☐
- English not a first language ☐

I have read the above and understand the nature of this study and agree to participate. I also understand that I have the **right to refuse to participate** and that **my right to withdraw from participation at any time will be respected with no coercion or prejudice.**

Name (Please Print Clearly): ________________________________

Signed: ____________________________ **Date:** ____________

Signed (Researcher): __________________________

This research project has been approved by the Departmental Ethics Committee

If during your participation in this study you feel the information and guidelines that you were given have been neglected or disregarded in any way, or if you are unhappy about the process, please contact the Secretary of the National University of Ireland Maynooth Ethics Committee at research.ethics@nuim.ie or +353 (0)1 708 6019. Please be assured that your concerns will be dealt with in a sensitive manner.

Appendix 2 – NART test sheet, Pronunciation guide and Conversion tables

Ache
Debt
Psalm
Depot
Chord
Bouquet
Deny
Capon
Heir
Aisle
Subtle
Nausea
Equivocal
Naïve
Thyme
Courteous
Gaoled
Procreate
Quadruped
Catacomb
Superfluous
Radix
Assignate
Gist
Hiatus

Simile
Aeon
Cellist
Zealot
Abstemious
Gouge
Placebo
Façade
Aver
Leviathan
Chagrin
Détente
Gauche
Drachm
Idyll
Beatify
Banal
Sidereal
Puerperal
Topiary
Demesne
Labile
Phlegm
Syncope
Prelate

FOR EXPERIMENTER'S USE

NART pronunciation and definitions

Word	**Say**	**Definition**
Ache	*Rhymes with* take	Any dull, continuous pain
Debt	Det	Anything which one owes to another
Psalm	Sahm	A sacred song or hymn
Depot	Deppo (or deepo)	A place where things are kept or stored
Chord	Kord	1. *Maths*: a straight line segment joining two points on a curve. 2. a string on a musical instrument 3. *Music*: a group of three or more notes played together in harmony
Bouquet	Bo-**kay** or boo**kay**	1. a bunch of flowers 2. the characteristic smell of wines or liqueurs
Deny	De-**nigh**	1. to declare as untrue 2. to refuse to believe or acknowledge 3. to refuse to grant
Capon	**Kay**-pon	A domestic cock which has been castrated to improve its flesh for eating
Heir	Air	1. a person who inherits, or will inherit, money, property, title, etc. 2. a person, group or society to which something such as tradition, ideas, etc. Is passed on
Aisle	Ile	Any passage between blocks of seats, as in a theatre
Subtle	**Sutt**'l	Fine, slight or delicate, so as to be difficult to detect, etc.
Nausea	**Naw**sia	1. a feeling of sickness in the stomach, often followed by vomiting 2. a feeling of extreme disgust or loathing
Equivocal	Ik**kwi**vvi-k'l	Ambiguous or unclear
Naïve	Nie-**eev**	Unaffected or unsophisticatedly simple and artless (free from deceit or cunning)
Thyme	Time	A low shrub with fragrant leaves used in cooking
Courteous	**Ker**tius	Polite and well-mannered
Gaoled	Jaled	Also spelt **jail**: a building where convicted criminals are kept
Procreate	**Pro**-kree-ate	To produce offspring
Quadruped	**Kwod**roo-ped	Any animal with four feet
Catacomb	**Katta**-koom *or* **Katta**-kome	(*usually plural*) an underground cemetery consisting of tunnels with recesses for graves
Superfluous	Soo-**per**floo-us	More than is needed
Radix	**Ray**-diks	Maths: a number used as the base of a system of numbers, logarithms, etc.
Assignate	**Ass**-ignate	Arrnage to meet in private, arrange rendevouz

