An Investigation of Visual Memory : The Nexus Between Visual Perception and Memory

Submitted by

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Abstract

Memory is one of the oldest and most researched cognitive domains, and while much is established about verbal memory, research about visual memory is largely inconclusive. Past research acknowledges that visual memory is a complex function and research regarding visual perception, in particular the two streams hypothesis, clearly highlights an anatomical and functional demarcation between spatial and object processes. The current project consists of three experiments that investigate performance on a series of visual memory tasks that were designed to measure memory for spatial information and for object information separately. Each of the experiments extended upon the results and ideas that emerged from the previous experiment's findings.The purpose of the three experiments included:

1. The development and piloting of an electronic visual memory test battery that has clear assessment tasks that measure spatial and object abilities separately for short term, working and long term memory function.
2. Investigating the differences between spatial and object memory performance to determine whether each stream potentially has a distinct capacity for visual information in comparison to the other.
3. Developing further assessment tasks to assess performance capabilities for information within each stream. This experiment explored the impact of frame of reference on spatial information and for contextual cues on object information.

Major findings from the series of experiments suggest that visual memory is a complex cognitive system and that performance and capacity for information, is dependent on the nature of the information being remembered. This thesis highlights that spatial memory function and object memory function should be considered separate to both each other and to verbal memory function. Furthermore, context and the ability to verbalise visual information has the ability to enhance visual memory performance, even when presented with simplistic geometric lines. The utilisation of electronic media as a mode of assessment showed promise and allowed stimuli to be presented in a dynamic and standardised manner. While the developed electronic tasks showed promise further development is needed to successfully incorporate virtual reality into psychometric test batteries as well as to establish if a distinct capacity for each component of visual memory exists to mirror the known standard capacity of verbal memory.

Declaration

"I, Kate Kelly, declare that the PhD thesis entitled '**An Investigation of Visual Memory : The Nexus Between Visual Perception and Memory**' is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature Date 1/11/18

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CHAPTER 1

THE ENDEAVOUR TO UNDERSTAND VISUAL MEMORY

Our ability to remember our experiences is what makes us uniquely human and without our visual memories we would have no ability to share and replicate our stories, yet a conclusive understanding of the visual memory system has eluded researchers for decades. While much research has investigated this particular sub system of memory, no definitive storage capacity for information has been established (Luck & Vogel, 1997; Zimmer, Popp, Reith and Krick, 2012; Sorenson & Kyllingsback, 2012; Zhang & Luck, 2008). The current understanding of visual memory has grown out of information gleaned from the much easier to measure body of information discovered about verbal memory. However, it is possible that the incorporation of this verbal memory paradigm itself is the reason for the current inconclusive findings. While the visual and verbal memory systems share similar memory processes, the perceptual and cognitive components that underpin them are distinct, in terms of both the anatomical structure and function of them**.** It is with that understanding that the contention of the present thesis aims to investigate visual memory performance by incorporating established visual processing theories for a more comprehensive perspective.

The intersection between visual processing, perception and memory is evident in research and it is accepted that the processes involved during visual perception are precursors to those involved in visual memory (Miyashita, 1993; Lalonde & Chaudhuri, 2002). Visual perception refers to ability of the brain to interpret and give meaning to what the eyes see (Murray, Bussey, & Saksida, 2007). It is a complex process whereby initially information is processed through a number of sub cortical regions and the occipital lobes (Blumenfeld, 2002). Subsequent higher order processing is dependent on the nature of the stimuli, and can be distributed to the parietal, temporal and frontal lobes. The current understanding of this complex distribution of higher order visual perception is best understood using the two streams hypothesis (Milner & Goodale, 1992). This hypothesis states that visual information is processed by two distinct anatomical pathways, known as the dorsal stream (that processes spatial information) and the ventral stream (that processes information related to objects). In recent times the understanding of the complexities of spatial information has resulted in a further subdivision based on the two frames of references that humans process spatial information through, these perspectives being allocentric (from a third person perspective) and egocentric (from a first person perspective) (Ishikawa & Montello, 2006; Poirel, Zago, Petit & Mellet, 2010). Similarly, analyses regarding object information have also indicated the need for a further subdivsion into processing for features (Peissig, Young, Wasserman & Biederman, 2000) and objects (Schurgin & Flombaum, 2017). While this demarcation is well established in research and in measures of visual perception, it is less successfully reflected in cognitive assessments that aim to measure visual memory performance.

A necessary precursor to all memory and perceptual function is attention (Treisman, 1969). In terms of visual perception, the conceptualisation of covert and overt attention has been the driving force in the development of most visual processing tasks. This notion asserts that when stimuli is presented directly to the individual's eye it is processed more efficiently than when presented to the extremities of their field of vision (Calvo & Castillo, 2009). Interestingly, a similar notion underpins most assessment of visual memory, however, within this domain it is referred to as 'precuing', a process that primes individuals to where the stimuli will be presented to enhance one's ability to encode and recall (Posner, 1978). Overt attention and precuing share theoretical, structural and functional underpinnings and this further asserts that the presence of a nexus between visual perception and visual memory warrants further investigation.

Visual memory is a subsystem of memory that aims to preserve characteristics and information related to visual stimuli (Baddeley & Hitch, 1974). It is a multifaceted storage system that is capable of storing mental representations of objects, navigational information, places, and people. Memory is understood to be a serial process whereby information must pass through each storage system in a sequential fashion (Atkinson & Shiffrin, 1968). Much is known about how verbal information is encoded and stored within the memory systems (Chen & Cowan, 2009; Jaeger, Galera, Stein, & Lopes, 2016) however, inferences derived from that research have not always been the most accurate way to describe the visual memory system (Baddeley & Hitch, 1974). Past research has established that verbal and visual memory are two independent sub systems that involve divergent processes conducted by different neural networks (Baddeley & Hitch, 1974; Gathercole & Pickering, 2001). While recently more research exists investigating the visual memory system specifically, these investigations have focussed on specific types of information (e.g. spatial or object) and have utilised various cognitive models of memory and perception (Bays, 2018; Nosofsky & Gold, 2018; Ye, Hu, Li, Liu & Liu, 2017). Memory is considered an integrative skill and relies on the integrity of other cognitive processes (attention, visual processing etc) to function effectively (Mapou & Spector, 1995). Thus, when investigating memory systems, models and knowledge of related cognitive systems must be considered. Due to the integrative nature of memory, the understanding of the two streams hypothesis has the potential to inform researchers about the mechanisms that underpin visual memory and subsequently may assist in identifying why variations in performance are present among different tasks.

Anatomically, functionally and mechanically memory structures are well understood which has facilitated the development of a number of assessment tasks designed to measure visual memory functions (Wechsler, 2009; Gathercole & Pickering, 2001; Ruff & Allen, 1999; Milner, 1965; Benedict, 1997). However, in reality the available assessment tools within the clinician's armamentarium are fraught with limitations on several fronts. In relation to the theory regarding the two streams hypothesis (Milner & Goodale, 1992), assessment tasks have begun to evaluate spatial and object memory separately, however these tasks lack specificity and precision and are all categorised as the more holistic category 'visual memory measures'. While these tests are psychometrically sound, a comprehensive series of tasks that pays homage to both memory theory and acknowledges the dual nature of visual processing, allowing for clear comparisons to be made between the various functions remains elusive.

By applying the principles established within both the visual processing and memory paradigms, this thesis aims to investigate visual memory performance for immediate span, working memory and delayed recall for spatial and object based stimuli. It asserts that understanding and investigating performance for the various components of visual memory is a crucial first step to further developing an overall cohesive understanding of this memory subsystem. A subsidiary aim is to develop and validate a comprehensive, electronic assessment battery for visual memory to facilitate ongoing research in the field. An analysis of the two streams hypothesis follows this introduction, where the duality of this theory will be reviewed in detail. Following this, a comprehensive review of the current visual memory research is presented. The notions of memory and the two streams hypothesis that were critically analysed and put forth are then used to provide context to evaluate the current visual memory assessments within Chapter 4.

Based on the review of the literature, prior to conducting any experimental research an electronic visual memory battery of assessments was developed for the purpose of this project. In this chapter the theoretical and psychometric notions that underpinned the development of each of the assessment tasks are discussed. To address the aims of this thesis, three experimental research studies were conducted. Chapter 6 presents the methods and findings of Experiment 1. This experiment acted as a pilot study for the developed tests to ensure the tests were reliable and valid measures of what they claimed to assess. Chapter 7 presents Experiment 2 that builds off the findings discussed in Experiment 1 and addresses methodological issues that arose during the piloting of the developed tests, before investigating whether performance differences exist between the two streams. Chapter 8 presents Experiment 3, that further explores the influence that the two streams hypothesis has on the serial nature of visual memory, by incorporating additional measures of visual memory that attempted to investigate further nuances that are present within the streams. Finally, Chapter 9 integrates the findings of the three experiments to discuss conceptually what the findings of this thesis demonstrate.

CHAPTER 2

THE TWO STREAMS HYPOTHESIS OF VISUAL PERCEPTION

Visual perception, how one interprets and understands what is seen, is a complex process, due the wide variety of visual information an individual is required to process every moment of the day. Visual perception allows knowledge of the immediate environment to be acquired, interpreted and stored in long term memory. Therefore, it also allows for the information to be easily retrieved later, when faced with similar stimuli or situations. A level of reasoning is involved during the interpretation of visual stimuli, this ensures that we do not get lost when navigating familiar territory and allows objects to be identified based on their environment. This reasoning process is derived from the context of the environment and is also facilitated by memory when incorporating knowledge from past experiences. The two streams hypothesis of visual processing was proposed to account for extensive neuroanatomical research, initially on primates (Ungerleider & Mishkin, 1982) and then further established in humans , (Macko et al., 1982), that investigated the regions of the brain that are employed during visual perception tasks. This model highlights the complexity of visual perception and acknowledges that the visual perceptual process differs, both cognitively and anatomically, depending on what kind of sensory information is being interpreted. The two streams hypothesis is the most widely accepted and influential model of visual processing. Developed by Milner and Goodale (1992), this hypothesis argues that visual information follows two distinct pathways, each responsible for processing different kinds of visual information. These pathways extend from the occipital lobe and are activated after primary sensory processing has occurred. The dorsal stream which processes spatial information, is located primarily in the parietal lobes and extends to the rostral regions of the frontal lobes. Alternatively, the ventral stream which processes information about objects, transfers information from the occipital lobes to the temporal lobes.

The Dorsal Stream : The Anatomical Pathway for Spatial Information

The dorsal stream, also known as the ‘where’ or ‘how’ stream, is responsible for understanding and interpreting spatial information. This stream allows us to process where objects are located in space, and then guides any motoric movements necessary to work with them (Valentinos, Nikas, Safiullah, Klatzky & Ungerleider, 2015). The dorsal stream must constantly hold a detailed map of the current visual field and continuously update as the individual or objects move within the environment (Wokke, Scholte & Lamme, 2014). Thus, key characteristics of the dorsal stream include its ability to detect, process and analyse movement.

The Anatomy of the Dorsal Stream

The dorsal stream contains multiple circuitry systems each responsible for different aspects of spatial processing. Based on the findings that were generated from animal research (Undgerleider & Mishkin,1982) and specific case studies (Goodale, Milner, Jakobson & Carey, 1991) the structural and functional aspects of the dorsal stream were able to be established. This research allowed for the development of a new neural framework for the dorsal stream of visual processing (Read, Philipson, Serrano-Pedraza, Milner & Parker, 2010). Kravitz and colleagues (2011) aimed to further explore the multiple circuitry systems of the dorsal networks. Prior to their research, the dorsal stream was more simply defined as the pathways between the posterior regions of the inferior parietal lobule and the striate cortex, however their extensive review suggested that the dorsal stream is more widespread than previously thought. As their review acknowledges both the conscious and unconscious aspects of a broad range of visuospatial processes, they proposed that the dorsal stream is not confined to the occipital and parietal lobes, but alternatively spreads across a number of cortical regions, including the frontal and temporal lobes, and the limbic system. This recently developed circuitry system further divides the dorsal stream into four pathways that intersect with each other, but each have their own distinct role in spatial processing. These four pathways address aspects of visuospatial processing that include but are not limited to navigation, spatial working memory and visually guided motoric actions (Kravitz, Saleem, Baker & Mishkin, 2011). Depicted in Figure 2.1 is the current understanding of the multiple dorsal circuits as portrayed in Kravitz and colleagues work (2011).

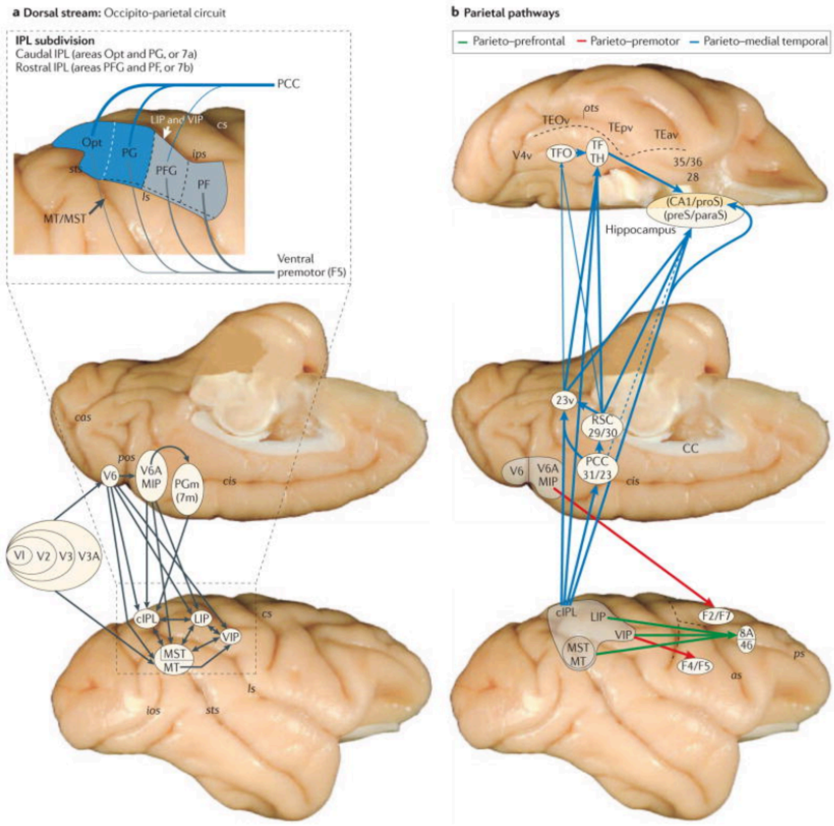

Figure 2.1. *Anatomy of the Four Pathways. From 'A new neural framework for visuospatial processing' by Kravitz et al., 2011, Nature Reviews : Neuroscience, 12, p. 219. Copyright 2011 by Kravitz et al., Reprinted with permission*

Visual information is analysed in each circuit and the occipito-parietal circuit is generally the antecedent to the parieto-medial-temporal pathway with each of the circuits distinguished based on the functions that they are purported to perform. The dorsal networks are now understood to include a series of projections from the primary visual processing network to posterior regions of the parietal cortex. Based on this updated map of the dorsal stream network, the structure and function of the four pathways have been found to be involved with differing components of visuospatial processing; the occipito-parietal circuit that connects to the primary visual network and serves as the origin of the three secondary pathways, the parieto-prefrontal pathway responsible for spatial working memory and controlling eye movements, the parietopremotor pathway responsible for visually guided action such as reaching and finally, the parieto-medial-temporal pathway responsible for navigation particularly from an egocentric view point (Kravitz, et al., 2011).

Spatial Processing: The Primary Cognitive Function of the Dorsal Stream

Cognitively, the dorsal stream allows us to make sense of where we are in our visual world and is the primary network for our ability to process spatial information. Structurally the anatomical research clearly highlights that the dorsal stream network overlaps and has relationships with the cortical regions that process movement, guide motor action and help us understand where we are in space (Blumenfeld, 2002). How we interpret and think about our visual experience is also a complex phenomenon. Within the dorsal stream, visual spatial information can be observed and encoded via two different viewpoints, when completing visual cognitive tasks: Allocentric and egocentric frames of reference (Ishikawa & Montello, 2006; Poirel, Zago, Petit & Mellet, 2010; Nadel & Hardt, 2004). Research suggests that information can be encoded using both frames of reference at the same time (Poirel et al., 2011) and that being able to process from both frames of reference is necessary, to effectively make conclusions about the environment (Crundall, Crundall, Burnett, Shalloe & Sharples, 2011). Nonetheless, evidence supports the notion that allocentric and egocentric processing represent two different functions and should be treated as such, despite both often being described under the overarching term of spatial processing (Feigenbaum & Morris, 2004). In keeping with this, each will be outlined separately in the coming sections.

