ASSESSING EVOLUTIONARY EXPLANATIONS OF HUMAN BEHAVIOUR USING VISUAL COGNITION

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Declaration

I declare that this thesis, *Assessing Evolutionary Explanations of Human Behaviour Using Visual Cognition*, represents my own work. None of the work presented in the present thesis has been submitted or accepted to any previous applications for higher educational degrees at this or any other University or institution. All quotations used have been distinguished by quotations marks and the sources of information specifically acknowledged.

Submitted by Antonia D. C. D'Souza

Signature of candidate:

Date:

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Abstract

The ‘hunter gatherer hypothesis’ posits that prehistoric environments and social roles have resulted in the evolution of specific, yet distinct cognitive abilities in men and women (Silverman & Eals, 1992). The majority of previous research however has focused solely on sex differences in spatial cognition. In a series of eight experiments, the present thesis examined the hunter gatherer hypothesis using visual cognition paradigms. Chapters 2 and 3 failed to support the hunter gatherer hypothesis when assessed by attentional and perceptual paradigms respectively. For instance, men are not better at tracking moving object relative to women, as would be predicted by the theory. Chapter 4 does however find support for the hunter gatherer notion; a task and effect that is thought to be related to foraging (i.e., social inhibition of return) is larger when undertaken by pairs of women, as opposed to pairs of men or mixed-sex pairings. Overall, the results from the present work show limited support for the hunter gatherer hypothesis.

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CHAPTER 1

Man differs from woman in size, bodily strength, hairyness, &c., as well as in mind, in the same manner as do the two sexes of many mammals.

The Descent of Man (1871)

Volume 1, Chapter 1, page 12

Charles Darwin

1.0 General Introduction

1.1 Darwin's theories on evolution

Stemming from evolutionary biology where one assesses "functions", purpose, and the mechanics of the different aspects of our physiology, evolutionary psychology applies the same principles to the study of the human brain and mind. It investigates the brain's ability to process information and the "programmes" it uses to produce any given behaviour (Mayr, 1982; Daly & Wilson, 1983; Cosmides & Tooby, 1997; Buss, 2015). Although a number of previous theories had been posited (for example, Lamarck's (1744-1829) view of acquired characteristics), Charles Darwin provided the currently accepted explanation for the physiological differences between and within animals with his works on *The Origin of the Species* (1859) and *The decent of Man and Selection in Relation to Sex* (1871, eds. Bonner & May, 1981). His first piece of work introduced the concept of natural selection. Darwin aimed to provide an explanation for why organisms seemed to be perfectly adapted for the environment in which they existed. Although Darwin himself was not aware of genes, one central aspect of adaptation is the process in which genetic material that is passed onto the next generation contains a variation. In order for this variation to be 'selected', it must have a positive impact upon the organism's reproductive success. This includes the organism's ability to successfully find food and shelter, a mate to produce offspring with, and to circumvent an environmental issue that may interrupt this process. Crucially, this variation must be heritable in order to be of benefit to subsequent generations. If these criteria are met, then the next generation may contain more individuals with the advantageous genetic material than those without it. Eventually those individuals who possess the advantageous trait dominate the population, and those that do not, die off.

Darwin's related notion of sexual selection is sometimes said to be a theory that fills in 'gaps' that cannot be explained by natural selection (Buss, 2009). Specifically, it aimed to explain the sexual dimorphism found between the sexes, one that Darwin viewed as *"an important variation upon the theme of natural selection with certain traits in the male (or, less commonly, the female) making him (or her) more successful in mating"* (Darwin, eds. by Bonner & May, 1981, page ix). In particular, the sex of the species that chooses a member of the other sex to mate with will do so based on specific criteria, known as *inter*sexual selection or preferential mate choice. As a result, those with the desired traits will sire offspring, resulting in an increased population frequency of those traits. Members of the sex to be chosen, compete with each other in order to present themselves as the best of the selection available, known as *intra*sexual selection. Thus, the traits or characteristics that directly result in the winner’s success are passed onto the next generation, again resulting in an increase in frequency for particular traits. Darwin noted that in most species the 'choosey' sex is typically the female and the one to be chosen is the male. Males tend to be highly decorated with ornamentations; phenomena that Darwin thought could not be explained by natural selection. He noted that these ornaments made the animals more visually salient or physically impeded their ability to escape predators; these ornaments were seemingly costly to the animals. Thus, Darwin concluded that the males who were able to successfully defend themselves and their territory, to find food and to a find a mate, were able to demonstrate their fitness in regard to being able to circumvent the physiological cost (Goss, 2012). This results in high fitness males being chosen by females as potential mates for any future offspring she may have.

1.2 The modern synthesis

Darwin did not introduce the concepts of genes and genetic inheritance. He proposed that traits were passed onto progeny from the parents via pangenesis, or “blending”, as it was then known. This was a hypothetical mechanism for inheritance (Holterhoff, 2014), whereby every aspect of the progeny would have been formed via the mixing of cellular data from all living and functional parts of the parents (Browne, 2002). Independently of Darwin, Gregor Mendel established what would later be known as the Mendelian inheritance (Henig, 2000), where his work on hybridisation resulted in formation and development of modern genetics (Lorenzano, 2011; Smykal, Varshney, Singh, Coyne, Domoney, Kejnovsky, Warkentin, 2016). Mendel’s work regarding plant hybridisation was not widely known at the time of publication. This has been attributed partly to his use of methodologies employed by nineteenth century physicists rather than biologists (Smykal et al., 2016), and it has been proposed by William Bateson that Darwin's work eclipsed Mendel’s, causing it to go unremarked (Fisher, 1958). However, in 1900, three botanical scientists independently, rediscovered Mendel’s work - De Vries in Holland, Correns in Germany and Von Tschermack in Austria (Roberts, 1929). Bateson was a strong advocator of Mendel’s work (Fisher, 1958; Reid & Ross, 2011; Smykal et al, 2016), who was also credited as the originator of the term ‘genetics’ (Shepherd, 2010).

By the 1930's, Darwin's theories and Mendel’s view on genetic inheritance had been combined to form what was known as the ‘modern synthesis’, becoming a central concept to biology (Bock, 1981). This theoretical progression sought to bridge misunderstandings between many biological and archaeological factions, such as genetics, cytology and palaeontology, whilst also confirming Darwin's theories, e.g., the effect of natural selection on evolutionary change (Rose & Oakley, 2007).

1.3 Evolution and behaviour

By definition, successful adaptations result in a change in physiology and behaviour. For instance, dogs that have been bred for a particular physical stature or appearance typically have associated behavioural patterns, i.e., large, strong guard dogs may demonstrate greater levels of aggression compared to smaller, docile dogs. Although a number of authors had previously examined function, it was not until the mid 20th century that ethologists began to systematically examine the effect of evolution on behaviour. Konrad Lorenz (1965) famously demonstrated the concept of innate or pre-programmed learning in ducks. Upon hatching, ducklings “imprint” upon the first moving object they see, typically their mother. Lorenz established that the imprinting mechanism is not able to discern whether the first moving object seen, and therefore imprinted onto, is adaptively beneficial to the baby animal. Newly hatched ducklings were presented with Lorenz's moving leg during the critical imprinting phase, resulting in the baby ducks imprinting on and following him, instead of their mother. This may be seen as an example of an adaptive mechanism generalising or even ‘failing’.

Following ethology, Hamilton (1964) proposed that natural selection was not solely driven by reproductive success. Rather, he suggested that traits and behaviours that cause an organism’s genetic material to be passed on, *irrespective* of direct genetic relation were favoured, what he referred to as "inclusive fitness". Hamilton's theory is often expressed mathematically; that is, inclusive fitness can be calculated as the sum of the organism's reproductive success, plus the effects their actions have on the reproductive success of their genetic relatives. In humans, parents, children and siblings share 50% of their genetic material, with this degree of relatedness decreasing the more distantly related the individuals are (Buss, 2015). Webster (2003) identified that the degree of relatedness directly impacted the amount of lottery winnings an individual would grant a relative. The more distantly related the individual, the smaller the portion would be. Furthermore, Burnstein, Crandall and Kitayama (1994) demonstrated that participants are less likely to help distant relations in a life or death scenario than those with high levels of relatedness, i.e., siblings. Inclusive fitness also provides a potential explanation for parental care. According to Daly and Wilson (1995), selection favours parents to invest more in the offspring that is more likely to go on to reproduce themselves. This provides a greater genetic investment return for the parents, who have then ensured that their genetic material will be passed onto future generations.

This follows on from Triver's (1972) parental investment theory. Based itself on Darwin's sexual selection theory, Triver's parental investment theory proposed that the sex which invests more in their offspring, will be more selective in their choice of mate (*inter*sexual attraction). In contrast, and fitting with sexual selection, the sex that invests less will compete more with other members of the same sex for access to the selective sex (*intra*sexual competition). The theory is defined as *"any investment by the parent in an individual offspring that increases the offspring's chance of surviving (and hence reproductive success) at the cost of* *the parent's ability to invest in other offspring."* (Trivers, 1972, page 55). Thus, investment can range from physical contributions, (i.e., the production of gametes), to any activity that promotes the survival of the young.

The emphasis on gamete size is central to understanding the degree of investment that each sex imparts. Male sex cells in most plants and animals are miniscule in comparison to female sex cells. In most species, the female sex cell is large and static, whereas the male's is small and mobile. In regard to each sex's reproductive success, males are therefore relatively unlimited in their ability to produce sperm cells; rather they are limited by their ability to use them for fertilisation. The converse is true for females; they are limited by their ability to produce their sex cells, not by their ability to ensure fertilisation (Bateman, 1948; Trivers, 1972).

Whilst Darwin's theory of sexual selection (1871) provided many answers that the *Origin of the Species* (1859) could not address, it still lacked a framework that provided a theoretical relationship between sex-linked inheritance, differential morality, parental care, and mating strategies (i.e., monogamy, polygyny, polyandry, and promiscuity; Trivers, 1972). Bateman (1948) put forward an argument regarding the female choice and male-male competition, whilst Fisher (1958) developed an energy investment, sex-ratio model, which aimed to explain sex ratios at conception. Here, Fisher argued that energy and time are measures of parental expenditure or investment. However, Trivers posited that Fisher's proposal does not truly represent the effort a parent would impart in all aspects of caring for and protecting their offspring. Trivers suggested that the only relevant variable required to understanding and calculating an organism’s reproductive success is their parental investment. For instance, Fisher would classify a parent distracting a predator from their offspring as a low to moderate investment, based on the amount of time and energy required to complete the task. In contrast, Trivers would classify the risk of being injured or killed by the predator as a large parental investment.

Empirical support for Trivers' (1972) theory is abundant in the animal behaviour literature. Females of many species that invest more in their offspring than males are typically the more choosey of the sexes (Buss, 2015). However, there are a few species where a ‘role reversal’ occurs. Consider the Syngnathidae family that includes seahorses and pipefish. After fertilisation, the male syngathid’s carry the zygotes in specialised structures in the abdomen or the tail (Wilson, Ahnesjö, Vincent, Mayer & Crespi, 2003). Within some members of this species family, the females engage in female-to-female combat for a male to mate with. Where the males are the ‘choosey’ sex and the females are larger, more aggressive and are selected by demonstrated high fitness levels based on their victory (Sogabe & Yanagisawa, 2007).

1.4 Evolution and human behaviour

At the end of *On the Origin of Species*, Darwin predicted that research in “*Psychology will be securely based on … the necessary acquirement of each mental power and capacity by gradation. Much light will be thrown on the origin of man and his history*” (Darwin, 1859, page 862). His theories are an approach, or a way of thinking and understanding phenomena, one that has led to the development of many different factions of human psychology. For example, facial expressions and emotion (Ekman 1970); developmental psychology (Charlesworth, 1992); parental investment and mate choice theories (Fisher, 1958; Trivers, 1972; Miller, 2000); spatial abilities (Silverman & Eals, 1992; Eals & Silverman, 1994); domain specific memory systems (Nairne & Pandeirada, 2008); and leadership (King, Johnson & van Vugt, 2009; Maner & Mead, 2010), amongst many other phenomena.

The methods of acquiring and consuming food employed by human ancestors are reported to be vastly different from other primates. Tooby and DeVore's (1987) "man the hunter" model proposed that the rapid development in human evolution was due to the complex cognitive and physical requirements for successful large game hunting. However, the gathering hypothesis provided a counter argument for the hunting theory. It draws specifically on the proportion of plant matter within the diet of current hunter gatherer societies (Marlow, 2005; Wood, 2006) and that the development and use of tools arose to help with digging and cutting up plant matter (Tanner, 1983). In addition, there is evidence from modern hunter gatherer societies that the quantity of subsistence a woman gathers is significantly related to the proportion of meat the man successfully hunts (Hawkes, Hill & O'Connell, 1982). Nevertheless, evidence that suggests a consistent stability in the consumption of plant matter throughout human evolution does not account for differential behaviours observed between modern men and women.

1.5 The Hunter Gatherer Hypothesis

The division in labour that is thought to have been present throughout a multitude of ancestral societies, (e.g., Hawkes, O'Connell & Blurton Jones, 1997; Wood, 2006; Cashdan, Marlowe, Crittenden, Porter & Wood, 2012), with men as hunters and women as gatherers, may have partly resulted in the development of specific cognitive functions and abilities that facilitated hunting and gathering tasks. Initial theories regarding dimorphic spatial abilities between the sexes were proposed to be due to differences in natal dispersal (Greenwood, 1980; 1983) and differences in mating strategies (Gaulin & Fitzgerald, 1986). Natal dispersal refers to the distance an animal travels between its birthplace and its breeding place. This distinction is not limited to one sex; Greenwood proposed that males that travel to find a mate employ a ‘mate defence’ strategy, where for example, a male travels and takes over a group of females for potential mates (i.e., a new lion taking over a pride). On the other hand, females that travel to find a mate employ a ‘resource defence’ strategy, whereby males as potential mates are selected on the basis of their ability to attain and defend their resources. Thus, the sex that has greater reproductive success by traveling the furthest would be favoured due to their superior spatial abilities.

Gaulin and Fitzgerald (1986) expanded on Greenwood’s theory and proposed that larger home ranges (and therefore greater spatial abilities) were due to polygamous (one male with multiple females), polyandrous (one female with multiple males) or promiscuous mating strategies being employed. Using behavioural and observational studies, Gaulin and Fitzgerald confirmed that male meadow voles (that employ a polygamous mating strategy) would have superior spatial abilities compared to their male prairie and pine vole counterparts (monogamous mating strategy employed). Jacobs, Gaulin, Sherry and Hoffman (1990) also established that the hippocampal size between the males and females of polygamous and monogamous voles differed. Specifically, the size of the hippocampus in the male polygamous voles was significantly larger than their female counterparts and the male monogamous voles, providing some support for the notion that the hippocampus is essential for spatial cognition (Moser, Moser & Andersen, 1993).

Silverman and Eals (1992) utilised these theories for the groundwork of their "hunter gatherer" hypothesis, by applying the concept of non-human travel and dispersal, to human evolution and the resulting effects on human spatial abilities. Their paper was seminal in the sense that it provided a stepping-stone for the examination of the female advantage in spatial abilities. Prior to this publication, the literature had focused on the male advantage of navigation and way finding (e.g., Bennett, Seashore & Wesman, 1947; van den Berg & Kuse, 1978).

Silverman and Eals' (1992) hypothesis posits that many dimorphic visuo-spatial specialisations within Homo sapiens are due to assigned social roles of hunters (males) and gatherers (females) in the Pleistocene period of hominoid history (Tooby & DeVore, 1987). Both roles required a specific set of skills for efficacy and efficiency. According to Silverman and Eals, hunters would have been required to navigate from a base camp to different locations whilst looking for or tracking their prey. This behaviour would require a number of cognitive mechanisms such as good spatial memory (Postma, Jager, Kessels, Koppeschaar & van Honk, 2003), cognitive mapping (O'Laughlin & Braubaker, 1997), an orientational navigation strategy based on Euclidian co-ordinates (Stenstrom, Stentstrom, Saad & Cheikhrouhou, 2008), or a proprioception method (Ecuyer-Dab & Robert 2004). The authors also proposed that gathering would have involved individuals remembering locations of stable food sources and returning to these areas multiple times. They argued that gathering would have favoured those who were able to learn and recall objects and the array in which they are placed. Silverman and Eals assessed this by asking participants to identify objects that had moved by presenting them with an original array of random objects, before presenting the critical array, where a number of objects had swapped locations. The participants were also asked to identify the locations of objects from the room they waited in before beginning the experiment. In both assessments, the results indicated that women had significantly higher object location memory recall and object recognition rates than men.

Silverman and Eals's (1992) suggestion that men developed different cognitive spatial abilities to women have been corroborated numerous times since publication. Support for the male advantage is found in many paradigms, including 2D mental rotation tasks, (Jordan, Wüstenberg, Heinze, Peters & Jäncke, 2002), 3D mental rotation tasks, (Voyer, Voyer & Bryden, 1995), a Corsi Block-Tapping Task, (Capitani, Laiacona & Ciceri, 1991), and for cognitive mapping and navigational strategies within an experimental setting using virtual reality methods (Picucci, Caffo & Bosco, 2011; Andersen, Dahmani, Konishi & Bohbot, 2012).

Empirical support for the female advantage has also been demonstrated. Eals and Silverman (1994) established that women demonstrate an object location and object recognition advantage for stimuli that cannot be clearly defined by a label. Silverman, Choi and Peters (2007) confirmed the universality of spatial sex differences with men and women in 40 countries demonstrating superiority in mental rotation tasks and object location memory tasks respectively. Nonetheless, there have also been mixed findings in regard to the reported female advantage. James and Kimura (1997) found that whilst the female advantage is present in the standard object location memory task (i.e., when the objects switch positions), it disappears when the objects are moved to previously unoccupied locations. In addition, Cashdan et al., (2012) failed to find the female advantage among the

Hadza hunter gatherer tribe in Tanzania, instead they found that males exceeded in most tasks, and Voyer, Postma, Brake and Imperato-McGinley, (2007) have pointed out that the female advantage effect size is small.

1.6 Sex differences in Visual Cognition

Irrespective of the mixed findings regarding the female advantage in spatial cognition, Silverman and Eals' (1992) emphasis on the impact that social role division had upon the evolution of cognitive development and specialisation has also been applied to areas of visual cognition. Unfortunately, very few visual cognition research papers provide the sex of participants as a comparative variable (Abramov, Gordon, Feldman & Chavarga, 2012). Halpern (2000) proposed that the majority of researchers omit this variable because it provides little theoretical interest to the researcher. The assumption is that little or no sex differences occur within visual cognition, and as a result, it is difficult to discern the impact the participant's biological sex has on available findings.

Despite this, in recent years a number of publications have addressed sex differences in areas such as selective attention (e.g., Bayliss, di Pellegrino & Tipper, 2005; Stöet, 2010; 2011; 2017), visual perception (e.g., Ling, Herrernan & Hamilton, 2006; Sanders et al., 2007; Stancey & Turner, 2010; Abramov et al., 2012) and inhibition of return (e.g., Brown, 2013), to name a few.

1.6.1 Sex differences in Attention

Research assessing attention capturing mechanisms has established that visual cues presented in the periphery result in faster responses for peripheral targets (Posner, 1980). Eye movements directed towards peripheral stimuli in the temporal visual field are preferred under monocular viewing conditions (Posner

& Cohen, 1980), and increased brain activity in the contralateral parietal lobe was observed for peripherally presented stimuli (Neville & Lawson, 1987). Furthermore, behavioural results demonstrate that peripheral cue onsets automatically attract attention (e.g., Yanis & Jonides, 1990); faster response times (RTs) are elicited when 'valid' peripheral cues are used (e.g., Posner & Cohen, 1984); when feature conjunction targets (multiple salient features) are presented (Briand & Klein, 1987), and when static objects become dynamic (Abrams & Christ, 2003; 2005).

Peripheral cues are not always valid or informative. Bayliss, et al., (2005) demonstrated that the presentation of irrelevant information impaired the RTs given by female participants in comparison to males. They employed an adapted version of the Posner (1980) cuing paradigm, whereby a face (Bayliss, et al., Experiment 1) or arrow (Bayliss, et al., Experiment 3) looking or pointing left or right directed the participant's attention. In both experiments, the directional cues were invalid for half the trials, and women showed greater cuing effects than men. Stöet (2010) points out that the sex difference found could be accounted for by the stimuli Bayliss et al. employed, which were explicitly spatial in nature and therefore may have had a male advantage (Sanders, 2013). Thus, Stöet aimed to clarify this by combining a 'flanker task' (Eriksen & Eriksen, 1974) and a go/no-go task. Participants were instructed to respond to valid flanker-target combinations, but to withhold a response for the invalid combinations. The findings corroborated Bayliss et al's., findings; women demonstrated impaired performances for invalid combinations compared to men. Stöet also argued that these findings provide support for Silverman and Eals' (1992) hunter gatherer hypothesis. Specifically, Silverman and Eals' suggested that efficient gathering might be achieved by increased peripheral perception abilities. That is, the successful foragers should be able to perceive stimuli within the non-central parts of their vision. The implication here is that gatherers, as opposed to hunters, should be "*open to all response alternatives*" (Stöet, 2010, page 637), and therefore having greater orientating (attention capturing) abilities. This is not to say that hunting would not require the use of peripheral vision, however, as it is highly sensitive toward motion detection (Lachenmayr, 2006).

Therefore, whilst it is reasonable to conclude that sensitivity to visually peripheral stimuli, irrespective of its validity (i.e., Bayliss et al., 2005), is a result of a uniform selection pressure, the impact irrelevant information has on the processing abilities of each sex is variable. Human vision spans approximately 160˚ to 180˚ from the left temporal field to the right temporal field (Komogortsev & Khan, 2004). Consequently, fast responses to the appearance of peripheral stimuli that could represent a threat, (particularly in high adrenaline situations, i.e., hunting) would promote the survival of the individual in question.

1.6.2 Sex differences in Perception

As with many evolutionary theories of human behaviour, Silverman and Eals' (1992; Eals & Silverman, 1994) hypothesis is somewhat post hoc in that it attempts to explain existing data on spatial differences between the sexes and historical data regarding human evolution (Tooby & DeVore, 1987). Thus, a central problem with the hypothesis is that the situations in which the mechanisms are purported to have evolved are of course not testable within a controlled environment. Sanders et al., (2007), however, developed a paradigm that allowed for an artificial, yet potentially direct assessment of the hunter gatherer hypothesis. The authors argued that the social roles hunters and gatherers presumably held required distinct visual processing abilities. Individuals that are required to ‘hunt’ are concerned with processing the global environment, i.e., far visual space. Furthermore, the acquisition of prey items requires good visual processing and coordination, good proximal arm muscles for strength and accuracy in aim (Sanders & Walsh, 2007), as well as large scale navigational systems (Eucyer-Dab & Robert, 2004). By contrast, those that are required to 'gather' would be concerned with processing the immediate local environment, i.e., near visual space. The gathering of staple foods (i.e., plant matter) also requires good distal hand muscles necessary for constant movement and grasping actions (Sanders & Walsh, 2007) and developed small-scale navigational systems (Eucyer-Dab & Robert, 2004). Therefore, the authors proposed that, in line with the evolved specialisation based on the social roles, men as hunters should demonstrate superior visual processing in far visual space instead of near, and women as gatherers in near visual space as opposed to far.

Sanders et al., (2007; Sanders & Walsh, 2007) assessed this by presenting participants with stimuli in both near and far visual space. In one experiment, participants were required to complete a large foam board puzzle. Their view of their hands and the puzzle was occluded, and these stimuli were projected, via a live video feed, onto a screen located in near and far visual space. Results showed that whilst women completed the puzzle more efficiently than men, when the video image was viewed in near visual space in comparison to far, men demonstrated superiority for far visual space as opposed to near visual space in comparison to women. Sanders et al., argues for neurological support for the near/far distinction via positron emission tomography (PET) findings from Weiss et al., (2000). Weiss et al., examined neural activation when near and far visual space was attended to. They found that the ventral stream, which plays a role in object recognition, is activated for far visual space processing and the dorsal stream, involved in depth perception and action, for near visual space processing (for further information see: Ungerleider & Mishkin, 1982; Goodale & Milner, 1992; Ungerleider & Haxby, 1994; Milner & Goodale, 1995, 2008; Schenk & McIntosh, 2010). Based on these data alone, Sanders et al., concluded that differential visual space processing abilities reflect a sex-based bias for the visual streams, with men being 'ventral stream dominant' and women being 'dorsal stream dominant'.

Associated with the ventral and dorsal streams are the parvocellular (P-) and magnocellular (M-) pathways. The P-pathway is sensitive to colour vision and relatively fine detail, i.e., high spatial frequency. By contrast, the M-pathway is sensitive to motion and low spatial frequency due to its specialisation for movement and dim light. A recent paper by Abramov et al., (2012) investigated spatio-temporal contrast sensitivity in regard to sex. Their results indicated that both sexes have similar levels of sensitivity to low spatio-temporal frequency stimuli, (where the movement in the stimuli was salient). However, the sensitivity threshold for women tailed off for high spatio-temporal frequency stimuli (where the movement was less salient), whilst the male sensitivity became more apparent. These findings led Abramov and colleagues to conclude that men have greater sensitivity to high spatio-temporal frequency stimuli and are therefore able to detect fine motion better than women. They also suggest that their findings are in line with Sanders et al.'s (2007) argument in regard to sex differences and visual space. Specifically, they posited that visual information presented in far visual space is more associated with high spatial frequency, which, as their findings suggest, males are sensitive to. This in turn suggested that men as hunters would be able to process visually far information to a greater degree than women as gatherers.

Near visual space, or peri personal space, is often defined as an area of the environment that is within arm's reach. However, research assessing the effects of tool use suggests that the length or distance of this area of circumference may not be as was once assumed. Longo and Lourenco (2006) employed a line bisection task where the participants were required to bisect a horizontal line into equal halves using a laser pointer or a stick within near or far space. The results indicated that across both visual spaces, line bisection performance was similar when the participants used the stick, compared to the laser pointer. That is, the laser pointer elicited more accurate bisections than the stick. Crucially, these results were also similar to the near visual space condition with the laser pointer. That is, the use of the stick extended the participants near space range, resulting in near space being re-mapped to include the area of the stick. Stancey and Turner (2010) examined differences between men and women using Longo and Lourenco's methodology. Similar to Sanders et al. (2007), they found that when using the laser, women were more accurate in near space and men in far space. Importantly, when women used the tool in the far condition, accuracy rates increased relative to the use of the laser in the far condition. Thus, providing additional support for the notion that elongated tools can extend the perceived distance that can be reached, thus re-mapping near space.