FOR EXPERIMENTER’S USE

Gist	Jist	The essential part of something
Hiatus	High-**ay**tus	A gap or interruption
Simile	**Simm**i-lee	A figure of speech in which two unlike things are compared
Aeon	**ee**-on	An immensely long period of time
Cellist	Chellist	
Zealot	**zell**ot	1. an eager of enthusiastic person 2. a fanatic
Abstemious	Ab-**stee**mius	Tending to eat and drink sparingly
Gouge	Gowj	1. *noun* a chisel with a curved blade for cutting blades 2. *verb* to scoop out with or as if with a gouge
Placebo	Pla-**see**bo	A medicine given to a patient for psychological reasons and having no physiological effect
Façade	Fa-**sad**	1. the outside of a building 2. a false or deceptive exterior
Aver	a-**ver**	To declare in a positive way
Leviathan	Lev-**eye**-a-th’n	Anything which is very large, especially in the sea
Chagrin	**Shag**rin *or* sha**green**	A feeling of vexation or disappointment
Détente	Day-**tont**	An easing or relaxing of strained relationships between countries
Gauche	**goash**	Awkward or tactless
Drachm	Dram	A unit of mass equal to about 3.89g
Idyll	**Eye**-dill *or* **idd**il	A short poem or piece of descriptive music concerned with romanticized rural life
Beatify	Bee-**att**i-fie	
Banal	Ba-**nahl**	Hackneyed, ordinary or trivial
Sidereal	Sigh-**deer**iul	Of or relative to the stars
Puerperal	Pew-**er**-peral	Of, relating to, or occurring during childbirth or the period immediately following
Topiary	To-**pie**-ary or Toe-pee-ary	Of, relating to, or being the practice or art of training, cutting, and trimming trees or shrubs into odd or ornamental shapes
Demesne	Da-**mane** *or* da**meen**	1. the possession of land as one’s own 2. the land and buildings possessed
Labile	**Lay**-bile	Changeable or unstable
Phlegm	Flem	Also called **sputum**: the thick mucus of the throat, brought up by coughing during a cold, etc.
Syncope	**Sin**-co-pay	1. the loss of consciousness resulting from insufficient blood flow to the brain 2. the loss of one or more sounds or letters in the interior of a word (as in fo’c’sle for forecastle)
Prelate	**Prell** it	A high-ranking clergyman, such as a bishop or archbishop

The WAIS-R Full Scale, Verbal and Performance IQs produced from the number of errors made on the NART

NART Errors	Predicted Full Scale IQ	Predicted Verbal IQ	Predicted Performance IQ	NART Errors	Predicted Full Scale IQ	Predicted Verbal IQ	Predicted Performance IQ
0	131	127	128	25	100	99	100
1	129	126	127	26	98	98	99
2	128	125	126	27	97	97	98
3	127	124	125	28	96	95	97
4	126	123	123	29	95	94	96
5	124	122	122	30	94	93	95
6	123	121	121	31	92	92	94
7	122	119	120	32	91	91	92
8	121	118	119	33	90	90	91
9	120	117	118	34	89	89	90
10	118	116	117	35	87	87	89
11	117	115	116	36	86	86	88
12	116	114	115	37	85	85	87
13	115	113	114	38	83	84	86
14	113	111	112	39	82	83	85
15	112	110	111	40	81	82	84
16	111	109	110	41	80	81	83
17	110	108	109	42	79	80	82
18	108	107	108	43	77	78	80
19	107	106	107	44	76	77	79
20	106	105	106	45	75	76	78
21	105	103	105	46	74	75	77
22	103	102	104	47	73	74	76
23	102	101	102	48	71	73	75
24	101	100	101	49	70	72	74
				50	69	70	73

Appendix 3 – CFQ

The Cognitive Failures Questionnaire
(Broadbent, Cooper, FitzGerald & Parkes, 1982)

Name: …………………….. Age …………… Date ………………….

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened to your in the past 6 months. Please circle the appropriate number.

		Very often	Quite often	Occasion-ally	Very rarely	Never
1.	Do you read something and find you haven't been thinking about it and must read it again?	4	3	2	1	0
2.	Do you find you forget why you went from one part of the house to the other?	4	3	2	1	0
3.	Do you fail to notice signposts on the road?	4	3	2	1	0
4.	Do you find you confuse right and left when giving directions?	4	3	2	1	0
5.	Do you bump into people?	4	3	2	1	0
6.	Do you find you forget whether you've turned off a light or a fire or locked the door?	4	3	2	1	0
7.	Do you fail to listen to people's names when you are meeting them?	4	3	2	1	0
8.	Do you say something and realize afterwards that it might be taken as insulting?	4	3	2	1	0
9.	Do you fail to hear people speaking to you when you are doing something else?	4	3	2	1	0
10.	Do you lose your temper and regret it?	4	3	2	1	0
11.	Do you leave important letters unanswered for days?	4	3	2	1	0
12.	Do you find you forget which way to turn on a road you know well but rarely use?	4	3	2	1	0
13.	Do you fail to see what you want in a supermarket (although it's there)?	4	3	2	1	0
14.	Do you find yourself suddenly wondering whether you've used a word correctly?	4	3	2	1	0