Allocentric Processing.

Allocentric processing is also known as 'object to object' processing and can be better understood as information that is processed from a third person point of view (Poirel et al., 2011).

Figure 2.2. *Allocentric Processing : Information About the Object is Encoded with Respect to Other Objects. From 'Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment' by Proulx et al., 2014, Nature Reviews : Frontiers in Psychology, 7, p. 5. Copyright 2014 by Proulx et al., Reprinted with permission*

In Figure 2.2 each object is understood and encoded based on its relationship to the other objects in the field of view. i.e. the bicycle may seem smaller than the other objects, as its distance is further from the viewer in relation to them. Location, distance, and form of an object are all processed relative to other objects in the visual field. Allocentric information can also be viewed from a survey, or 'birds eye view' perspective, and can be understood in both two and three dimensional space. Allocentric processing does not exist purely in the visual domain and there is evidence to suggest that other cognitive processes such as memory and executive function also incorporate an allocentric frame of reference to represent visual information.

The ability to process movement is a characteristic feature of the dorsal stream, and the ability to spatially update information is a cognitive process that utilises perceptual cues to allow individuals to compute the spatial relationship between objects as they move through their environment. Gaunet and colleagues (2001) conducted a computer based allocentric visual task, that involved individuals watching a screen that depicted movement through an environment. They found that a lack of physical movement from the participant did not affect their ability to spatially update information or accurately recall the relationship between objects within a scene. This indicates that findings produced in a controlled laboratory setting could potentially possess good ecological validity. These findings were extended Wraga and colleagues (2004), who found partial support only. In a similar study, they found that spatial updating was more difficult in scenes containing passive movement compared to those with active physical movement. The authors contended that this was due to active movements by and large being more dramatic, and subsequently alerting the individual to the change thereby facilitating stronger encoding.

Evidence suggests that images encoded from an allocentric frame of reference are stored in a lower resolution (lacking fine feature details) than those processed from an egocentric frame of reference. Despite lacking details, individuals who are processing images from an allocentric frame of reference have been found to encode movement more efficiently as the target to be remembered is in relation to other objects in the field, rather than the individual (Harris, Wiener & Wolbers, 2012). Thus, regardless of where in the visual environment the stimuli is presented individuals are able to efficiently and accurately identify the object based solely on its relation to other objects in the field. Research indicates that because of this allocentric memories are more accurate and stable compared to their egocentric counterparts (Harris, et al., 2012). Harris and colleagues compared performance between younger adults (20 - 29) and older adults (60 - 84) on an allocentric navigation task in an attempt to investigate age related decline. This task required participants to navigate through a virtual maze that at times forced them to switch between navigational strategies (allocentric and egocentric). Their research found that deficits in allocentric processing were only present in older adults under specific conditions. When an older adult was required to switch between different viewpoints, deficits were more likely to be present, however Harris and colleagues (2012) attributed this more to difficulties switching between the two frames of reference rather than due to a deficit in either. It was contended that reduced connectivity in the hippocampal to prefrontal region could also be a contributing factor to reduced navigational performance in the ageing population, where older adults were found to demonstrate a preference for egocentric strategies. Due to difficulties switching between viewpoints this preference often persists even when using an allocentric strategy would be a more efficient and accurate way of completing the task (Wiener, Kmecova & de Condappa, 2012).

These findings are informative as no deficits were present in the baseline allocentric task that measured allocentric processing without a switching component, which indicates that implications in allocentric processing during ageing are likely confounded by other variables (Harris et al., 2012). These findings further highlight the interlaced relationship between allocentric and egocentric processing, and while both can function independently in the dynamic visual world, the influence of each frame of reference on our ability to interpret the environment is profound.

There is evidence that allocentric processing occurs in other visual cognitive tasks. Spatial working memory in particular has been found to utilise an allocentric frame of reference when retaining information about locations (Jiang, Olson & Chun, 2000). Due to difficulties in standardising the presentation of movement less research has explored the link between movement and spatial memory. Wood (2010) endeavoured to investigate the connection between what was known about how the dorsal stream processes movement and what is currently known about visual working memory. His research was inspired by the lack of current spatial working memory literature that investigated how movement was stored when utilising an allocentric frame of reference. Thus, he conducted a series of allocentric processing tasks that explored movement, with the aim to determine the role of this form of processing. By utilising a stick figure human that was presented in various 'stances' and orientations, participants were asked to complete a series of tasks that involved memorising a sequence of the stick figure's movements. In some iterations the stick figure changed location and orientation in the individual's field of vision, in others the participant was physically moved in reference to the stick figure. The findings of this experiment yielded highly promising results that indicated that visual working memory has separate systems for processing movements and orientations or viewpoint variance. This conclusion put forward that memory performance was found to diminish when both movement and orientation where asked to be remembered concurrently. If the frame of reference the stimuli was presented in facilitated memory then an increase in performance would have been expected.

Furthermore, Wood (2010) conducted a second assessment that involved participants being shown a figure displaying a series of movements from an allocentric point of view, followed by an exemplar movement that depicted the figure static in one movements, however this time the figure was presented from a different orientation. Participants were then asked to identify, through the use of mental rotation, if the exemplar movement was in fact, one of the previously shown movements. Results indicated that performance was consistent regardless of what viewpoint the test figure was displayed at. While Wood (2010) endeavoured to explore allocentric memory exclusively he does however, discuss that while his research produced evidence that allocentric processing does occur during visual working memory tasks, it was difficult to determine if the individual completing the task was using an allocentric frame of reference or a retinotopic (egocentric) map. As the project did not include an egocentric designed component for comparative purposes, and the nature of the stimuli being examined made it possible to learn the objects/movements from an egocentric frame of reference, it is difficult to determine if these findings are limited solely to allocentric processing. In an attempt to investigate the influence of egocentric processing (despite significant methodological constraints), Wood contended that if movement was based on an allocentric frame of reference then participants should be able to recall the same number of movements regardless of what viewpoint the movements are encoded from. If participants recall was adversely affected by a change in viewpoint then this finding would be indicative that information is more likely encoded from an egocentric frame of reference. His findings supported his former experiment. As the results of this experiment indicated that encoding movement during a visual working memory task was relatively unaffected by changes in the orientation during presentation, it is likely that participants were encoding the stimuli using an allocentric viewpoint as the orientation did not impact the efficiency or accuracy of recall.

Egocentric Processing.

Egocentric processing, also known as 'self to object' processing can be understood as information that is processed from the first person point of view (Acredolo, 1978). Egocentric processing encodes information about an object relative to the body axis of the individual viewing it.

Figure 2.3. *Egocentric Processing : Information about the object is encoded in respect to the self. From 'Where am I? Who am I? The Relation Between Spatial Cognition, Social Cognition and Individual Differences in the Built Environment' by Proulx et al., 2014, Nature Reviews : Frontiers in Psychology, 7, p. 5. Copyright 2014 by Proulx et al., Reprinted with permission*

Egocentric information is always processed from a three dimensional perspective, as it is from the view of the individual (Rogers & Graham, 1979). It represents the positions of objects in the field relevant to the individual themselves (Ciaramelli et al., 2010). Unlike allocentric processing, egocentric processing must be constantly updated as the individual moves throughout their environment. This is because all visual stimuli in the environment are understood relative to the location of the individual. Thus, when the individual moves the egocentric frame of reference must update as all information within the visual field will also change relative to the location of the body.

Damage to the posterior parietal cortex is found to have an effect on motor co-ordination and spatial learning which causes disorientation in environments that were once familiar. This is suspected to occur as the individual is no longer able to represent where objects or landmarks are in relation to themselves. Interestingly, in patients who suffer from anterograde and retrograde amnesia, their object-location abilities are normally preserved (Gomez, Rousset, Bonniot, Charnallet & Moreaud 2015). This may be because damage is diffuse rather than focal in the posterior parietal cortex in individuals who suffer from amnesia.

Egocentric encoding can allow for a higher resolution percept (that includes more vivid details of the features included in the immediate environment of the individual), however recall is dependent on the individual remaining static and not changing their body orientation. When viewing a featureless environment (e.g. a plain hedge maze with no other visual stimuli present), minor details such as the edge of a wall can inform the somatosensory, vestibular and proprioceptive systems of the minor adjustments needed to accurately alter the body's orientation to successfully interpret the environment (Lester & Dassonville, 2014). Similar cues are also able to assist a person in determining direction and distance to facilitate in identifying an object's spatial location (Howard, 2012). While these visual cues can be helpful they also have the potential to be deceptive (Lester & Dassonville, 2014). For example illusions have the ability to distort the reality that the participant is observing.

Neuroimaging has facilitated the establishment of the neural structures involved in making allocentric judgements about objects however, within the egocentric frame of reference much less is known about how minor visual cues that emerge from an otherwise featureless environment (such as a flower located on one wall of the hedge maze), are processed. This has made it difficult to delineate the differences between the influence of the dorsal and ventral streams separately during egocentric tasks. Findings that have attempted to reduce the influence of objects during egocentric processing, have highlighted that during these processes it is likely the parieto-prefrontal pathway that is activated, due to the relationship between egocentric processing and physical movement. The body of research that has investigated egocentric processing exclusively is restricted due to the methodological limitations of accurately measuring what someone is able to see and by the number of confounding variables that potentially influence performance. Subsequently, many studies have aimed to use what is known about allocentric processing to compare and evaluate performance on egocentric tasks (Wood, 2010; Ruotolo, van Der Ham, Ineke, Iachini & Postma, 2011). These studies likely have increased ecological validity as in practice the two frames of reference are integrated to allow us to make sense of our world.

The Integration of the Allocentric and Egocentric Frames of Reference

Allocentric and egocentric frames of reference are two distinct ways which individuals can orient themselves in space. While both function as part of the dorsal stream, within that stream they show different areas of activation. Despite this, individuals do not view an environment from either an egocentric or allocentric frame of reference exclusively. Instead research suggests that during every day life people incorporate both frames of reference to gain the greatest understanding of what they can see (Ruotolo et al., 2011). Due to methodological limitations, less research has been conducted exploring the depth of egocentric processing when compared to allocentric, however, most of the research conducted does demonstrate considerable overlap with other cognitive processes making it difficult to discern exactly how each frame of reference functions on its own.

An example of a function that highlights the conjunctive nature of these frames of references is driving. Allocentric processing is necessary for map reading and providing a general navigational understanding for direction. Egocentric processing, on the other hand, is utilised during the actual process of driving and when interpreting road signs. When comparing these two functions in light of this example, allocentric processing is more enduring as it often involves recalling an environment outside of the current visual field, and from a different perspective to the individual (Tenbrink & Salwiczek, 2016), whereas egocentric processing tends to encode the immediate environment more effectively without the ability to make predictions based on anything but the objects within the individual's current visual field. Furthermore, in a task that required participants to point to a remembered target Lemay, Bertram and Stelmach (2004) identified that the target could be stored allocentrically, egocentrically or even in both frames of reference at the same time. The choice of what frame of reference information is stored in can have profound effects on determining the quality of the memory representation and subsequently task performance. Proprioceptive (egocentric) information is also more susceptible than allocentric information to decay over time as it relies on the individual to continually update where objects are located in space, this in turn makes it difficult to rehearse information as the objects location is constantly changing relative to the individual (Desmurget, Vindras, Grea, Vivani & Grafton, 2000).

Ciaramelli, Rosenbaum, Solcz, Levine and Moscovitch (2010) further highlighted the conjunctive nature of these two functions. By utilising a clinical sample (which included patients who had suffered from damage to the posterior parietal region) they investigated the extent that damage affects both spatial frames of reference in comparison to healthy controls. Based on past research they identified and tested the four main components of spatial processing involved within the visuospatial network; the ability for egocentric processing to be conducted (Stark, Coslett & Saffran, 1996), the ability for allocentric procedures to be processed from the posterior parietal cortex to the retrosplenial-posterior cingulate cortex (which links allocentric processes to episodic memory) (Cammalleri et al., 1996; Maguire, 2001), the formation of allocentric spatial representations and therefore, the coding of new spatial locations which can then be stored in the medial temporal lobes (Bohbot et al., 1998) and finally the ability to perceptually identify landmarks within the visual scene (Cipollotti, Warrington & Butterworth, 1995). Ciaramelli and colleague's (2010) findings indicated that all participants with damage to the posterior parietal region demonstrated impaired performance on navigational tasks and landmark identification from an egocentric frame of reference. Surprisingly, there was no difference in performance between impaired individuals and healthy controls on allocentric tasks. While the clinical sample used in this research was small, the effect sizes provide further evidence that the differences between clinical participants and healthy controls on allocentric tasks was negligible (>1%), while on the egocentric tasks they were substantial (41%). Due to limitations measuring egocentric processing however, there were only two egocentric tasks utilised in this study in comparison to the five allocentric tasks.

While it is known that the two frames of reference are similar, research does also consistently highlight that the two should be measured separately as their differences can aid in differential diagnoses (Tu, Spiers, Hodges, Piguet, & Hornberger, 2017). Tu and colleagues (2017) identified that measures of egocentric memory were more sensitive in discriminating between frontotemporal dementia patients and patients with Alzheimer's disease. In their study while performance on both allocentric and egocentric tasks demonstrated an impairment in functioning. The Alzheimer's disease patients performed significantly worse on the egocentric memory task. Thus, this research highlights the importance of having adequate measures of each that attempt to isolate each function independently.

It has been acknowledged that virtual reality could be one of the best ways to incorporate a range of spatial environments into a laboratory setting. In the past many of the visual memory tests have been presented from an allocentric perspective due to methodological difficulties in measuring the egocentric function. With the advent of virtual reality researchers are now able to understand and measure more egocentric functions. Currently, much of what is known about egocentric processes is derived from clinical studies and animal research (Wraga, Flynn, Boyle & Evans, 2010; Lester & Dassonville, 2014). Since the late 90's computer programs have been utilised in an attempt to measure fine distinctions between different visual processes (Valmaggia, Day & Rus-Calafell, 2016). However, recent comparative studies that aimed to explore the ecological validity of computer based 'virtual environments' found that results deviate from those observed in real world situations (Teel, Gay, Johnson & Slobounov, 2016; Tenbrink & Salwiczek, 2016). This comparative research showed differences in path integration (Kearns, Warren, Duchon & Tarr, 2002), map drawing (Van der Ham, 2015), route learning (Ruddle et al., 2013) and way finding (Ruddle et al., 2011). Consistently among all studies it was observed that orientation is most likely lost in a virtual environment when there was an absence of physical motion or landmarks (Kearns et al., 2002; Van der Ham, 2015; Ruddle et al., 2013). When physical motion was present the lag in response times was virtually mitigated (Riecke et al., 2007). Tenbrink and Salwiczek (2016) acknowledged that due to the number of virtual reality studies, it is clear that researchers are attempting to utilise novel methods to gain insight into the cognitive processes and strategies that are utilised to maintain orientation in space. That being said most of the aforementioned studies were looking at desk top applications of virtual reality (Teel, Gay, Johnson & Slobounov, 2016; Tenbrink & Salwiczek, 2016). This is no longer the only avenue for measuring a virtual environment. With virtual reality head sets becoming increasingly common, and many only requiring the use of a smart phone, researchers are no longer confined to the limitations of desktop virtual reality tasks. This ability to measure cognition, particularly egocentric function, using a virtual reality headset allows for the incorporation of physical movement that Riecke and colleagues (2007) identified as being vital.

The Ventral Stream : The Anatomical Pathway for Object Based Information

The ventral stream also known as the ‘what’ stream is responsible for understanding and interpreting information about objects to discern, label and identify the different items present in one’s visual field (Tyler et al., 2013). The ventral stream is a more heavily researched and established domain in comparison to the dorsal stream (Lestou et al., 2014). As a whole the ventral stream is considered to consist of a singular network that extends from the occipital lobes, where the primary visual network ends, to the temporal lobes where the ventral stream works closely with the long term memory system to access stored representations of previously seen objects (Bussey & Saksida, 2002). This process could be conceptualised as the link between perception and memory. Through the use of prototypical models an individual is able to identify objects that they have not seen before, or known objects in obscure orientations (Grubert, Fahrenfort, Olivers & Eimer, 2017; Souza, Pessin, Shinzato, Osorio & Wolf, 2013). The more similar an item is to its prototypical model, the more swiftly it is able to be recognised. Similarly to the dorsal stream, the ventral stream can identify an object using two methods; feature processing or whole object recognition. Feature processing involves breaking down the object to its individual components (known as geons) and integrating these components together to distinguish the whole object (Biederman, 1987). Whole object recognition involves using the environment and the context that the object is presented in to identify the object. In whole object recognition all the individual features do not need to be encoded for the object to be identified rather, only a few key features are required for identification. Our ability to identify features to aid in object recognition exists on a continuum and both identification based on features or the object entirely demonstrate different ways of recognising the same information. Subsequently, there is intense overlap present in the literature. How we process information is dependent on the context of the environment and the features that are present, and much of the literature investigates how the combination of integrating connected features and environmental context aids in object recognition.