The assumptions on which Sanders et al. (2007; Sanders & Walsh, 2007) based their findings are consistent with a *Behavioural and Brain Sciences* target article by Previc (1990). This article was a substantial theoretical review of the evolution and development of the upper and lower visual field functions in relation to the visual system. Previc posited that the physiological developments that occurred during hominoid evolution either led to or were the cause of functional specialisations within the visual system. In particular, Previc discusses the potential impact that forward-facing eyes had on the development of binocular vision, and therefore depth perception, as well as the upright, bipedalism that freed the upper limbs from supporting the weight of the body and thus allowed for direct manipulation of the near environment. Previc postulated that this encouraged and facilitated hand to eye coordination and general vision by aiding depth perception. That is, objects that appear to be further away from the organism in question would typically be located within the upper visual field as opposed to the lower visual field where the objects are within arm's reach. The increase in visual information, obtained by standing upright as opposed to being on all four limbs, allowed the visual system to develop, particularly in resolution (e.g., Polyak, 1957), cone pigmentation (e.g., Snodderly, 1979), and a saccadic system that was not dependent on head movements (e.g., Andersen, Snyder, Bradley & Xing, 1997). This allowed for a more efficient method of searching and investigating far visual space (Previc, 1990). Thus, Previc (1990) argued that the lower visual field employs global processing and is engaged in activities that occur in one's peri personal space, i.e., the near visual environment that is within reaching distance. Therefore, Previc proposed that peri personal space has a downward bias due to the biomechanic placement of the upper limbs within the lower visual field. By contrast, the upper visual field uses local processing for recognition and visual search within one's extra personal space, i.e., the far visual environment. Extra personal space is primarily concerned with the position of the body within the environment. The processing of this region of space is utilised in navigation and orientation of the self within the distant environment.

Behavioural findings in relation to visual fields has also demonstrated that visually guided pointing tasks elicit faster RTs and more accurate arm movements when completed in the lower compared to the upper visual field (Danckert & Goodale, 2001). In addition, arm movements made within the lower visual field are consistently more accurate than those made within the upper visual field (Khan & Lawrence, 2005). These findings are congruous with Sanders and Walsh's (2007) proposal that near visual space (or the lower visual field) is related to the control of distal (hand) muscles. Unlike visual space, the corresponding upper and lower visual fields have not been investigated in regard to processing or attentional differences between men and women. What have been investigated are differences between the right and left visual fields. Rossell, Bullmore, Williams and David (2002) investigated sex differences during a lexical visual field task. Using functional magnetic resonance imaging (fMRI), they identified a male advantage towards the right visual field with more left-brain activation, and a female advantage towards the left visual field, with greater right brain activation. That is, their results indicated that men and women differentially employ neural activation methods for language processing.

1.6.3 Sex differences in Inhibition

As mentioned above, hunting and gathering are tasks that require a number of specific cognitive skills. In regard to gathering, one particular cognitive process/mechanism has been suggested as a facilitator for this role. Klein (1988) put forward Posner and Cohen's (1984) basic inhibition of return (IOR) paradigm as a mechanism that encourages efficient foraging behaviour i.e., efficient visual search (e.g., Taylor & Klein, 1998; Klein, 2000; Wang & Klein, 2010). Klein argued that efficient searching of a visual environment requires a system that informs the forager that an area has just been attended to. Thus, Klein's proposal submits IOR as the mechanism that achieves this efficiency because IOR is argued to place an attentional tag onto an area or item that has recently been attended to, and as a result does not require further action (e.g., Abrams & Dobkin, 1994a; Klein, 2000; Chica, Taylor, Lupiáñez & Klein, 2010).

Posner and Cohen's classic paradigm (Posner & Cohen, 1984) employs a spatial cuing design, whereby attention is captured by a cue in one of two peripheral boxes and is followed by the appearance of the target presented at either the ‘cued’ or ‘uncued’ location. The typical measure for this paradigm is RT from the onset of the target. Posner and Cohen included a variable time delay between the cue and the onset of the target (i.e., stimulus onset asynchrony (SOA)). For short SOAs (i.e., < 300 ms), targets appearing at a cued location elicit shorter RTs than those at an uncued location. Conversely, at longer SOAs (i.e., > ~ 300 ms), RTs are prolonged for cued location as opposed to uncued locations. This response delay represents IOR. Specifically, it reflects a bias toward responding to new locations, as opposed to old locations. Therefore, Klein argues that this mechanism evolved to prevent the gatherer from returning to a location that has just been examined. As noted, natural selection posits that an advantageous trait is more likely to be passed onto the next generation if it positively impacts survival and reproductive success. Thus, this argument is in line with Silverman and Eals' (1992) hunter gatherer hypothesis. The spatial sex differences identified by

Silverman and Eals indicate that there are different attentional biases for men and women. The object memory and object location memory advantages displayed by women suggest a bias towards object–based attention, whereas superior mental rotation and long-distance navigation skills demonstrated by men indicate a bias towards location–based attention. Brown (2013) utlises this argument and proposes that a location–based IOR paradigm may result in men eliciting *less* IOR. That is, if men have greater orientation biases towards location–based attention, then responding to a previously attended location would not result in delayed responses. Brown controlled for the distinct attentional biases by employing stimuli that would specifically activate the neural correlates associated with object- and location–based attention. Stimuli designed to activate the processes related to object–based attention are high in spatial frequency, i.e., they activate the P-pathway. Whereas stimuli designed to activate processes corresponding to location–based attention are low in spatial frequency, i.e., they activate the M–pathway[1].

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[1] The M-pathway, i.e., the main input into the dorsal stream is argued by Brown (2013) to be biased towards men, but towards women by Sanders et al., (2007), whereas Abramov et al., (2012) argue that men demonstrate greater sensitivity to high spatio-temporal frequency stimuli that activates the P-pathway, and thus provides input to the ventral stream. This provides an example of the contradiction within the literature. Neither pathway is fully independent of the other, nor are they fully dependent either. With respect to the topic at hand, researchers seem to have ascribed a bias of one pathway to a particular sex based on performance in particular behavioural paradigms. Whilst this thesis will not

Previous work by Brown and Guenther (2012) found that locations containing high spatial frequency information (e.g., information regarding colour, shape and texture) are inhibited to a greater degree than those containing information consisting of low spatial frequency. Therefore, Brown predicted that M–pathway activating stimuli would elicit lower IOR effects as opposed to stimuli that activates the P–pathway. This reduction in IOR should then be more evident in men than in women, and indeed, this is what they found. Female participants elicited greater IOR in comparison to males across both stimulus types, and this effect was more pronounced for stimuli that activated the P–pathway.

Brown (2013) argues that these findings provide a new interpretation to James and Kimura's (1997) replication of Silverman and Eals' (1992) object location memory task. As mentioned previously, James and Kimura manipulated where items to be moved would be placed for the memory task, i.e., items would swap positions (the location–exchange condition), or the items would move to a previously unoccupied space (the location – shift condition). James and Kimura's findings matched Silverman and Eals' for the location–exchange condition, however they did not replicate the finding for the location–shift condition. This led the authors to suggest that the female advantage is a weak effect. Brown's interpretation is that the location–shift condition activated the bias towards location–based attention in men, due to the spatial 'relatedness' between each item in the array changing, resulting in their increased performance.

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explore biases for these pathways in depth, the contradictions are noted and will be kept distinct between chapters and experiments.

As previously stated, IOR refers to a slowed response to a previously attended location, and it is therefore argued that this mechanism encourages reorientation towards novel locations (Posner & Cohen, 1984; Tassinari, Aglioti, Chelazzi, Peru & Berlucchi, 1994; Taylor & Klein, 1998; 2000; Klein, 2000; Wang & Klein, 2010). Klein (1988) proposed that this mechanism evolved to enhance foraging efficiency by encouraging the forager to investigate new locations as opposed to investigating old (or just attended to) locations. However, evidence from modern day hunter gatherer societies, and from social animals, suggests that foraging for food is not completed individually but within a group (Lee & DeVore, 1968; Hawkes et al., 1997; Panter-Brick, 2002). Therefore, if gathering evolved as a group activity, then the principles and effects underlining the foraging proposal should also apply to areas searched by a fellow forager or task partner. That is, as it would be inefficient for an individual to search a previously examined area, it would be equally inefficient to search an area that colleagues have just searched themselves. Humans are of course social animals (Dunbar & Shultz, 2007), but experimental paradigms that have been employed to assess the evolutionary implications of IOR typically have participants completing tasks in isolation. Thus, Welsh, Elliot, Anson, Dhillon Weeks, Lyons and Chua, (2005) addressed this issue by presenting the IOR paradigm to two jointly acting participants simultaneously. Participants sat opposite each other and performed rapid aiming movements to a two-target alternation sequence (co-actor A responded to the first two targets and co-actor B to the following two, i.e., AA, BB, AA, etc). This two-target alternation sequence allowed the authors to measure the effect of co-actor A's first response upon their second response (i.e., within participant IOR) and the effect of their second response on co-actor B's first response (i.e., between participant IOR). As expected, the participants were slower to respond to a location they had just responded to, however, crucially, they were also slow to respond to a location their co-actor had just responded to. This supports the notion that observing an action activates the corresponding neural networks within the observer (Rizzolatti & Craighero, 2004), resulting in socially induced IOR (coined *social* IOR by Skarratt et al., 2010).

As mentioned, foraging is an activity that is reported to be carried out within groups (Hawkes et al., 1997; Panter-brick, 2002), and one that requires the individuals to be able to efficiently search their environment for specific items. It is also a social role that is argued to have been achieved by females (Silverman & Eals, 1992; Silverman et al., 2000; Cashdan et al., 2012). However, Stöet (2010) showed that women were more affected by distractors than men and were slower to search a visual scene compared to men (Stöet, 2011). If searching the environment is completed by a systematic inspection, then perhaps Stöet's findings support the notion that the male attentional system disengages faster than females, i.e., Brown (2013).

1.7 Thesis outline

Despite the abundant research that followed on from Silverman and Eals' (1992) paper, it is only recently that the influence the division of social roles may have had on cognition has been examined. This thesis aimed to explore the hunter gatherer hypothesis using cognitive paradigms.

Chapter 2 examined whether men and women attend to stimuli presented in particular visual fields and space differently. It was suggested that the social roles outlined by the hunter gatherer hypothesis necessitated in ancestral hunters and gatherers developing sex-based biases towards different visual fields and space (Sanders & Walsh, 2007; Sanders et al, 2007). Thus, Experiment 1 examined whether the generalised upper visual field bias is more pronounced in men than in women, using a change blindness task. Experiment 2 examined the same question, whilst using a visual search task. Experiment 3 physically manipulated the participant's visual space in relation to the stimuli presented whilst utilising the flanker task (Eriksen & Eriksen, 1974). Here, it was expected that the processing of flankers should be more pronounced in women in near visual space, compared to men.

Chapter 3 investigated whether men and women differed in their perceptual abilities, with respect to motion, susceptibility to a visual illusion and depth processing. It was proposed that hunters evolved biases towards motion tracking and would demonstrate a visuo spatial advantage in an illusion comprised of spatial components. In addition, this chapter suggested that gathering is particularly reliant on depth perception and women's performance, therefore, would be negatively affected under monocular viewing. Thus, in Chapter 3, Experiment 4 examined male sensitivity to fine motion, whilst also manipulating the proximity of the stimuli. Again, it was expected that the male bias towards far visual space would result in men outperforming women in this task (Abramov, et al, 2012; Sanders & Walsh, 2007; Sanders et al, 2007). Experiment 5 made use of the Poggendorff illusion and aimed to establish whether the male advantage would still be present under a visual space manipulation (Ling et al., 2006; Knudson, Woodland & Wilson, 2012). Experiment 6 manipulated stereoscopic viewing whilst the participant's completed a classic children's game, the 'buzz wire' task.

Chapter 4 investigated if inhibition abilities as proposed by parental investment theory (Trivers, 1972) differ between men and women in cognitive based tasks. The first half of the chapter reanalysed Experiments 1, 2 and 3 from Chapter 2, to assess differences in motor inhibition. Experiment 7 aimed to replicate an existing finding, whereby women demonstrated significant levels of inhibition (Brown, 2013) and therefore employed a standard inhibition of return paradigm (IOR; Brown & Guenther, 2012; Brown, 2013). Experiments 8 assessed inhibition of return within a social setting (i.e., social IOR) to establish whether inhibition effects are enhanced when the co-actors are both female, versus both male and mixed sex (e.g., Hawkes et al., 1997; Panter-brick, 2002).

Chapter 2

"Oh, Edmund... can it be true?

That I hold here, in my mortal hand, a nugget of purest

Green?"

Lord Percy Percy,

Black-adder II: Money, 1986

2.0 Attention and the hunter gatherer hypothesis

The primary goal of the first empirical chapter was to investigate the hunter gatherer hypothesis by examining whether there are any behavioural sex differences in attention to upper/lower visual fields and in near/far visual space. Upper and lower visual field biases have been reported in numerous studies (Dankert & Goodale, 2001; Previc & Naegele, 2001; Khan & Lawrence, 2005) and, as discussed below, Previc (1990) argued that the upper field is functionally synonymous with far visual space and the lower field with near visual space.

As mentioned in Chapter 1, any differences between men and women in regard to visual space processing have only been assessed in recent years. For example, works by Sanders and colleagues posited that men have an advantage over women when processing visual information in far visual space due to their supposed hunting past (2007; Sanders & Walsh, 2007; Sanders & Perez, 2007; Sanders, Madden & Thorphe, 2008; Stancy & Turner, 2010; Sanders, 2013). The basic rationale and interpretation of their findings is that ancestral men as hunters would have been required to be successful at processing information from their extra personal space (far visual space). This would be needed in order to efficiently and effectively identify, locate, and track prey animals, and anticipate the trajectory of a missile against a moving target. By contrast, ancestral women as gatherers would have needed greater expertise in processing visual information from their peri personal space (near visual space) in order to physically interact with their immediate environment and identify necessary items.

Unlike near and far visual space, upper and lower visual field biases have not, as far as this author can determine, been assessed in regard to sex differences. Previc (1990) argued that the evolved upright stance of hominoid ancestors encouraged a lower field processing bias for stimuli within the peri personal (near visual space) environment due to the placement of the upper limbs. Specifically, Previc suggested that both the lower and near visual space are functionally associated with ocular and upper limb movements, i.e., online tracking and monitoring the movement of the hand or object as it interacts with the near environment or as it is brought closer to the body. Visuomotor movements performed in the lower visual field are more controlled and spatially accurate in comparison to those performed in the upper visual field (i.e., Dankert & Goodale, 2001; Khan & Lawrence, 2005). Conversely, more extensive and faster visual search is completed in the upper visual field, compared to the lower (Chedru, Leblanc & Lhermite, 1973), and briefly presented displays in the upper field elicit shorter RTs in contrast to the lower visual field (Chaiken, Corbin & Volkman, 1962).

Previc (1990) argued that the influence of the upright stance on the upper visual field follows similar reasoning, in that visual information increases in relation to the eye height of the individual (Leyrer, Linkenauger, Bülthoff, Kloss & Mohler, 2011). Thus, the total area of the visual environment that can be processed increases. Visual information that occurs in the distance, i.e., towards the horizon (far visual space), and is therefore in the upper field, is generally perceived to be smaller and further away than information presented in the lower and near visual space.

However, evidence to support Previc's (1990) notion that upper and lower visual fields are functionally equivalent to far and near visual space respectively, is limited. The majority of the research implies that the equivalency is present due to the asymmetrical activation of the cortical pathways. That is, the ventral and dorsal streams are proposed to be important for the perception of objects and for visually guided action respectively (Goodale & Milner, 1992). These asymmetrical activations are reported to maps onto the upper and lower visual fields. Indeed, behavioural studies have identified that visually guided actions are magnified in the lower visual field (e.g., Dankert & Goodale, 2001; Khan & Lawrence, 2005), and tasks that require focused attention should demonstrate greater degree detection or performance in the lower visual field (He, Cavanagh & Intriligator, 1996). Furthermore, an fMRI study identified greater neural activation within the brain regions that are associated with reaching movements, when the participants grasped objects presented in their lower visual field as opposed to their upper visual field (Rossit, McAdam, Mclean, Goodale & Culham, 2013). The authors argued that their findings corroborated with existing research that suggests an over-representation and advantage for the lower visual field in visuomotor areas. This cortical difference between the visual fields suggests a connection with the cortical regions for visual space. Using PET, Weiss et al., (2000) established that the ventral stream was activated when stimuli were presented in the far visual space, and dorsal stream was activated for near visual space. Thus, the suggestion of functional equivalence between upper and lower visual fields and far and near visual space may require some clarification, however this will not be addressed in this thesis.

From an evolutionary standpoint, Previc (1990) suggested that there are distinct visual processing advantages for both upper and lower visual fields and therefore both near and far visual space locations. When reviewed in combination with Sanders et al.,'s (2007) interpretation of near and far visual space in relation to the hunter gatherer hypothesis, the implication suggests that the male and female advantages Sanders et al. found with regards to far and near visual space, respectively, will map onto the corresponding visual fields. For example, as mentioned in Chapter 1, visual search abilities are more efficient in the upper field (Previc & Naegele, 2001); confirming the expectation would be that men as hunters would have superior visual search skills for information presented in far visual space. Furthermore, if the lower visual field and near visual space are functionally equivalent, then it would be expected that women as gatherers would have greater visual abilities in the lower visual field.

In the present chapter, Experiments 1 and 2 examine whether there is a sex difference in upper and lower visual fields when employing a change detection and visual search task respectively. These two experiments thus follow Previc's (1990) notion that visual space and fields are functionally linked. Thus, in Experiments 1 and 2, far visual space will be assumed to be associated with the upper field, and near visual space with the lower visual field. Experiment 3 examined sex differences in near and far visual space more directly. Here, participant's visual space with respect to the stimuli is physically manipulated with the inducing stimuli being either close to the participant (50cm) or placed at a distance of 500 cm.

2.1 A note on liberal and conservative hypotheses

It is not entirely evident how strict the present hypotheses should be with regards to what the hunter gatherer theory precisely predicts. A strict hypothesis would predict that women should be slower (and or less accurate) than men in the upper visual field and far visual space conditions *as well as* being faster and more accurate in the lower visual field and near visual space conditions, with the opposite pattern occurring for men. That is, a classic cross over interaction, where the interaction is significant, but the main effects are not. With respect to theory, women would perform better in one situation than another, and vice versa for men. However, a more liberal hypothesis predicts that there would be differences in performance between men and women for upper and lower visual field *only* (or near and far visual space). That is, a sex difference in one condition but no differences in another.

Furthermore, Sanders (2013) makes specific distinctions on predictions regarding sex differences of motor control and visual processing of stimuli in near and far visual space. Sanders argues that sex differences that are consistent with the predictions of evolutionary selection of hunting and gathering related skills for men and women, are *within* sex differences, i.e., the classic cross-over interaction, women perform better in near visual space than far, and vice versa for men. Sanders classified this as a 'reciprocal' sex differences, where this occurs in "... a sex neutral task performed under two different conditions" (Sanders, 2013, p. 358), i.e., a manipulation of near and far visual space. The sex neutral task therefore, would be one that does not elicit a sex difference without an additional manipulation, unlike, for example, object location memory tasks (e.g., Silverman & Eals, 1992; Postma et al., 1998) and mental rotation tasks (e.g., Collins & Kimura, 1997); tasks that favour females and males respectively, and that Sanders would define as a 'traditional' sex difference.

2.2 Experiment 1

Change Blindness is the phenomenon in which a change to the visual environment goes unnoticed by the observer. This can be a failure to detect a change that occurs in the physical structure of an object, its spatial location, and/or whether a new object appears, or one disappears (Simons & Levin 1998). There are two related paradigms that have been employed to index this phenomenon. In the 'continual alternation' paradigm (Rensink, O'Regan & Clark, 1997), participants are shown a stimulus, followed by a mask, and then a second stimulus that may or may not have changed. The two stimulus displays alternate until the participant indicates whether a change has occurred; therefore, the primary measure is reaction time. By contrast, in the 'one shot' paradigm participants are shown the two stimulus displays once only before they are required to respond; thus, the measure here is typically accuracy (Simons, 1996), although response time can also be taken. Both of these paradigms instruct the participant's to sometimes expect a change within the display; yet failures to detect changes still occur (Simons, 2000; Simons & Rensink, 2005; Cole & Liversedge, 2006; Jensen, Yao, Street & Simons, 2011).

This phenomenon has also been demonstrated in real world interactions. For example, Simons and Levin (1998) staged a scenario where an experimenter approached a participant with a map asking for directions. After the participant had been talking to the experimenter for approximately 10-15 seconds, two confederates carrying a door walked between them, obscuring the participant's view of the experimenter. As this occurred, one of the confederates holding the door, swapped places with the initial experimenter. Only half of the participants noticed that the person they were talking to changed.

Experiment 1 will employ a change detection one shot paradigm where the target change could occur in the upper or lower segment of the visual display. Whilst previous work has shown an upper visual field advantage (e.g., Chaiken et al., 1962; Chedru et al., 1973; Previc & Naegele, 2001), no research has been carried out to identify if there is a sex difference in the ability to detect a change.

Given the upper visual field effect described above, it was expected that accuracy in change detection would be greater in the upper field than in the lower. With respect to the present central rationale (i.e., the hunter gatherer theory; Sanders et al., 2007; Sanders, 2013), it also follows that the upper visual field bias would be more pronounced in men, (due to hunting related abilities) than in women.

2.2.1 Method

2.2.1.1 Participants:

Fifty-five participants (22 males), from two educational institutes in Essex, were employed in this study.

2.2.1.2 Stimuli and apparatus:

The letters were presented in the four quadrants of the display and a black fixation-cross indicated the centre. Eight letters of the English alphabet were employed; A, C, E, F, H, P, S, and U. The changes were randomised. These ranged from a single feature subtraction or addition, i.e., 'E' to 'F' or vice versa, and double feature alteration, i.e., 'U' to 'H'. The letters were black against a grey background. The experiment was carried out on an iMac with a 2560x1440 resolution.

2.2.1.3 Design and procedure:

A 2x2 mixed design was employed, with sex as the between participant variable and visual field (upper/lower) as the within participant variable. Each participant was presented with a demonstration of the trial. This illustrated the progression of the task and the correct responses required. The change occurred in one of the four quadrants, of not at all. Each trial began with a 500ms presentation of the first letter array, followed by a 250ms blank, then the reappearance of a letter array (see Figures 2.1 - 2.3). Participants were required to indicate whether they detected a change, or not, in one of the letters. They pressed a left-hand button (on a standard keyboard) if they detected a change, and a right-hand button if no change occurred or they were unsure. Participants were tested individually and were seated approximately 50cm from the display. There were 20 upper change trials, 20 lower change, and 40 no-change trials.

Fig 2.1 A change occurring in the upper segment of the visual display.

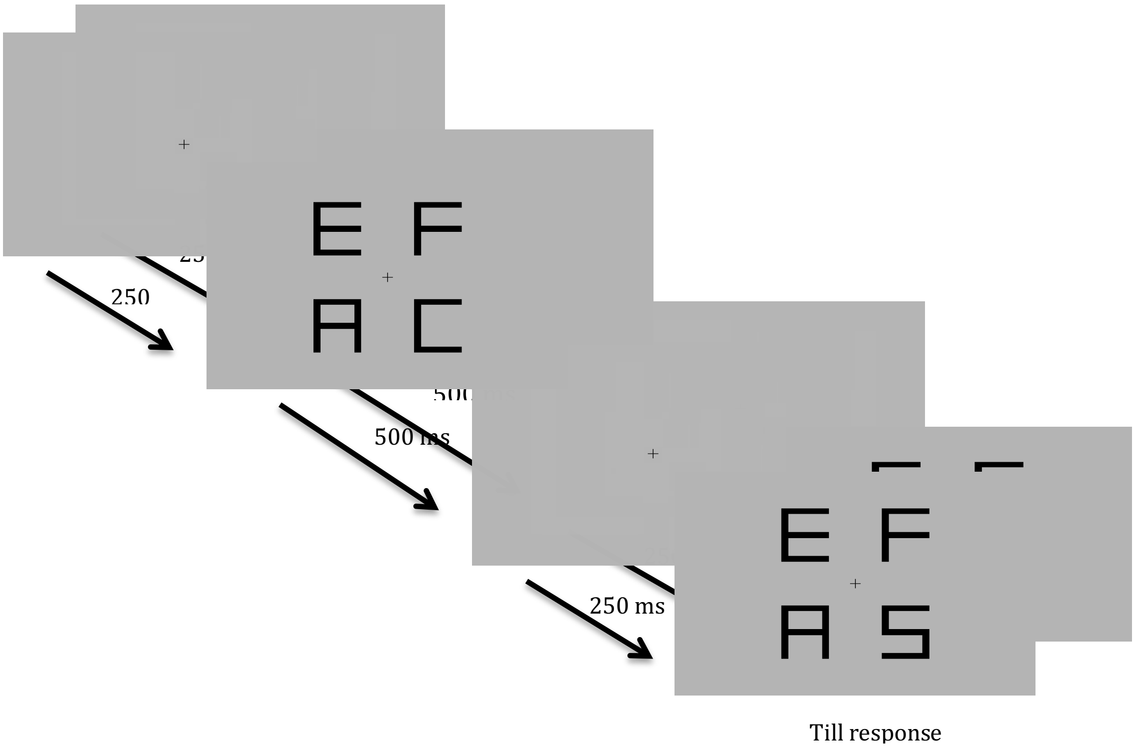
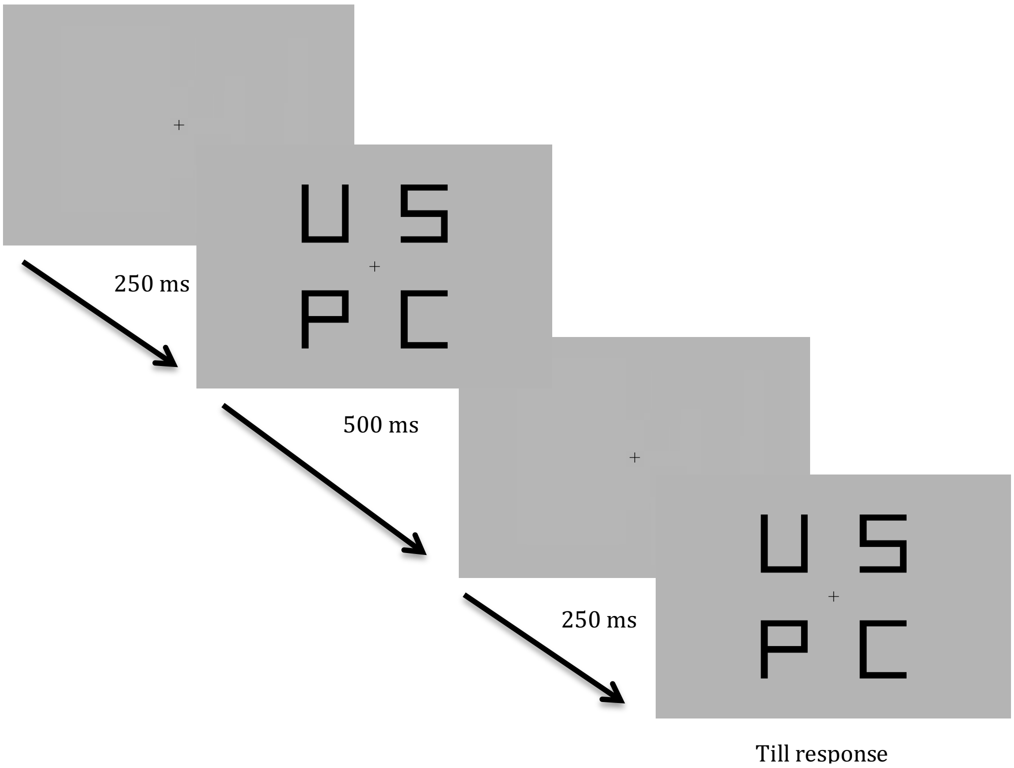


Fig 2.2 A change occurring in the lower segment of the visual display.