		Very often	Quite often	Occasion-ally	Very rarely	Never
15.	Do you have trouble making up your mind?	4	3	2	1	0
16.	Do you find you forget appointments?	4	3	2	1	0
17.	Do you forget where you put something like a newspaper or a book?	4	3	2	1	0
18.	Do you find you accidentally throw away the thing you want and keep what you meant to throw away – as in the example of throwing away the matchbox and putting the used match in your pocket?	4	3	2	1	0
19.	Do you daydream when you ought to be listening to something?	4	3	2	1	0
20.	Do you find you forget people's names?	4	3	2	1	0
21.	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	4	3	2	1	0
22.	Do you find you can't quite remember something although it's "on the tip of your tongue"?	4	3	2	1	0
23.	Do you find you forget what you came to the shops to buy?	4	3	2	1	0
24.	Do you drop things?	4	3	2	1	0
25.	Do you find you can't think of anything to say?	4	3	2	1	0

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Appendix 4 – Trail Making Task: Instructions, samples and test sheets

Trail Making Test (TMT) Parts A & B

Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

Step 1: Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.

Step 2: Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).

Step 3: Time the patient as he or she follows the "trail" made by the numbers on the test.

Step 4: Record the time.

Step 5: Repeat the procedure for Trail Making Test Part B.

Scoring:

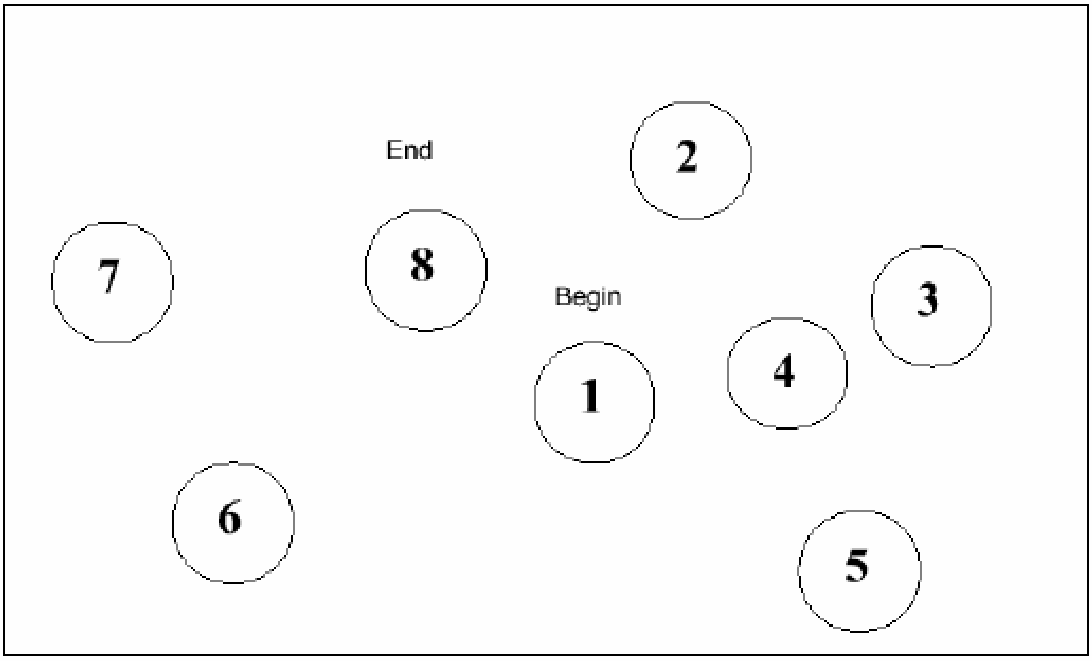
Results for both TMT A and B are reported as the number of seconds required to complete the task; therefore, higher scores reveal greater impairment.

	Average	**Deficient**	**Rule of Thumb**
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 3 minutes

Sources:

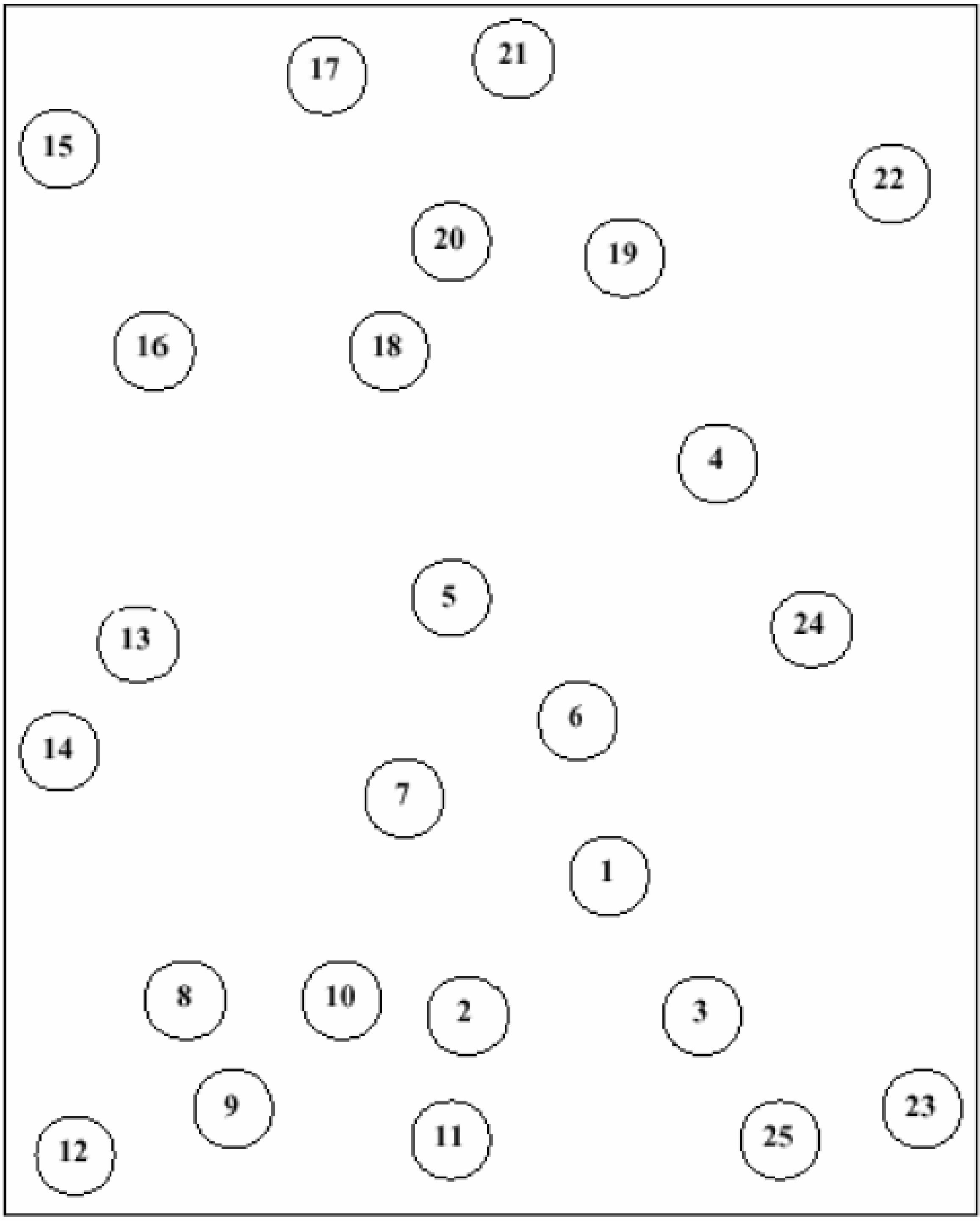
- Corrigan JD, Hinkeldey MS. Relationships between parts A and B of the Trail Making Test. *J Clin Psychol*. 1987;43(4):402–409.
- Gaudino EA, Geisler MW, Squires NK. Construct validity in the Trail Making Test: what makes Part B harder? *J Clin Exp Neuropsychol*. 1995;17(4):529-535.
- Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment*. 4th ed. New York: Oxford University Press; 2004.
- Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958;8:271-276.