The Anatomy of the Ventral Stream

The ventral stream is a hierarchical process that involves primary visual operations that begin in the ventral occipito-temporal region as well as other higher order functions that are conducted in the perirhinal cortex, located in the anteromedial temporal lobes. In relation to the higher order processes, most research has focussed on two key regions in the temporal lobes: The fusiform gyrus and the anteromedial temporal lobe (Murray, Bussey & Saksida, 2007; Mahon & Caramazza, 2009). These two areas have been identified as being responsible for being able to establish semantic category differences however, they focus on different types of objects. The fusiform gyrus is an area dedicated to facial recognition and deficits in this area are associated with neurocognitive conditions such as prosopagnosia, where people are unable to identify faces. Alternatively, the anteromedial temporal lobe is responsible for the identification of all other objects and subsequently, is associated with a wide range of neurocognitive disorders. The hierarchical nature of the ventral visual system analyses the features of an object beginning with the simple form and colour and then becoming increasingly complex as stored representations and context are taken into account (Tyler et al., 2013). Initially components such as colour and form are identified in the ventral occipito-temporal cortex, and then the analyses of the object become increasingly complex before culminating in the perirhinal cortex. The perirhinal cortex is responsible for the most complex feature integrations that are necessary to discriminate differences between highly similar objects (Murray et al., 2007).

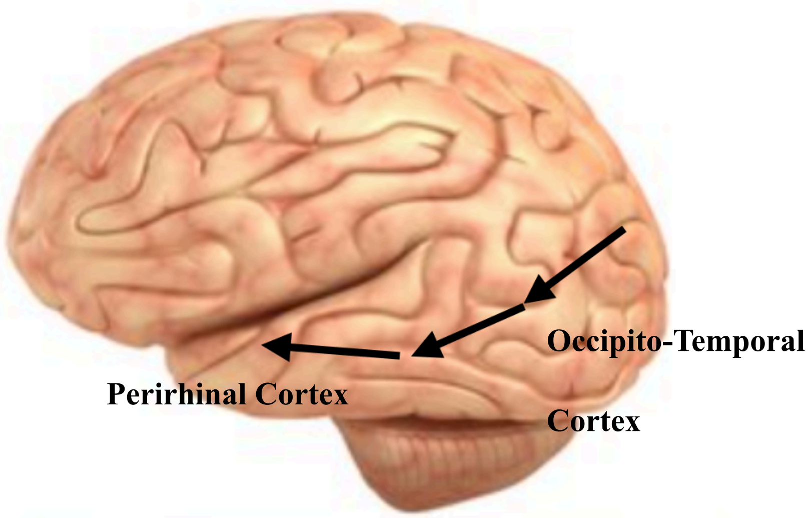

Figure 2.4. *Anatomy of the Ventral Stream*

Object Processing : The Primary Cognitive Function of the Ventral Stream

Understanding Object Related Information: Information Processing Models.

The ventral stream analyses object related information using top down or bottom up processing. Top down processing incorporates contextual cues while combining a series of features to identify what an object is within the context of its environment. It involves pattern recognition and a Gestalt approach that views the environment as a whole instead of the sum of its parts. In bottom up processing, perception begins with the sensory input of the stimuli (Styles, 2005). Conversely to top down processing, it is a data driven approach to perception that utilises the individual components of a stimulus and incorporates them together to make a whole. Bottom up processing involves looking at all the individual features that make up an object to identify what the object is.

From a behavioural perspective, bottom up processing can be better explained by the recognition by components theory (Biederman, 1987). This theory proposes that an individual is able to recognise an object based on only a few geons, or components. It acknowledges that all objects are simply basic geometric shapes, that humans have the ability to combine together and then based on key features recognise as an object. This does rely on the necessary components unique to that stimuli being present at the time of interpretation, otherwise the image may be too ambiguous to be discerned. However, if perception was determined solely by bottom up processing it would only need to rely on the primary visual network and no higher order cognition would be necessary (Oliva & Torralba, 2007). As highlighted above this is not the case. A limitation of bottom up processing is that it is a raw, data driven approach that does not rely on the context of a situation. Based purely on geons, a cup, bucket, canister and any number of basic cylindrical objects could be easily misconstrued at the same object. Hence, top down processing becomes important. Top down processing takes into account the present environment, an individual's prior knowledge and their current expectations. Research has shown that an individual can be exposed to the same set of geons but based on the location and orientation of the geons the individual is able to identify a range of objects (Oliva & Torralba, 2007)

Processing Feature Based Information.

Recognition by components theory attempts to explain the bottom up processes by which object recognition occurs (Biederman, 1987). This theory proposes that all objects are able to be identified by separating the main components of it into what are called ‘geons’. In Biederman’s (1987) seminal paper he contends that geons are generally three dimensional shapes that can be assembled in a variety of arrangements to potentially make an unlimited number of objects. Biederman (1987) derived this notion from research on speech. He asserted that if speech is made up of a series of phonemes amalgamated together, then it is logical that perceptual processes for other senses occur in a similar manner. This same theory proposes that the term “viewpoint invariance” describes our ability to identify objects at any angle. The reason that we are able to do this is due to the unchanging (invariant) properties of geon edges. By analysing the edge properties of any object we are seamlessly able to combine a series of geons to make a whole object that is easily recognisable in any orientation. Viewpoint invariance has been a contentious issue with a number of studies identifying that changing the orientation of an object can make it difficult to identify (Farah, Rochlin & Klein, 1994). In response to this Beiderman and Gerhadrstein (1993) proposed that recognition by components would always occur seamlessly providing that three principles were met. 1. Objects must be decomposable into parts. 2. To be discriminated objects must consist of different parts. 3. At least two viewpoints must lead to the same configuration of geons. However, they also acknowledge that the influence of environment and context will also affect the object recognition process. Recognition by components theory explains the basis for feature identification, but in a complex three dimensional world research contends that the environment is more intricate than the alphabet of geons put forward by Beiderman (Hayward & Tarr, 1997).

Individual features aid in understanding the complexities of our visual world. Distance, size and colour can inform the individual about the spatial location of the object within their field of vision (Treisman 1988). The use of shade, and shadow can alert an individual to an objects location relevant to the sun, as well as inform an individual about the depth and shape of the object. Size, colour and orientation can inform the individual about the nature of the object's design to aid in quick recall or classification of the object being viewed. Size can also inform the individual about the object's overall dimensions or magnitude. Orientation describes the current rotation of the object (Shepard & Metzler, 1971). Objects that appear in 'expected' or prototypical orientations are more easily identified than when viewed from obscure or non traditional viewpoints (Al-Janabi & Greenberg, 2016). Finally, motion can also be a component of spatial and object processing (Okada, 1996). This construct differs however, as it informs the observer what the object is currently doing in space. Understanding how an object functions not only facilitates identifying what the object is, but also its role within the visual field and other information about how the environment is changing and evolving.

Conceptual representations that are component based in nature, have informed much of the research investigating how features are integrated (Smith & Medin, 1981; Mirman & Magnuson, 2008; Tyler et al., 2013). This research acknowledges that objects are made up of several smaller elements of meaning (Tyler et al., 2013). Regardless of how feature integration studies are conducted the findings remain similar and highlight that individuals store objects in categories based on feature similarity (Smith & Medin, 1981). This understanding is well established in cognitive psychology (Mirman & Magnuson, 2008), and this is partially due to the fact that it accounts for the semantic processing of objects (Taylor, Devereux, Acres, Randall & Tyler, 2012). Feature based models also provide the potential to understand the characteristics that differentiate objects from one another. Conceptual representations have two key components that form the basis of many feature binding studies (Tyler, et al., 2013). One component is the extent to which an object's features are shared. Living things tend to have far more shared components than non living things, and their components tend to not be as distinct as their non living counterparts e.g. cats and dogs generally have four legs and a tail whereas furniture tends to be structurally quite different (Cree & McRae, 2003). The second component is related to feature integration. Feature integration tends to be best facilitated when objects have highly correlated features that co-occur e.g. an object has four legs and a tail is likely an animal. Taylor and colleagues (2006) found that living things are much more difficult to differentiate from one another due to this overlap in features, when compared to non living things. Therefore, as these objects do not tend to have 'distinctive' features much higher demands are placed on the visual cognitive system and higher order feature integration computations must be made to discern the differences between like objects, and factors such as context and environment become more imperative during interpretation. Hence both top down and bottom up processes work in conjunction with one another to facilitate the prompt identification of the current stimuli presented in the visual field.

Object Recognition: The Influence of Context and Semantic Meaning.

There is more to understanding an object than a simplistic visual analysis of its features (Tyler et al., 2013). Semantic and contextual meaning can have profound implications on our ability to recognise not only previously seen objects, but also new information. It can be assumed that the ventral system operates using a conceptual hierarchy, which employs semantic knowledge about an object in conjunction with feature knowledge to draw accurate conclusions (Tyler et al., 2013). This facilitates the recognition of previously seen objects, and assists with drawing logical assumptions based on knowledge already stored in the visual cache. The ventral stream network is closely related to the memory systems in the temporal lobes which enables meaningful information about an object to be recognised and recalled. The principles underlying the visual processes conducted in the ventral stream rely on the assumption that there is a focus on the category structure of an object (Mahon & Caramazza, 2009) and how the object is organised. Storage by visual components, involves descriptors of an object such as form, orientation, etc. When an object is stored by its functional properties, other cognitive components, such as memory are relied on to give the object meaning. Lastly, an object can be stored by its motor properties, which is by what it does. The more often that an object is viewed, encoded and stored the more readily it can be recognised and the more easily it can be compared to other similar objects to aid in discriminating between like objects and also in identifying new objects.

While object recognition involves complex processes it is generally performed with a high degree of accuracy (Schurgin & Flombaum, 2017). When faced with unfamiliar patterns or objects the brain is able to evaluate, understand and construct a three dimensional representation of the object. It can seamlessly and automatically perceive objects that are placed or rotated at different angles and rotate them into their correct orientation. It can infer that hidden parts of objects still exist and can rapidly identify which objects are partly hidden from view or in some other way incomplete. The main reason that this skill must be completed so quickly is because the visual world is ever changing and we must be able to identify, understand and adapt to the changes without exerting much effort. An early theory put forward in an attempt to explain how humans are able to swiftly recognise objects is template matching (Grubert et al., 2017; Souza et al., 2013). This theory assets that, humans have a large database of internal constructs regarding objects they have seen across their life, that is held in the stored representation component of long term memory. When these constructs are paired with sensory information from the environment and a match is made, the object will then be recognised. The template matching theory formed a strong basis for research investigating how objects are encoded. A great strength of this theory is that it acknowledges the link between visual perception and long term memory stores (Schlagbauer, Mink, Muller & Geyer, 2017). Its limitation is that very rarely will an object match perfectly to an internal construct, and instead an individual must draw on cues from the environment to make a valid and logical decision about the object presented to them. Advancing theories have incorporated the importance of feature analysis during the matching stage, and from past findings prototype matching theory was born.

Prototype matching theory suggests that, rather than using specific templates or features to discern what an object is, a generalisation of patterns is stored in the long term memory (Solso & McCarthy, 1981). This provides a more useful explanation than the template matching, that asserts that objects must be closely matched. Instead, prototype matching acknowledges that most objects have a number of variations, and being able to recognise variants of the same objects is something that happens seamlessly. An object in the environment is then matched to a prototype or general image of the object, and if a match is present the object is recognised. This explains how humans are able to recognise novel objects based on small, similar features. In an experiment exploring prototype formation it was found that participants were more likely to recall seeing a stimuli that matched a general prototypical model of an object more readily than images that were less related to the prototypical model (Solso & McCarthy, 1981). Solso and McCarthy (1981) coined this phenomenon ‘pseudo-memory’ (pp. 18) and explained that prototypes are developed based on exposure to common features that are then stored in an individual’s long term memory. When presented with an object that includes a number of common features the brain activates more strongly compared to images that include less features (Contini, Wardle & Carlson, 2017). This research showed that if an individual is shown a series of similar objects that are more abstract or less prototypical than the standard reference representation of the object, then on recognition they are less likely to report seeing them than the non presented more typical figure.

The Two Streams in Practice

While it is acknowledged that the dorsal and ventral streams process different components of visual information, as with many cognitive functions there is some overlap and communication between the two systems. There is however, clear evidence that suggests that the two streams function as independent entities. The visual world is a complex environment and rarely is an individual presented with spatial or object information in isolation, subsequently, often the two streams work in conjunction with one another to provide an explanation of the holistic visual experience (Zachariou, Klatzky & Behrmann, 2013). When attempting to understand the world around us both the shape and location play a fundamental role. Evidence from this research leaves no doubt that object related properties are processed in the temporal lobes, via the 'ventral stream', and location or spatial position is processed separately in the parietal structures of the 'dorsal stream'. However, due to the overlapping existence of information within the visual environment it has been suggested that to interpret all information both streams have some responsibility in mediating visual functions e.g. both streams are utilised when determining what an object is based on its size or location (Wilkinson et al., 2000). This mediation of functions is not only observed within two streams when processing the visual environment. There is also integration from a number of other cognitive domains.

Attention : The Nexus Between Visual Perception and Memory

Attention is the precursor to all higher order cognition. Without the ability to attend to specific stimuli in our environment, most information cannot be perceived for further processing. Visual attention, has two distinct components : overt and covert. Overt attention occurs when a shift in attention is accompanied by movement of the eyes, whereas covert attention occurs when the shift in attention is not accompanied by any eye movement. Covert attention is often referred to as attending to an object out of the corner of one's eye e.g an individual becoming alerted to a light flashing in their peripheral vision. Researchers from the various fields of cognition have subsequently investigated the role that attention has within their particular area (Gorman, Abernethy & Farrow, 2018; Carlos et al., 2017; Gogler et al., 2016) and there is often similarities present between the attention mechanisms for different cognitive domains. Therefore, investigating attention models and theories for the separate cognitive domains can assist in identifying the similarities between processes and where convergences of function may occur.

General models of visual attention note that for visual information to be captured an individual must orient and attend to various components of the stimuli; distance, orientation, colour, motion and size (Treisman, 1988). These models contend that the more of these components that are attended to, the more accurate deduction an individual is able to make about what they are viewing in their current visual field (Gogler et al., 2016). Treisman's (1988) visual attention model was developed to extend her former model and aimed to incorporate feature integration theory (Treisman & Gelade, 1980). Nearly 40 years later feature integration theory still forms the basis for how cognitive researchers understand attention in relation to object perception (Wolfe, 2014). Feature integration theory provides evidence for how during the early stages of visual attention, individual features become bound together, which then allows the brain to recognise these series of features (or geons) as an object (Treisman, 1988). Feature integration theory combines both the spatial and object pathways of visual perception, as this theory posits that features are integrated depending on the individual's attention being allocated to the specific location where the features are placed within visual scenes. Features that are allocated to the attended location are more readily recalled and processed than those placed on the outskirts of the attended visual scene. Once the individual features have been attended to, the stored representation/knowledge area of the brain is activated, which allows for the binding of features and identification of the whole object.

Treisman (1988) further solidified feature integration theory when she was able to provide conclusive evidence for what are now distinguished as conjunction and feature based visual searches. These two kinds of visual searches state that when a target has clearly distinct features from other distractors in the visual field, identification and recall of the target is generally efficient and accurate. However, when individuals are asked to search for an item that is less identifiable by its features (e.g. a blue A among a sea of blue H distractors) identification is generally inefficient and less accurate. This is because in a scene where the features are not readily identifiable during the visual search, the individual must readily attend to each object in the field to distinguish the target. When the feature is clearly definable the individual is able to scan the field swiftly to identify which is different.