Fig 2.3 The control condition, no change occurred throughout the whole display.



2.2.2 Results and discussion

Accuracy rates are presented in Figure 2.4. A 2x2 mixed analysis of variance revealed a non- significant main effect of sex, ($F(1,55) = 0.11$, $p = 0.75$, $\eta_p{}^2 = 0.002$) but a significant main effect of visual field, ($F(1,55) = 22.14$, $p < 0.001$, $\eta_p{}^2 = 0.29$). The interaction was not significant; ($F(1,55) = 1.1$, $p = 0.31$, $\eta_p{}^2 = 0.02$). An additional 2x2 mixed analysis of variance was carried out for RTs (see Figure 2.5). A non- significant main effect of sex, ($F(1,55) = 011$, $p = 0.74$, $\eta_p{}^2 = 0.002$) but a significant main effect of visual field, ($F(1,55) = 16.41$, $p < .01$, $\eta_p{}^2 = 0.23$) was found. The interaction was also not significant; $F(1,55) = 0.27$, $p = 0.60$, $\eta_p{}^2 = 0.005$. These results support previous research showing an upper visual field advantage, (e.g., Chaiken et al., 1962; Chedru et al., 1973; Previc & Naegele, 2001). However, it was predicted that men would demonstrate a more pronounced upper visual field bias (e.g., Previc, 1990), due to their hunting past. However, this prediction was not met, either by accuracy detection or RT, and therefore this experiment did not support the theoretical assumptions relating to the hunter gatherer hypothesis, as proposed by Sanders et al., (2007). In Experiment 2, a further attempt is made to reveal sex differences, if any exists, in upper and lower visual field processing using a visual search task.

Lastly, it is worth noting that employing a sensitivity index could have been an alternative method of analysis. For example, d'Prime analysis can be calculated by measuring the difference between noise and signal using units of standard deviations (Stanislaw & Todorov, 1999). In other words, it provides a score based on mean ‘hit’ rate in relation to mean ‘miss’ rate. This method is mostly utlised in signal detection theory paradigms, where the target is present in one condition or absent in the other (e.g., Dickman & Meyer, 1988; Tsoi et al., 2008). It was not however used for the present analysis because there were two target-present conditions (i.e., in the upper and lower visual fields). In other words, a relatively high false positive rate by an individual participant could not account for any *differences* that they also might have generated in the upper/lower visual field conditions.

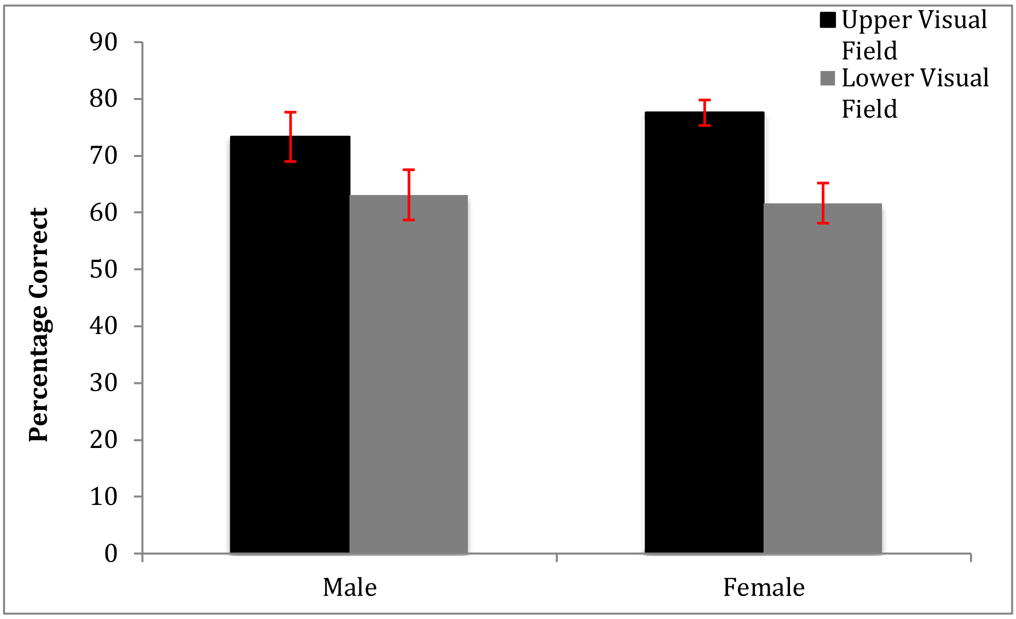


Fig 2.4 Accuracy for change detections across upper and lower visual fields as a function of sex. Error bars represent standard errors of the mean.

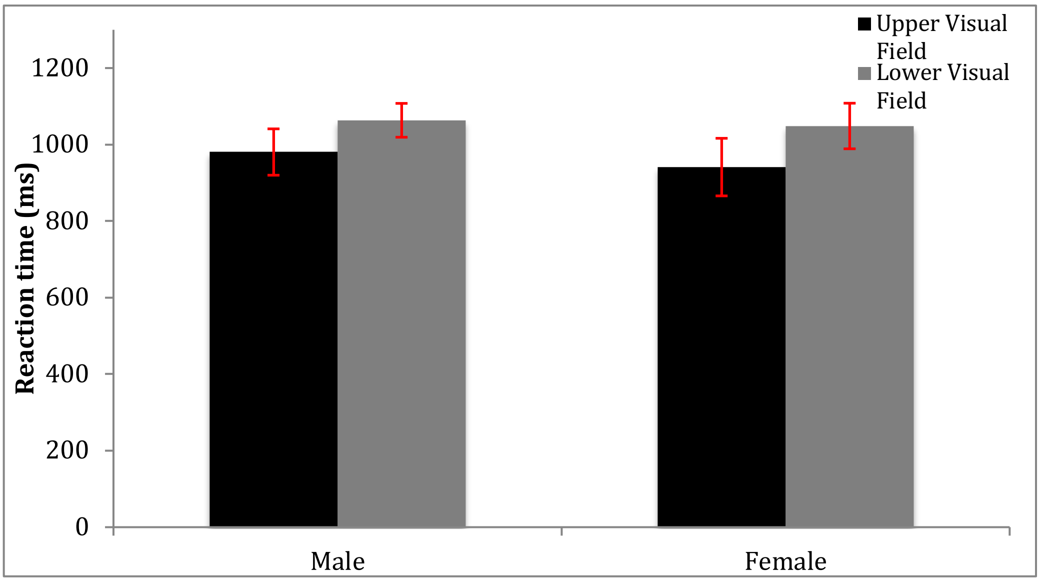


Fig 2.5 Mean RT for change detections across upper and lower visual fields as a function of sex. Error bars represent standard errors of the mean.

2.3 Experiment 2

Experiment 2 employed the same theoretical rationale as Experiment 1 concerning the upper and lower visual fields and the hunter gatherer theory. Here, the theory was examined using a standard visual search paradigm. Searching our visual environment is a task carried out whenever we look for something. This occurs whenever we, for instance, look for a bunch of keys, a phone, a car in a parking lot, and a friend or family member in a crowd. The success of a search is partly dependent on the properties of the visual display and the top-down set employed by the observer. The typical paradigm presents a target among distractors, in which the participant is required to respond as soon as the target has been detected and/or discriminated. Treisman and Gelade's (1980) Feature Integration Theory proposes that the distinction between the target and the distractors may lie in one feature (associated with an 'efficient search'), such as colour (Treisman & Gormican, 1988), shape and depth (Nakayama & Silverman, 1986; Godwin et al., 2016), orientation (Inverso, Sun, Chubb, Wright & Sperling, 2016), size and motion (Abrams & Christ, 2003), or a combination of two or more (associated with 'serial' or non-efficient search). For example, if the saliency of the target were such that it 'pops out' of the display, this would constitute an efficient search, (e.g., a red target among green distractors; Nagy & Sanchez, 1990). Visual search experiments typically manipulate the number of items in the search display enabling a 'visual search index' to be generated. This is the difference in mean RT across the different display sizes divided by the difference in display size number (Moore, Egeth, Berglan & Luck, 1996; Wolfe, 1998).

Whilst there are many papers investigating the mechanisms of visual search, only one has investigated the effect of sex (Stöet, 2011). In two of three experiments, Stöet (2011) identified that men outperformed women when searching for a single target (Experiment 1) and multiple targets (Experiment 2). Consequently, it could be argued that this represents a traditional, i.e., well established male advantage (Sanders, 2013). However, the present experiment will examine this finding under the context of evolutionary predictions (Silverman & Eals, 1992; Sanders et al., 2007), in that the upper visual field bias (e.g., Chaiken et al., 1962; Chedru et al., 1973) would be more pronounced in men as hunters than women as gatherers.

2.3.1 Method

2.3.1.1 Participants:

There were 70 participants (34 males); they had not participated in the previous study. They were recruited from the University of Essex for course credits.

2.3.1.2 Stimuli and apparatus:

The target was either the letter H or S. The distractor letters were A, C, E, F, P and U. The target was placed either above or below the horizontal meridian line of the display. The number of distractor letters present was either 2 or 6. Thus display sizes were 3 and 7 (see Figures 2.6-7).

2.3.1.3 Design and procedure:

A 2x2 mixed design was employed, with sex (male, female) as the between subject variable and visual field (upper, lower) as the within subject variable. Each participant was informed that their task was to search for the target letter as fast as they could whilst keeping errors to a minimum. Participants pressed a left hand button for S and a right hand button for H. The targets were either presented above the horizontal meridian, i.e., the upper visual field, or below the horizontal meridian, i.e., the lower visual field. The distractor letters were randomly placed and equally distributed in the display. A reorientation of the participant's gaze was enforced by presenting a fixation cross in the centre of the display between each trial. The next trial commenced after the participant had made their response. The participants were presented with a total of 108 trials equally divided amongst the four trial types (i.e., upper and lower visual field, S and H target).

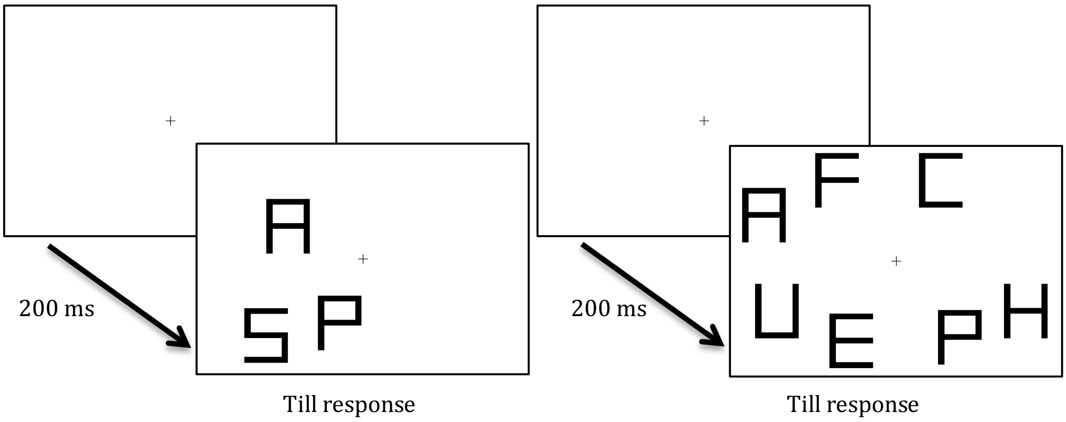


Fig 2.6 Set size 3 and set size 7, where the target (S or H) is present in the lower segment of the display.

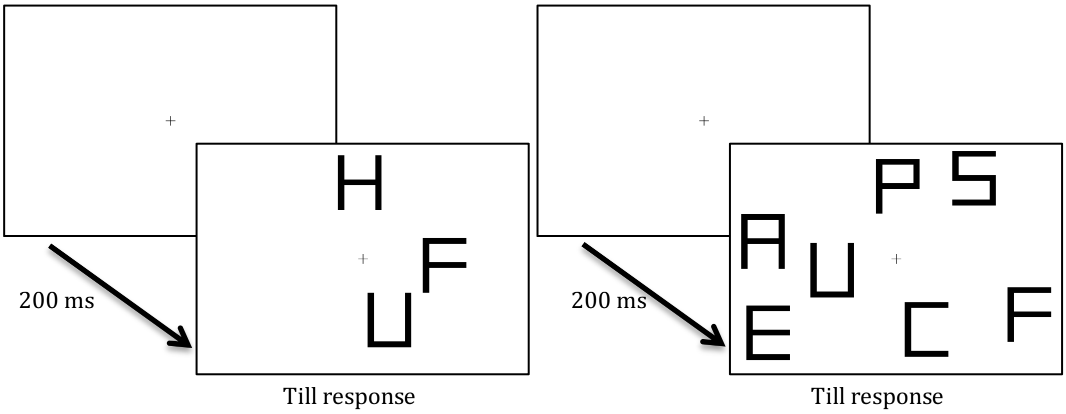


Fig 2.7 Set size 3 and set size 7, where the target (S or H) is present in the upper segment of the display.

2.3.2 Results and discussion

After collation, one participant's (male) data was deemed to be an outlier (mean RT > 5s), and was removed from further analysis. A mean search efficiency index was computed for each participant by collapsing across the set sizes of three and seven to take averages of the upper segment and the lower segment respectively. This provided a mean RT visual search index score for each visual field, and is shown in Figure 2.8. A 2x2 mixed analysis of variance revealed no significant main effect of sex; $F(1,67) = 1.37$, $p = 0.25$, $\eta_p^2 = 0.02$, a significant main effect of visual field, $F(1,67) = 23.2$, $p < 0.001$, $\eta_p^2 = 0.26$, and no significant interaction, $F(1,67) = 0.12$, $p > 0.05$, $\eta_p^2 = 0.02$.

As in Experiment 1, the data show a large upper visual field advantage (Chaiken et al., 1962; Chedru et al., 1973; Previc & Naegele, 2001). However, importantly, no significant sex difference was found and no interaction between sex and visual field. This again, fails to support existing findings relating to the hunter gatherer theory (Sanders et al, 2007; Stöet, 2011). In Experiment 3, a more direct assessment of possible sex differences in near and far visual space was employed.

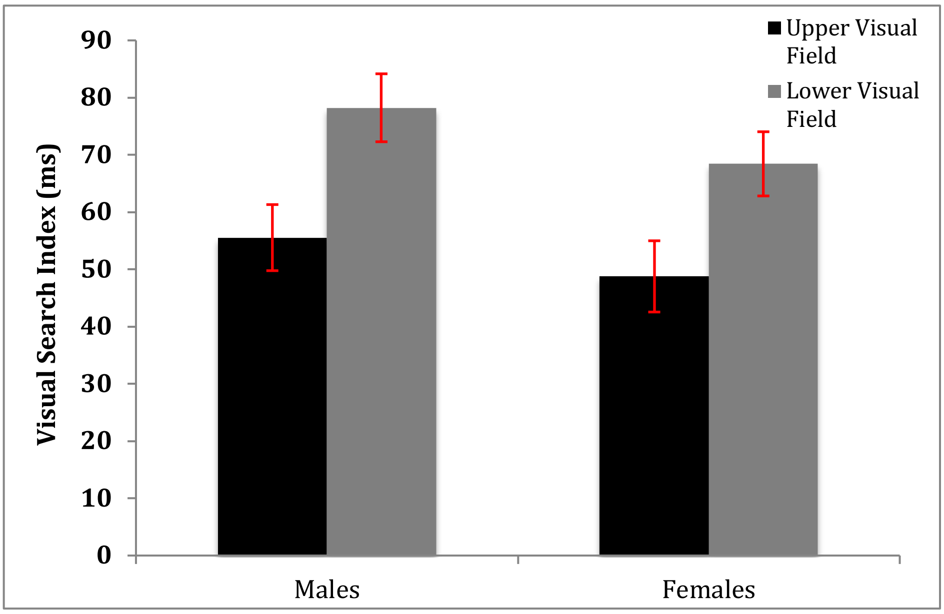


Fig 2.8 The visual search index for targets presented in the upper and lower visual fields as a function of sex. Error bars represent standard errors of the mean.

2.4 Experiment 3

One can argue that in Experiments 1 and 2 near and far visual space was only indirectly manipulated. As mentioned, this was based on the rationale that upper and lower visual fields are functionally equivalent to near and far visual space (Previc, 1990). However recall that this assumption is far from certain. Much of the research focuses on assessing behavioural differences in visual fields only (e.g., Brown, Halpert & Goodale, 2005), or in combination with cortical asymmetries (e.g., Lee, Kaneoke, Kakigi & Sakai, 2009; Rossit et al., 2013), but not in conjunction with visual space. Therefore, the current experiment directly manipulates visual space. That is, the target stimuli were placed either 50 cm from the participant or 500 cm.

Eriksen and Eriksen (1974) designed a task that examined the effect of distractors upon identifying a target letter. Their initial aim was to assess the effect of distractors on identifying a target within a visual search paradigm. Participants were presented with a central target letter, with compatible, incompatible, similar or dissimilar letters that flanked the target letter on each side. They were tasked with identifying the central letter as rapidly as possible, by depressing the appropriate key. The results indicated that noise letters (flankers) that were incompatible with the target letter elicited the greatest impairment in RTs. This showed that they were processed at some level. This interference measure has resulted in the flanker task being used as a paradigm in multiple disciplines; for instance, in the investigation of executive control (Kopp, Rist & Mattler, 1996); positive and negative priming (Botella, Barriopedro, Joula, 2002); inhibition of motor response (Verbruggen, Liefooghe & Vandierendonck, 2004), and sex differences in selective attention (Bayliss, di Pellegrino & Tipper, 2005).

Bayliss et al., (2005) provided data that women are more distracted by irrelevant stimuli. These results were verified by Stöet (2010), who argued that women should be more 'open' to peripheral information due to their gathering past; an effect that would facilitate foraging. Stöet therefore predicted that females would show greater flanker interference on the classic flanker task (e.g., Eriksen & Eriksen, 1974). Results showed this to be the case. Whilst Stöet made predictions based upon evolved cognitive differences between men and women, evolutionary theory was not directly assessed. Therefore, the present experiment will examine the female flanker effect in near and far visual space, with the predicted effect being more pronounced in near visual space.

2.4.1 Method

2.4.1.1 Participants:

There were 76 participants (38 males); all were University of Essex Undergraduates who participated for course credits or monetary reimbursement.

2.4.1.2 Stimuli and apparatus:

A single target letter was presented in the middle of the display, flanked by two letters, one either side. The letters were black against a uniform white background. Luminance values of the letters and background were 0.1cd/m^2 and 67 cd/m^2 respectively. The target was either an 'S' or a 'H' and the two distractors either matched the target or did not. Both distractors were always the same as each other (see Figure 2.9 for an example of the incongruent and congruent display conditions).

Note that Stöet (2011) identified a difference between the sexes using a go/no-go task combined with a modified flanker task. Stöet concluded that irrelevant (incongruous) distractors negatively affected the female participant's performance, ascribing this to the flanker effect. Thus, the decision was made to forego the use of similar and or dissimilar stimuli in order to attempt to replicate Stöet's findings and to, at first, identify a difference in the effect between men and women, using a traditional flanker design. If the results do indicate an effect, then a follow up experiment would be carried out to further examine the underlying mechanisms driving the sex difference using the similar and dissimilar conditions.

When viewed from 50 cm, the stimuli measured 5.1° of visual angle in height and 3.8° in width. A black fixation cross (a plus sign) was located in the centre of the display that appeared at the beginning of each trial. The experiment was carried out in a well-lit room and was driven by an iMac comprising a CRT monitor.

2.4.1.3 Design and procedure:

A 2x2x2 mixed design was employed, where sex was the between participant factor and congruency of distractor and visual space as the within participant factors. A congruent trial was one in which the distractors matched the target, and an incongruent trial was when they did not match. Each trial began with the presentation of a fixation point for 1000 ms before the letters appeared. Participants were asked to indicate, as rapidly as possible, whether the central letter was an 'S' or a 'H' by pressing a left hand button (for 'S') or a right hand button (for 'H') on the keyboard. An emphasis was placed on speed whilst maintaining accuracy. The beginning of a trial was initiated by the participant's response on the previous trial. The participants were seated 50 cm away from the display in the near visual space condition and 500 cm from the display in the far visual space condition. A total of two hundred and fifty-six trials were presented equally divided between the different trial types and conditions. The two visual space conditions were blocked and their presentation order counterbalanced.

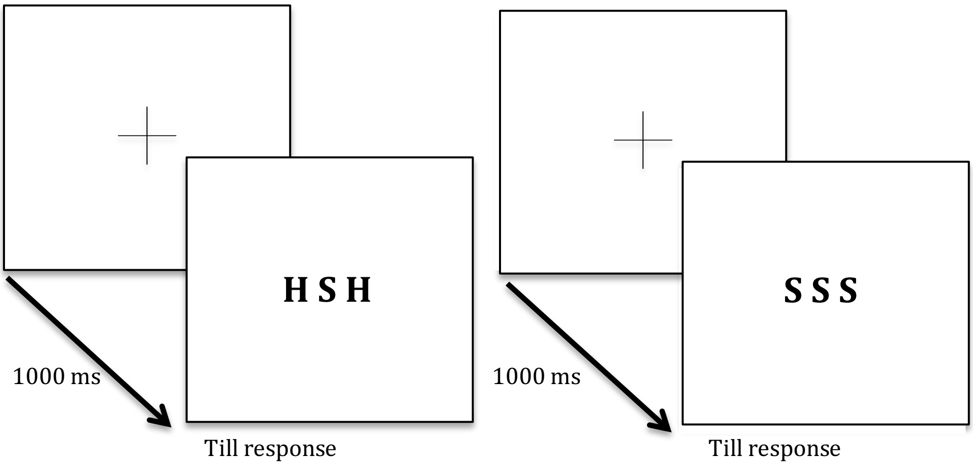


Fig 2.9 A representation of the incongruent (left) and congruent (right) conditions; where the distractors differed (left) or matched (right) the target.

2.4.1.3.1 An issue of control:

When conducting visual space experiments, a typical methodological control is to correct the visual angle of the stimuli in far visual space. Controlling for visual angle controls for retinal size, i.e., in this context, the size of the image on the retina would remain the same across both visual space conditions. This methodology seems to be prevalent in low level vision research, where visual angle could be a confounding factor. However, with respect to higher-level vision research, there seems to be very little by the way of explanations as to why this control is employed.

Multiple published works have included this restriction in their design, and have identified accuracy and reaction time differences between men and women (i.e., Longo & Lorenceo, 2006; Sanders et al., 2007; Sanders, Madden & Thorpe, 2008; Stancy & Turner, 2010; etc.) Majority of these papers (i.e., published work by Sanders and colleagues) interpret their findings, and or make predictions based upon evolutionary theory. Where they argue that men should have greater success when performing tasks in far visual space as opposed to women, and vice versa for near visual space. Whilst these predictions are sound, based upon the hunter gatherer hypothesis (Silverman & Eals, 1992), the use of the visual angle control becomes questionable. Homo Sapiens did not evolve with the ability to ensure that one's retinal size remained constant irrespective of the distance between them and their target. Rather, their visual abilities were adapted based upon their environment (Previc, 1990). Bipedalism increased the degree of visual information available to our ancestors, by the elevation the head and thus the eyes, allowing for an increased view of the visual plane. The retinal size is one of many components that influence the perception of depth, informing the viewer of their location with respect to their visual target. If this is controlled for, then an aspect of depth is controlled for, what then does this mean for the published results? If the visual angle and the retinal size of the images remain equivalent in far visual space as it is in near visual space, then the computation for the brain to compute distance or depth is not complete. This calls into question the significant findings within the literature, highlighting the suggestion that the effect was being driven by an underlying factor or mechanism. Moreover, can claims be made with respect to evolved cognitive mechanisms and perceptual abilities when the stimulus presentation does not represent an ecologically valid perspective?

Thus, for this thesis, an executive decision was made to not control for visual angle, but to keep the same retinal size for both visual space conditions. This was applied to Experiments 3, 4 and 5; all three experiments were carried out in the same room and under the same computer set up. Environmentally, despite not adjusting the visual angle of the stimuli employed, the basic set up of the room emphasised the sensation of distance. That is, the smaller size of the computer monitor, relative to items closer to the participant, serves as a location cue (i.e., Ittelson, 1951)

If a difference between the sexes were found under this methodology, then the experiment would be carried out again with additional controls that focused examining the underlying mechanisms.

2.4.2 Results and discussion

Two participant's (one female) data were omitted from the analysis due to an error rate of more than 20%. Means are shown in Figures 2.9-10. A mixed ANOVA with congruency, visual space and sex as factors found a significant main effect of congruency, $F(1,72) = 219.35$, $p < 0.001$, $\eta^2p = 0.75$; a significant main effect of visual space $F(1,72) = 39.04$., $p < 0.001$, $\eta^2p = 0.35$; but no significant effect of sex, $F(1,72) = 0.01$, $p = 0.92$. The interaction between congruency and sex was not significant $F(1,72) = 0.70$, $p = 0.41$, $\eta^2p = 0.01$; nor was the interaction between visual space and sex, $F(1,72) = 0.8$, $p = 0.78$, $\eta^2p = 0.01$; neither was the 3-way interaction, $F(1,72) = 2.3$, $p = 0.13$, $\eta^2p = 0.03$. The interaction between visual space and congruency was however significant, $F(1, 72) = 18.5$, $p < 0.001$, $\eta^2p = 0.21$.