Trail Making Test Part A – *SAMPLE*

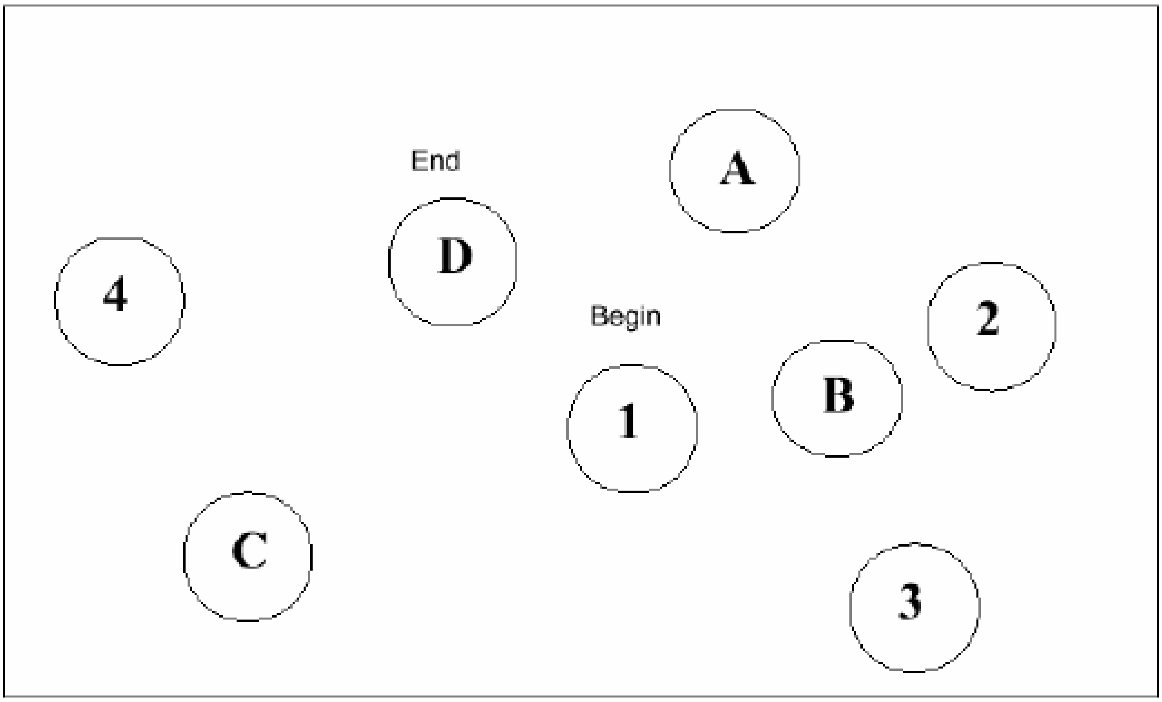


Trail Making Test Part A

Patient's Name: ______________________ Date: ______________

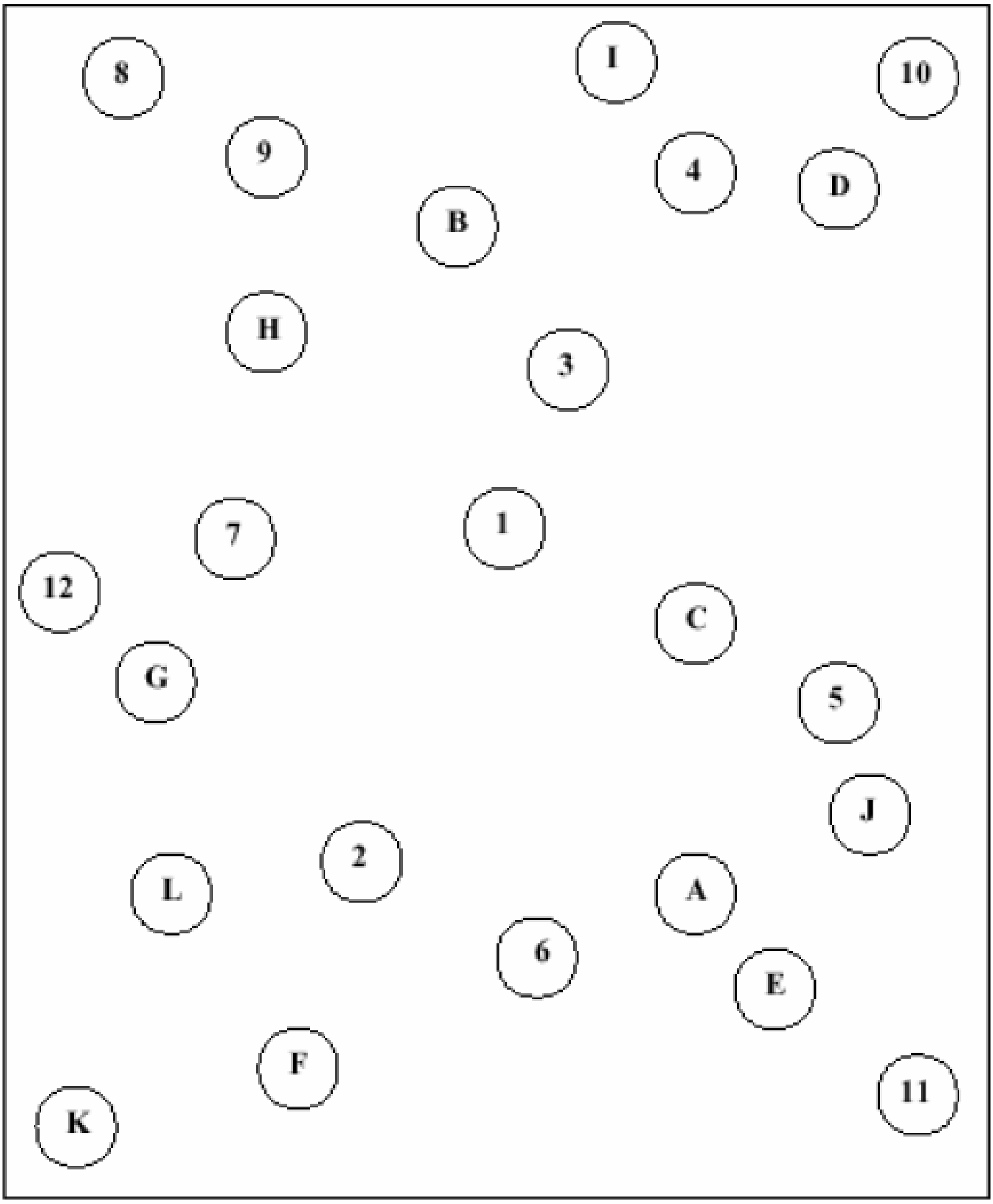