Feature integration theory not only informs researchers of how visual attention functions, but in turn it is able to make predictions about how features and objects are stored in long term memory (Humphreys, 2016). One prediction that this theory posits is that if attention is limited (eg. in a conjunction search) errors in feature integration are more likely to occur. It also acknowledges the importance of cueing, noting that if an individual's attention can be cued to where the target stimuli will appear, then regardless of the types of distractors present recall is relatively efficient. This notion of cueing intersects with theories of attention in memory explicitly. Posner (1978) asserts that pre-cuing individuals to where stimuli will be presented gives participants the best opportunity to correctly alert themselves to the information that they are required to remember (Posner, 1978). When pre-cuing is not present it is difficult to determine if a memory failure in performance is due to an inability to recall or if the information was never attended to and encoded correctly to begin with. Most spatial tasks are dynamic in nature and thus, have pre-cuing inherently built into them, as the participant tracks the information presented to them. Object based attention tends to be more complex, and it is necessary to treat feature based tasks and object based tasks as separate as the nature of the task and the requirements of what to remember can have a profound influence on recall performance (Johnson, Hollingworth & Luck, 2008). Treisman (1980) also found that learning did not enhance or affect the efficiency of identification. Even with practice when presented with an array that includes similar distractors to the target, participants are forced to attend to each individual object to identify the target. The more cognitive resources an individual can dedicate to attending to the target stimuli, the more efficiently they are able to bind the features to be matched to a stored representation in their long term memory allowing for the accurate recall and identification of what they are looking at.

Furthermore, Hollingworth and Beck (2016) contended that efficient visual search across a scene relies on attention to be guided strategically towards relevant objects and that this process is essentially governed by visual working memory. In fact there has been much contention in the literature that suggests that there is strong evidence that visual attention and visual working memory constitute as part of a single system that aids in object selection and binding of features within a visual scene (Tas, Luck & Hollingworth, 2016). However, findings demonstrate that visual working memory is only similar to attention in specific scenarios and the relationship between them is dependent on the memory demands of the orienting behaviour during attention.

Attention has a fundamental role in both visual perception and memory (Johnson et al., 2008). Therefore, in the assessment of memory capacity it is necessary to ensure that attention is as focussed as possible on the task at hand with little environmental influence, otherwise an underestimation of performance is likely to occur. The aforementioned research suggests that there are similarities present in the attention literature that focuses on visual processing and memory. Attention may therefore form a nexus between these two cognitive domains highlighting that when investigating visual memory it is important to incorporate theories of visual processing as this function likely forms the basis for the higher order process that is memory.

CHAPTER 3

VISUAL MEMORY

An Introduction to Memory

Learning and memory are integrated skills that rely on the incorporation and coordinated functioning of an intact attention, sensory, executive and visuospatial system to complete tasks effectively (Mapou & Spector, 1995). Similarly, to most cognitive functions, memory is a serial process whereby information must progress through each stage of processing in an ordered sequence (Schwarb, Nail, & Schumacher, 2016). Pioneers of this line of reasoning are Atkinson and Shiffrin (1968) with their modal model of memory, that highlights the serial process of memory and subsequently has informed much of the successive research into this cognitive domain. This model (depicted in Figure 3.1) demonstrates the serial nature of memory and highlights the key fractionations.

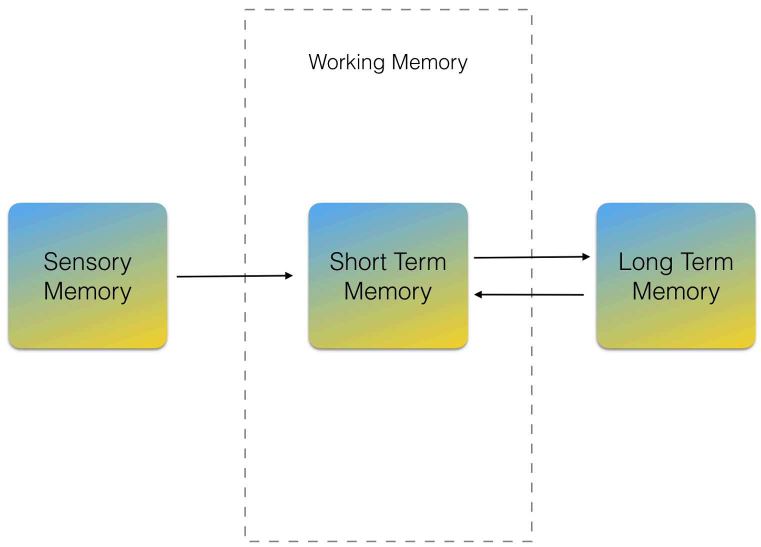

Figure 3.1. *The Modal Model of Memory Developed by Atkinson and Shiffrin (1968).*

Sensory memory is only activated for a fraction of a second, and most information will decay within two, unless progressed to short term memory. Sensory memory has no further role in the higher functions of memory such as consolidation (Lichtenberger & Kaufman, 2012), however, it is important to understand its role, which is to provide the brain with a complete sensory experience, from which information can be selected and moved into short term memory storage (Baddeley, Eysenck & Anderson, 2014). Sensory memory is modality specific and storage and processing of information is dependent on the nature of the stimuli.

Short term memory can hold information for approximately 30 seconds, and will quickly decay unless rehearsed or maintained. Short term memory is capacity limited, on average capable of storing 7 verbal items (+-2), however, the capacity of visual short term memory is largely unestablished (Luck & Vogel, 1997; Alvarez & Cavanagh, 2004; Milner, 1965). Short term memory consists of three key components: encoding, maintenance and retrieval. Encoding is the process by which information is transformed into memories. Encoding from the sensory store to the short term memory store involves taking the relevant sensory information and applying a cognitive focus to it in an attempt to remember it. The maintenance component involves keeping the information at the forefront of an individual's mind. By keeping the information online, the individual can attempt to keep it from being decayed or interfered with. It also allows for it to be available for manipulation (through use of the working memory system). If information is maintained and rehearsed it may then be encoded into the long term memory store. Lastly, the retrieval process brings information from the unconscious long term storage into the conscious focus of the mind. The retrieval component allows information from the past to be reactivated in ways it was previously stored. Long term memory is theoretically limitless in its capacity. Information must be retrieved from the long term system and brought back into the short term memory store for an individual to be able to process or be aware of it. Atkinson and Shiffrin (1968) also acknowledge the working memory component, that incorporates short and long term memory and allows for the manipulation of information, however, this function was better explored and established by Baddeley and Hitch (1974) (investigated further in this chapter). Baddeley and Hitch's (1974) model was the first predominant theory that clearly defined separate processes for verbal and visual memory highlighting that different operations exist for the varying senses.

Classic models of working memory have concentrated on capturing distinctions between the sensory modalities (verbal and visual) as well as the link between different components (short term and long term memory) (Baddeley & Hitch, 1974). Working memory inherently is a limited capacity store for retaining information over a brief period of time. While this information is being stored, mental operations are performed on the content of the current store. The contents of a working memory store are not only sourced from sensory inputs as short term memory is but instead can also be sourced from an individual's long term memory. Although sometimes classed as a component of short term memory, working memory differs from it in two key ways : Short term memory is concerned with the storing of information for a brief period of time, whereas working memory is concerned with the manipulation of information held in limited capacity storage during complex cognition (Awh & Jonides, 2001). Short term memory also consists of a single unitary process, working memory, alternatively, has a number of components. Working memory contains information that can be acted on, processed and manipulated in the context of an individual's current environment. In the absence of external cues working memory allows information (new or old) to guide behaviour (Lowe et al., 2016).

It has been established that memory is a modality specific function, as there are different underlying mechanisms that process the different sensory experiences for all stages of memory (short, working and long term) (Gabrieli, 1998). Information that is received through multiple modalities is likely to be consolidated more effectively into long term stores than information that is presented to a single sense; affirming Hebb's (1948) seminal notion, that the more neural networks that are involved with encoding a memory, the stronger the consolidation of the memory into long term storage.

Due to substantial research into verbal memory, the structure, function and nuances of this area are fairly established (Chen & Cowan, 2009; Jaeger, et al., 2016). Subsequently most research that aims to investigate visual memory does so by utilising the notions and methods that have been established within the verbal memory paradigm. However, as highlighted in chapter 2, memory for features and objects are accumulated in their own subsection, known as the 'stored representations' of long term memory. Studies also suggest that visual memory capacity differs from verbal memory (Brady, Konkle, & Alvarez, 2011). However, due to a lack of consistency in the findings among established, standardised, visual memory assessments, most research investigating capacity is drawn from experiments that incorporate the Corsi Blocks visual memory task (a block tapping spatial span task where a participant is asked to mirror the sequence that the examiner touches the block array in) (Milner, 1965). More recently, other boutique visual memory tasks that aim to measure capacity have been found to yield varying results in comparison to both Corsi Blocks, as well as one another. There are many theories that have attempted to explain why, these differences have occurred and most have indicated that these tasks focus on the object pathway and acknowledge that differences in capacity are likely related to how features are integrated (Sperling, 1963; Sewell et al., 2014; Mercer, 2014). It is necessary to further investigate visual memory capacity in reference to the two streams hypothesis, to not only discern differences in the object pathway but also investigate spatial memory more thoroughly, to provide a more holistic view of the capabilities of the visual memory network. From our understanding of how the visual processing system works, as highlighted in the previous chapter, it could also be argued that visual memory in itself needs a demarcation from the traditional modal model to pay homage to the dual system pathway. Figure 3.2 demonstrates this division.

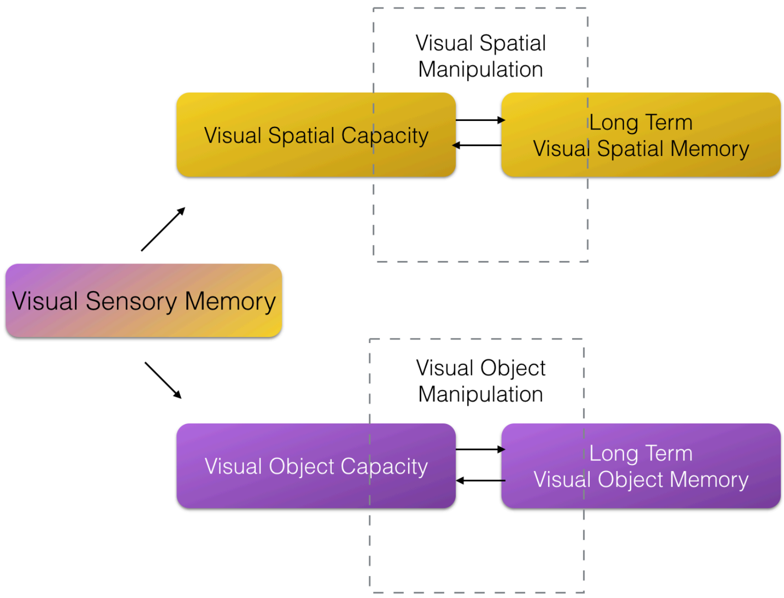

Figure 3.2. *An Adapted Version of the Modal Model of Memory That Acknowledges the Two Streams Hypothesis*.

This figure shows the demarcation of visual memory into the spatial system and the object system, which each have their own serial pathway. This model also incorporates the spatial/object demarcation in the visuospatial sketchpad that has already been recognised in visual working memory (Gathercole & Pickering, 2001). This proposed model of visual memory will form the basis for the following chapter and subsequently the present thesis. This model acknowledges the dual streams hypothesis of visual perception, which is thought to have differences in the capacity of information that can be encoded, the attention demand required for encoding and the perceptual resource allocation.

The Working Memory Model

The Advent of the Separation Between Visual and Verbal Memory

Baddeley and Hitch (1974) developed the first memory model that acknowledged that there were separate subsystems for verbal and visual information. Their seminal work has informed much of all visual memory research and their development of the visuospatial sketchpad has guided much of the work on visual memory capacity (Baddeley & Hitch, 1974; Awh & Jonides, 2001; Pickering, 2001; Ueno et al., 2011; Blacker et al., 2014). Their influential articulated model of working memory is depicted in Figure 3.4 below.

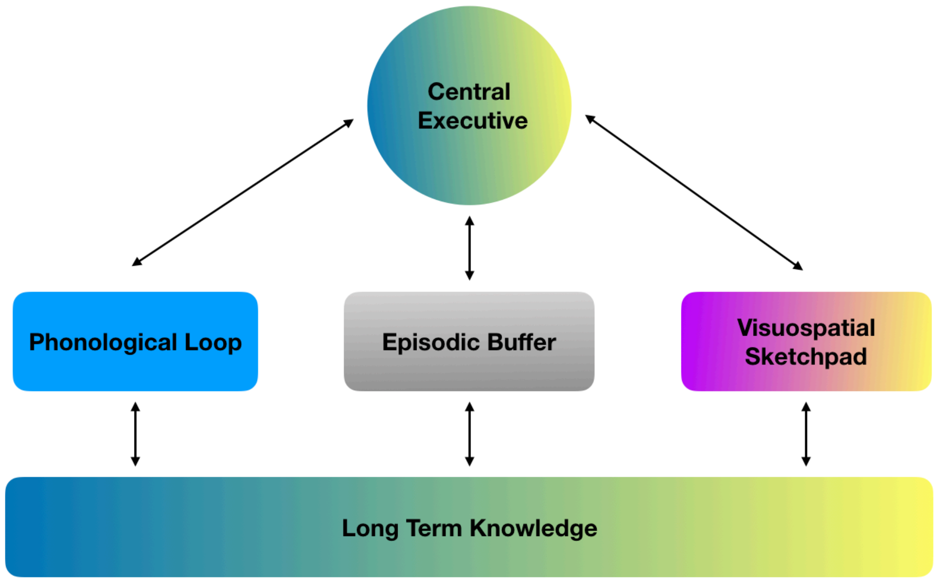

Figure 3.3. *Baddeley and Hitch's (1974) Model of Working Memory (with the Inclusion of the Episodic Buffer (2000))*

In this model, working memory was initially partitioned into a supervisory control system aided by two peripheral slave systems. The central executive controls the visuospatial sketch pad and the phonological loop and forms strategies for using the information that each contain. The phonological loop only holds and manipulates verbal and auditory information. The visuospatial sketchpad alternatively holds visual and spatial information. Both the visuospatial sketchpad and the phonological loop are directly connected to the central executive. The central executive is where most of the extensive working memory processes occur. Using the activity provided by the phonological loop and the visuospatial sketchpad, the central executive is able to focus attention on specific parts of a task and switch between them when required. The central executive pulls information from long term memory storage and uses this relevant information to co-ordinate the tasks of the peripheral slave systems. One of the main goals of the central executive is to determine how attention should be divided or allocated between different tasks. Baddeley and Hitch (1974) conceptualised their model as a limited capacity attentional control system. This system is responsible for the control and coordination of cognitive processes as well as having a role in strategy selection for dealing with complex cognitive problems. In 2000, Baddeley identified that this model was failing to explain the results occurring in a number of experiments. Acknowledging that this was likely due to the link between long term memory and working memory, which previously had not been explored in detail, he added the inclusion of the episodic buffer to his model. He proposed that the episodic buffer was a system that stores information that is received from the peripheral slave systems and the long term memory stores as well as other perceptual knowledge.

The current model of working memory has been widely researched and is well established as the leading exploratory model of memory functioning in both clinical and non clinical populations, as well as in adults and children (Baddeley & Logie, 1991). It is likely that one of the main reasons that isolating the visuospatial sketchpad has hardly been researched is because of the difficulty involved with presenting stimuli that are only encoded using visuospatial means. Finding stimuli that carry no phonological or semantic representation is exceptionally difficult and thus, there is often an overlap between the functions measured in experiments that aim to look solely at visual memory. “Pure” measures of visual memory have been found to be the one of the most difficult types of memory tests to develop in humans, as working memory in murine models is well established (Pickering, 2001; Wechsler, 2009). Until this point the Corsi Blocks (Corsi, 1972) and the Visual Patterns Test (an object based short term memory task, where individuals are asked to recall abstract images presented in a matrix)(Della, Sala et al., 1999) seemingly meet the criteria as pure measures of the visuospatial sketchpad however, more recently the validity of these measures has been questioned, due to the tasks inability to truely separate spatial and object functions, as both appear to incorporate some overlap from the other. Baddeley and Hitch (1974) do however acknowledge the demarcation of spatial and object processes within the visuospatial sketchpad and highlight the importance of treating these two aspects as different functions.

The Two Streams Hypothesis and Working Memory

Research investigating the two streams of visual perception has been largely informed by clinical neuropsychology and neuroscience research (Carlesimo, Perri, Turriziani, Tomaiuolo, & Caltagirone 2001; Darling, Della Sala, Logie, & Cantagallo, 2006; Goldman-Rakic, 1988). This research has indicated the presence of a double dissociation between spatial working memory and visual memory, suggesting that these two components while integrated in many ways, do function independently of one another (Hanley, Young & Pearson, 1991). Furthermore, anatomical research has solidified these findings by suggesting that while some areas of shared activation are present on neuroimaging during both spatial and visual working memory tasks, distinct differences can also be observed. Spatial working memory tasks demonstrate sustained activation in the superior frontal sulcus whereas visual working memory tasks (that involve memorising different objects) demonstrate sustained activation in the inferior frontal gyrus (Courtney, Petit & Maisog, 1998). These findings have inspired research that has aimed to investigate how anatomical and functional differences impact on an individual's ability to complete visual memory tasks. Furthermore, this understanding of visual memory consisting of distinct components has been acknowledged and has begun to be incorporated within cognitive models of memory.