In regards to accuracy, there was a significant main effect of congruency, $F(1,72) = 25.7$ $p<0.001$, $\eta^2p = 0.26$. None of the other main effects or interactions were significant, all F's < 2.14, p's > 0.14.

Overall, these data are consistent with the classic flanker effect; RTs were significantly slower when the flanking letters were one of the two possible targets (Eriksen & Eriksen, 1974). Importantly however, is the finding that this effect was no larger for females than males, an effect that was itself not influenced by visual space. Not only does this fail to support the predictions based on the hunter gatherer hypothesis, it also suggests that the female flanker effect Stöet (2010) reported may not have been due to flanker processing, as predicted by ancestral environments, *per se*, but due to some other unknown aspect of the stimuli and/or task Stöet employed. One other notable aspect of these data is the effect of visual space. RTs were compromised both in terms of its main effect and interaction with congruency. This is likely to be due to the flanking letters being more central (i.e., less peripheral) in the far visual space condition and thus exerting their effect to a greater degree.

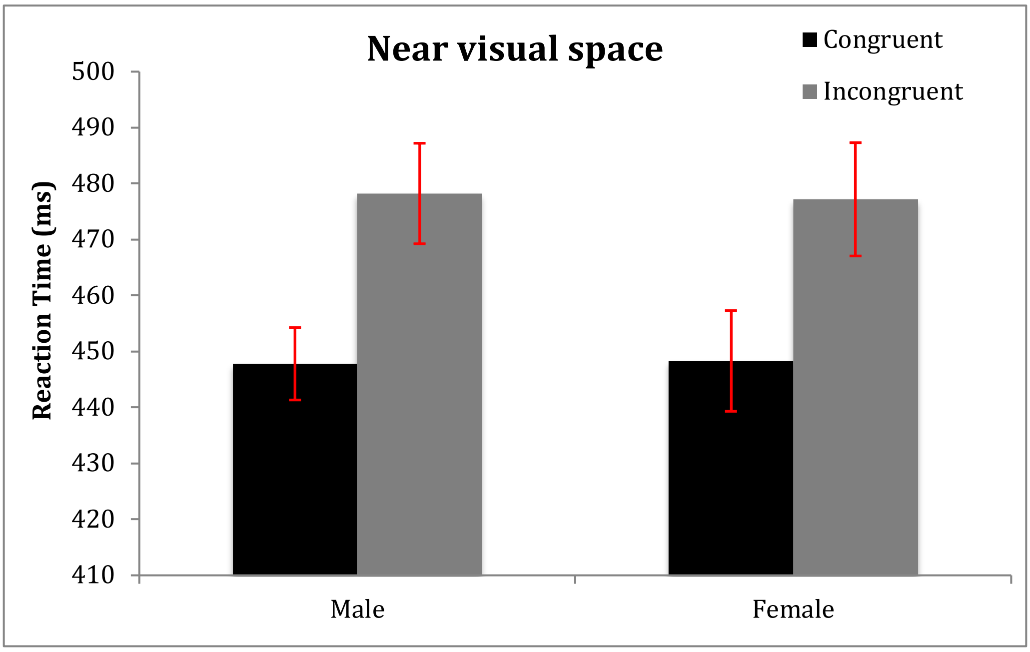


Figure 2.10 Mean RTs for congruency in near visual space for men and women. Error bars represent standard errors of the mean.

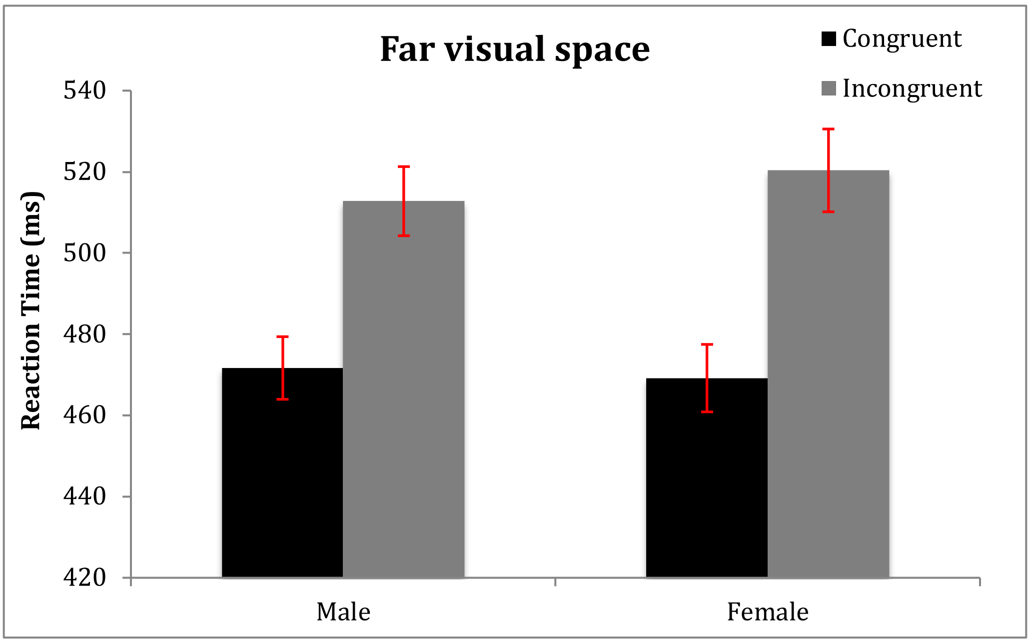


Figure 2.11 Mean RTs for congruency in far visual space for men and women. Error bars represent standard errors of the mean.

2.5 Discussion

Chapter 2 assessed the hunter gatherer hypothesis in relation to visual fields and visual space. Specifically, it argued that ancestral men as hunters would have evolved more efficient processing of stimuli occurring in far visual space compared to women. Furthermore, as gatherers, ancestral women would have evolved greater abilities in processing stimuli that occur in near visual space in comparison to men (Silverman & Eals, 1992; Eals & Silverman, 1994; Sanders & Walsh, 2007; Sanders et al., 2007; Sanders & Perez, 2007; Stancey & Turner, 2010; Stöet, 2010; 2011). Consequently, if these environmental circumstances and social roles were influenced by natural selection, one might expect these effects to be revealed in behavioural experiments.

The predictions made in regards to visual field were supported (Dankert & Goodale, 2001; Previc & Naegele, 2001; Khan & Lawrence, 2005). However, in all three experiments, predictions regarding a sex difference in visual space/field were not supported (Sanders et al., 2007; Stancy & Turner, 2010). Experiments 1 and 2 followed the assumption that visual fields are functionally equivalent to visual space (Previc, 1990; Previc, Declerck & de Brabander, 2005), and should therefore exhibit similar findings to previous research that has identified a male advantage in far visual space (Sanders & Walsh, 2007; Sanders, Sinclair & Walsh, 2007; Stancey & Turner, 2010).

Experiment 1 used a 'one shot' change detection paradigm to assess this. Here the change either occurred in the upper or lower segment of the visual display, or not at all. The results showed that participants were more accurate at detecting a change if it occurred in the upper portion of the visual display, providing support for the upper visual field advantage (Dankert & Goodale, 2001; Previc & Naegele, 2001; Khan & Lawrence, 2005). However, no effect of sex was found, indicating that both men and women were equally able to detect a visual change. Experiment 2 elicited similar results to Experiment 1. A visual search paradigm was used and found support for the well-documented upper field advantage (Dankert & Goodale, 2001; Previc & Naegele, 2001; Khan & Lawrence, 2005). However, there were no differences in visual search abilities between men and women for this task. Experiment 3 manipulated visual space more directly by placing the stimuli either 50 cm or 500 cm away (Sanders & Walsh, 2007; Sanders, et al., 2007; Stancey & Turner, 2010). The results demonstrated the classic flanker effect, whereby RTs were faster when both distractors were incongruent with the target and slower when they matched the target. It was also argued that the flanker effect, i.e., the slowing of RT for congruent target-distractor pairings, would be more pronounced in women than men (Previc, 1990; Sanders et al 2007). However, this prediction was not supported, thus the issues regarding similar and or dissimilar stimuli and visual angle were not addressed further in this chapter.

The present findings indicate that visual search and recognition mechanisms which are purported to be associated with upper visual field and far visual space processing were most likely selected due pressures from the environment of evolutionary adaptiveness (Cosmides & Tooby, 1987) that impacted both sexes during hominoid evolution equally, and were not segregated by sex due to the demands of the suggested social roles (Silverman & Eals, 1992). Thus, the present work can also be considered to be in contrast with Silverman and Eals hypothesis (1992; Easl & Silverman, 1994). To review, the hunter gatherer hypothesis proposes that ancestral men were hunters and ancestral women were gatherers. As a result of this division in social roles, it has been argued that the associated cognitive abilities required to successfully complete these tasks were selected preferentially. Whereby hunters would have been required to locate and track mobile targets in the distance, and gatherers to be able to locate specific items among irrelevant ones. Empirical research has garnered some support for the hunter gatherer hypothesis (see: Silverman et al., 2000; Voyer, Postma, Brake & Imperato-McGinley, 2007), and criticism (James & Kimura, 1997; Postman, Izendoorn & de Haan, 1998; Ichini, Sergi, Ruggiero & Gnisci, 2005; Stöet, 2011; Cashdan, Marlow. Crittednden, Porter & Wood, 2012), since it's publication. Silverman and Eals' female advantage is found if the original paradigm is followed. However, when a different methodology is employed to assess the intricacies of this advantage, the effect seems to break down, and the results are mixed.

As mentioned in the introduction of the present chapter, Sanders (2013) proposed a distinction between reciprocal and traditional sex differences. Respectively, these refer to differences that occur under two manipulations for a sex neutral task, and those that occur in tasks that favour a particular gender. The change blindness paradigm employed in Experiment 1 conforms to Sander's notion of a sex neutral task. The visual search task utilised in Experiment 2 was proposed as sex neutral due to limited support for a sex based advantage. However, the effect of sex was not present for either of these experiments suggesting, as mentioned previously, that evolutionary pressures may not have differentiated between the sexes for change detection and visual searching abilities.

The present findings also fail to provide support for the Sanders et al., (2007) distinction in visual space based upon evolved spatial differences. The authors posited that processing visual information in far visual space might have resulted in the activation of the corresponding cortical pathways being employed differentially between the two sexes. It must be noted that irrespective of the sex differences found by Sanders and colleagues (2007; Sanders & Walsh, 2007;

Sanders & Perez, 2007), visual information that is near to or far from the observer differs in its retinal size, with closer objects being larger and further objects being smaller. As a result, the brain is able to infer the distance between the observer and the objects within the environment. In addition, objects that are further away from the observer have lower contrast levels than those that are nearer (O'Shea, Blackburn & Ono, 1994). Furthermore, objects in far visual space have a smaller retinal image, which means that they also appear to be more central to the observer. In other words, they appear to be less peripheral, and can therefore increase perceptual load, making it difficult to distinguish between the objects within the visual display (Parker, 2016; Verhoef, Vogels & Janssen, 2016). In relation to Experiment 3, this may explain why all participants' performance was modulated by the flanker task in far visual space, therefore failing to demonstrate the male advantage as suggested by Sanders and colleagues.

Experiment 3 also failed to support Stöet's (2010) female flanker effect, whereby women demonstrate greater distraction towards flankers than men. Stöet's explanation for this effect suggested that as ancestral women were presumed gatherers, women in general should be "open to all response alternatives" (Stöet, 2010, p637). This conclusion was corroborated by Stöet's (2011) use of the visual search paradigm where participants were required to locate the target as quickly as possible in the classic paradigm (Experiment 1), to assess the female superiority at gathering (Experiment 2) and to identify it's relationship with the object location memory advantage (Experiment 3). Across all experiments, Stöet determined that men outperformed women (Stöet's Experiments 1 and 2) and that there were no sex differences to be found (Stöet's Experiment 3). This lead to the conclusion that males are superior to females in ignoring flankers and visual search tasks due to the possibility that women aren't optimised for gathering, rather gathering occurs as a default social role, seconded to child rearing. The findings imply that women are unable to disengage from available visual stimuli as quickly as men (Stöet, 2011).

Stöet's (2010; 2011) conclusions are based upon findings that identified a male advantage in the flanker and visual search tasks, however the present author argues for an alternative viewpoint. Whilst the current findings do not support the strict criteria of the hunter gatherer hypothesis, they do fit within the context of existing research. Conducting a search of the visual environment for a specific target is a task that is applicable to both gathering (near visual space) and hunting (far visual space), both roles require efficiency and accuracy. From a low level vision perspective, males are more sensitive to high spatial frequency than females and have greater visual acuity (Abramov et al., 2012), indicating that they are better at tracking finer motion and finer detail. However this may not fully transpose onto the ability to track moving targets. With respect to the evolutionary perspective, hunters would need to track prey in order to successfully capture it. However, from a survival point of view, both hunters and gatherers would need to be aware of, and be able to track each other's movement and that of any object or animal that poses a threat. This logic also applies to being able to detect a change in the environment. Both hunters and gatherers would need to be "open to all response alternatives" (Stöet, 2010, page 637) in order to efficiently succeed in moving about and surviving within their environment.

To clarify, this argument may only apply to the visual attention paradigms used within this chapter. All paradigms used here require the capturing of attention via the target or distractors; experiments designed to assess perceptual manipulations may not support this argument (see Abramov et al., 2012, for an example). In addition, the findings in this chapter do not fully address the validity of the near and far visual space paradigm as proposed by Sanders et al., (2007; Sanders & Walsh, 2007; Sanders & Perez, 2007; etc.). The null findings found here are somewhat inconclusive, and the visual space manipulation will be assessed further in Chapter 3.

Chapter 3

"What you do in this world is a matter of no consequence," returned my companion, bitterly. "The question is, what can you make people believe that you have done?"

A Study in Scarlet

Sherlock Holmes

Part 2, Chapter 7, page 83

Arthur Conan Doyle.

3.0 Perceptual differences between men and women under the context of Evolutionary Psychology

By definition, visual perception is what you can see and therefore understand, using your eyes and brain. When what someone perceives alters, the visual information from the environment does not change, rather it is the change in their interpretation based upon their knowledge and experience that alters their perception. A classic example of this is the “My wife and Mother-in-Law” illusion by the artist Hill in 1915. The properties of this drawing are such that whichever image is perceived first, be it a young woman or an old woman, can be dictated semantically. That is, if an individual has been primed with words semantically related to ‘young’, they are more likely to identify the drawing as a young rather than old woman. This encapsulates the main principles of top-down processing (Gregory, 1970). Gregory postulates that not all sensory information is processed, or that there are existing gaps in the information that is available. In both cases, the brain is able to ‘fill in’ these gaps by drawing on knowledge and past experiences in relation to the current context. For example, the concave features in the hollow mask illusion are perceived to be convex when viewed straight on due to the viewers’ knowledge on the normal physiological structures of faces (Hill & Johnson, 2007). Bottom-up processing by contrast, proposes that sensation is perception (Gibson, 1972). The primary premise is that all sensory information is processed and none is lost (Connor, Egeth & Yantis, 2004). This view suggests that basic and raw visual data inform the viewer of their environment. For example, optical flow patterns represent what direction the environment surrounding them is travelling in. If the optical flow pattern is moving away from the viewer’s fixation point, then the viewer is travelling towards this point. Conversely, if the optical flow is moving towards the viewer’s fixation, then the viewer is travelling away from this point. Both viewpoints propose substantial arguments, but neither theory is able to answer all available questions exclusively. The physical world is constantly changing, and the perceiver’s view of the world alters via movement and orientation. Therefore, it can be argued that one cannot solely perceive the environment by simple sensory data. Indeed, attention may be modulated or captured via bottom up mechanisms, however the information received may trigger memory retrieval from a schemata or it may alter the schemata. This will then provide additional information regarding what is being perceived, or more information will be encouraged to be obtained (Neisser, 1978).

As mentioned, an important notion, is that irrespective of whether perception is primarily influenced by bottom-up or top-down mechanisms, the ‘picture’ we see does not change. Indeed, a fundamental tenet of visual perception is that whilst one's knowledge and attribution of what one can 'see' can be altered; the physiological structures and components that make up the image remain constant. Pylyshyn (1999) is an advocate of the concept that vision cannot be modified in this regard; the picture remains the same, despite the interpretation possibly changing – vision in this context is said to be ‘cognitively impenetrable’ (Firestone & Scholl, 2016). The central point with respect to the present chapter is that vision, i.e., the actual precept, is not influenced by the knowledge and experience of participants, or at the very least, it is far less likely to be. Experiments based on pure perception, rather than attention, may therefore be a more useful way of assessing hunter gatherer predictions as vision is not contaminated by the experiences and knowledge that participants have. One does have to note however, that it is of course not entirely clear where perception ends and attention begins and many paradigms access mechanisms associated with both. Although the present Experiment 4 does include a non-perceptual component (i.e., cognitive load implications for motion object tracking), Experiments 5 and 6 were based on pure perception, (i.e., the Poggendorff illusion and binocular disparity).

As mentioned in Chapter 2, from an evolutionary perspective sex differences have been proposed in visual processing abilities due to the division in labour in hominoid evolution. Sanders et al., (2007) argued that visual processing abilities in men and women have evolved differentially due to past social roles as hunters and gatherers respectively. A trait that has been attributed to being a successful hunter is the ability to track moving objects, i.e., to track motion (Sanders et al., 2007). In this context, Abramov et al., (2012) employed sinusoidal luminance gratings to assess men and women's contrast-sensitivity functions using six spatial frequencies at five temporal rates. Their findings indicated that men, as opposed to women, demonstrated a greater degree of sensitivity for high spatio-temporal frequency presentations. In other words, they were able to detect fine detail and rapidly moving stimuli to a significantly greater degree in comparison to women. Furthermore, the male participants also demonstrated finer visual acuity across all temporal frequencies than for women. They suggested that these findings are consistent with existing interpretations of sex differences based upon the hunter gatherer hypothesis and knowledge regarding modern societies.

The ability to identify objects in far visual space requires visual processors that are able to identify and categorise these items efficiently. That is, being able to detect a prey item or a predator in far visual space is enhanced by the ability to see fine detail and to detect fine motion. Furthermore, the early visual system is reported to be able to track up to five objects without encoding any salient properties (Pylyshyn, 2000). With respect to hunters, this system may provide an advantageous bias for tracking a prey item.

Abramov et al., (2012) also provide an additional insight in regards to gatherers. Their findings indicate a 'tail-off' in sensitivity for high spatial frequency in women. Abramov et al., suggested that this indicates a specialisation for slow moving or static targets within near visual space, concurring with Sanders et al.,'s (2007) findings. The female specialisation for near visual space, as proposed by Sanders et al., provides potential insights concerning depth perception and binocular disparity. As Previc (1990) highlighted, the development of forward facing eyes in hominoid evolution was crucial for the enhancement of depth perception. When items in the visual scene appear to be far away, their retinal size decreases, as does the clarity and detail of the image, for example. These aspects allow the viewer to perceive depth without binocular vision. The placement of the eyes on a horizontal plane allows for different views of the same environmental point from each eye. This difference is known as binocular disparity or stereoscopic vision, and is used by the visual system to calculate depth from 2D retinal images (i.e., Dodgson, 1993; Read, Begum, McDonald & Trowbridge, 2013). The advantages of binocular viewing are highlighted when examined against monocular viewing. For example, Servos, Goodale and Jakobson (1992) assessed prehension movements and found that participants underestimated the distance and therefore size of the reached-to object, resulting in slower movement times and smaller grip apertures when under monocular viewing. Indeed, binocular vision and thus binocular disparity provides the viewer with more information in which grip apertures and trajectory movements can be adjusted (Melmoth & Grant, 2006).

Sanders and Walsh (2007) further proposed that in addition to Sanders et al., (2007), findings whereby women have faster responses and higher accuracy rates when performing tasks in near visual space, efficient gathering requires good distal hand muscles for movement and grasping motions in order to effectively interact with the local environment. When taken together, this provides a tentative suggestion that binocular vision may have evolved differentially between men and women, though to date there are no findings to support this notion.

Thus, the present chapter will assess the view that men and women have differentially evolved abilities to efficiently process visual information (i.e., perception) in near and far visual space. In accordance with Sanders et al. (2007), and, similar to Chapter 2, it would be expected that men would demonstrate a superior ability to track moving objects, and that this would be emphasised in far visual space (Experiment 4). Moreover, it could be argued that the spatial processing bias demonstrated by men (Voyer, et al., 1995) may result in fewer errors in far visual space compared to women, when performing perceptual judgement tasks on the Poggendorff Illusion (i.e., Experiment 5; Ling et al., 2006; Knudson, et al., 2012). The final experiment (Experiment 6) within this chapter will assess whether females, who can be considered as 'near space dominant' (as presumed gatherers), rely more on binocular vision than males.

3.1 Experiment 4

Pylyshyn and Storm (1988) identified that the human visual system is capable of tracking multiple and independent moving objects in the visual scene, by maintaining the focus of a visual feature of the object as it moves. The authors assessed this ability by presenting participants with displays of 10 '+' symbols, to denote the targets, where one to five '+' flashed intermittently for 10 seconds, after which all items moved around the display. The participants were required to track the targets and respond via key press when one of the intended targets changed shape. The results indicated a trade off between performance and the number of targets presented. Accuracy levels declined and error rates increased when the number of targets rose, in other words, performance tailed of significantly when five or more targets were presented. In addition to the quantity of targets affecting accuracy rates, additional variables such as the velocity of the targets and non-targets, and the spacing between the objects has been investigated. Alvarez and Franconeri (2007) found that the velocity of the mobile items influences accuracy rates, as does the spacing. For instance, if the moving items travel at a fast speed and are spaced close together, accuracy levels decrease and vice versa. Consequently, at slow speeds with wide spacing, participants were able to track up to eight items if these variables were kept constant

Whilst the visual system's ability of tracking motion in humans has been examined, differences between humans, i.e., between men and women, have not been assessed. Abramov et al.,'s (2012) findings indicate greater sensitivity levels for finer motion, finer detail detection and finer visual acuity in men, as opposed to women. Indeed, Abramov et al concludes that these male biased sensitivities are indicative of the notion that the sexes differentially evolved task specific cognitive abilities (Sanders et al., 2007).

In order to assess this further, the present experiment will examine men and women's ability to track multiple moving objects in near and far visual space. A variant of the standard tracking task will be employed, (Pylyshyn & Storm, 1998; Pylyshyn, et al., 2008; Alvarez & Franconeri, 2007; Feira 2012), where variables such as the total quantity of items, the spacing and the velocity will remain constant throughout all of the trials. The only variation will be the number of targets per trial, ranging from two to five. Therefore, in Experiment 4, participants were presented with a display of moving items, and were required to track a subset of these in near and far visual space. When considering the role of a hunter, who presumably hunted for mobile prey, it is reasonable to assume that men should possess greater motion tracking ability compared to women. In addition, this effect should be more pronounced in far visual space.

3.1.1 Method

3.2.1.1 Participants:

There were 84 participants (42 males); all were University of Essex Undergraduates who participated for course credits or monetary reimbursement.

3.1.1.2 Stimuli and apparatus:

Ten solid white discs (r= 25 pixels) were presented within a white-bordered rectangle (700 pixels^2) against a black background. Luminance values of the discs and background were 68 cd/m^2 and 0.2 cd/m^2 respectively. A black fixation cross was located in the centre of the display between trials. Of the ten discs, 2 - 5 discs intermittently flashed red, for 300ms, to identify themselves as targets.

In order to optimise the participant's motion tracking performance, across all target quantity conditions the velocity of travel was kept at constant rate of 3.3 pixels per frame (Alvarez & Franconeri, 2007). In addition, to maintain the impression that the discs were travelling on the same depth plane, all of the discs 'bounced' off of each other and the edges of the display (Pylyshyn et al., 2008) The experiment was carried out in a well-lit room, driven by an iMac with 2560x1220 resolution.

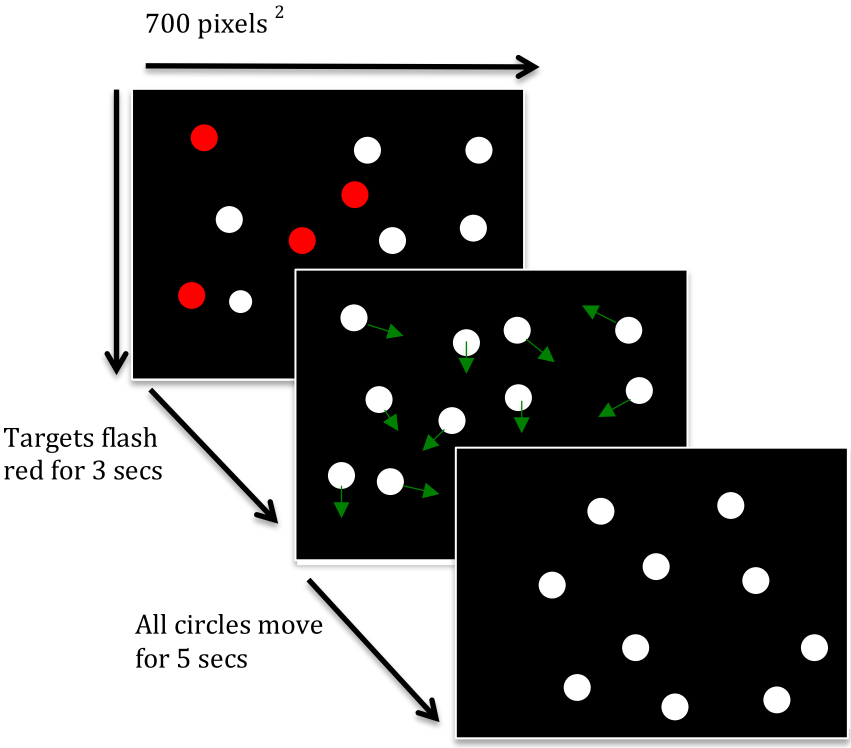


Fig 3.1 An example of a multiple object tracking trial. Green arrows were not present during the trials.

3.1.1.3 Design and procedure:

A 2x2 mixed design was employed, with sex as the between subjects variable, visual space as the within subjects variable, and percent correct as the dependent variable. Participants were instructed to visually track the targets whilst they were in motion, indicating via a mouse click, which discs they believed were the targets once movement ceased. To proceed to the next trial, participants were required to click the mouse outside the rectangular display.

The order of which the number of targets was presented was randomised and counterbalanced. Each target quantity was presented ten times, which provided a maximum correct limit that was relative to the number of targets present in the display. For instance the maximum correct limit for two targets was twenty, and for five targets was fifty. The percentage correct was then calculated for the analysis. The participants were seated approximately 50cm away from the display in the near visual space condition and approximately 500cm from the display in the far visual space condition. As mentioned in Experiment 3, the near and far manipulation in this experiment and the next will not include a visual angle correction in order to facilitate an ecologically valid design.