Trail Making Test Part B – *SAMPLE*

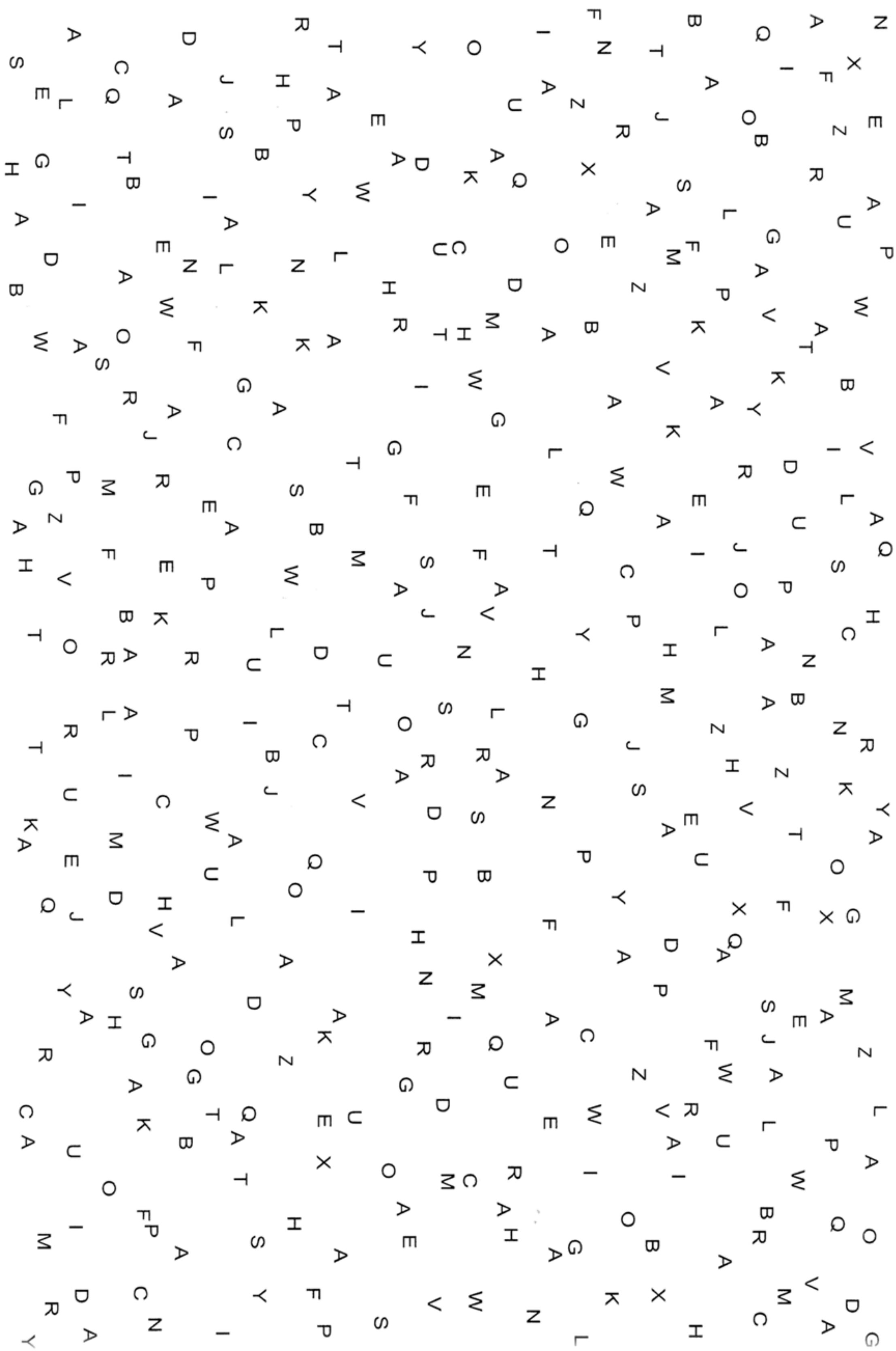


Trail Making Test Part B

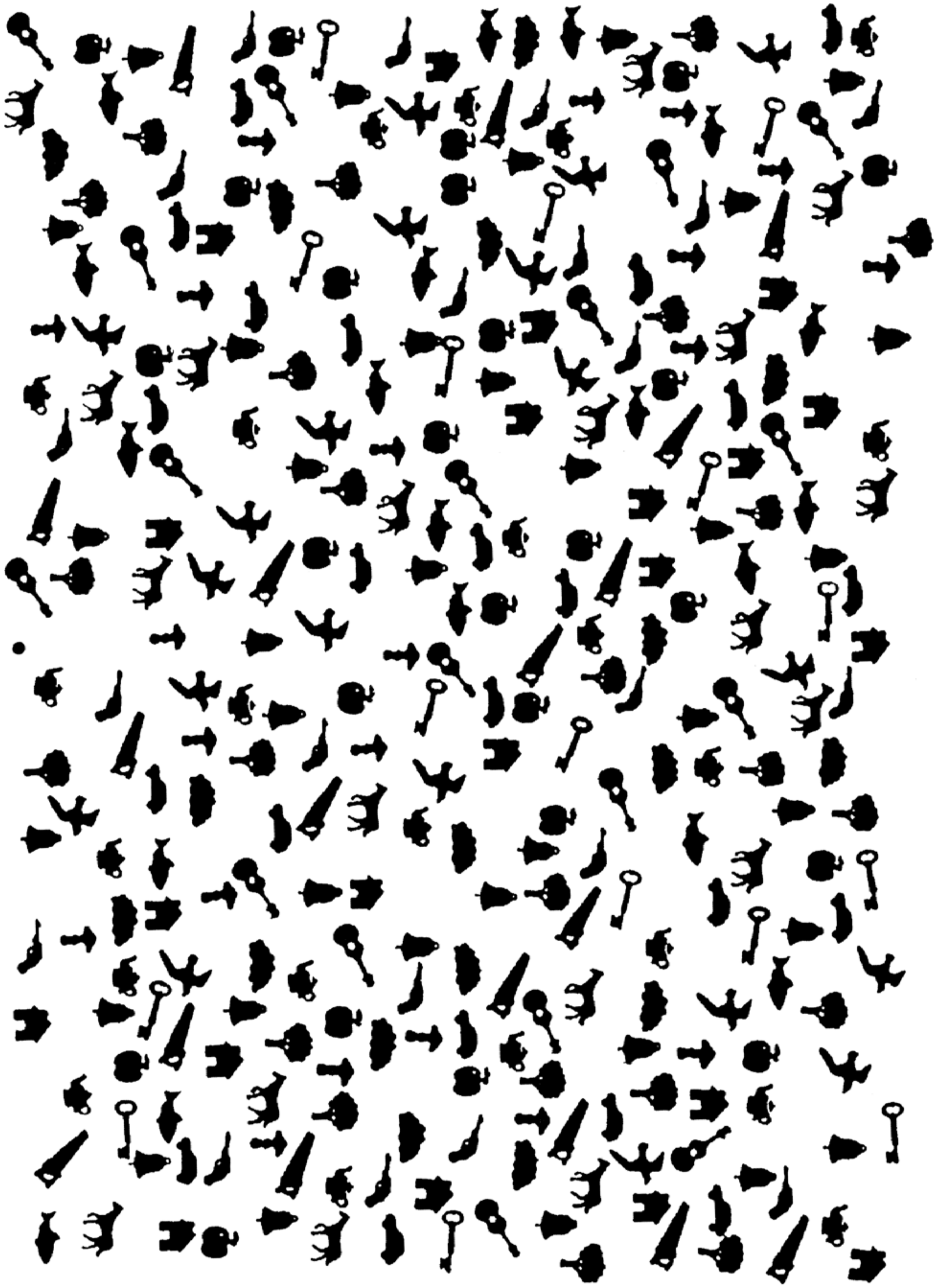
Patient's Name: ________________________________ Date: ______________________



Appendix 5 – Letter Cancellation



Appendix 6 – Bell Cancellation



<u>Line Bisection Task</u>

Please indicate the centre of each horizontal line by drawing a vertical stroke where you think the <u>centre</u> of each line is located.