Pickering, Gathercole, Hall and Lloyd (2001) have conducted extensive research on the visuospatial sketchpad particularly. The purpose of their research was to further investigate if the visuospatial sketchpad is composed of two separate subsystems, one for visual (object) information and one for spatial information. This contradicts past theories that suggested the visuospatial sketchpad was a unitary system that interpreted and manipulated all visual information. This investigation was not completely unique, on further review there is a number of both experimental and neuropsychological studies that allude to the possibility that there are two different systems for locations and appearance of visual information (Baddeley & Hitch, 2006; Hitch 1990). The proposal of this demarcation put forward in their research is outlined in figure 3.4 below.

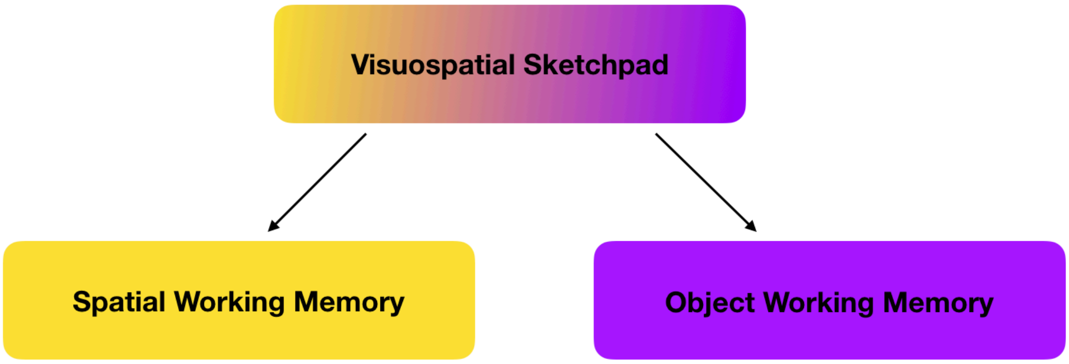

Figure 3.4. *Pickering, Gathercole, Hall and Lloyd's (2001) Demarcation of the Visuospatial Sketchpad*

By investigating this demarcation, Pickering and colleagues (2001) attempted to encourage a shift in research to further explore the visuospatial sketchpad in light of these differences. That being said, research that explores the object component of the visuospatial sketchpad is far more common than the spatial component (Gathercole & Pickering, 2001). Furthermore, it is acknowledged that this is due to the methodological limitations that exist when attempting to measure spatial memory (e.g the difficulty to display dynamic stimuli in a standardised manner using pen to paper tasks). The studies and assessments of spatial working memory that do exist tend to have overlap with other cognitive functions, like object encoding or executive components (Milner, 1965; Wechsler, 2009). When incorporating knowledge derived from tasks of spatial perception it is understood that spatial information is quite complex, and thus can be manipulated in various ways e.g. spatial rotation (Shepard & Metzler, 1971). While these ideas have been considered and a shift is beginning to be seen in how the visuospatial sketchpad is measured, much of our understanding of visual working memory is still derived from object manipulation tasks.

Within the literature, there is an ongoing debate regarding how information is conceptualised within the visual working memory system (Pickering et al, 2001). One of the most accepted ideas suggests that integrated object representations are the main kind of visual information stored and manipulated within visual working memory (Luck & Vogel, 1997). Wheeler and Treisman (2002) argued against this multi feature idea of integrated representations that Luck and Vogel (1997) put forward. They contended that in Luck and Vogel's (1997) research, participants were not asked to maintain the bindings between features of the object but instead were encouraged to maintain the multiple features contained within each object (e.g. Instead of remembering a cat's face they were encouraged to remember, whiskers, nose, ears, mouth etc.). This makes data interpretation difficult as it is difficult to discern whether individual features are stored in parallel individual stores (like a number is in Digit Span) or if the entire object is stored as a bound unit where features can be extracted for evaluation. In the latter example regardless of the number of features in the object, the object is considered one unit and additional features have no additional perceptual load cost. This contention has formed much of the research investigating the capacity of visual short term, working and long term memory (Zhang and Luck, 2008; Hardman & Cowan).

Every visual object contains different features, and it is these features that make an object identifiable. Object recognition tends to involve working memory processes as often what is seen must be manipulated to match the stored representation in long term memory. Each of these features are analysed separately initially yet, the brain is able to segregate overlapping information within the visual field to determine which features belong to the same object, which in turn, allows us to understand the world (Mecklinger & Pfeifer, 1996). When difficulties occur here, they are referred to as an integration (or binding) problem (Treisman, 1998). Luck and Vogel (1997) believe that while this process occurs the first time an object is viewed, once it has been bound, it is stored as a unitary image and is processed in this format. Surprisingly, this integration is not solely mediated by the visuospatial sketchpad but also relies heavily on the episodic buffer and central executive (Shen, Huang & Gao, 2015). Shen and colleagues (2015) work further contributes to the understanding that visual perception and visual working memory are very similar by highlighting the similarities in the results, between their object perceptual tasks and their object memory tasks. Recently Cohen and Tong (cited in Shen et al., 2015) explored the links between object attention within a perceptual task from a neuroanatomical perspective. They also were able to find links between object based attention and the early visual areas. Recent fMRI studies have found that there is a similar neural basis for the integration processes in visual perception and in visual working memory (Jackson, Morgan, Shapiro, Mohr & Linden, 2011). Finally, Emrich and Ferber (2012) also found that increasing the amount to remember, or the individuals perceptual load led to a rise in integration errors (particularly with colour) during a visual working memory task.

Visual Memory Capacity

Both the short term and working memory stores are limited capacity systems. Memory capacity refers to the amount of information an individual can hold at any one time and this limitation of memory appears to be neurologically based as it not bound by cultural or environmental differences (Wagner, 1974). In memory, capacity is typically measured using span tasks. Hence, an individual’s memory span is the longest list of items that an individual can accurately recall immediately and consistently. Visual short term memory's role is to maintain small amounts of visual information over short periods of time (Christophel et al., 2012). In recent years, a surge in research has been seen in an effort to understand and identify the characteristics and nature of visual short term and working memory, and this includes but is not limited to a focus on capacity limitations (Mercer, 2014). Visual short term memory is constantly forced to update itself due to the dynamic nature of changes in our environment. This causes numerous temporary representations to be developed and these representations are generally vulnerable and susceptible to interference and disruption caused by incoming information (Makovski, Susan & Jiang, 2008).

While the capacity of verbal memory is well established a number of different studies exploring the capacity of visual memory have yielded different results (Brady et al., 2011; Wechsler, 2009; Christophel et al., 2012). Interestingly, the different results produced can be linked by the nature of the stimuli the individual is asked to remember. Studies that utilise the Corsi Blocks task produce an average span score of 5 (Milner, 1975). As this task is one of the most commonly used visual memory neuropsychological tests some researchers have accepted this capacity as the standard (Lezak et al., 2012). However, studies that use abstract shapes like visual reproduction or the visual patterns test have found capacity results that differ to this value (Della Sala, Gray, Baddeley, & Wilson, 1999; Wechsler, 2009). As discussed previously, visual information is highly complex and consists of many components (Nadel & Hardt, 2004). It is likely that this variance is attributed to the difference in stimuli more so than research design. It is possible that participants results on a range of different visual tests can be used to predict their capacities for different components of visual memory. The Corsi Blocks task is defined as a visuospatial span task, thus, rather, than thinking of a span of 5 as the global visual memory capacity, perhaps this value could be better considered as the spatial span capacity. Similarly the Symbol Span task in the Weschler Memory Scale is considered a visual working memory task, despite it not incorporating any spatial component, this assessment may be more accurately described as a measure of object working memory. Rather than reviewing the current visual memory research as inconclusive, it may be more beneficial to draw inferences between what is currently known and integrate this knowledge with what is known about the two streams hypothesis.

Object Memory Capacity: The Role of Feature Integration

As described previously understanding how individual features are integrated is crucial for understanding how memories are encoded, stored and retrieved (Hardman & Cowan, 2015). Luck and Vogel (1997) found that there was no difference in capacity for bound objects compared to single features. This finding was important as it highlights how swiftly multiple features are able to be integrated to create a whole object. It also highlighted that adding more features to an object did not add to the cognitive load in terms of encoding and retrieval. These findings were also confirmed by similar research conducted by Zhang and Luck (2008). Zhang and Luck (2008) proposed what is known as the *slot model* of visual working memory. This model implies that visual working memory has a predetermined number of slots (like short term memory), each able to maintain one item. Based on the findings of Luck and Vogel (1997) and the findings Zhang and Luck (2008), a single feature and a bound, multi feature object both take up the same amount of space within these slots. Hardman and Cowan (2015) further contend that based on this model objects are the only limiting factor and the number of features that can be bound is seemingly unlimited. While these results seem promising they cannot always be replicated seamlessly.

Contrary to Luck and Vogel (1997) Delvenne and Bruyer (2004) found contradictory results in their study that aimed to explore whether visual short term memory stored bound features. Using an array of stimuli (including colours and abstract designs) presented electronically, they found that the presence of a feature load effect appeared to be dependent on the nature of the stimuli being utilised. Deficits in accuracy were observed in situations where a participant was required to discriminate for colour-colour conjunctions, which occurred in instances where a single square stimuli was characterised as including two colours (one outline and one within the outline). However, improvements in accuracy were observed and features were encoded more efficiently when two distinctly different features (e.g. shape and texture) were asked to be recalled. Similar to Delvenne and Bruyer's (2004) initial findings Wheeler and Treisman (2002) also found similar evidence for a feature load effect in their study that demonstrated that the more features an object had, the poorer the accuracy on recall was. This coupled with Delvenne and Bruyer's (2004) findings indicate that feature loads are impacted by the number of features within an object as well as the similarity of the features. Hardman and Cowan (2015) aimed to replicate Luck and Vogel's (1997) seminal work exploring the capacity for features and objects. Hardman and Cowan (2015) hypothesised that if individuals had an unlimited store for feature capacity that regardless of whether participants were cued to what feature they needed to remember there should be no difference in recall. Their findings indicate that this was not the case and that accuracy was far worse when participants were not informed what feature was being tested. As all features were not encoded equally this indicates strong evidence for a capacity limited storage system. Hardman and Cowan (2015) conducted eight different experiments, exploring the effects that changing features had on encoding and retrieval and their results consistently indicated that memory for features was also capacity limited. Hardman and Cowan (2015) note when discussing their findings in light of Luck and Vogel's (1997) that their sample did not perform as well as Luck and Vogel's. They suspect that the lack of difference in Luck and Vogel's work may have been due to many participants hitting a ceiling effect, whereas they noticed a distinct difference due to many of their participants not attaining ceiling performance. Therefore, there is confounding evidence that makes it difficult to assume that the difference in performance between memory for features and memory for objects, can be explained solely in terms of individual feature integration being more demanding of general cognitive attention for their maintenance.

Object Memory Capacity: The Role of Attention

The role of focused attention in the maintenance of object information within the short term memory system is a heavily debated topic in the current literature (Delvenne, Cleeremans & Laloyaux, 2010; Resink, 2000; Wheeler & Treisman, 2002). Some studies have found evidence to support the notion that sustained focused attention is required during the active maintenance and linking of individual features within visual short term memory (Delvenne et al., 2010; Wheeler & Treisman, 2002). This process is akin to that of how attention is required to integrate features into objects during the visual perception process (Resink, 2000; Wheeler and Treisman, 2002). According to these findings once attention is removed from an object the object's representation within short term memory is collapsed into all its integral features. This allows memory for individual features to remain intact despite the object no longer being bound. Consequently, this process severely degrades memory for the bound object and subsequent contextual associations of the object (Delvenne, Cleeremans & Laloyaux, 2010).

Research comparing how individuals remember bound items in comparison to feature items has puzzled cognitive psychologists for decades (Luck & Vogel, 1997; Alvarez & Cavanagh, 2004). Wheeler and Treisman (2002) compared the role of attention in the memorisation of information from the ventral stream, under both feature and bound object conditions. Within the bound condition they found that successful change detection required observers to memorise what the key components were within an object that bound it together to make it a unified item. However, overall they found that performance was worse in the bound condition than in the feature condition. Contradictory to Wheeler and Treisman's (2002) findings, other research has proposed that during the maintenance and storage process of bound objects, the objects do not collapse into their individual features but instead are maintained in the encoded presentation without any evidence of increased perceptual resources to complete this task (Hollingworth & Henderson, 2002; Hollingworth & Luck, 2008). Contrary to both these findings Luck and Vogel (1997) found that their was virtually no difference for memory capacity for single objects in comparison to memory for bound objects. It is clear from this research that the role of attention in maintaining object information is unclear. However, as with most research the more a participant is able to focus their attention the greater the chance of accurately encoding the objects. The aforementioned research does however, focus more on the role of attention than the potential capacity of feature vs bound objects. That being said it is highly likely that variance in capacity will also be present during the short term, long term and memory processes.

When using visual working memory, attention is biased towards objects that are currently being maintained in the store (Hollingworth, Matsukura & Luck, 2013). There is evidence that visual working memory maintenance is dependent on activity within the visual sensory cortex (Harrison & Tong, 2009). It is understood that many visual working memory encodings can be held in the prefrontal cortex at the same time, however, there is a gating system that is biased to perceptual selection (Hollingworth & Beck, 2016). Alternatively, theories also state that the many items held in memory can all guide attention simultaneously (Beck, Hollingworth & Luck, 2012). By incorporating a capture method for attention, Hollingworth and Beck, (2016) were able to determine that the latter is accurate and multiple visual working memory encodings can interact simultaneously with perceptual and attentional processes. This confusion about how features and bound objects are stored is present in the attention, short term memory and visual working memory literature and understanding this first stage is fundamental in unveiling the exact structure and function of each skill. However, unlike other components of memory the role of attention in visual working memory is quite controversial (Hu, Hitch, Baddeley, Zhang & Allen, 2014). While storage capacity is limited to a number of objects, research suggests that there appears to be no limit to the number of features that can be held (Luck & Vogel, 1997). Based on this Wheeler and Treisman (2002) proposed that attention is only required for the maintenance of the integration of features into a whole object but not necessarily for individual features. Baddeley and Hitch (2014) found contradictory evidence however, that indicates that attention is equally involved for both features and bound objects and they proposed that this mediation occurred in the central executive. Similarly, Hu and colleagues (2014) suggested that the central executive is responsible for admitting relevant stimuli and filtering irrelevant stimuli as well as reactivating visual representations.

Vergauwe, Langerock and Barrouilet (2014) found that the variance in performance between memory for objects and memory for features could not be accounted for by attentional systems and that both were equally impaired when attention was disrupted. It is accepted that objects are distributed entities and cohesive memories rely on the bindings of these entities. While it has been established that an object can be bound semantically (based on the context of the environment) or by its physical properties (the individual features that make up the object). The integration mechanisms in visual memory are not yet fully understood (Shen, Huang, & Gao, 2015; Ding et al., 2015).

One of the most vital components to maintaining objects within the working memory system is an individual's ability to remember feature bindings (van Lamsweerde, Beck & Elliot, 2014). Understanding how this integration process occurs is not only useful for perceptual research but also memory research. There is contention among researchers on the role attention has in this maintenance process, with many researchers proposing that attention is not a fundamental component (van Lamsweerde et al., 2014; Baddeley et al., 2011). Using a modified version of the Baddeley and Hitch (1974) working memory model, researchers have suggested that working memory could possibly store both object based and feature based information (van Lamsweerde et al., 2014). Baddeley and colleagues (2011) put forward the notion that the binding of features into objects is developed within the visuospatial sketchpad and once bound, these representations are moved into the episodic buffer. Based on this idea Baddeley et al., (2011) believe that it is possible that while the episodic buffer maintains bound objects the visuospatial sketchpad maintains copies of each of the individual features. This is a pivotal finding as it highlights that working memory difficulties within the visual domain may manifest from different origins, and understanding how visual working memory is processed could aid in the ease of identifying possible clinical difficulties.

Van Lamsweerde and colleagues (2014) found contradictory evidence for these findings by exploring the impact on long term memory recall. They found that regardless of the nature of impairment object recall was the same for both features and objects. A limitation of this however, is that this notion of being able to maintain multiple representations may only hold true for working memory and not be applicable during long term memory processes. Finally, a possible explanation for why integration errors occur is also known as the ‘comparison effect’. This implies that on integration trials, stimuli that appear similar to one another are more likely to be recalled incorrectly, this phenomenon is less likely to occur in trials that involve the identification and recall of specific features.