3.1.2 Results and discussion

As mentioned, percentage correct was calculated based on the number of potential targets successfully identified in relation to the quantity in each trial (see Figures 3.2). A mixed ANOVA revealed a significant main effect of visual space, F (1,80) = 334.17, $p < 0.001$, $\eta_p^2 = 0.81$. No significant main effect of sex was observed, F (1,80) = 0.03, $p = 0.87$, $\eta_p^2 < 0.01$, and no significant interaction, F (1,80) = 0.01, $p = 0.23$, $\eta_p^2 = 0.02$.

As expected, the visual space prediction was supported; participants were able to track more objects in the near condition than the far condition (e.g., Sanders et al., 2007). However, these findings suggest that the sex of the participant has no effect on ability to track moving objects; that is, males are no better at tracking motion than females. In addition, support for existing findings regarding the effect target set size has on accuracy is demonstrated. That is, participant's performance decreased as a function of target set size, (e.g., Pylyshyn & Storm, 1988; Alvarez & Franconeri, 2007). Overall, these data fail to support the expected predictions based on the hunter gatherer hypothesis (e.g., Sanders et al., 2007). Similarly to Experiment 3, these data identified an interaction between visual space and target set size, where accuracy rates fell, across all participants, in far visual space. Once again it is likely that these findings reflect the experimental layout. As visual angle was not adjusted for far visual space, the moving targets appeared more central, and thus increasing the difficulty level when compared to the near visual space condition.

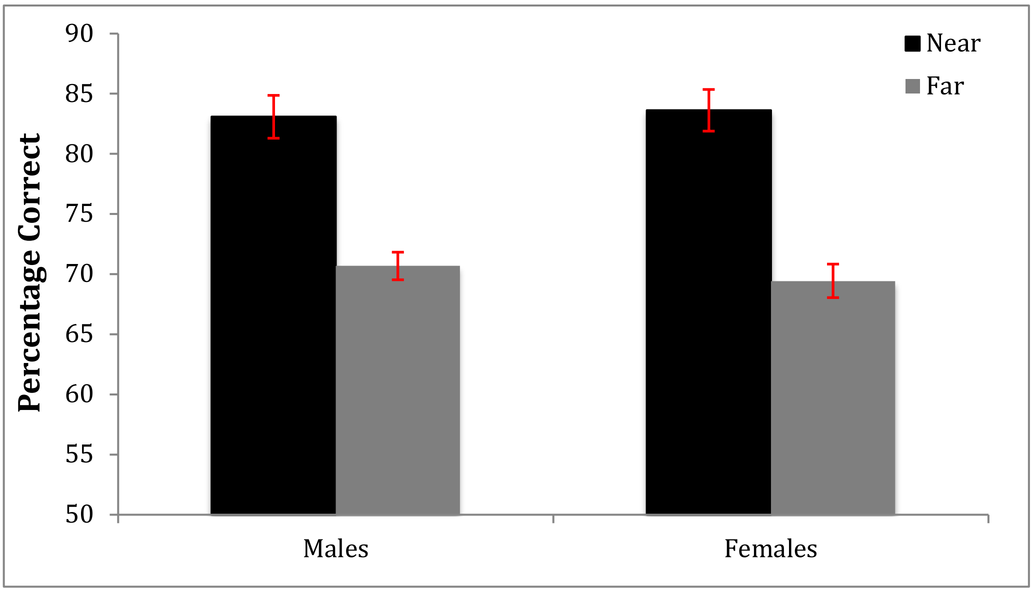


Fig 3.2 Accuracy scores for target detections across near and far visual space as a function of sex. Error bars represent standard errors of the mean.

3.2 Experiment 5

The Poggendorff Illusion occurs when a single oblique line is partly occluded by two parallel lines. The presence of these lines causes the continuity of the single oblique line to undergo a perceptual displacement. The end result creates the impression that the oblique lines are completely independent from one another (see Figure 3.3). The figure has been examined with respect to the illusion-inducing components. For example, Jones-Buxton and Wall (2001) established that the illusion persisted when the distance between the parallel lines increased. However, the illusion failed when the parallel lines moved beyond the oblique line, leading the authors to conclude that the intersection point between the oblique and diagonal induces the illusion.

In contrast to most perceptual phenomena, this illusion has been assessed with respect to sex differences. Ling et al., (2006) specifically assessed whether the perceived misalignment was modulated by the sex of the participant. Participants were first required to adjust one of two oblique segments, separated by a fixed gap, so that it appeared to be 'in line' with the other. No differences between men and women were observed here. However, when a rectangular block outlined the fixed gap, sex differences were found. Women made more errors aligning one oblique segment up to match the other when the box was present, compared to men. Thus the results support Jones-Buxton and Wall's (2001) conclusions in that the intersection of the two lines resulted in the perceived misalignment, with the additional suggestion that this effect may be modulated by sex.

Knudson, et al., (2012) further examined the notion that the intersection elicited the illusion by presenting participants with variations of the figure where the intersection is either present or absent. Knudson et al also assessed whether or not the effect of sex on the illusion is modulated by the intersection. They predicted that a sex difference should occur when the intersection is present as opposed to absent. However, their findings failed to support this; for both variants, women demonstrated greater illusions than men. Their results support Declerck and DeBrabander (2002) who also found a difference in the magnitude of the illusion between men and women when the oblique line did not contact the vertical line. The authors concluded that the geometric design and therefore the spatial components of the Poggendorff figure might represent a spatial ability advantage for men.

Experiment 5 then, aims to replicate the findings of Ling et al., (2006) and Knudson et al., (2012), with visual space (near and far) as an additional factor. As the visual space literature indicates, men are argued to have a far visual space advantage due to their evolved hunting past, and women for near visual space due to their evolved gathering past (e.g., Sanders et al., 2007). Therefore it would be expected that the perceptual performance in the Poggendorff Illusion reflect this difference, where men make more accurate judgements in far visual space than women. Secondly, as existing research by Ling et al., and Kudson et al., have previously identified a male advantage, it is predicted that this effect will be replicated in near visual space.

3.2.1 Method

3.2.1.1 Participants:

There were 84 participants (42 males); all were University of Essex Undergraduates who participated for course credits or monetary reimbursement.

3.2.1.2 Stimuli and apparatus:

The illusion employed by Ling et al., (2006) was used within this experiment. A black outlined rectangular box (150 x 50 pixels) and two oblique lines of x length on each side make up the stimuli, (see Figure 3.3). The illusion alternated between vertical and horizontal orientations (Howe, Yang & Purves, 2005). The intersection point, which varied for each trial, was either 30 or 10 pixels above or below the true centre of the rectangular box. In addition, the movable oblique line was always placed 100 pixels above or below the true point of intersection for that trial.

3.2.1.3 Design and procedure:

A 2x2 mixed design was employed, with sex as the between subject variable, visual space as the within subject variable and accuracy as the dependent variable. Each participant was informed that their task would be to manually adjust the movable oblique line until they perceived complete alignment with the other. This was accomplished via key presses that made fast or slow adjustments. Once the participants were satisfied with their alignment, they were instructed to press the space bar to initiate the next trial. The participants were seated 50 cm away from the display in the near visual space condition and 500 cm away in the far visual space condition. Again, visual angle was not adjusted. A total of 32 trials were presented equally a counterbalanced between each condition.

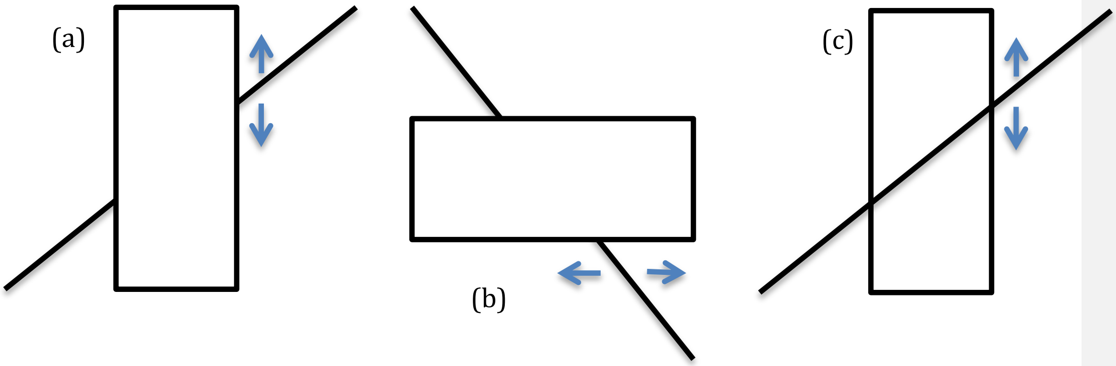


Fig 3.3 A vertical (a) and horizontal (b) representation of the stimuli used for the Poggendorff Illusion in this experiment. Figure 3.3(c) demonstrates the actual continuation of the obscured oblique line in Figure 3.3(a).

3.2.2 Results and discussion

Three participant's (2 male, 1 female) data were omitted from the analysis due to incomplete data. Error rates were calculated by subtracting the pixel distance between the participant's perceived end point and the true intersection of the adjustable oblique line. The sum of these errors were calculated for each participant, before being divided by the number of trials (i.e., 16). This gives an average pixel error rate per participant, (see Figure 3.4). A mixed ANOVA was calculated with sex and visual space as between and within subject factors, respectively. Results identified a significant main effect of visual space ($F(1,82) = 38.72$, $p < 0.001$, $\eta_p^2 < 0.32$), and sex ($F(1,82) = 4.3$, $p = 0.04$, $\eta_p^2 < 0.05$). However, no interaction was found ($F(1,82) = 0.8$, $p = 0.38$, $\eta_p^2 = 0.01$).

These results support previous findings regarding visual space, (e.g., Previc, 1990; Sanders, et al., 2007), whereby participants made less errors in near space compared to far space. The results also corroborate with previous research regarding the occurrence of sex differences for the illusion, whereby women demonstrate greater susceptibility to the illusion (Ling, et al., 2006; Knudson, Woodland & Wilson, 2012; Declerck & DeBrabander, 2002). However, whilst men made fewer errors than women, as predicted, this effect was not modulated by visual space, thus failing to support current predictions based upon the hunter gatherer hypothesis (Sanders et al., 2007). The results do highlight an unusual phenomenon in that errors made in far visual space across both sexes are not substantially larger than those made in near visual space. Currently, this is unexplainable, as visually, finer detail information is not readily available in far distances.

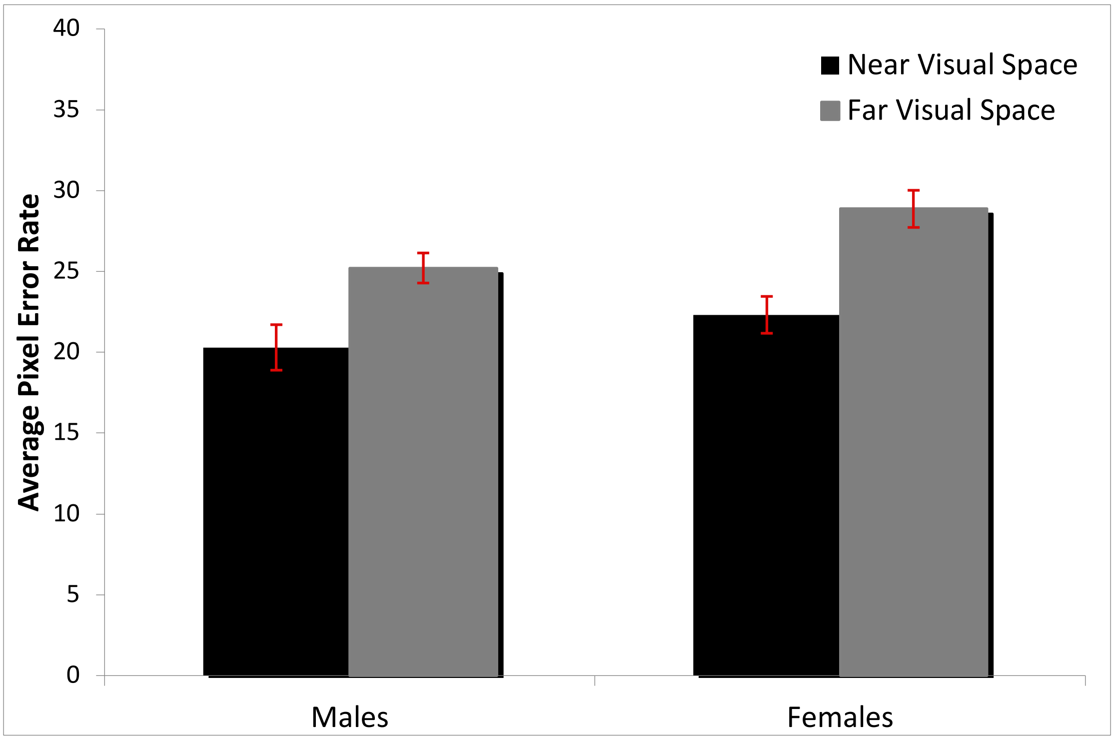


Fig 3.4 Average pixel error across near and far visual space as a function of sex. Error bars represent standard errors of the mean.

3.3 Experiment 6

Binocular disparity, or the advantage of binocular vision can be addressed and examined in many ways. For example, Read et al., (2013) used the Morrisby Fine Dexterity Test, in which participants were required to interact with and manipulate small items, and the findings indicated a clear binocular advantage. The authors also employed a variation of the classic children's game in which a person moves a metal ring along a wire and attempts to avoid touching the wire. Read et al. found that participant's performance on both tasks suffered under monocular viewing. This decrement was most pronounced for the buzz wire task, leading the authors to conclude that primarily relying on one sense (i.e., vision), in order to avoid contact with the wire (i.e., a motor task), results in this task being particularly demanding for depth perception.

As mentioned, binocular disparity has not been examined with respect to sex differences and the hunter gatherer hypothesis. The proposal for the present experiment is again based upon existing data that identifies women's abilities in visual cognition tasks having higher performance in near visual space (e.g., Sanders et al., 2007; Stancey & Turner, 2010; Abramov et a., 2012). Since binocular vision is advantageous for efficient interactions within near visual space, e.g., gathering, then females as presumed gatherers should show a greater decrement in performance under monocular viewing. To put another way, far-space-dominant-males should not rely on binocular vision to the same degree as females, and therefore should not display the same degree of cost induced by monocular vision.

3.3.1 Method

3.3.1.1 Participants:

There were 58 participants (31 females and 27 males); all were University of Essex Undergraduates who participated for course credits or monetary reimbursement.

3.3.1.2 Stimuli and apparatus:

The buzz wire apparatus was constructed from a "Kidz Labs" toy, powered by AA batteries (see Figure 3.6). The task required the participants to guide a wire hoop around the track, without touching it. If contact between the wire track and the wire hoop is made, a high frequency buzz is elicited until the wires are separated. As mentioned by Read et al., (2013), a vertical, 3D track allows for a more efficient analysis of stereoscopic vision. In addition to this, the wire track was moulded into a complex formation for difficulty purposes.

Audio recordings were made using Audacity 2.0.3. This allowed for accurate total reaction time, error duration, and error rate measurements to be taken. In addition, a paper eye glass with only one available lens, for the participant's dominant eye, was employed to allow for monocular viewing (see Figure 3.6).

The experiment was carried out in a well-lit room and the audio recoding was made using an iMac with a 3.4 GHz Intel Core i7 processor.

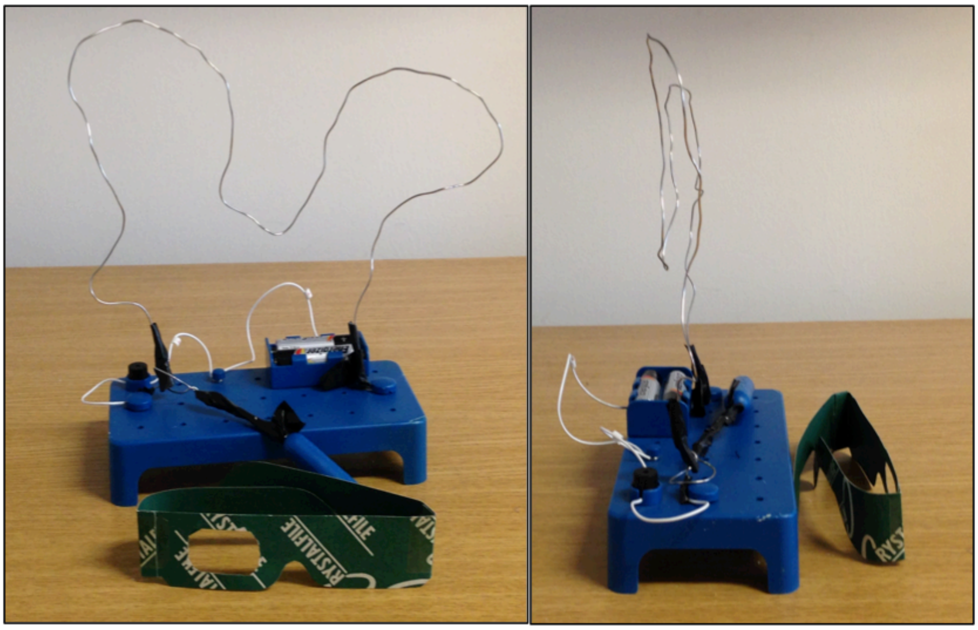


Fig 3.5 A stereo view of the buzz wire task, from the front (left) and the side (right).

3.3.1.3 Design and procedure:

Three separate 2x2 mixed design ANOVAs were employed, with sex as the between subject variable and binocularity as the within subject variable for all analyses. Three dependent measures were employed: total time, error duration, and error rates.

Prior to completing the buzz wire task, the participants completed three other measures. Firstly, the participant's near visual acuity was assessed using a 'Near Vision Test Card'. The participants were required to read the rows of letters that decreased in size aloud, until they reached a print that was not legible. The size of text above this point was recorded, as the participant's visual acuity level for near space, and the test card was positioned 16 inches away from the participant. Secondly, the participants performed a test to determine eye dominance. Participants were instructed to form a circle with their hand, holding it at arms length, and with both eyes open to fixate on an object in the distance, centred within the circle of their hand. The participants closed one eye and then the other, whilst maintaining the fixation with their open eye. Dominance was established by identifying which open eye could still see the object within the circle formed by their hand. The dominant eye was used in the monocular condition. Finally, as the primary aim of this experiment is to assess if there is a difference between the sexes, the distance between the participant's pupils was measured (inter-pupillary distance using millimeters). This measure was employed to control for skull size differences between men and women. The inter-pupillary distances were measured by placing a metal ruler on the participant's brow. The ruler was positioned in line with the centre of one pupil before taking the measurement of the other.

Participants completed both monocular and binocular conditions, both were counter balanced and due to the audio recording, they were asked to refrain from talking during the task.

3.3.2 Results and discussion

The audio files provided a count of the number and duration of errors (buzzes) for each participant, as well as the complete duration of the time spent travelling for each condition. The results for total travelling time (see Figure 3.7) found a significant effect of binocularity ($F(1,56) = 79.78$, $p < 0.001$, $\eta_p{}^2 = 0.6$). However, no effect of sex ($F(1,56) = 0.9$, $p = 0.35$, $\eta_p{}^2 = 0.01$) or an interaction ($F(1,56) = 1.83$, $p = 0.2$, $\eta_p{}^2 = 0.03$), were found. The duration of errors made (see Figure 3.8) also found a significant effect of binocularity ($F(1,56) = 99.76$, $p < 0.01$, $\eta_p{}^2 = 0.64$). No main effect of sex ($F(1,56) = 1.2$, $p = 0.3$, $\eta_p{}^2 = 0.02$) or interaction ($F(1,56) = 1.32$, $p = 0.3$, $\eta_p{}^2 = 0.02$) were found. For the number of errors (see Figure 3.9), similar results were found. Binocularity demonstrated a significant effect ($F(1,56) = 108.6$, $p < 0.01$, $\eta_p{}^2 = 0.66$), and no effect of sex ($F(1,56) = 1.82$, $p = 0.18$, $\eta_p{}^2 = 0.03$) or an interaction ($F(1,56) = 2.\ 3$, $p = 0.14$, $\eta_p{}^2 = 0.04$), were found. For all analyses, no differences were found between men and women for both binocular and monocular vision (all t's > 1.4, all p's > 0.15).

An independent samples t-test using sex found greater inter-pupillary distances for men's eyes in comparison to women's across both levels of binocularity ($t(56)=3.94$, $p<0.001$). Following this analysis, for each sex an average of the inter-pupillary distance was computed. This allowed a new binary variable to be created that stated whether the participant's inter-pupillary distance is wider or narrower than the average for that sex. Subsequently, disparity measures were computed for total time, error time and number of errors by subtracting the monocular scores from the binocular scores. This allowed a 2x2 between subjects ANOVA, with sex and width as variables found no significant effects or interactions for all measures (total time disparity, error time disparity and error rate disparity) between men and women (all F's < 0.01 and all p's > 0.2).

Overall, the predictions made regarding binocular disparity were supported; all participants were faster and made fewer errors in the binocular viewing condition, in comparison to the monocular condition. However, the prediction regarding the hunter gatherer hypothesis was not supported. Recall that the cost of performing the task in the monocular condition was predicted to be greater in females relative to males. This was posited because females, as presumed 'near-space gatherers', should rely more on binocular disparity. Interestingly, the direction of means for all three measures (i.e., total time, error duration, and error rate), concur with the prediction. Furthermore, and perhaps most importantly, these means rule out the problem of a speed-accuracy trade off. On a difficult task in which speed is the central measure, some participants may simply be fast because they have lowered their threshold for making a mistake. That is, they are fast but error prone. Others however, may be relatively slow but make few errors. Such a pattern of data would not reveal anything interesting about the phenomenon being examined; the data would just show a classic speed-accuracy effect. However, the present data shows that not only were females slower to complete the task, they also made more errors.

An additional issue to note here is the degree of difference between the monocular and binocular means for all three measures. For error duration and the number of contact hits, participants are almost performing at floor for the binocular condition, suggesting a lack of difficulty about the task. This indicates that a wire track with more 3D elements would provide a more in depth depiction of depth processing than the track employed.

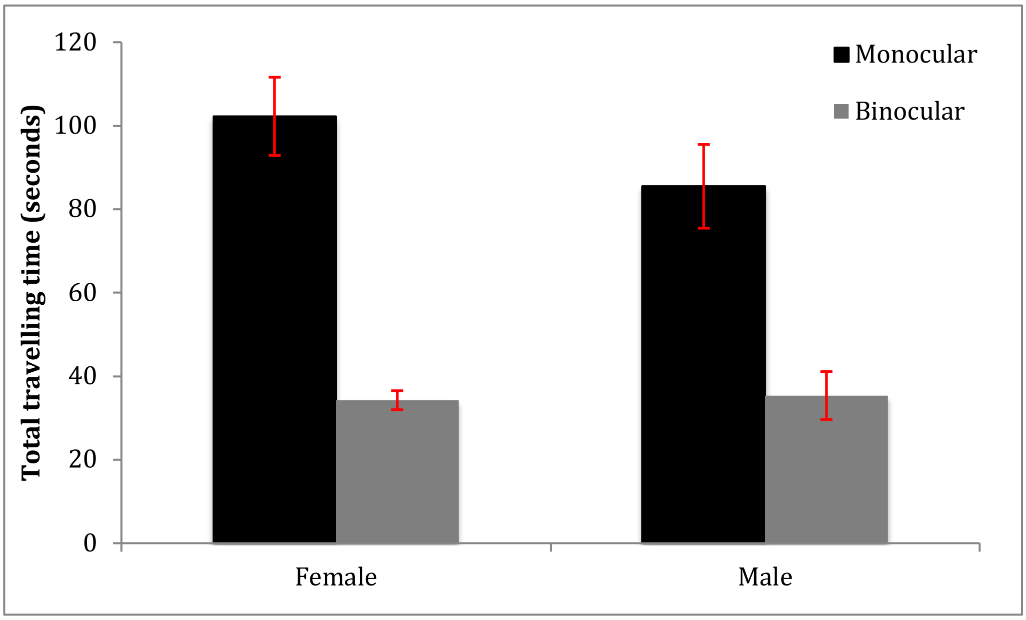


Fig 3.6 Total travelling time between men and women as a function of binocular vision. Error bars represent standard errors of the mean.

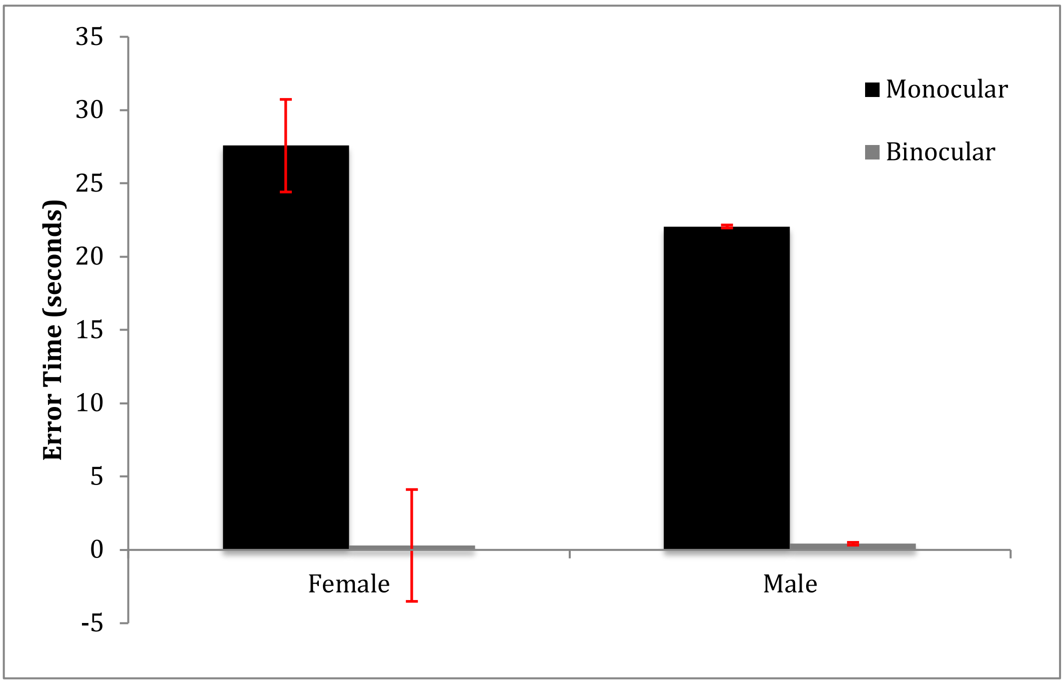


Fig 3.7 Error duration between men and women as a function of binocular vision. Error bars represent standard errors of the mean.