1. ____

2. ____

3. ____

4. __________________________

5. ____

6. ______________________________

7. ____________________

8. __________

9. ___________________________________

10.

____

Appendix 8 – Representational Line Bisection: Instructions and sample sheets

On-screen Instructions:

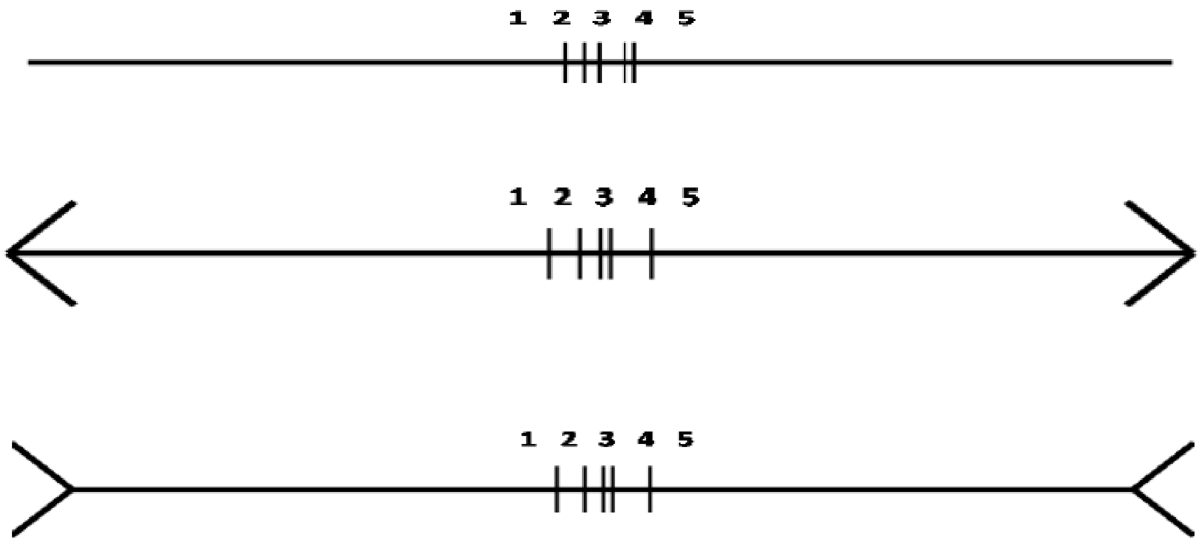
You will see a series of horizontal lines presented on screen. Some will have inward or outward going fins at the ends of them, while others will not. For every line, a set of 5 numbered vertical bars will appear around the middle.

Your task will be to press the number (1-5) corresponding to the bar at the true centre of the line.

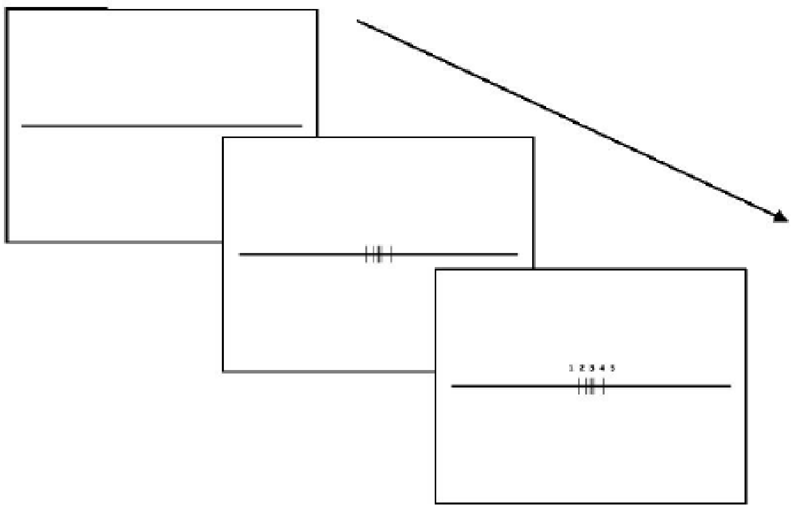
For some trials, the horizontal line will disappear before the vertical bars appear, but your task remains the same.

Hit the SPACEBAR to begin

Sample Line Types:



Perceptual Trial – Line stays on screen



Memory Trial – Line disappears