As working memory is also considered a component of the executive function subsystem it is likely that other executive controls (like attention, planning and organisation) also have a role in the encoding and maintenance of information (Allen & Hitch, 2014). Within the literature exploring individual differences in visual working memory many of them discuss how these differences are linked to the various aspects of visual attention (Hu et al., 2014; Ueno, Allen, Baddeley, Hitch & Saito, 2011; Mercer, 2014; Blacker, Curby, Klobusicky, Chein, 2014). One aspect all the findings are in agreement with is that it is clear that visual working memory is a fundamental process that allows us to sustain our attention on information across saccades and other visual interruptions. This allows individuals to use visual features to compare objects and scenes and to assist in navigation of the visual world. Visual attention allows individuals to select a location or a series of locations that contains relevant perceptual information within the present visual scene. While visual memory and visual attention are clearly understood cognitive abilities on their own, the individual differences between the two and the link between these functions constantly pervades literature (Hu et al., 2014). Previous research has focussed on two distinctive facets of visual working memory that relate directly to visual attention : the quality and the quantity of information stored in visual working memory (Ueno et al., 2011; Blacker et al., 2014). This clearly highlights that the union of both functions is pivotal to the amount of information an individual is able to store at any given point.

Visual Memory Decay

A simple way of looking at short term memory is to assume as new information is bought into cognitive focus excess information must be lost to facilitate it (Atkinson & Shiffrin, 1968). It is known that the short term memory store for verbal information can only hold information for a brief amount of time; generally 20 - 30 seconds, before it decays unless the individual intervenes in some way to attempt to keep the memory in the forefront of the conscious mind, through a number of different memory strategies (Parkin, 2016; Howes, 2007; Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1986). While this decay time for auditory information is widely accepted, estimated decay times for visual information has produced widely varying results (Paivio & Bleasdale, 1974). Paivio and Bleasdale (1974) proposed that unlike verbal information there may be no consistent, measurable time constant for visual short term memory. Alternatively, they suggest that estimates vary largely based on the nature of the stimulus material, and can also be influenced by a range of other variables. Paivio and Bleasdale (1974) were able to identify that physical similarity and comparison stimuli were relevant, but they also acknowledge that their study has a number of limitations, such as the type of memory measured (short term vs working), and verbalisation. Although there is uncertainty about the effect that time has on the accuracy of visual short term memory, one likely possibility is that visual information does slowly decay as time passes, with precise features becoming less pronounced and the visual image losing detail (Mercer, 2014). However, this is not the only hypothesis about how decay occurs. Some researchers (Mercer, 2014) believe that the information will distort over time whereas other researchers such as Gold, Murray, Sekuler, Bennet and Sekular, (2005) believe that during the decay, changes within the representation actually occur. Opposing the aforementioned 'decay theories', distinctiveness models focus on the role of relative time that has passed in relation to other events (Mercer, 2014). Temporally isolated memories are more readily recalled because they are distinct to the other words/images that are presented in a set.

Factors that Influence Memory

While, there is no established standard capacity for visual memory (or its demarcations), a number of studies have found factors that can enhance or diminish one's ability to encode and retrieve information correctly (Mayer, Kim & Park, 2011; Ricker, Spiegal & Cowan, 2014; Ginsburg et al., 2017; Pickering et al., 2001; Xie & Zhang, 2017; Brandimonte, Schooler & Gabbino, 1997).

Rehearsal and the Serial Position Effect

Since the early beginnings of short term memory research, researchers have been intrigued by the decay and forgetting mechanisms that effect human life (Ricker, Vergauwe, & Cowan, 2016). While there is still strong debate over why decay does occur, it has been agreed upon and established that regardless of ones memory function employing rehearsal processes have the ability to prevent dramatic loss over time (Ricker et al., 2014). Short term memory is not a passive process (Parkin, 2016). Most people have the ability to command which information is in their current short term memory storage. Rehearsal is the most common way people ensure information stays in their current short term memory, without other stimuli interfering and pushing the needed information out of cognitive focus. This mental repetition is needed if an individual wants to keep specific information in the fore front of their cognitive focus. Rehearsal is also one of the most effective tools to consolidate short term memories into long term storage. The more context, knowledge and understanding an individual has about the information they are attempting to remember and store, the easier it becomes to consolidate in a meaningful way.

Most memory tests for short term memory require the participant to recall a list of words or numbers they have just heard (Murphy, West, Armilio, Craik & Stuss, 2007). Makovski and colleagues (2008) suggest that there are two components within the serial visual short term memory system: one that involves the final item and is impervious to executive disruption and the other is involved in early maintenance and is hypersensitive to perceptual load. While the serial position effect has been mostly explored in relation to verbal memory more recently interest has sparked about whether it exists for visual memory as well (Allen, Baddeley & Hitch, 2014; Ginsburg, Archambeau, van Dijck, Chetail & Gevers, 2017). An individual's performance on a word recall task generally shows evidence of the serial position effect. The serial position effect refers to the likelihood that a person will recall the words that are located at the start or the end of the list more often than words in the middle of the list (Neath & Knoedler, 1994). This phenomena is also often referred to as the primacy and recency effect. It is hypothesised that the reason the primacy effect occurs is due to those words having more time to be encoded into long term memory retrieval systems. They are rehearsed for a period of time as the initial list is read and this rehearsal may be enough to consolidate these words in a way that it is actually the middle words on the list that are more likely to be missed. The primacy effect has been shown to reduce greatly if words are read out quickly (thus, reducing the chance for an individual to rehearse and encode them into long term memory effectively). Researchers suspect that the reason for the recency effect is that these words are still in the short term memory store of an individual's mind when they are asked to recall what they remember (Neath & Knoedler, 1994; Greene, 1986; Howard & Kahana, 1999). These words are the current cognitive focus, due to them being rehearsed and potentially bumping out previously heard words they are recalled readily. This may in turn cause researchers to assume that the words read first on the list would be less likely to be recalled, as new words bump them out of cognitive focus. This however, is not the case.

Allen and colleagues (2014) suspect that the serial position effect may influence the role of visual working memory functions. As with the serial position effect, serial visual working memory involves two components. The recency component involves the final item and seems to be immune to executive disruption and the primacy component that is sensitive to interference and executive load. Engle (2002) suggests that executive control is important for protecting information that appears earlier in the list, that are most susceptible to interference. Past research indicates that executive support has a role in the maintenance of working memory but how has not always been clear (Allen, Baddeley & Hitch, 2014). As visual memory is generally dynamic, it must constantly update. Therefore, even slight changes in the environment leave current representations vulnerable. Gilchrist and Cowan (2011) found that when attention is focused on one single chunk of information the most recently encountered item will be the most easily recalled as it is encoded directly into the active focus of the attention system, thus, producing a more accurate performance. Alternatively, while Oberauer and Hein (2012) acknowledge that the visual memory system is capable of storing four chunks of information, Gilchrist and Cowan (2011) determined that a single chunk will always be more accurate.

Ginsburg and colleagues (2017) attempted to determine that the serial position effect itself is actually a spatial function. With words or images that are presented first appearing on the left side of ones conscious mind and word or images presented last appearing on the right side of an individual's mental whiteboard. This contradicts previous research that suggested the serial position effect is due to associations and bindings that occur during the time of presentation (McElree & Dosher, 2001) Due to the highly spatial nature of this process Ginsburg and colleagues (2017) attempted to determine if there were modality specific differences within the serial position effect. Previous research by Jones and colleagues (1995) showed evidence that similar errors were present during a task of this nature between both verbal and visual styles of presentation. After exploring the ordinal effects on words, locations, abstract stimuli (that were difficult to name) and known stimuli (that were easy to name) they were able to conclude that the serial position effect is only evident when information was easily verbalisable and participants implemented a verbal strategy. Interestingly, the serial position effect persisted through tasks that involved articulatory suppression. Ginsburg and colleagues (2017) believe that this is due to the semantic information being preserved which was also observed in Poirier and colleague's (2010) work. Despite the findings of this current research these breakthrough findings do contradict other recent work that suggests a unitary model of serial encoding where all types of information (verbal, spatial and object) share a similar representation (Hurlstone, Hitch & Baddeley, 2014).

Mode of Presentation

Pickering and colleagues (2001) investigated the influence of the dual stream hypothesis on memory by stating that in memory it does not solely depend on whether information is spatial or object in nature but whether it is presented in a static or dynamic form. Pickering, Gathercole, Hall and Lloyd (2001), suggested the visuospatial sketchpad's activation in particular depended on the stimuli's mode of presentation. They proposed that within the visuospatial sketchpad there is a further demarcation that suggests static and dynamic visuospatial information is processed by separate subsystems. Their research was inspired because at the time the visuospatial sketchpad is far less understood in comparison to the phonological loop.

An alternative approach to the common studies of visual memory involves the examination of patterns between performance on visual (object) tasks and performance on spatial tasks (Pickering et al., 2001). A common limitation in studies looking at visuospatial performance is when comparisons of tasks are made, but one task is dynamic in nature and the other static (Kessels, van Zandvoort, Postma, Kappelle & de Haan, 2000; Corsi, 1972). Essentially what is then being made is a comparison between two different functions, one would not expect similarities in performance for this reason. For example the common Corsi blocks task is dynamic in nature whereas the Visual Pattern Tasks is static (Kessels, et al., 2000; Corsi, 1972). Comparisons are commonly made as in the past they were both viewed as measures of the visuospatial sketchpad, now further understanding exists which demonstrates that this methodology was not the most accurate. As two cognitive functions are being tested, when inferences are made between the two it becomes difficult to determine which function is responsible for the patterns in performance that are observed.

Logie (1995) introduced a fractionated sub system that attempted to explain how different information was stored within the visuospatial sketchpad. The visual cache is described as a passive storage system that is used to hold the static visual objects in a scene (Vasque, Basso Garcia & Galera, 2016). Alternatively, the inner scribe is the visual caches active counterpart. The inner scribe's role involves the storing and rehearsal of dynamic information, that is most often spatial in nature. These two components are closely involved with the central executive within the visual working memory system. As with most memory systems both the visual cache's processes and the inner scribe's are susceptible to interference and changes in attentional demands. The introduction of visual noise, or irrelevant information, to a scene has been shown to reduce the efficiency and accuracy of both the encoding and the retrieval of information within these sub systems when present. That being said visual information that is considered relatively simple to encode, as it has reduced attentional demands and is presented in a controlled environment is far less susceptible to this interference that occurs in real word environments.

Pickering and colleagues (2001) in an attempt to determine if there were separate components to the visuospatial sketchpad were able to identify that the object subcomponent develops faster in children than the spatial one. They explain these two separate sub systems for manipulating visual information based on Logie's (1995) notion of the visual cache (for static information) and the inner scribe (for dynamic information). While they are two separate sub systems they do work in partnership when manipulating visual information. They proposed that the visual cache system is linked closely to the visual perceptual system and deals with information such as form and colour. The inner scribe, alternatively, is believed to be responsible for the understanding and manipulation of movement sequences and comparisons have been made between it and the subvocal rehearsal process counterpart in the phonological loop. Pickering and colleagues (2001) examined children, and found that when given a matrices task, children performed far more superiorly in the static version than in the dynamic version.

When an adult sample was incorporated to determine if the findings were generalisable some inconsistencies in results were present (Pickering et al., 2001). In tasks that were particularly demanding on the participant's perceptual load, there was virtually no impact on adult's performance in comparison to children who struggled to complete the task. It was suspected that this task was not as attentionally demanding to adults as it was to children and thus, likely used less executive resources, owing to differences in functional maturity. Thus, while this understanding forms a strong foundation, future research is necessary to understand the relevance and impact of these findings within an adult population.

Evidence for a fractionated sub system for static and dynamic information is also present within human biology. Visual processes that eventually lead to higher order processes begin as early as in the rods and cones (Zilmer et al., 2008) even processes that can lead to deficits in the 'what' and 'where' pathways. The nerve endings in the rods and cones send visual information to the lateral geniculate within the thalamus (Blumenfeld, 2002). The lateral geniculate then processes this information using two independent cells. Parvocellular cells process predominantly colour, contrasts and different hues. These cells are often much smaller than their counterpart the much larger magnocellular cells that process movement and location detection. This indicates that the bifurcation of object and spatial processing occurs very early on in the primary visual pathway. Neuroanatomical research demonstrates a further distinction in the visual processing network (Wist, Schrauf & Ehrenstein, 2000). The magnocellular pathway is best at processing dynamic stimuli, or stimuli in motion (Zeki, 1993). It has been described as having a low spatial but high temporal resolution. Alternatively, the parvocellular pathway is more attuned to interpreting static patterns and fine details. It is described as being high in spatial and low in temporal resolution.

Despite the obvious need to incorporate both static and dynamic measurements of visual memory, stimuli that is dynamic in nature is not routinely included in visual memory assessments (Wist et al., 2000). Dynamic stimuli is also rarely included in tests of visual perception. These limitations however are not due to the notion that researchers and clinicians feel that there is little clinical utility in incorporating tests that are dynamic in nature. Instead these tests are often excluded because the current measures that do incorporate movement are cumbersome, can result in poor reliability and are inconvenient for use in clinical practice or on the field. However, with the recent technology boom the ability for researchers to incorporate dynamic stimuli is now readily available at their fingertips. With tablet and laptop devices becoming more mainstream clinicians are no longer limited by physical (due to the heaviness of the equipment) or technological limitations. The use of technology does not only allow for dynamic stimuli to be easily presented in a standardised format, it also allows for a more streamlined scoring process and less physical burden to the clinician, allowing for an overall more standardised assessment with less room for experimental error in administration.

Familiarity of Object Based Information

Xie and Zhang (2017) explored the effect the familiarity has on visual short term memory consolidation. Using a sample of young adults and stimuli that was familiar and relevant to them (Pokémon characters) they found that known or familiar stimuli was encoded much faster into short term memory than unfamiliar stimuli. As short term memory is constrained by time as well as capacity they proposed that this speed could potentially increase the capacity of short term memory as individual’s are able to process and encode more stimuli more efficiently. This supports previous studies that also found when visual information was familiar, storage capacity appeared to be higher (Zimmer, Popp, Reith and Krick, 2012; Sorenson & Kyllingsback, 2012). There is also evidence to support that there is a clear relationship with the ability to consolidate information quickly and high visual short term memory capacity (Jannati, McDonald & Di Lollo, 2015). Object memory effectively relies on familiarity. As we understand that object information is collated in the 'stored representations' in the brain, a stronger representation in long term memory for familiar information could lead to faster recognition and therefore, more efficient consolidation in visual short term memory also (Sun, Zimmer & Fu, 2011). Visual information that is placed in a meaningful scene is also more easily recalled and than information that is considered meaningless (Endress & Potter, 2014). When information is meaningful it is likely a stored representation has already been developed within the brain, and verbalisation is more likely to take place (both factors are known to enhance one's recall ability). Finally, objects that have already been encoded regardless of the saliency will be able to be recalled efficiently, whereas, abstract objects that have never been viewed will require a level of encoding to be undertaken. This is a pivotal component when assessing visual memory, as known objects do not require encoding and thus, without the use of abstract stimuli, most object memory tasks could be classified as recognition assessments rather than recall.

The Development of a Linguistic Preference to Encoding

Prior to age seven children respond better to visual stimuli than auditory stimuli (Gathercole & Hitch, 1993). However, as a child gets older and their cognitive processes become more efficient they are able to complete tasks prior to the memory decay occurring. Since the advent of Gathercole and Pickering's (2001) Working Memory Test Battery for Children, normative data and trajectories that better explain working memory development have been established. These findings solidify that working memory tends to improve with age, however, a change in preference from visual information to auditory information is present around the advent of formal schooling. They also noted that not only did this relationship exist but it was also the biggest influence on task performance.

Gathercole and Pickering's (2001) study comprised of a number of experiments, with one exploring the effects of articulatory suppression. Contrary to other studies (Peterson, Decker, Reed & Moshe, 2018) that looked at visuospatial information more broadly, Pickering and colleagues found that articulatory suppression had no detrimental effect on performance in the static condition. Pelizzon, Brandimonte and Favretto (1999) found support that suggests articulatory suppression has the ability to improve performance in some visuospatial tasks.

Pickering (2001) conducted a study exploring the development of the visuospatial sketchpad. In terms of relevant findings for the present study Pickering found that young children who named the objects presented to them, out performed those that attempted to encode purely visually. She also found that only children in the youngest age group (the 5 year olds) were affected when the stimuli was visually similar. From this finding along with the notion that the older group were significantly affected by the length of the name of objects Pickering was able to deduce that even when presented with visual stimuli individuals encode the information using phonological strategies (2001).