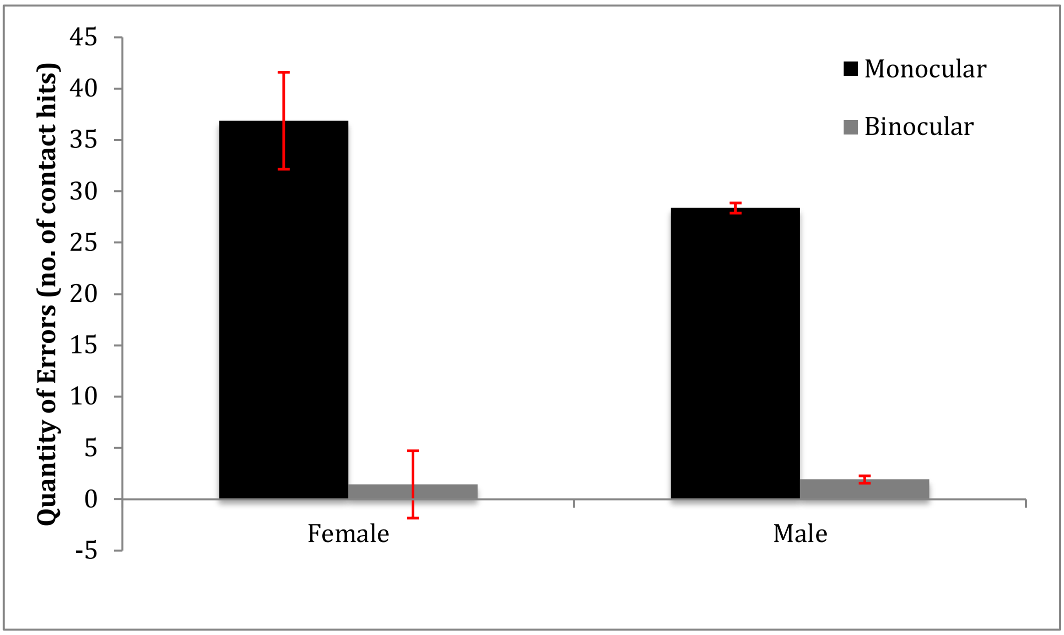


Fig 3.8 Number of contact errors made between men and women as a function of binocular vision. Error bars represent standard errors of the mean.

3.4 Discussion

Chapter 3 assessed the hunter gatherer hypothesis with respect to visual perception. In line with Chapter 2, this chapter proposed that the prehistoric social roles of men and women as hunters and gatherers, respectively, might have differentially influenced visual perception abilities between the sexes. Specifically, men as hunters would have evolved greater abilities to visually perceive stimuli that occurred in far visual space, and women as gatherers would have been more efficient in near visual space (Silverman & Eals, 1992; Sanders et al., 2007; Abramov et al., 2012).

The findings within this chapter are somewhat mixed. For Experiments 4 and 5, predictions made with respect to visual space were supported (e.g., Sanders et al., 2007; Sanders & Walsh, 2007). All participants were more accurate in near visual space in comparison to far visual space. In addition, the prediction regarding the effect of binocular vision was supported in Experiment 6. Across the sexes, all participants' performance was significantly impaired in the monocular vision condition (Read et al., 2013). However, for all three experiments, predictions made regarding the hunter gatherer hypothesis were not supported. Men and women did not differ in their ability to track multiple moving objects (Experiment 4; Abramov et al., 2012), nor do they differ in their performance when stereoscopic vision is impaired (Experiment 6). However, whilst Experiment 5 failed to support predictions made, a difference between men and women was found, although this was independent of visual space. Therefore, all three experiments in this chapter failed to support Sanders et al.,'s (2007) sex based distinction on visual space.

Experiment 4 employed a motion object tracking task (e.g., Pylyshyn & Storm, 1998; Alvarez & Franconeri, 2007), presented in both near and far visual space (e.g., Sanders et al., 2007; Sanders & Walsh, 2007). The results indicated that participants were able to track more objects in near visual space, in comparison to far visual space, (Samders et al., 2007). However, the suggestion that men would demonstrate a higher performance in tracking moving objects was not met (Abramov et al., 2012). That is, both sexes were equally able to track the targets. Experiment 5 utilised the Poggendorff illusion, requiring participants to manually adjust one of two oblique lines until they perceived complete alignment. The experiment was also presented in near and far visual space. Once again, a visual space bias was found; participants were more accurate in their perceptual judgements within near visual space than far visual space. In addition, and in contrast to the previous experiment's findings, a sex effect was found. As predicted, men displayed greater accuracy than women in the task, (Ling et al., 2006; Knudson et al., 2012). However, this was found across both near and far visual space, failing to support Sanders et al., (2007). Experiment 6 manipulated stereoscopic vision and presented participants with a buzz wire task (Read et al., 2013). The results supported predictions regarding binocularity, in that all participants were slower and made more errors under monocular viewing. It was also proposed that in agreement with Sanders and colleagues (2007; Sanders & Walsh, 2007), women would demonstrate a greater degree of impairment during monocular viewing, however this prediction was not supported.

The present findings indicate that performance on a task is inversely related to the distance between the performer and the target stimuli. This is in agreement with the primary findings of the visual space literature (e.g., Previc, 1991; Sanders et al., 2007; Sanders & Walsh, 2007; Stancey & Turner, 2010). Specifically, items located in far visual space are lower in contrast, brightness and sharpness, and are overall, harder to process than those within near space (O'Shea et al., 1994). However, critically, the present chapter proposed that visual perception and processing abilities have been shaped by the task demands required of the ancestral social roles (i.e., hunting and gathering). In particular, Abramov et al., (2012) identified that men have greater sensitive visual acuity than women, indicating greater visual clarity, specialised for far visual space. In conjunction with men's greater sensitivity towards high spatial frequency stimuli (i.e., fine detail and fine motion), it was proposed that men would have greater performance in far visual space in comparison to women. Moreover, it was also argued that women would demonstrate a greater reliance on binocular viewing than men in near visual space. Sanders et al. (2007; Sanders & Walsh, 2007) highlighted that gathering requires constant interactions within near visual space and found that not only were women more accurate in their performance in near visual space (Sanders et al., 2007), they also demonstrated greater dexterity with their distal muscles (Sanders & Walsh, 2007). Both tasks require stereoscopic vision; therefore this chapter proposed that performing a task with only monocular vision would be detrimental to female performance. Nevertheless, both predictions were not met and therefore failed to support the hunter gatherer hypothesis (Silverman & Eals, 1992).

As in Chapter 2, the failure to support the hunter gatherer hypothesis could be related to the suggestion that tracking motion, making perceptual judgements, and having a binocular advantage were selected by evolutionary pressures that influenced both sexes equally (Cosmides & Tooby, 1987). However this conclusion is in contrast to existing findings and raises a number of issues.

Abramov et al., (2012) found that men are more sensitive to fine motion and fine detail by employing luminance gratings that varied from low to high spatial frequency (i.e., variation in detail) and low to high temporal frequency (i.e., variation in motion). On the basis of these findings, the present Experiment 4 aimed to assess motion detection ability by using a multiple object tracking task (i.e., Pylyshyn & Storm, 1998). However, the stimuli employed conformed to the methodology of Pylyshyn and Storm, in that all objects in the display were identical. Pylyshyn (2000) suggests that identical, multiple objects can be tracked despite the lack of saliency between the objects. This is accomplished by the early visual system that is able to identify and track a number of objects without encoding any distinct properties (Marr, 1982; Pylyshyn, 1999). Brown and Guenther (2012; see the present Chapter 4 for more information) also identified a male bias towards high spatial frequency stimuli, which, they argued, equates to a bias towards parvocellular pathway activation (i.e., object based neural activation). This leads to the suggestion that predictions may have been supported had discs of luminance gratings been employed as opposed to white discs. Thus, Experiment 4 argued for, but failed to find a male bias towards motion tracking.

Ling et al., (2006) and Knudson et al., (2012) reported a perceptual judgement difference between men and women for the Poggendorff illusion. Whilst neither paper explicitly related this difference to the hunter gatherer hypothesis, the general conclusion focused on the spatial properties of the illusion's structure (see Figure 3.4). Relating back to Chapter 2, the Poggendorff illusion, can be classified as one that elicits traditional sex differences whereby the components of the illusion are biased towards males over females (Sanders, 2013). This classification can also be applied to Experiment 4. However, if this equates to men outperforming women overall due to the task, then this was not met. Conversely, if this classification implies that men's overall performance increased, relative to a sex neutral task, then perhaps this would result in equal performance rates across both sexes (see Brown's (2013) interpretation of James & Kimura's (1997) findings for another example).

Indeed, whilst men did display more accuracy than women in Experiment 5, this did not occur in far visual space. This result could be explained by the notion that stimuli and objects that are further away from the observer are smaller in retinal size and therefore appear as more central in vision (Parker, 2016; Verhoeg et al., 2016). With respect to Experiment 5 then, the task of discerning whether minute adjustments were required increased in difficulty when the stimuli were in far visual space. Whilst this expectation was somewhat met, the degree of difficulty was not as substantial as what would have been expected. That is, whilst performance in far visual space was significantly different to that of near visual space, the effect was small.

It was additionally argued that greater visual acuity experienced by men would result in less inaccuracy than women in far visual space (Abramov et al., 2012). Indeed, Figure 3.5 does demonstrate a trend in this direction, however it was not significant.

Although near and far visual space was not manipulated in Experiment 6, the premise behind the paradigm was. Specifically, Sanders et al.,'s (2007) and Sanders & Walsh's (2007) findings suggest that women have an advantage within near visual space due to their gathering past. The inference from this is that depth perception (which relies on binocular viewing) is beneficial to this task and allows for efficient gathering. Furthermore, this suggests that performance during a monocular viewing task would be worse, relative to binocular viewing for women. This interpretation is novel and has not been previously assessed within the literature.

In sum, the present chapter aimed to assess the hunter gatherer hypothesis in relation to visual perception. It primarily proposes that the social roles of early hominoids required specific cognitive mechanisms that resulted in evolved sex based advantages (Silverman & Eals, 1992; Eals & Silverman, 1994; Silverman et al., 2000). Experiment 4 failed to support the notion that men would demonstrate superior multiple object tracking skills in relation to women, and that this would be emphasised in far visual space due to greater visual acuity (Sanders et al., 2007; Abramov et al., 2012). Experiment 5 found that whilst men made less perceptual judgement errors than women across visual space for the Poggendorff illusion, neither sex presented the desired pattern (Ling et al., 2006; Sanders et al., 2007;

Knudson et al., 2012). Finally, Experiment 6 confirmed that monocular viewing is detrimental to performance (Read et al., 2013), however the expected disadvantage was not found for women. Sanders et al.,'s (2007) sex based visual space hypothesis was not therefore supported.

Chapter 4

"Listen very carefully; I shall say this only once."

Michelle Dubois

'Allo 'Allo

4.0 Parental investment theory and the hunter gatherer hypothesis.

Over the last two decades, cognitive inhibition has been an area of research that has received an increasing amount of attention. Bjorklund and Harnishfeger (1995) posited that successful cooperation, leadership, and social cohesion, within early hominid groups required the ability to withhold responses and behaviours that may have resulted in negative outcomes. Bjorklund and Harnishfeger furthered their argument by utilising Trivers' (1972) parental investment theory. Trivers' theory highlighted the contrasting degrees of 'investment' that males and females dedicate to their offspring. For example, human females have relatively large, immobile and limited number of sex cells, or gametes, compared to males. They additionally have a gestation period of nine months that results in offspring who are physically immature and require further investment for a number of years after (see Chapter 1 for more information). Trivers' conclusion is that females will consequently be more selective in regards to mating partners due to the unequal investments. Following on from Trivers' theory, Bjorklund and Kipp argued that this selectivity resulted in the necessity to inhibit particular behaviours and responses in order to assist in the selection of the best mate. They additionally suggested that the evolutionary pressure on females resulted in an inhibition ability that extended beyond inhibiting maladaptive sexual and aggressive responses, and underwent exaptation for similar abilities and scenarios (Gould & Vrba, 1982). For example, in tasks measuring abilities such as the delay of gratification, impulse control or the control of emotional responses, Bjorklund and Kipp suggest that women should demonstrate an inhibitory advantage over men, as these traits may have been key to ensure their survival and reproductive success.

Bjorklund and Kipp (1996) proposal can be said to be domain specific. That is, they suggest that any inhibitory advantage that women have will not be present in any situation that isn't directly associated with inhibiting sexual arousal or issues with regards to child rearing. This is in line with Cosmides and Tooby's (1987) view, whereby cognitive information processing mechanisms evolved due to pressures experienced in the environment of evolutionary adaptiveness to cope with specific problems. Therefore the authors noted, that a female advantage could occur in social tasks that investigate control of emotional responses; in behavioural tasks that investigate control over temptation resistance; and in cognitive tasks where the participant is required to inhibit one particular response in preference to another, e.g., the Stroop task (Stroop, 1935). Bjorklund and Kipp reviewed numerous papers and identified support for a female advantage in withholding emotional responses in children (Feldman & White, 1980) and young adults (Friedman & Miller-Herringer (1991), with respect to social inhibition. For behavioural inhibition tasks, resisting temptation and delayed gratification, young female participants were more likely to succeed in comparison to young males (Kochanska, Murray, Jacques, Koenig & Vandegeest, 1996). In terms of motor inhibition or impulse control boys were rated as more likely to be impulsive than girls by their teachers (Bjorklund & Butler, 1973). For cognitive inhibition, Bjorklund and Kipp noted that young girls made fewer errors than boys in a matching task (Salkind & Nelson, 1980), girls were less distracted by irrelevant stimuli compared to boys (Day, 1978), which is in contrast to more recent findings by Bayliss et al., (2005) and Stöet (2011), and finally no differences were found for the Stroop task. The authors believe that cognitive inhibition abilities are not directly related to mate choice or child rearing abilities and therefore parental investment theory. If sex differences are subsequently found, they argue that it could be evidence of a domain general inhibition ability, whereby evolutionary pressures resulted in these abilities generalising to all areas of human behaviour that require an inhibitory response. If no differences are found in cognitive tasks, then this indicates the domain specific nature of inhibitory abilities.

Conversely, since the publication of Bjorklund and Kipp's (1996) paper, recent research examining sex differences in cognitive inhibition tasks have found differences between men and women. These tasks are reported to include those that require focused attention, removal of irrelevant stimuli from attention and working memory, and inhibiting motor responses (Yandon, Bugg, Kisley & Davalos, 2009). Bayliss et al., (2005) identified that women were more distracted by irrelevant stimuli, and Stöet (2011), as reviewed in Chapter 2 of the present thesis, corroborated their results. Taken under the context of cognitive inhibitory abilities, female participants were slower to respond to targets. This indicates greater inhibition due to the inability to prevent irrelevant stimuli from occupying attentional processes. Stöet investigated this attentional difference in more depth and established that women were slower to respond to targets in the presence of distractors (2010), slower at visual search (2011), and responses are slower after mistakes are made during a Simon task (2016) when compared to men. This indicates moderate support for the notion that inhibition abilities in women may have generalised across other domains.

Cognitive inhibition is typically measured by the effect the stimulus has on RT, i.e., the slowing of RT in response to a target stimulus. A common example is IOR (Posner & Cohen, 1984); the slowing of responses to stimuli presented at a previously attended region and/or object. To recap, the paradigm employed to index this type of inhibition involves the presentation of three horizontal boxes. One peripheral box is 'cued' via an increase in luminance, thus attracting attention. Attention is then redirected back to central box, via a second cue, followed by a target appearing in one of the two peripheral boxes. The participant is required to press a button as soon as they perceive the target. A target appearing in a cued box elicits slower RT than one appearing in an uncued box, if the cue-target interval is over approximately 300 ms. Thus, the inhibition manifests itself in terms of slower RTs to detect a target at a previously attended location.

Importantly, IOR is thought to have a large *motor* component. Indeed, some argue that the effect is solely a motor phenomenon (i.e., Chica, Taylor, Lupiáñez & Klein, 2010; Cowper-Smith, Eskes & Westwood, 2013; Cowper-Smith & Westwood, 2013). This notion suggests the slowing of RTs to previously cued objects/locations is not because attention is slower to return; rather, it is because the motor system is slower to act upon the cued object/location. This has been demonstrated by research examining saccadic IOR, whereby eye movement responses to visual targets are delayed when the target appears in a previously responded-to location (i.e., Taylor & Klein, 2000; Wang, Satel & Klein, 2012; Cowper-Smith, Eskes & Westwood, 2012). Further support comes from the finding that motor IOR is elicited via an upper limb reaching movement, and not from response keys being spatially consistent with targets (Welsh et al., 2005; Cowper-Smith, Harris, Eskes & Westwood, 2013; Cowper-Smith et al., 2013).

The IOR mechanism has been proposed as an evolutionarily advantageous searching or foraging mechanism that avoids repetition towards already visited areas (Posner & Cohen, 1984; Tassinari, et al., 1994; Klein, 1988; Taylor & Klein, 1998; Klein, 2000; Wang & Klein, 2010). However, from an ecological perspective, systematically shifting attention by responding to different locations is an efficient strategy for static targets only. If the target of interest were dynamic (i.e., in motion), then inhibiting the location of the target would be an inefficient strategy. Tipper, Driver and Weaver (1991) addressed this issue and examined whether IOR could be linked to the object within the location, rather than the location itself. They achieved this by modifying the original paradigm (Posner & Cohen, 1984) to directly test the object–location based issue. After the cue had been presented, the two peripheral boxes rotated 90° clockwise. Tipper et al., theorised that if IOR was based upon the location of the target, then RTs for the cued and uncued boxes should be equivalent. Conversely, if IOR is based upon the object representation, then the effect should be present. That is, RTs for the cued box should be longer than the uncued box. Indeed, that is what was found. Tipper, Weaver, Jerrat and Burak (1994) assessed this further and included two vertical boxes in the display. Thus, when the cued box moved by 90° clockwise, it moved to an uncued location, and if IOR occurred for stimuli presented within the uncued location it represents object–based IOR. Whereas if targets appeared in the unoccupied previously cued location and elicited inhibition; it provides support for location–based IOR. Both manipulations resulted in slower RTs for cued boxes and locations as opposed to uncued boxes and locations. Indeed, it has been argued that IOR is a multicomponent mechanism that utilises low level (location based) and high level (object based) neural systems (Fuentes, Boucart, Vivas, Alvarez & Zimmerman, 2000). These findings are consistent with conclusions drawn by Brown and Guenther (2012). Here, the authors used M/dorsal biased (i.e., low spatial frequency targets), and P/ventral biased (i.e., high spatial frequency targets) stimuli to measure location-based IOR. They found that P/ventral biased stimuli elicited greater IOR than M/dorsal biased stimuli.

Brown (2013) assessed sex differences in cognitive inhibition using the IOR paradigm employed by Brown and Guenther (2012). The findings demonstrated that female participants were slower to respond to stimuli appearing in the same location in comparison to male participants, and that this effect was most pronounced when the stimuli were targeted towards the P-pathway. Brown bases the rationale for his research upon the sexual division of labour within hominoid evolution (Tooby & DeVore, 1987; Silverman & Eals, 1992), whilst Bjorklund and Kipp (1996), proposed that inhibition abilities evolved due to mate choice and child rearing demands.

Contemporary research has posited that the cognitive processes behind any differential abilities between men and women were shaped by activities that were carried out cooperatively (Skarratt, et al., 2010; Skarratt, Cole & Kuhn, 2012; Doneva, Atkinson, Skarratt & Cole, 2015). As mentioned, Klein's (1998) proposal put forward the IOR mechanism as a foraging facilitator. Recent findings assessing this phenomenon have established that IOR also occurs when two people cooperatively perform a target detection task, (i.e., 'social IOR'; Skarratt et al., 2010). In the basic paradigm, two individuals alternate reaching responses, in which they touch a target presented visually on a flat touch screen monitor located between the co-actors (see Figure 4.7; Welsh et al., 2005; Skarratt et al., 2010; Doneva et al., 2015). The findings revealed that IOR occurs when participants respond to a target presented at the same location that their co-actor had just responded to. In other words, this suggests that humans inhibit reaching to a location that another person has just reached to. Research assessing the properties and characteristics of this mechanism has demonstrated that the effect occurs only for a real person co-actor and not a virtual co-actor (Skarratt et al., 2010); is not modulated by endpoint goals (Cole et al., 2012); occurs even when co-actor's target stimuli are occluded from view (Welsh et al 2005) and when both target and response are occluded (Skarratt et al., 2010); and the effect is not modulated by the co-actors affect (Doneva et al., 2015). Furthermore, this reaching inhibitory effect also occurs *within* individuals; participants are slower to respond to a target that is presented at a location that they themselves recently reached to. That is, humans are slower to repeat a motor action (e.g., Welsh et al, 2005; Cowper-Smith et al., 2013; Cowper-Smith & Westwood, 2013), providing further support for the theory that IOR has a motor component.

The joint-action search and efficient foraging argument is substantiated when anthropological research is taken into account. Subsistence gathering has been reported as an activity that is carried out in groups as opposed to individually due to an increase in efficiency; more subsistence can be gathered when more individuals are present (Imamura-Hayaki, 1996; Hawkes, O'Connell & Blurton Jones, 1997). Furthermore, the notion that an individual's search activity can influence the search efficiency of another person suggests additional support for existing anthropological findings that demonstrate increased cooperativeness when completing a beneficial task (Hawkes et al., 1997; Hawkes, Hill & O'Connell, 1982; Sinervo, 1997; Panter-brick, 2002), providing insights into the hunter gatherer hypothesis (Silverman & Eals, 1992; Eals & Silverman, 1994). These insights are particularly pertinent to the cognitive abilities that developed from the supposed division in labour and Brown's (2013) findings that propose greater IOR occurs in women due to their gathering past (Hawkes et al., 1997; Panter-Brick, 2002; Silverman et al., 2000; Cashdan et al., 2012). Thus, it would be inefficient for a fellow forager to search an area a colleague has just attended to.

As the primary interest of this chapter is cognitive inhibition, Posner and Cohen's (1984) IOR effect will be employed to assess the female IOR effect (Brown, 2013). IOR is a robust effect; therefore it would be expected to be present in tasks where locations are repeatedly revisited and/or motor responses are made, as was the case in all experiments in Chapter 2. If a sex difference were found in motor inhibition, in which the effect is larger in females, this would support the foraging hypothesis as put forward by Klein's (1988). Conversely, if no sex differences are found, then this would be more in line with Bjorklund and Kipp's (1996) interpretation that dimorphic inhibition abilities would not extend beyond faculties that are not directly related to mate choice or child rearing skills. To this end, what immediately follows is a reanalysis of the data collected in Chapter 2 (i.e., the first empirical chapter) to examine sex differences in any motor inhibition that may have occurred in those experiments. Two new experiments are then reported, which also examine sex differences in motor inhibition (Experiments 7 and 8).

4.1 Further Analysis

In all three experiments in Chapter 2 participant responses were limited to pressing one of two buttons depending on the stimuli presented. This enables an analysis of RTs for repeated button presses versus different button presses. Thus, the slowing of a repeated response is taken as an index of inhibition.

4.1.1 Further Analysis of Experiment 1

Recall that this experiment utilised a change blindness one shot paradigm. This was indicated by a single depression of one of two keys, to show if they noticed a change or did not.

4.1.1.1 Further Analysis Experiment 1: Results and Discussion

Using the raw data from Experiment 1, each data file was analysed in relation to key presses and the corresponding RTs. A 2x2 mixed model ANOVA with sex as the between subject factor, and key press as the within subject factor revealed no significant main effects of sex ($F(1,55) = 0.01$, $p = 0.92$, $\eta_p^2 < 0.001$), key press $F(1,55) = 0.07$, $p = 0.8$, $\eta_p^2 = 0.08$) and no significant interaction, ($F(1,55) = 0.36$, $p = 0.55$, $\eta_p^2 = 0.001$; see Figure 4.1). These findings fail to support the notion that repeating an action results in a slowed RT. Therefore, the hypothesis that slowed RT should be more pronounced in women compared to men was not supported.

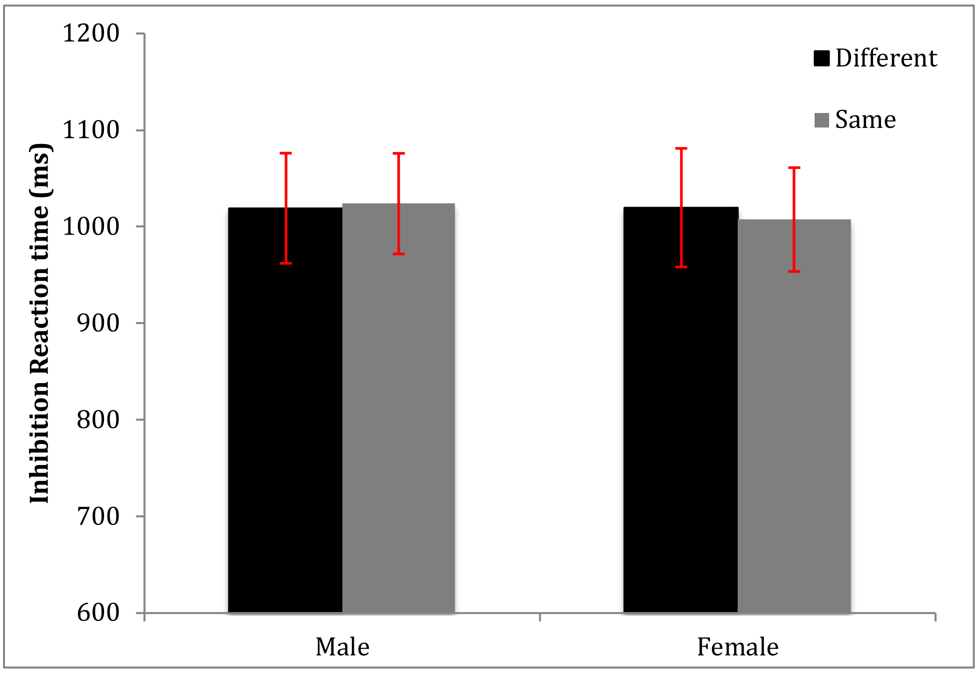


Fig 4.1 Mean RTs for different versus same key presses for men and women. Error bars represent standard errors of the mean.

4.1.2 Further Analysis of Experiment 2

Recall that this experiment employed a visual search paradigm where participants were required to press one of two keys when they found the specified target.

4.1.2.1 Further Analysis Experiment 2: Results and Discussion

As in Experiment 2, one participant was excluded from the analysis due to a condition mean RT of 5s. A 2x2 mixed model ANOVA with sex as the between subject factor, and key press as the within subject factor revealed no significant main effects of sex ($F(1,68) = 0.21$, $p = 0.65$ $\eta_p^2 = 0.003$) or interaction ($F < 1$). However, a significant main effect of key press was found ($F(1,68) = 6.32$, $p = 0.01$, $\eta_p^2 = 0.09$; see Figure 4.2), whereby responses were faster for repeated key presses as opposed to different ones; indicating a 'task switching' effect (i.e., Monsell, 2003). Although inhibition of a repeated response is a well-established phenomenon (e.g., Mackay, 1987; Welsh et al., 2005), processes and mechanisms associated with 'task switching' are likely to have been larger and thus overridden any inhibition effect. A task switching cost occurs when a participant is required to switch task or set. Pressing a different button compared with the previous response clearly involves switching set (e.g., from S to H). As in the further analysis of Experiment 1, these results do not support the predictions made regarding differential inhibition abilities between the sex differences.

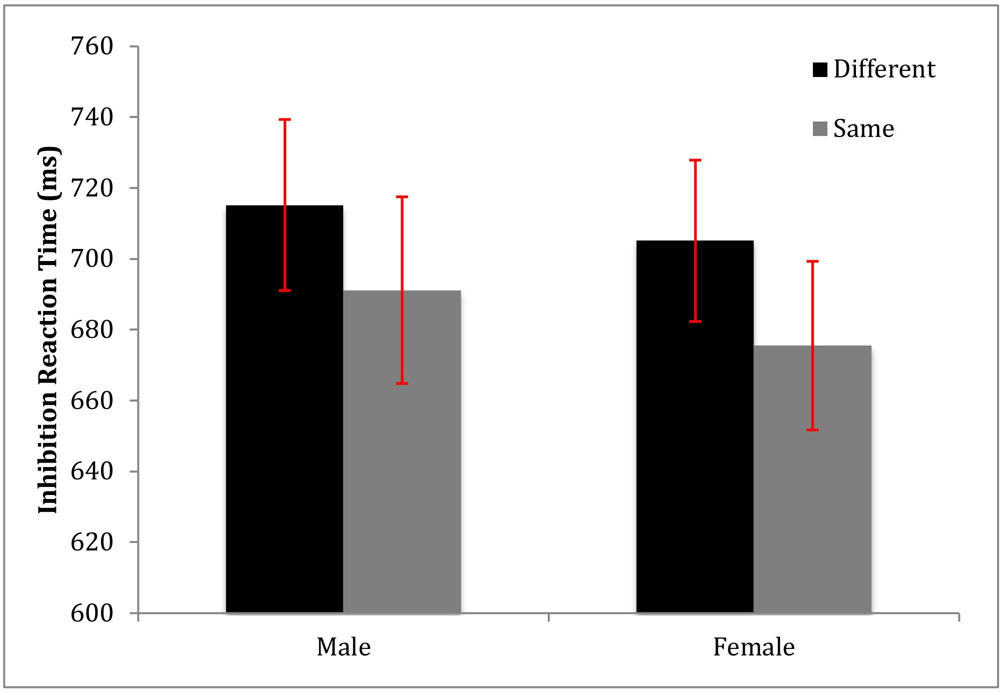


Fig 4.2 Mean RTs for different versus same key presses for men and women. Error bars represent standard errors of the mean.

4.1.3 Further Analysis of Experiment 3

Experiment 3 utilised a classic flanker paradigm, whilst also assessing the participant's visual space (near and far). Again, participants were required to press one of two keys.

4.1.3.1 Further Analysis Experiment 3: Results and Discussion

As in Experiment 3, two participants (one female) were excluded due to an error rate of more than 20%. A 2x2 mixed model ANOVA with sex as the between subject factor, and key press as the within subject factor revealed no significant main effect of sex, ($F < 1$, $p = 0.68$, $\eta_p^2 = 0.002$), no two-way interactions between sex and key press ($F < 1$, $p = 0.98$, $\eta_p^2 < 0.001$), sex and space ($F(1,70) = 0.04$, $p = 0.85$, $\eta_p^2 = <0.001$) and between space and key press ($F(1,70) = 0.46$, $p = 0.5$, $\eta_p^2 = 0.007$) The three way interaction was also non significant ($F(1,70) = 0.01$, $p = 0.90$, $\eta_p^2 < 0.001$). However, the main effects of key press ($F(1,70) = 5.5$, $p = 0.02$, $\eta_p^2 = 0.07$) and space ($F(1,70) = 41.43$, $p < 0.001$, $\eta_p^2 = 0.37$) were significant (See Figures 4.3 and 4.4).

Again, predictions regarding visual space were confirmed; participants were overall, slower to respond to stimuli presented in far visual space as opposed to near visual space (e.g., Sanders et al., 2007). This is in line with the findings of the present Experiment 3. Stimuli presented further away from the observer appear smaller and closer together (O’Shea et al., 1994). As a result, the flanking stimuli were more central and therefore increased the perceptual grouping during the discrimination task, resulting in slower RTs across far visual space. In addition, whilst these findings failed to support the present prediction, they are in line with existing research that identifies a task switching effect (Monsell, 2003).

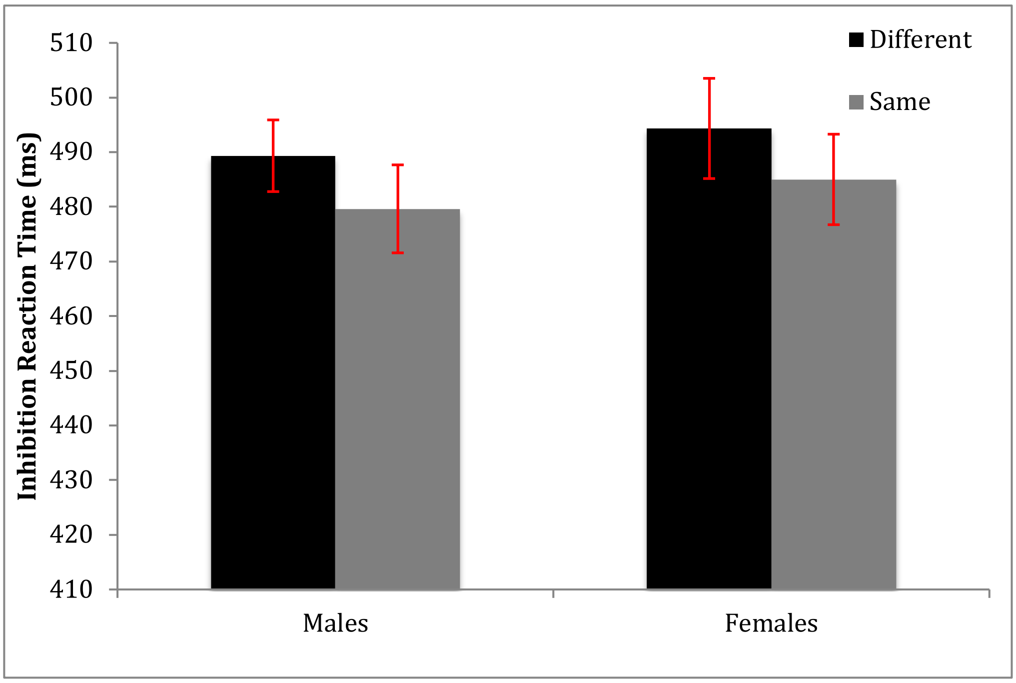


Fig 4.3. Mean RTs for different versus same key presses in far visual space for men and women. Error bars represent standard errors of the mean.

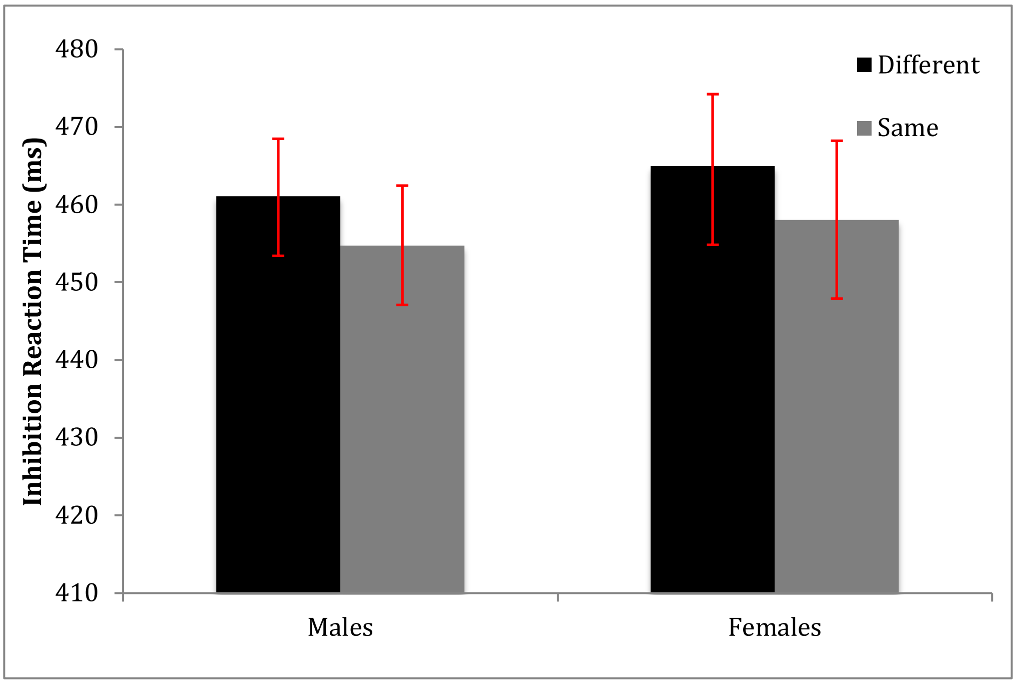


Fig 4.4. Mean RTs for different versus same button presses in near visual space for men and women. Error bars represent standard errors of the mean.

Overall, the present reanalysis of the experiments undertaken in Chapter 2 have not supported the evolutionary-based predictions. For both males and females, repeated actions were found to be faster than different actions in two of the three experiments. That is, an inhibitory effect was not found. Therefore, in the following experiment, a replication of a previously reported inhibition sex difference was undertaken.

4.2 Experiment 7

As mentioned, Brown's (2013) paper established that across stimulus type (low or high spatial frequency), women were slower to respond to a previously attended location than men. The IOR effect, using the basic IOR procedure was more pronounced when high spatial frequency stimulus patches were employed. Thus, the present experiment aimed to replicate their findings by presenting participants with high spatial frequency stimuli patches in the standard IOR paradigm (Posner & Cohen, 1984).

4.2.1 Method

4.2.1.1 Participants:

All 44 participants (23 female, 21 male) were recruited from the University of Essex for either course credits or monetary reimbursement.

4.2.1.2 Stimulus and apparatus:

Three horizontal boxes were centrally placed equidistant from each other, on a black screen. The left and right boxes were light grey with a darker border. The central box was black with a dark border and a green dot as fixation (see Figure

4.5). The experiment was carried out in a well-lit room on an iMac with a 1920 x 1080 resolution display.

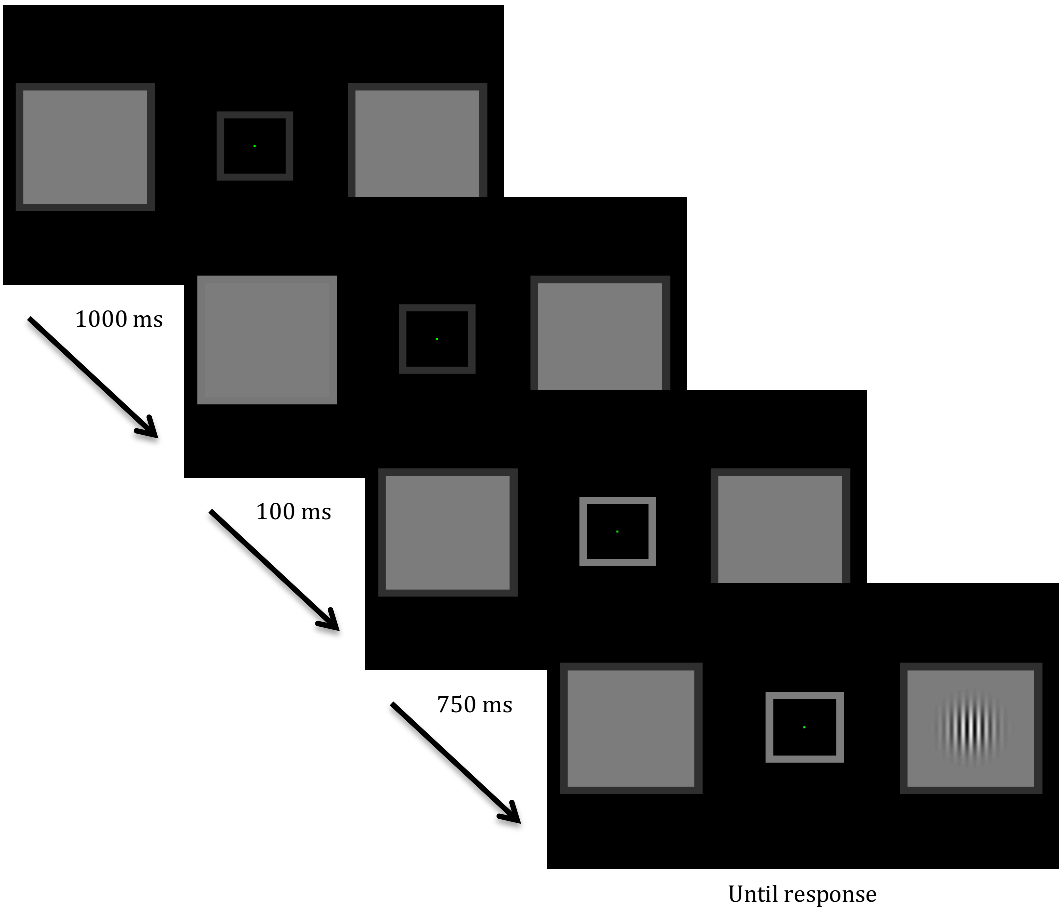


Fig 4.5. An example of an incongruent location trial.

4.2.1.3 Design and procedure:

A 2x2 mixed design was employed, with sex as the between participant factor and location as the within subject factor. There were 44 trials per location congruency (i.e., the cue and target appearing in the same location or different locations). In addition, there were 14 catch trials where the participants were required to withhold their response.

The participants were instructed to maintain fixation at the central square throughout the experiment. Each trial began with the presentation of a fixation point for 1000ms prior to the cue appearing. A cue was the left or right box increasing in luminance for 100 ms before attention was brought back to fixation by a luminance increase for 750 ms. After this, the target appeared in either the left or the right box. Participants were required to respond via a single button press upon detecting the target, and to withhold the response when no target appeared (i.e., on catch trials).

4.2.2 Results and Discussion

Means are presented in Figure 4.6. A mixed model ANOVA revealed a main effect of location congruency ($F(1,42) = 34.0$, $p < 0.001$, $\eta_p^2 = 0.45$) and no effect of sex was found ($F(1,42) < 1$, $p = 0.61$, $\eta_p^2 = 0.006$). The interaction was also not significant ($F(1,42) = 0.27$, $p = 0.60$, $\eta_p^2 = 0.006$).

As above, these results support previous research demonstrating the IOR effect, specifically that motor responses are slower for a repeated location versus a different one (e.g., Posner & Cohen, 1984; Tassinari, et al., 1994; McAuliffe et al., 2006). However, crucially these results fail to support Brown's (2013) findings; the effects of IOR were equivalent across both sexes. This in turn does not support the general evolutionary based hypothesis, i.e., that females will show greater inhibition on a task thought to be related to foraging.

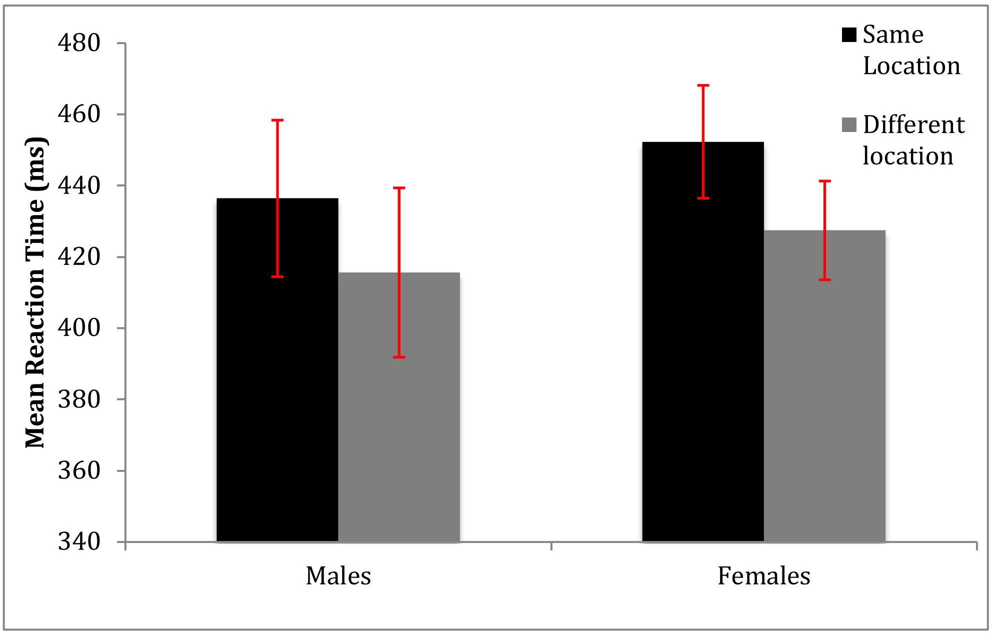


Fig 4.6 Mean RTs for the same versus different spatial locations as a function of sex. Error bars represent standard errors of the mean.

4.3 Experiment 8

The premise of the present experiment was to establish whether IOR is enhanced under conditions in which males and females perform a social, or joint, search task. Given the notion that IOR is a foraging facilitator (e.g., Klein, 1988; 2000) and also the idea that females gathered cooperatively with other females (Hawkes, et al 1997), we should expect that any foraging inhibition effect to be larger when females are searching cooperatively with other females, as opposed to when males search with other males. Thus, we examined sex differences in a joint search/detection task in which pairs of participants undertook the basic social IOR paradigm. Importantly, the pairs of participants were two females, two males, or one male and one female. To reiterate, due to the social role of females as gatherers, an activity that is proposed to have occurred in groups, the hunter gatherer hypothesis predicts that the social IOR effect should be greater in female pairs compared to male and mixed sex pairs. Thus, it would be expected that greater IOR would be found for same sex co-actors as opposed to opposite sex co-actors. Crucially, this should be more pronounced for female co-actors compared to male and mixed sex co-actors.

4.3.1 Method

4.3.1.1 Participants:

There were 48 participants (24 males). All volunteers were either first year Psychology undergraduates who took part in exchange for course credits or other members of the university who participated for monetary reimbursement. All participants were naïve to the aims of the experiment and gave informed consent. The University of Essex's ethical committee provided approval.

4.3.1.2 Stimulus and apparatus:

All stimuli were presented on a 22” LCD monitor that was built into a tabletop where each participant sat opposite each other, (see Figure 4.7). A touch-screen monitor was placed on top of the LCD monitor in order to record each motor response made by the participants. This monitor was approximately 740 mm above the floor and the participants sat approximately 240 mm from the ‘home’ button. A black square measuring 10 mm in width (0.3 cd/m^2 measured on screen) was presented centrally on the display and acted as the fixation point on a white background (67.3 cd/m^2). Two other squares of the same size and luminance flanked the central square. Each trial was instigated by the rapid onset and then offset of one of the flanking squares (i.e., they flashed), the participants responded to the target by removing their hand from the ‘home’ button and touching the target. An RM Pentium, running custom software controlled stimulus generation and recorded responses.

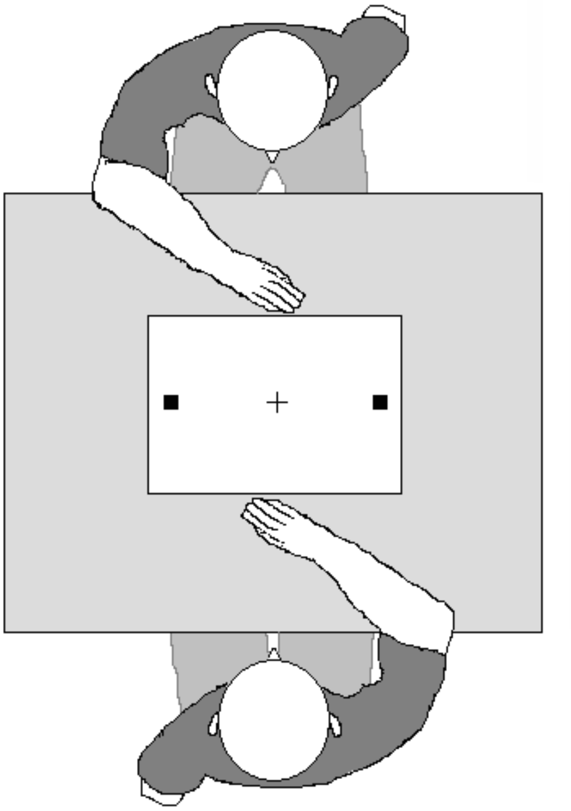


Fig 4.7 A topographical view of the social IOR apparatus.

4.3.1.3 Design and procedure:

The experiment employed a 2 x 3 mixed design, with partner type (female co-actors, male co-actors and mixed sex co-actors) as the between subjects factor and target location (repeated and opposite) as the within subjects factor.

The participants were asked to make reaching movements to the targets with their preferred hand, resting it on the home button in between trials. Responses were completed in an alternation sequence where co-actor A responds and then co-actor B makes a reaching motion (i.e., ABABABABAB…etc.). The participants were asked to maintain fixation on the centre square until they were required to make their response, during which they were asked to fixate the target. Participants were instructed to respond as quickly and as accurately as possible and that other than to pay attention to the alternating responses; they should ignore their partner's response. The time interval between the target appearing and the 'home' button being released was recorded (i.e, RT), as well as the time interval between the release of the 'home' button and contact with the touch screen (i.e., movement time; MT). There were 209 trials in total, 104 within subject trials and 105 between subject trials presented to the participants. In addition, no target appeared on the same side of the screen for more than four instances in a row. As social IOR measures the performance of one trial against another, the first trial of each block was not analysed, resulting in 104 trials per participant per block.

Each participant completed the social IOR task three times, once against the same sex co-actor and twice against each opposite sex co-actors, allowing for a direct assessment of social based sex differences in IOR. Four participants attended each session (2 female, 2 male), this layout resulted in an unequal sample size for mixed sex pairings, however excluding half of the mixed sex data did not alter the significance of the overall ANOVA.

4.3.2 Results and Discussion

Due to a technological malfunction, one session of four participants (2 female) was excluded from the analysis. Figure 4.7 illustrates the mean RTs for the six conditions.

A mean RT for each pairing combination was calculated, rather than for each individual, by averaging the mean RT for each pair, (e.g., $male_1$ with $male_2$, $female_1$ with $female_2$, $male_1$ with$female_{1,}$ and $male_2$ with $female_2$), for each target location, resulting in one mean RT, per location, per pair.

A mixed ANOVA with location congruency (repeated or opposite) and pairing type (female with female, male with male and mixed sex) revealed a significant main effect of location congruency, $F(1,85) = 268.88$, $p < 0.001$, $n^2_p = 0.76$, confirming the presence of social IOR, in that participants responded to opposite locations to that of their co-actor faster than repeated locations. The main effect of pairing type was also significant, $F(2,85) = 6.1$, $p < 0.01$, $n^2_p = 0.13$, indicating that the sex of the participants influenced RT responses. Additionally, the interaction was also significant, $F(2,85) = 4.87$, $p = 0.01$, $n^2_p = 0.10$, such that the social IOR effect was modulated by the partner combination.

Follow up analysis revealed that for all pairing types, participants were faster to respond to the opposite location than the repeated location (all t's > 7.99, all p's < 0.001). In other words, social IOR was present for all pairing types. A comparison of critical importance is whether the effect of social IOR is greater in the female pairing than the male pairing, this was confirmed with a significant interaction in a 2 (pairing type: male versus male and female versus female) by 2 (target location: repeated or opposite) analysis of variance, $F(1,42) = 7.96$, $p = 0.007$, $n^2_p = 0.16$.

Overall these data *do* support the hunter gatherer hypothesis. Foraging, as indexed with social IOR, was greater when performed by two female co-actors, as opposed to two male co-actors, or mixed sex pairings.

4.3.2.1 A confounding issue:

It must be noted that there is a co-actor confound within this design. All participants within the mixed sex are also present in either the female only co-actors, or the male only co-actors, resulting in the Pairing Type variable not being a fully between subjects variable. An alternative statistical procedure would be to employ multilevel modelling, as this would firstly account for the nesting of participant groups, where there may be variability between the groups as well as within them. Secondly, this method will overcome the limitation of independence, and allow for a comparison between RT scores for each sex and their same or different sex co-actor. Additionally, it might be that the proportional differences between the levels of location (i.e., repeated and opposite) may not differ significantly for the female and male only pairings. Thus being able to assess each sex in relation to their co-actor may provide more insight into this finding.

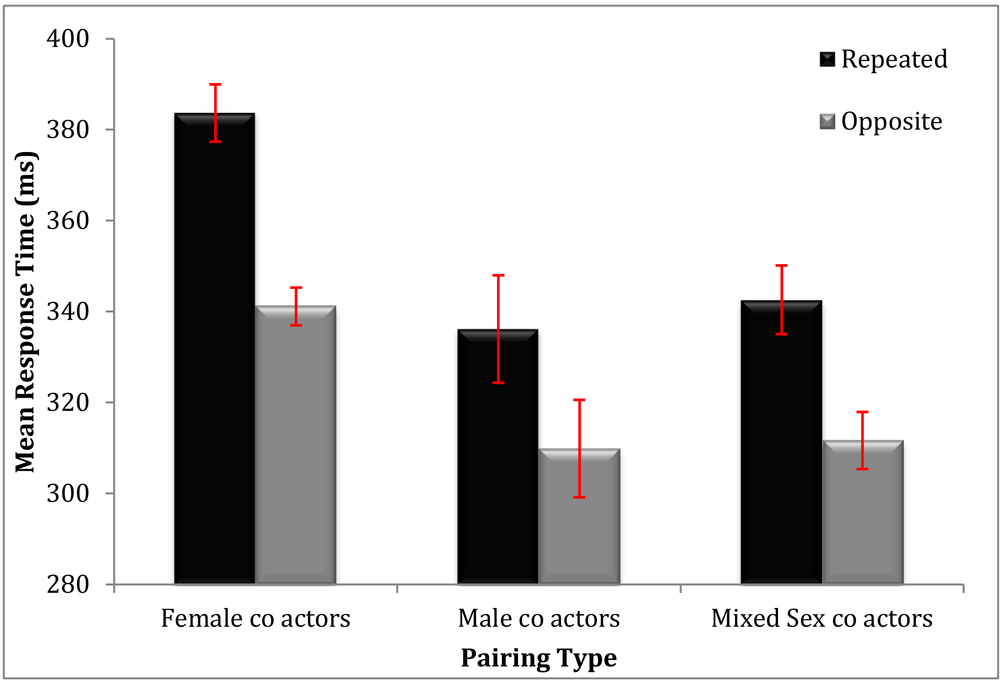


Fig 4.8 Mean RTs to locating targets as a function of pairing type and target location. Error bars represent standard errors of the mean.