Hitch and colleagues (1988) proposed that young children store visual information in terms of features. When different stimuli or objects share similar visual features problems can occur in the recall and reconstruction of items. This explains the difficulty with stimuli that was visually similar that Pickering (2001) also found in her study. This reliance purely on the visual component of working memory dwindles with age and individuals begin to adopt an encoding method that evolves verbally labelling objects instead of encoding them based on appearance. In a way this allows the visual stimuli to then be maintained by the phonological loop. Miles and colleagues (1996) also found that when able to older children and adults will attempt to apply phonological processes to complete what researchers regard as ‘pure’ visual measures. While it would appear that from the onset of literacy individuals would prefer to encode information via their phonological loop this is not necessarily the case. Surprisingly adult’s performance on the Corsi Blocks is somewhat unchanged with the inclusion of articulatory suppression, this suggests that adults do not use phonological encoding during this task and the two sub systems are working parallel to one another (Pickering et al., 2001).

Levels of Processing and the Influence of Verbalisation

Craik and Lockhart (1972) shifted the focus of memory to understanding how differences in encoding specifically can attribute to why different memories are able to be retrieved more easily than others. They identified the encoding process to be pivotal to the strength of long term memory storage. The deeper the processing, the better a memory was encoded and the greater the chance of retrieval with high amounts of detail. They found that when individuals make meaningful connections between objects (even objects with seemingly no semantic relations), memories are more easily recalled with high levels of accuracy. Alternatively, information that is encoded using shallow processing that focuses on the characteristics or the physical features of the object rather than the meaning, it is unable to be retrieved as easily. It is difficult to prompt the retrieval of information that is coded shallowly as clinicians cannot use semantic connotations in an attempt to cue participants. An object presented within an environment it is generally more easily recalled than an object presented in isolation, as the context of the environment allows the individual to create meaningful inferences to aid in deep processing. Individual's who are able to encode even arbitrary information in a more meaningful way are more likely to increase their span and recall more information more readily.

Avons and Phillips (1986) proposed that when encoding abstract visual patterns two different levels of processing occur. Similarly to Craik and Lockhart's (1972) levels of processing these also vary in aiding one's ability to recall. The lower order process involves encoding patterns at a featural level and the higher order process relies on pre existing knowledge and verbally labelling objects. These higher order processes still occur despite visual pattern tasks tending to be abstract in nature. Avons (1980) also found that when the pattern contained shapes that could be identified as letters memory improved.

There is now a growing volume of research that looks at the effects of verbalisation (Brown, Brandimonte, Wickham, Bosco, & Schooler, 2014; Fiore & Schooler, 2002). It is now understood that verbalisation can both impair and enhance performance on a range of non verbal tasks. Past research has demonstrated that the mismatch between verbal and non verbal knowledge is likely due to each being processed by different mechanisms (Brown et al., 2014; Brandimonte & Collina, 2008). Brown and colleagues (2014) make an important contribution as their research clarifies how different forms of verbalisation influence visual memory. Their research acknowledges how the differences in verbalisation affect visual memory depending on where in the encoding process verbalisation occurs, as well as the nature of the verbalisation (naming vs description). Depending on its nature verbalisation has the potential to hinder, aid or have no effect on visual memory performance. When verbalisation is an impairment it is also referred to as verbal overshadowing and has been found to implicate visual memory for faces, maps, and a number of other components of visual imagery (Brown, et al., 2014). When using verbalisation to understand images individuals tend to name objects rather than apply a detailed description, this tends to tie the visual form to a single word concept.

It is likely that verbalisation effects memory performance in a number of quantifiably different ways. Verbalisation is always utilised during the encoding process and is often reactivated when attempting to recall visual stimuli. When measuring the effect verbalisation has on visual memory several methods have been employed to manipulate whether or not a participant is able to name or not during encoding. These methods can be both overt and covert in nature. Some tests and studies compare performance on ‘easy’ to name stimuli vs ‘hard’, with ‘hard’ to name stimuli not prompting naming initially and therefore, attempts to reduce the interference by the verbalisation process, allowing for a more ‘pure’ measure of visual memory performance (Boettcher & Wolfe, 2012). The effect of verbalisation has become the main component of the modality mismatch assumption theory which explores further why memory and other cognitive functions that revolve around imagery are often heavily implicated by this process (Schooler et al., 1997).

There is now a significant body of research to show that verbal mediation can impair performance on a range of non verbal tasks (Schooler & Engsler - Schooler, 1990; Brandimonte et al., 1997). This phenomenon is often referred to as verbal overshadowing and has been found to influence memory for faces and colours (Schooler & Engsler - Schooler, 1990), maps (Fiore & Schooler, 2002), and images (Brandimonte et al., 1997). Whats important is that these studies all employ different methodologies, which it is vital to be mindful of when drawing comparisons. Some individuals will verbally mediate with a detailed description, entailing many words that may be difficult to rehearse and maintain, whereas some individuals choose to adopt a 'naming' approach in which they apply a single word verbal concept to a visual form. Currently, it is unknown whether the effects of verbal mediation are driven by the same mechanism (Brown, Brandimonte, Wickham, Bosco & Schooler, 2014). It has been consistently found that performance on imagery recall is poorer when verbal mediation is encouraged at encoding than when it is actively discouraged (Brown et al., 2014). However, it is likely that the influence on memory performance is occurring in qualitatively different ways.

Over time several methods have been used to manipulate the presence or absence of naming during the encoding process of memory (Brown et al., 2014, Fiore & Schooler, 2002; Schooler & Engsler - Schooler, 1990; Brandimonte, Schooler & Gabbino, 1997). Some studies use covert methods and others use overt methods for naming in an attempt to find consistent differences (Brown, Brandimonte, Wickham & Bosco, 2014). Other studies attempt to use easy to name stimuli vs hard to name, or known objects vs abstract objects (Brandimonte & Collina, 2008). It is crucial to understand that in the imagery paradigm, verbalisation is believed to occur during the encoding process, it involves naming of the stimuli and retrieval of the visual stimuli is generally tested using an image manipulation task (Brown et al., 2014). Several methods have been used to manipulate absence of naming during the encoding process. These methods acknowledge that naming can be overt or covert, even though these terms are generally only used to describe eye movements in visual processing. Objects that are considered easy to name will prompt spontaneous naming as soon as the object is seen and are less susceptible to interference than objects that are difficult to name.

It is generally accepted that verbal memory and visual memory are two distinct unitary functions (Milner, 1971). However, Saling (2009) contests that this notion of modality specific memory may not be as clearly defined as previously thought. He acknowledges through a review of the effects on verbal memory that arise as a result of temporal lobe epilepsy (TLE) that there is considerable overlap between the two functions. Prior work has suggested that verbal memory function resides in the left temporal lobes and non verbal memory function resides in the right (Dobbins et al., 1998). While significant evidence suggests the former, the associations seen within the latter are not as strong. It is likely that in the case of TLE patients that both sub systems are implicated to some degree and in an attempt to maintain function the brain reacts in a compensatory manner to ensure minimal long term cognition is lost. Similarly, an overlap in these two functions can be observed in healthy, intellectual adults. A skilled learner understands that encoding information through dual pathways will create more neural connections as per Hebb's (1948) notion and subsequently be able to readily recall more information. This is a learnt behaviour that has strong correlations with both intelligence and education attainment (Chevalier, Parrila, Ritchie & Deacon, 2017). This complicates researcher's abilities to make a pure memory test of either modality. As even in a verbal list learning tasks, a skilled learner will often not only remember the words but also encode a visual construct of the information (Clark, Deshler, Schumaker, Alley & Warner 1984). This is a passive, unconscious ability that cannot be removed in its entirety, however, it furthers highlights the need to attempt to suppress this ability when attempting to develop pure modality specific tasks and attempting to measure each.

Articulatory suppression can be used to attempt to prevent participants from spontaneously naming stimuli when presented with easy to name forms, and surprisingly is found to improve imagery performance despite what would seem to be initial interference (Brown et al., 2014). Verbal overshadowing is found to impede memory performance as when verbally naming an object, individuals will name on a global level and this is at the cost of encoding specific featural knowledge. This generally results in poorer performance if an individual then has to identify the imagery presented post encoding from a feature by feature basis. Using the modality mismatch assumption it can be assumed that the process of naming emphasises global understanding and knowledge too heavily at the expense of what may be critical specific features of an image. Alternatively Brown and colleagues (2014) identified that when naming occurs post encoding it benefits performance. Their contribution is of particular importance as it clarifies that verbal overshadowing is not the result of a single phenomenon but instead consists of many components that effect the recall of different kinds of images. The fact still exists that verbalisation has the potential to effect memory performance in both a positive and negative manner. To gain a more pure measure of imagery performance it is necessary to try and avoid any aspect of functioning that may impact performance. Thus, in an attempt to define visual memory capacity it is necessary to try and reduce the potential of verbalisation occurring.

Brown et al., (2014) acknowledge that the term verbal overshadowing is often used to describe an impairment in visual memory performance due to verbalisation. However, the nature of verbal overshadowing differs depending on both the timing and nature of the verbalisation task. Tasks that involve a description after encoding has taken place yields different results to a task that involves naming during encoding. The former actively attempts to create false memories or cause an individual to forget, the latter enhances the encoding process. Furthermore, a post encoding description has been more heavily researched within the verbal domain (Hatano, Ueno, Kitagami &

Kawguchi, 2015; Mickles, 2015). Within the verbal domain, the description technique allows an individual to break a verbal object into individual components, or in a visual sense, its features. Whereas naming makes it much easier for individuals to chunk information. This would likely function the same way within the visual domain, with naming allow a global representation of the object to be created, at the possible loss of some features. This would allow for a higher number of global images to be stored however, the cost is a reduction in feature accuracy.

From Visual Memory Theory to Practical Assessment

While as expected visual working memory complex span tasks do have some overlap with simple span tasks, complex span tasks also have several unique processes that are working as well (Chein, Moore & Conway, 2011; Unsworth & Engle, 2006). Visual working memory is a ubiquitous process that allows us to maintain a stable representation of the visual world. Regardless of the constant utility of visual working memory there is a severe capacity limitation to the system. While many of the factors that influence memory capacity have been heavily researched and are subsequently well established (Brown et al., 2014, Xie & Zhang, 2017; Pickering et al., 2001), these influences are not consistently present or controlled for in current visual memory assessments. Frequently in the literature findings are constrained by the current methods of measuring visual memory. Due to the complexity of the visual memory system, isolating and measuring the various components has been found to be difficult. The following section will explore the strengths and weaknesses of the current visual memory assessments in light of the research discussed in the previous chapters.

CHAPTER 4

THE ASSESSMENT OF VISUAL MEMORY

Memory tests include some of the oldest neuropsychological and cognitive assessments that are still used routinely today (McConkey, 1996; Styles, 2005; Strauss, Sherman & Spreen, 2006). From list learning tasks such as the Rey Auditory Verbal Learning Test (RAVLT) (Rey, 1964), that measure verbal span for arbitrary information, to story recall, which is a verbal measure of associative memory (Wechsler, 2009), measures of span, working memory, learning and delayed recall have been incorporated into clinical and research settings for an extensive number of years (Strauss et al., 2006).

A consistent characteristic of most established, reliable and valid memory assessments is that they are measures of verbal memory. While a number of visual memory assessments exist, their psychometric properties are less robust than their verbal counterparts. Due to methodological difficulties displaying dynamic visual stimuli in a standardised fashion, in the past, measures of visual memory were scarce or lacked validity. However, in recent years, there has been an improvement in the assessment of visual memory with developers acknowledging the need to incorporate visual processing theories with visual memory theories to develop sound comprehensive tests, as well as exploring the potential for electronic administration (Wechsler, 2009). Nonetheless progress has been slow, and many of the measures of visual memory are still limited in what they are able to assess as they are conducted using pen to paper tasks. Moreover, when current assessments have been modified for electronic administration, this has involved a direct adaptation of the pen to paper tasks with no further development to include dynamic or complex stimuli. Furthermore, compared to verbal memory there is little research investigating the relationship between the serial processes of visual memory (e.g. the influence of span scores on working memory scores), addressing each component of the two stream hypothesis separately.

Assessing Visual Memory

Visual memory is a complex process that involves many different aspects of cognition, and, cognitive researchers are consistently endeavouring to develop assessments that isolate each of these individual aspects (Gathercole & Pickering, 2001; Baddeley & Logie, 1999). While in reality cognition is a holistic process that allows an individual to interpret and evaluate their world, without the ability to isolate each function it is difficult to understand where and why deficits occur (Mapou & Spector, 1995). Similarly to verbal memory, visual memory includes a short term, working and long term component (Schwarb et al., 2016). Unlike verbal memory, it is also suspected to have different storage facilities for different kinds of information (e.g. spatial and object). Thus, when assessing an individual's visual memory, the task implemented should be reflective of what region of the brain and stimuli are of interest.

While most memory assessments are verbal in nature and have been derived from longstanding research that has investigated memory for auditory information, the established paradigms that underpin these assessments do have theoretical ties with memory for all senses (Kirchner, 1958; Rey 1964). Perhaps the most commonly used method of memory assessment administration draws inferences from the span paradigm established by nback tasks conducted by Kirchner (1958). This is a continuous performance task that is designed to measure memory span and working memory capacity. This was measured by asking participants to remember a sequence forwards, to gain a measure of span, and then complete a task where they are asked to remember specific portions of the sequence that occurred earlier. For example, N-2 would require participants to remember, the stimuli that they were told 2 steps prior to the final one. The nback task has evolved over time with Jaeggi et al (2003) developing a dual nback task that required individuals to recall stimuli from different modalities (generally verbal and visual). While the nback tasks are less commonly used today, most of the established span and working memory tasks share theoretical underpinnings with this seminal test. This notion of a span assessment paradigm has allowed the development and utilisation of a broad range of clinical and research assessment tools (Wechsler, 2008; Milner, 1965).

Similarly, to the nback tasks establishing a span paradigm that most current span and working memory assessments are derived from. List learning tasks have had a profound impact in the development and establishment of the most commonly used learning and delayed tasks (Lezak et al., 2012). List learning tasks have a long history in memory research, and are still used routinely today (Strauss et al., 2006). The predominant reason for their success is due their ability to measure a number of memory components in a brief period of time. The research that has been derived from early list learning tasks such as the Rey Auditory Verbal Learning Task (Rey, 1964) aided in the formation of the administrative and theoretical paradigm that underpin most learning and delayed assessments today.

The greatest barrier when developing visual memory assessments, is overcoming the methodological limitations that have been continuously identified when trying to present visual information in isolation (Wechsler, 2009). This includes the ability to allow abstract information to be presented in both static and dynamic formats. Visual memory is also influenced by the use of language, as language is heavily embedded in adult cognition and is very difficult to suppress especially when asking individuals to recognise known objects. Despite the promising results a number of assessments have yielded, long administration times, the difficulty discriminating between verbal and visual encoding strategies, and the inability to present dynamic information in a standardised manner, highlight the range of issues researchers face when developing visual assessments (Gathercole & Pickering, 2001; Wechsler, 2009; Lezak et al., 2012). Furthermore, research that aims to generate normative data for visual memory assessments has consistently noted that visual memory assessments tend to have poorer validity and reliability coefficients than verbal memory assessments (Strauss et al., 2006). The following subsection will aim to describe the current limitations when measuring the various components of visual memory, before highlighting how current assessments have attempted to combat these known limitations during their development phases.

Limitations in the Assessment of Visual Short Term Memory

Within memory assessments as a whole, span tasks are the most common measures of short term memory, as an individual's span is synonymous with their short term memory capacity. It has been clearly established for decades that the average verbal span is 7 items +- 2 (Baddeley, 1996; Chow, et al., 2016). This suggests that there is a potential definitive capacity for specific aspects of memory. However, the current assessments that have aimed to measure visual span have yielded inconclusive results in relation to capacity (Zhang & Luck, 2008; Delvenne & Bruyer, 2004; Wheeler & Treisman, 2002). There are a number of factors that have been identified as being able to influence memory capacity regardless of modality. Some of these are due to normal sources of experimental error and are thus difficult to control, e.g. mood, stress and hunger. However, a number of factors related to test construction can also influence performance, e.g. perceptual demand, mode of presentation and stimuli familiarity, and these can potentially be controlled for during development.