4.4 Discussion

The present chapter investigated differences in cognitive inhibition abilities in relation to men and women. Specifically, the premise proposed that women would display greater inhibition effects compared to men due to the distinct pressures exerted on the sexes during human evolution.

For Experiments 1, 2 and 3 (reported in Chapter 2), participants responded to the targets by one of two single key presses (i.e., they provided a motor response). The choice of one of two options allowed for the analysis of motoric RT responses (Taylor & Klein, 2000). Experiment 1 employed a 'one shot' detection task, and failed to support any predictions made; RTs were equivalent for novel and repeated locations, and between men and women. Experiment 2 utilised a visual search task. Again, RTs were similar between the sexes, however a task switching effect (e.g., Monsell, 2003) was found, as opposed to motor inhibition, failing to correspond with existing research by Klein and colleagues (e.g., Taylor & Klein, 2000; Wang & Klein, 2010). Experiment 3 employed a flanker task in near and far visual space. Once again, a motor task switching effect was present in both visual space conditions, but was not modulated by it. In line with Experiments 1 and 2, no sex differences were found for Experiment 3. Experiment 7 employed a classic cuing paradigm (Posner & Cohen, 1984; Klein, 1988). Following Brown's (2013) findings, the targets displayed were high frequency grating patches. Once again, an inhibition effect was observed (i.e., IOR). However, in contrast to Brown, women did not demonstrate greater IOR than men. Experiment 8, made use of the social IOR paradigm (e.g., Welsh et al., 2005; Skarratt et al., 2012; Doneva et al., 2015) and manipulated the participant's pairing type combination. As predicted, social IOR was found; across all pairing types participants were slower to respond to targets presented at repeated locations as opposed to a novel, i.e., opposite, locations. In line with the general premise of Klein's (1988) foraging proposal and the hunter gatherer hypothesis (Silverman & Eals, 1922; Eals & Silverman, 1994;

Silverman et al 2000) IOR was more pronounced in female co-actor pairings than in male or mixed sex co-actor pairings.

Under the context of parental investment theory (Trivers, 1972), Bjorklund and Kipp (1996) argued that inhibitory differences between men and women in social and behavioural inhibition are due to differential evolutionary pressures for mate choice and child rearing skills. They posited that this does not extend to cognitive inhibition because it is unrelated to the differential evolutionary pressures, suggesting that women's inhibitory abilities are domain specific. If sex differences did occur for cognitive inhibition tasks, Bjorklund and Kipp proposed that this would indicate a domain *general* ability, whereby women's inhibition skills 'overflowed' or generalised to other areas of behaviour that requires a response to be withheld. Indeed, a number of studies have now demonstrated that there is a difference between the sexes and cognitive inhibition abilities, where women are more distracted by irrelevant stimuli (e.g., Bayliss, et al., 2005; Stöet, 2010), and demonstrate slower RTs for high spatial frequency stimuli in an IOR task (e.g., Brown, 2013). However, these findings can also be argued within the context of the hunter gatherer hypothesis in which the prehistoric roles of men and women, as hunters and gathers, resulted in the development of specific cognitive abilities and advantages. Klein's (1988) foraging proposal built upon this theory and suggested that efficient visual search for edible items required a mechanism that prevents individuals from repeatedly searching the same area. Furthermore, existing anthropological data support this notion and demonstrates that gathering is a group activity that is predominantly carried out by women (Hawkes, et al., 1997). Therefore, in relation to these theories, Stöet (2010) and Brown (2013) proposed that women would be slower to respond to targets when surrounded by irrelevant stimuli, as due to their gathering past they would need to process all necessary and available stimuli in a visual search (Stöet, 2010) and reorientate towards novel locations (Klein, 1988; Brown, 2013).

Thus, the present work demonstrates mixed support for previous findings and interpretations. Klein's (1988; 2000) foraging proposal and the general premise of the hunter gatherer hypothesis (Silverman & Eals, 1992) suggest that women as gatherers ensure efficiency by favouring a reorientation mechanism that redirects them to novel locations. However, under examination this conclusion is not fully supported. Indeed, with respect to Bjorklund and Kipp's (1996) interpretation regarding sex based differences in cognitive inhibition, the reanalysis of Experiments 1 to 3 and Experiment 7 provide support for the notion that differential cognitive inhibition abilities between men and women are not domain general. That is, the ability to inhibit a response for recently responded to locations is not related to mate choice selection or child rearing inhibition abilities.

The findings for Experiment 8 however, do not support this interpretation; rather it suggests that a domain *general* inhibition ability may be related to efficient foraging (Bjorklund & Kipp, 1996). The degree of social IOR demonstrated by male co-actor pairs did not differ from mixed sex pairs. This provides support for Brown's (2013) proposal that males are biased towards location-based attention, which proposes that they are able to disengage from the previously attended location faster than females. In addition, this finding provides a novel insight into Stöet's (2011) visual search task conclusions. In his paper, Stöet finds that men are more efficient at searching a visual scene in comparison to women. However, if research regarding visual search based IOR is taken into account, then Stöet's findings correspond with Brown's suggestions and also provide support for Klein's (1988) foraging proposal.

Female co-actors were slower to respond to a location their co-actor had previously visited, in comparison to male or mixed sex co-actors. As previously mentioned, the prediction and findings are based on the premise that efficient gathering encouraged a bias away from already responded to stimuli and locations (Klein, 1988; 2000; Wang & Klein, 2010). Furthermore, the efficiency and efficacy of the task relies on Gatherer A not only being biased away from areas they have just attended to, but also from areas Gatherer B has interacted with. This results in the implication that the efficiency of teamwork and therefore the task of completing the same goal are influenced by the sex of the co-actor. However, research examining the social IOR paradigm has established that the final kinematic movement, that is, the end point goal, does not modulate the magnitude of the effect (Cole et al., 2012). Welsh, Manzone and McDougall (2014) confirmed that knowledge of a completed action alone is not enough to elicit the inhibitory mechanism associated with the social IOR effect if the completed action is not visually observed. In addition, the components of the final goal are not limited to the termination of the action. Rather, observing an arm movement could induce the social IOR effect, or it could capture attention, resulting in the shift of attentional processes (Doneva & Cole, 2014; Cole, Atkinson, D'Souza, Welsh & Skarratt, 2017). Indeed, any bias towards inhibited response times to repeated locations for female co-actors would be supported by the notion that women are susceptible to the attention capturing properties of peripheral stimuli (Silverman & Eals, 1992; Stöet, 2010; 2011).

With regards to all the experiments, ranging from the reanalysis of Experiments 1-3 and more direct assessments of IOR on the individualistic and social levels, this chapter investigated cognitive inhibition abilities between men and women. The majority of the present findings support the notion that differential inhibition abilities between the sexes would not arise unless related to mate choice or child rearing skills, (Bjorklund & Kipp, 1996). However, the final experiment suggests that this view may not apply to joint action foraging behaviour.

Chapter 5

"I solemnly swear that I am up to no good,

...

Mischief managed."

The Weasley twins

Harry Potter and the Prisoner of Azkaban

J. K. Rowling

5.0 General Discussion

The present thesis primarily explored the hunter gatherer hypothesis (Silverman & Eals, 1992) and also parental investment theory (Trivers, 1972) using visual cognitive paradigms. The general premise was derived from the notion that evolutionary environments fostered and favoured specific adaptations in their inhabitants. In the years subsequent to the publication of Darwin's Origins, these adaptations mostly concerned physical differences that might have been selected due to a combination of natural and sexual selection (e.g., Darwin, 1859; 1871; Trivers, 1972). More recently has been the proposition that functionally specific adaptations encouraged and facilitated cognitive mechanisms (e.g., Silverman & Eals, 1992). Tooby and DeVore (1987) suggested that innovative methods for food acquisition assisted the rapid development of hominoid evolution. For example, the "man the hunter" model (Tooby & DeVore, 1987) and the gathering hypothesis place emphasis on the development and use of tools for subsistence as a critical factor for human history.

Sex-based spatial abilities were initially proposed to have evolved due to mating strategies applicable to mammals (i.e., Greenwood, 1980; 1983; Gaulin & Fitzgerald, 1986) and then applied solely to humans (Silverman & Eals, 1992). According to the Silverman and Eals hypothesis, each sex evolved a different set of spatial skills and abilities for their social role. For instance, whereas long distance navigation and spatial abilities would assist men as hunters, object location memory would be beneficial for gatherers. The majority of the follow up research focused on replication (i.e., James & Kimura, 1997) and ecological validity (i.e., Silverman et al, 2007; Cashdan et al., 2012). However, recent research has begun to apply Silverman and Eals's arguments to cognition more generally (e.g., Sanders et al., 2007; Stöet, 2010; 2011; 2017; Abramov, et al., 2012). However, the findings have been mixed, suggesting support and contradictions for evolved sex differences based upon social roles (i.e., Bayliss, et al., 2005; Sanders et al., 2007; Stöet, 2010; Abramov, et al., 2012; Brown, 2013). Thus, in three empirical chapters, the present work aimed to investigate sex differences in cognition by employing attentional and perceptual paradigms.

5.1 Summary of the present findings

Chapter 2, employed well-established attentional paradigms, and assessed the hunter gatherer hypothesis with respect to visual fields and visual space. The general premise of the chapter proposed that biases towards particular visual fields or space might have evolved due to the social roles of hunting and gathering. Specifically, males as hunters would demonstrate a bias towards upper visual field and far visual space, and females as gatherers would demonstrate a bias towards lower field and near visual space.

Experiment 1 applied the assumption that visual fields and visual space are functionally equivalent (Previc, 1990). That is, the lower visual field is primarily for processing near visual space, and the upper visual field is primarily for processing far visual space. A change detection task was employed, and whilst greater overall performance occurred in the upper visual field, this was not influenced by the sex of the participant. Experiment 2 utlised the same theoretical rationale as Experiment 1 whilst using a visual search task (i.e., Stöet, 2011). Results showed increased visual search efficiency for the upper visual field but again this was not modulated by sex. The final experiment in this chapter presented participants with classic flanker stimuli that occurred in either near or far visual space. Results showed that whilst congruent flankers presented in both visual space conditions elicited faster RTs, the results were also not modulated by sex. Thus, overall the results do not support the hunter gatherer theory. Whilst both Experiments 1 and 2 found support for the upper visual field bias (Chaiken et al., 1962; Chedru et al., 1973; Previc & Naegele, 2001), this effect was not influenced by sex. Women did not demonstrate superiority in the lower visual field or in near visual space, neither did men for the upper visual field and far visual space (Silverman & Eals, 1992; Sanders et al., 2007).

Chapter 3 employed perceptual paradigms to examine the hunter gatherer hypothesis. The visual space manipulation was again employed for Experiments 4 and 5, proposing that irrespective of the task, men and women would demonstrate a bias towards far and near space respectively. Experiment 6, examined depth perception via binocular disparity.

Experiment 4 presented a multiple object tracking task in near and far visual space. The rationale was that males, as presumed hunters, should be more efficient than females at tracking moving objects, particularly in far visual space. This however was not supported. Experiment 5 employed the Poggendorff illusion and again presented the stimuli in near and far visual space. The findings indicated that greater perceived alignment was achieved in near visual space as opposed to far visual space. In addition, men made fewer errors than women in both near and far visual space, supporting existing literature (i.e., Ling et al, 2006; Knudson et al, 2012). However, predictions regarding the hunter gatherer hypothesis were not supported; the effect of sex was not modulated by visual space. Experiment 6 used the ‘buzz wire’ task to assess the influence of binocularity on depth perception.

The rationale was that binocular disparity is more important when manipulating objects within near visual space, as females (i.e., gatherers) are presumed to have done. It was predicted that the monocular viewing condition would impede the performance of women to a greater degree than men, who as presumed hunters would not have relied on binocular disparity so much. Whilst overall performance was worse for monocular viewing, this was not influenced by sex. Thus, overall, Chapter 3 supported previous work with respect to the processing of visual space and binocularity, (i.e., Sanders et al., 2007; Read et al., 2013), but did not firmly support the hunter gatherer hypothesis.

Chapter 4 assessed inhibition with respect to Bjorklund and Kipp's (1996) view on inhibition abilities and Klein's (1988; 2000) foraging hypothesis. These are based upon the parental investment theory (Trivers, 1972) and the hunter gatherer hypothesis respectively. In terms of the former, withholding a maladaptive response or behaviour, in regards to mate choice and parenting skills, in females might generalise to other cognitive tasks, i.e., basic inhibition. In terms of the latter, it was proposed that women, as cooperative foragers, would be slower than men to respond to a location just attended to by another individual. That is, IOR should be greater in females relative to males.

The further analysis section analysed RT data for repeated button presses versus different button presses for all experiments that were undertaken for Chapter 2. This analysis failed to find any motor inhibition in Experiment 1. Conversely, this analysis for Experiments 2 and 3 both found motor facilitation, and not motor inhibition; participants were faster to press the same button when required in quick succession. In addition to no motor inhibition, no sex effect was found. Experiment 7 aimed to replicate Brown's (2013) IOR findings. However, sex did not modulate RTs for same or different locations. The final experiment of this thesis, Experiment 8, aimed to assess whether social IOR is modulated by the sex of the co-actors. Based on the assumption of cooperative gathering (i.e., Hawkes et al., 1997), in conjunction with Klein's (1988) foraging proposal of IOR, it was predicted that the social IOR effect would be more pronounced when female co-actors performed the task. Indeed, this is what was found; female actors were slower to respond to a location that a fellow female co-actor had just responded to.

5.2 In relation to the literature

Stöet (2010; 2011) proposed that women, as gatherers, would be more receptive to stimuli presented in the periphery, in comparison to men. In addition, Sanders et al., (2007), Sanders and Walsh (2007), and Stancey and Turner (2010), indicated that performance abilities in visual space is modulated by the sex of the participant, in that men outperform women in far visual space and vice versa for women in near visual space. Moreover, Abramov et al., (2012) identified a male advantage in detecting high spatio-temporal frequencies, indicating a bias towards object perception, and Brown (2013) found greater IOR in females, with this effect being more pronounced for high spatial frequency patches, concurring with Abramov et al.,'s findings. However, the findings within this thesis do not support the existing literature with specific reference to the hunter gatherer hypothesis. Women did not demonstrate greater sensitivity to peripheral stimuli in comparison to men (Experiment 3; Stöet, 2010). Similarly, men did not perform better than women in far as opposed to near visual space, and women did not perform better than men in near compared to far visual space (Experiments 3-5;

e.g., Sanders et al., 2007). This effect of space was also not compatible with visual fields (Experiments 1-2; Previc, 1990; Sanders et al., 2007). Furthermore, women did not demonstrate greater inhibition levels for a location based IOR (Experiment 7; Brown, 2013), the binocular advantage was not significantly distinct between men and women either (Experiment 6). Thus, with perhaps the exception of this experiment, the evolutionary impact of prehistoric roles on human cognition was not supported within Experiments 1-7.

The final experiment in the present thesis, however, was suggestive of a hunter gatherer effect. Experiment 8 employed the social IOR paradigm with respect to the foraging hypothesis (Klein, 1988; 2000; Wang & Klein, 2010). Recall that social IOR is the phenomenon in which observing a reaching action to a location results in a delayed response when the observer is then required to reach to the same location (e.g., Skarratt et al., 2010). In Experiment 8, female co-actors showed greater social IOR compared with male co-actors and mixed-sex pairings.

Experiment 8 may thus index the cognitive mechanisms underlying one aspect of the hunter gatherer hypothesis. Indeed, the fact is that some experimental paradigms, and dependent measures, are more sensitive than others in revealing an effect. This has often been associated with differences in RT and non-RT accuracy measures (e.g., threshold reporting for stimuli presented briefly). As noted by Santee and Egeth (1982), both measures are unlikely to be the same with respect to sensitivity. RT is reflective of higher-level response forming factors, such as motor movements, whereas non-RT accuracy rates reflect low-level stimulus duration limitations, for example the change blindness task (Cole, Kuhn, Heywood & Kentridge, 2009). In other words, social IOR may just happen to be a particularly sensitive measure of the mechanisms associated with gathering.

Taken in combination with the notion that IOR is a mechanism that encourages efficient foraging (Klein, 1988; 2000), the findings from Experiment 8 do seem to suggest that the IOR (or foraging) effect is specifically enhanced in women, in a social setting. However, this may be countered by recent research. Welsh et al. (2014) found that simply *knowing* (but not seeing) where a co-actor has just reached to (via an auditory cue), is not enough to elicit social IOR (Welsh et al, 2014). Social foraging and the hunter gatherer hypothesis would presumably predict that simply knowing where another person has just searched should facilitate foraging.

An alternative interpretation of the female co-actor IOR effect in Experiment 8 is in relation to the social component of the paradigm. Bjorklund and Kipp's (1996) review of inhibition mechanisms identified that young girls and women demonstrate greater social inhibition abilities (i.e., cooperation or the concealment of emotions) than their male counterparts (Friedman & Miller-Herringer, 1991). Indeed, Eagly & Wood (1991) note that, whilst this difference is not absolute, men and women tend to develop traits related to agency, and communal and expressive behaviour, respectively. That is, boys are reported to be more aggressive than girls, and girls as more friendly, demonstrating less physical aggression, concurring with Bjorklund and Kipp's review. Thus, since women are thought to be more socially receptive than men (Macooby & Jacklin, 1974; Feldmen & White, 1980), this could explain the findings. The female co-actors may have simply been more receptive to the presence and/or actions of their partner, therefore inducing a larger IOR effect.

5.3 Criticisms of the Hunter Gatherer Hypothesis and of Evolutionary Psychology

The hunter gatherer hypothesis is seen as important because it provides a basis for the interpretation of long known and well-established sex differences on many cognitive tasks. Relatedly, it also outlined a scenario regarding the differentiated development of cognitive capabilities between men and women during prehistoric life based upon limited archaeological evidence (Tooby & DeVore, 1987; Silverman & Eals, 1991). As its name suggests, the theory argues that men hunted and women gathered, where specific social roles were causally related to the development of specific spatial abilities. As is well known, particularly amongst its critics, a fundamental issue of evolutionary theories on human behaviour is its post hoc theorising. The central charge is that modern society and culture has lead to the generation, or 'social construction' of the hunter gatherer notion. Current social roles in contemporary human societies still portray man as the provider and women as the caregiver (Eagly & Wood, 1999). Consequently, it is unclear whether contemporary societal structures and their associated behaviours, or even knowledge of modern hunter gatherer lifestyles, influences perceptions regarding prehistoric social roles and interpretations of their related cognitive abilities. Indeed, whilst archaeological research supports the occurrence of hunting and gathering, there are no physical findings that allow archaeologists to substantiate the assumption of a sexual division of labour (e.g., Wynn, Tierson & Palmer, 1996; Wynn, 2002). Moreover, observations of modern hunter gatherer societies fail to support the notion that the division of labour is as stringent as suggested by Silverman and Eals. For example, Hawkes et al., (1982) recorded men, women, and children from the Aché of Eastern Paraguay working together in groups to gather vegetation and small game. In addition, young boys and girls of the Hadza tribe accompany their mothers and grandmothers while foraging for plant matter (Hawkes et al., 1997; Crittenden, Conklin-Brittain, Zes, Schoeninger & Marlow, 2013). Furthermore, the Agta women of the Philippines hunt wild pig and deer, using bows and arrows as tools, and dogs to aid in subduing prey animals (Estioko-Griffin & Griffin, 1985). Moreover, Estioko-Griffin and Griffin report that the Agta women complete this task with their offspring secured to their back.

The issue of reconstructing prehistoric human life is often referred to 'just-so story telling' (Gould & Lewontin, 1979). Rudyard Kipling devised 'Just So Stories' in 1902 as children’s stories that 'explained' why an animal currently has the physical structure that it does (i.e., the stretching of the elephant's trunk, or the food supply in the camel's hump). Such stories have been described as 'Lamarckian' (Gould, 1978), in that modifications or characteristic acquisitions made during the organism’s lifetime are passed onto the next generation, (i.e., the heritability of acquired characteristics). Indeed, the notion of ascribing any or all features as evolutionary adaptations is one that the eminent evolutionary biologist George C. Williams referred to as solving "problems that do not exist" (Williams, 1974, p4). Thus, Gould and colleagues ascribed the notion of just so story telling toward evolutionary theories that aimed to understand physiology, behaviour, features and traits of organisms on the basis of prehistoric eras (Gould & Lewontin, 1979; Gould & Vrba, 1982; Gould, 1991). In agreement with Williams' view that over-describing features as evolutionarily advantageous is at best problematic. Gould and Vrba (1982) proposed that characteristics of an organism that have a function and enhance fitness, but have not been selected by nature as an adaptation, are exaptations. Here, an already evolved feature is later 'co opted' for another purpose, or alternatively, a feature that is useful, although non adaptive, arises due to consequences of other adaptive features. Bird feathers are an example of a co opted feature, which are now thought to have originally evolved for thermal regulation prior to being employed for the purposes of flying (Buss, Haselton, Shackelford, Bleske & Wakefield, 1998). Physical features in dogs, such as long, fluffy ears and short curly tails, are also thought to be non-adaptive features (i.e., they do not increase the animal's fitness), but are corporeal by products from selective breeding for a tame disposition (Fodor, 2007). Fodor (2007) also makes the point that post hoc theorising can be used to rationalise unexpected findings. In terms of the hunter gatherer theory and the present paradigms, consider Stöet 's (2011) conclusion regarding men's greater performance compared with women on a visual search task. Specifically, he stated, "*women might have chosen to do the gathering, not because they were adapted to it, but because it was the task that remained to be doing*" (Stöet, 2011, p 421). Stöet 's inference does not account for the inhibitory effects in visual search (Klein, 1988) nor does it question the sensitivity of the experimental designs employed. Rather, the conclusion seeks to find a related, yet alternative viewpoint based upon ancestral societies. DeBruine (2009) highlights that whilst some evolutionary explanations do support the just so stories view, acknowledging robust theories (biological or anthropological, i.e., observable), allows for testable hypotheses to be made and explored. Although it is rarely conceded, one does have to note however that a just so story may not necessarily be wrong (DeBruine, 2009).

5.4 Future Research

Due to the findings within this present work, future experiments should, in the first instance, further examine the underlying mechanisms or properties regarding the social foraging experiment (i.e., Experiment 8, Chapter 4). As mentioned above, agency is thought to be characteristic of males, and communion, of females (Spence, Helmreich & Stapp, 1973; Eagly & Wood, 1999). However a meta-analysis has found that men and women no longer differ in traits of agency but that women score significantly higher on traits of communion than men (Twenge, 1997). These measures, presented in combination with a measurement of empathy may determine whether biological sex is actually driving this effect, or whether it can be explained via stereotypical traits regarding agency and communion. Participants would be screened for their scores on agency, communication abilities, expressive behaviour and empathy. Two groups of participants would then be generated; a group of males who show high social traits and a group of females who show low social traits. If the effect observed in Experiment 8, is due to evolved mechanisms based upon the hunter gatherer hypothesis, then women should still demonstrate greater social IOR than men. Conversely, if the social aspect of the paradigm is generating the effect, then highly communicative, expressive and empathetic scoring men should elicit greater levels of social IOR than women who scored low on those measures.

A number of studies have assessed object location memory (New, Krasnow, Truxaw & Gaulin, 2007) and navigation or wayfinding abilities (Schmitz, 1997; Pacheco-Cobos, Rosetti, Cuatianquiz & Hudson, 2010) within the real world. As well as the virtual world, for object location memory tasks (Levy, Astur & Frick, 2005; Spiers, Sakamoto, Elliott & Baumann, 2008) and visual search tasks

(Thomas, Ambinder, Hsieh, et al, 2006). To the best of the author’s knowledge however, these tasks have not been assessed under a cooperative setting with a common goal. The social IOR literature has identified that the effect is not modulated by a common or different goal (e.g., Cole et al., 2012). Therefore, if the findings in the present thesis' Experiment 8 were due to the social nature of the task, 'foraging' whilst having different goals would still elicit the social IOR effect, with female co-actors demonstrating slower RTs compared to male or mixed sex co-actors. On the other hand, contemporary research has noted that gatherers tend to forage for multiple items (Hawkes et al., 1997) that may involve different action goals. Thus, if the foraging proposal (Klein, 1988; 2000) were biased towards common stimuli, then the social foraging effect would be diminished, whereby no difference would occur between the sexes.

5.5 A note on the ‘replication crisis’.

In the past five or six years, experimental psychologists have raised the issue of low replicability within the field. Maxwell, Lau and Howard (2015) suggest that the failure to replicate many findings may be due to a number of reasons such as subtle methodological differences and intentional differences. With respect to the present thesis, Experiments 3, 5 and 7 attempted replications for Stöet's (2010) flanker task, Ling et al.,'s (2006) variant of the Poggendorff illusion and Brown's (2013) IOR paradigm respectively. Stöet employed a flanker task combined with a go no-go task. His findings indicated that incompatible flankers impaired women’s RT. However, Experiment 3 in the present thesis failed to find a sex based flanker effect. Whilst it could be argued that this was a conceptual replication, the failure of the original flanker design to elicit a replicable effect suggests that Stöet's findings may be due to the specific stimuli employed, and note solely due to the flanker effect. Ling et al., found that men made fewer perceived alignment errors than women. Whilst Experiment 5 failed to support predictions made with respect to the hunter gatherer hypothesis, it did support Ling et al.,'s findings. That is, in near visual space, men made fewer errors than women. Brown reported that women exhibited greater IOR than men, with this effect being more pronounced for high spatial frequency stimuli. Experiment 7 presented participants with high spatial frequency patches in the standard Posner and Cohen paradigm (1984), yet it failed to support the notion of a female IOR effect. Thus, the present work does indeed suggest that there is a replication crisis.

5.6 Summary

The present thesis primarily investigated the hunter gatherer hypothesis using visual cognition paradigms. Of the eight experiments undertaken, only one (Experiment 8) has shown an effect consistent with the theory. Therefore, one can neither reject nor accept the notion that it has been refuted or supported. It may be reasonable to conclude that ‘limited’ evidence has been found for the theory.

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