Furthermore, difficulties in isolating the visual memory components of interest have been present when developing and scoring visual memory assessments (Wechsler, 2009; Benedict, 1997). In the past it has been difficult to create a measure of visual short term memory that utilises free recall (rather than a discrimination/recognition paradigm) without the use of a motor component. As a number of individuals who present for a memory assessment also suffer from other areas of dysfunction, sometimes it is difficult to determine whether poor performance is the result of poor visual memory or poor motor control. This has lead to many short term visual memory assessments including recognition methods to measure capacity. As recognition tasks can be completed relying on cues that activate associative memory, they are often considered more simple than free recall tasks. Individuals may not be capable of spontaneously recalling the information due to memory dysfunction, however, when presented with an array may be able to recognise the image in question based solely on a few key defining features. It is known that in healthy adults verbal recognition tasks generally produce high ceiling effects (see. RAVLT, HVLT, CVLT) (Strauss et al., 2006), although these ceiling effects are not always observed in visual tasks. It is however, difficult to evaluate performance on a recognition task without a recall analogue for comparison.

The difficulty in presenting information that is dynamic in nature has plagued cognitive researchers for decades. The incorporation of computer assisted elements to display dynamic information has been used for a number of years. These tasks (e.g. flanker tasks) have yielded important research findings, however they are seldom used in clinical settings due to their lack of portability and cumbersome nature (Rensink, 2002). During pilot phases researchers have attempted to incorporate some computer assisted elements into their memory batteries, however these have been ultimately removed in favour of the more portable pen and paper option (Gathercole & Pickering, 2001). More recently, with the advent of tablet devices an increasing number of researchers are exploring their utility in clinical assessments (Oesterlen, Eichner, Gade, Seitz-Stein, Katja, 2018; Atkins, et al., 2017; Grant et al., 2017). While a number of assessments have been developed for research purposes (Walterfang & Velakoulis, 2016) it is only very recently that established batteries are being converted to tablet form (Wechsler, 2016). At the time of writing, these converted batteries do not include updated dynamic stimuli in their measurement of spatial memory.

Finally, it is difficult to develop and include measures of visual memory that do not include a verbal component. It is well established that language, once acquired, becomes automatic, and therefore eliminating any verbal component is virtually impossible in the assessment of visual memory. Hence, researchers must create ways to reduce verbalisation as much as possible (Brown et al., 2014). The use of abstract imagery is generally incorporated as it reduces spontaneous naming since individuals do not have a word for the image already stored (Wechsler, 2009). When encoding abstract images, initially individuals are required to focus on the separate features of an object without relying on their verbal memory to assist them. This however means that no visual memory assessments can include any known or established landmarks. It is also difficult to stop language being used during encoding of spatial information as individuals will often verbalise left/right or the cardinal directions to orient themselves (Kozlowski, Wesleyan & Bryant, 1977). While verbalisation cannot be eliminated it is a vital component to consider during development as its inclusion can inflate a participant's performance.

Considerations When Developing Visual Short Term Memory Assessments

The greatest barrier when developing visual memory assessments, is overcoming the methodological limitations. In order to overcome these limitations, assessments need to be developed that would allow abstract information to be presented in both static and dynamic formats, would reduce the impact of verbalisation and would allow for free recall without the requirement of a motor component. For years researchers have attempted to combat these limitations by researching and refining their developed tests continuously (Wechsler, 2009). The impact of these limitations is well documented and understood, however, despite best efforts, these problems persist. The Wechsler Memory Scale - IV currently represents the most robust and refined measure of visual short term memory and this is the result of rigorous evaluations of each task that occur between each iteration. The pilot notes in the WMS-IV manual outlines a number of the limitations discussed in the previous section, of this thesis including, issues minimising verbalisation, utilising dynamic stimuli and the reliance on motor control and then subsequently describes the development process to highlight how these limitations were considered and managed during the development of the fourth version (Wechsler, 2009). This section will discuss key considerations in relation to three immediate visual memory assessments from the WMS-IV. These tests have been selected as the provide a current, relevant example of how researcher's have attempted to address the limitations present in the development of visual memory assessments.

Designs (WMS-IV) : Utilising Abstract Stimuli to Reduce Verbalisation.

A new addition to the WMS - IV, the Designs subtest is an assessment of visual immediate and delayed memory. It was developed with the intent to reduce verbalisation, motor control and visuospatial processing, though based on analysis of the findings in the pilot study a spatial component was ultimately included (Wechsler, 2009). This task involves participants being presented with a grid that has a number of designs located on it. Participants are then asked to replicate the pattern that they saw in the presented design from a series of cards. This is a recognition/discrimination task as there are a number of distractor cards that the participant will have to ignore. This task includes both an immediate and a delayed component. When developing the individual stimuli that were used, the researchers ensured no stimuli were used in more than one trial to reduce interference effects between trials. The items used in this subtest were designed to be abstract and difficult to verbalise in an attempt to limit the extent that verbal mediation could improve visual memory performance. During the development phases a number of different methods of administration were trialled. Originally the developers trialed having the participant view each symbol individually and then point to where on the empty grid it belonged. This method yielded very poor results and individuals were unable to use other symbols that they had viewed or the spatial locations they had already selected to prompt recall performance. In this form the task would have been more reflective of executive functioning and working memory as participants had to plan ahead and maintain which exact squares they had already utilised. The eventual final implemented method involved utilising cards that are placed on to a grid. This allows individuals to discriminate between the correct pattern, trial the pattern in a range of positions to determine which they recognise as correct, and to view and evaluate the final input that incorporates all the patterns holistically. This removed the element of planning and working memory and instead focussed more so on the recognition/discrimination paradigm.

A criticism of this assessment is however, the discrimination component. As participants only view the overall board for 10 seconds it is difficult to encode all the individual features of each pattern in a manner that would allow for discrimination between very similar designs. This can result in participant's scores underestimating their memory function. Furthermore, there is also an element of guesswork that can be incorporated when discriminating between two similar designs. As highlighted above, when measuring memory performance where possible free recall is nearly always a more accurate and representative measure when compared to recognition tasks. However, recognition tasks that are used to complement free recall tasks can yield more accurate findings that are indicative of which part of the memory system is dysfunctional. Designs does include a recognition component where participants are asked to recall which designs they have previously seen, however, comparisons between the recall and recognition components are potentially confounded by the aforementioned limitations.

Family Pictures (WMS-IV) : An Attempt To Reduce the Impact of Verbalisation.

During the development of the WMS-IV researchers also endeavoured to reduce the level of verbalisation that was present in some of their visual assessments (Wechsler, 2009). They acknowledged that with some assessments it was difficult to discern whether a visual memory deficit was present due to an individual being able to rely on their verbal memory to complete a task. Family Pictures was a subtest that was included in the WMS - III that was ultimately removed from the WMS - IV. This subtest was a component of the immediate and visual memory scales and required the participant to respond verbally to visually presented images. The test measured visual- verbal associative memory (e.g., picture-name, object-activity) as well as spatial memory (e.g., location of characters in the picture) (Wechlser, 2009). It was identified that poor performance on this task was often due to a fault encoding the information verbally rather than visually, therefore an attempt was made to improve this subtest for the WMS-IV. The new version incorporated different images that aimed to be less easily verbalised compared to its predecessor. However, despite these changes, the test demonstrated poor reliability as many examinees lost points for mislabeling the names of the characters rather than as a result of poor memory, which indicated that the task still relied largely on a verbal strategy to recall visual information. As these modifications did not improve the subtest by addressing the verbalisation limitation, Family Pictures was ultimately excluded from the WMS-IV.

Visual Reproduction (WMS-IV) : An Evaluation of Scoring Parameters.

Visual Reproduction is a free recall short term memory task where participants are presented with an abstract design and then asked to immediately replicate it by drawing it on blank paper. In the WMS - III low Visual Reproduction scores may have been more indicative of poor motor functioning than poor memory skills. Thus, the scoring went through an overhaul to be more relevant to the memory components of the test rather than the motor components. This process involved more stringent and descriptive scoring procedures that included analysing each of the lines, the orientation of the lines and the overall inclusion of all components in the picture. This aimed to encapsulate an individuals memory performance more accurately, rather than punishing them for an inability to draw well. This adaptation proved to be promising with pilot data indicating that under the new scoring system results were less susceptible to motor deficits and more representative of memory performance. During this review, the administration and stimuli of Visual Reproduction remained the same as previous iterations of the WMS.

Limitations in the Assessment of Visual Working Memory

Many of the limitations present when developing short term memory assessments also affect the ability to measure working memory effectively. As outlined in Chapter 3 working memory is a distinct sub system of memory that allows for the manipulation of stored information. It incorporates facets of short term memory and long term memory, to manipulate information in the conscious mind to make higher order decisions about it. Baddeley and Hitch (1976) acknowledged that the visuospatial sketchpad could be further fragmented into what they coined a 'spatial' component (that is involved in processing movement, orientation and location) and a 'visual' component (that is involved in processing colour, shape and texture). This is particularly noteworthy as these two fragments mirror the demarcation of the two streams of visual perception. While much research has been conducted on the visuospatial sketchpad in general (Navarro et al., 2013; Thompson et al., 2006; Holmes, Adams & Hamilton, 2008), much less research has been conducted on the further spatial and visual divisions as proposed by Baddeley and Hitch (1976). Nonetheless, established research in the visual memory field that focuses on the visuospatial sketchpad has enabled a number of inferences to be made about how visual memory span and long term storage may function (Beck & Elliot, 2014; Thompson et al., 2006; Holmes et al., 2008). These inferences have in turn, formed the basis for the development of a number of visual working memory assessments.

Similarly to visual short term memory, a gap in the literature also exists in terms of identifying a definitive visual working memory capacity. Although a number of studies have attempted to discern what the working memory capacity is for visual memory (van Lamsweerde, Beck & Elliot, 2014; Vergauwe et al., 2014), without a well defined visual span analogue for comparison, it is difficult to determine whether the findings are reliable, valid and pertinent, or confounded by other variables. Digit Span is one of the most common short term/working memory verbal subtests (Wechsler, 2008). It is particularly useful as it incorporates the same stimuli and format for both the short term and working memory components. The only difference between the tasks is the manipulation aspect in the backwards trial. This allows clinicians and researchers to make a direct comparison between an individual's verbal short term memory capacity (their immediate span) and their working memory capacity, as this allows confounding variables to potentially be controlled for. The only current forwards and backwards visual assessment that is implemented routinely is the Corsi Block Tapping Task, which involves the clinician tapping a series of blocks in a predetermined order and participants repeating the sequence back to them in either the same, or the reverse order (Corsi, 1972). However, for such a routinely used assessment there is a paucity of reliability data available and depending on the administration procedures and sequences employed for the task there is little to no standardisation in both block arrangement and sequencing procedures (Berch, Krikorian & Huha, 1998; Pagulayan, Busch, Medina, Bartok & Krikorian, 2006). Berch and colleagues (1998) conducted a review of research that utilised the Corsi Blocks task and highlighted the difficulty in using this data for comparative purposes between other studies that utilised the Corsi Blocks task, due to the large variation in a number of parameters of the task (e.g. the sequence of the blocks, timing between taps, sequence lengths etc).

Currently short term and working memory visual analogues that isolate the spatial and object streams and allow for comparisons between the two do not exist. It is possible that the current inconclusive results observed when measuring visual short term and working memory span are due to most assessments incorporating both spatial and object processes together. This allows a participant to inherently choose their preferred method of processing during encoding, and therefore could account for variability in results. If spatial and object memory do have different span capacities, then the ability for participants to choose their mode of encoding is likely to have profound effects on performance outcomes. Being able to assess performance of the two functions separately can have an impact in both research and clinical settings. As each function is processed by a different region of the brain, deficits in one area could be indicative of a range of pathologies and symptoms that are distinguishable from the other (Milner & Goodale, 1992). The ability to assess each stream separately may aid researchers and clinicians in being able to identify exactly where deficits in an individual exist, and subsequently make decisions about appropriate remediation strategies.

Considerations When Developing Visual Working Memory Assessments

The Working Memory Test Battery for Children - (Gathercole & Pickering, 2001).

Working memory assessments as highlighted above are impacted by many of the same limitations as short term memory assessments. Gathercole and Pickering (2001) identified that there was a gap in paediatric working memory assessment and subsequently developed a comprehensive battery for this specific cohort. The development of their Working Memory Test Battery for Children (WMTB-C) involved piloting innovative new techniques that aimed to investigate the visuospatial sketchpad and the phonological loop separately. Furthermore, they pursued numerous avenues for presenting dynamic stimuli in the hopes of incorporating assessments capable of measuring the inner scribe in a standardised fashion. The pilot data in the Working Memory Test Battery for Children manual outlines a number of the aforementioned limitations, and then subsequently describes the development process of their own subtests to highlight how these limitations were considered and managed during the development of the battery (Gathercole & Pickering, 2001). This section will discuss their key considerations. The tests selected for discussion highlight how the limitations in the previous section were considered and addressed. Not all subtests will be included only those that address key issues that have been continuously outlined during the review of visual memory assessments.

After the initial prototype battery had been developed and trialled, both Gathercole and Pickering (2001) acknowledged that the visuospatial sketchpad subtests required modification in a number of ways, largely due to methodological constraints. Gathercole and Pickering acknowledged that these were limitations that they tried to avoid but based on the results of the prototype battery were unfortunately inevitable. A large focus of this battery was the incorporation of both static and dynamic versions of visual assessments. However, this was also where they faced their biggest challenge.

The Mazes task which is a measure of spatial working memory, originally had both a static and dynamic trial. In this subtest, children were presented with the image of a man in a maze in front of them. Unlike a traditional maze, this maze consisted of rectangles surrounding the man with two possible exits (or gaps in the maze). In the dynamic version of the subtest the examiner drew the pathway the child would be required to remember from the centre of the maze out. This was difficult to standardise as variation in the speed and accuracy of the examiners drawing was present. In the static version of this subtest children were presented with a still image of the maze with the pathway already drawn and asked to remember it, prior to reproducing it. Gathercole and Pickering (2001) compromised and in the final version of this test the maze was presented in static format and then the examiner would trace the route out of the maze with their finger to provide a dynamic component, however, this form of presentation raised its own problems. As identified previously, static and dynamic information are processed using different components within the brain and by amalgamating both into the one task it becomes difficult for examiners to discern whether variations in performance are due to difficulties with the visual cache or the inner scribe. It also allows individual's to compensate for a weakness in one function by relying on the other, thereby, possibly leaving difficulties undetected.

The visuospatial sketchpad portion of the WMTB-C also contained a measure that revolved around remembering static and dynamic visual matrices (Gathercole & Pickering, 2001). However, both the matrices static and dynamic tasks were eventually removed from the battery and replaced with other established measures of visuospatial working memory. When devising the matrix tasks, Gathercole and Pickering (2001) attempted to introduce a computer assisted element to their battery which allowed them to display dynamic information in a controlled and standardised manner. This was ultimately removed, in favour of a pen to paper analogue, in this case the Visual Patterns Test (Della Sala et al., 1997). While not specified it is likely this change occurred so a computer was not necessary for test administration. It can be seen from the original idea that Gathercole and Pickering (2001) acknowledged the capabilities and utility of computers for the administration of visual tasks, however at the time of development tablet devices were not available and desktop computers were more common than laptops. Unfortunately, likely due to physical constraints, and the reduction in test portability, these computer based tasks were removed from the WMTB-C in favour of more portable pen to paper analogues.

The Visual Working Memory Index : Wechsler Memory Scale IV - (Wechsler, 2009).

In the fourth iteration of the WMS a specific index was added that measures visual working memory. The developers acknowledged that the visual memory index did not represent visual working memory performance in the WMS-III and based on this observation subtests and a subsequent index were developed that catered for this gap. The Visual Working Memory Index (VWMI) was a new index developed for use in the WMS-IV to acknowledge the difference between visual short term and working memory and two new subtests were developed to be included in the loadings for this index (Wechsler, 2009). From the beginning Spatial Addition, a test designed to be the visual analogue to arithmetic, displayed good reliability and clinical sensitivity. However, for the younger age groups it was deemed too easy and additional items had to be added to achieve a more representative ceiling. Throughout all the modifications a consistent floor problem was present in the older adults, which assisted in the decision to eventually exclude the entire VWMI from the older adults group. The Symbol Span task was developed with the intention that it was to be a visual analogue of Digit Span. It involves participants being presented with a line of symbols for a period of 5 seconds. After they are taken away the individual is presented with an array of symbols, some of which are correct and some of which are distractors. Participants have to recall the symbols that they initially saw from left to right. Initially, this subtest yielded poor results across the board and was considered to be too difficult. Despite the difficulties the participants experienced examiners reported that Symbol Span was easy to administer and score. Participants also reported that verbalising the images was difficult and they found themselves relying more on remembering the images visually rather than encoding them with names. A second pilot involved adjusting the difficulty level of some of the items. The findings of this trial were found to be more promising and the only subsequent modification prior to test publication was the inclusion of some more easy items to improve the floor in the older age groups. However, once again this proved to be unnecessary as the VWMI was eventually excluded from the older age group all together.

Limitations of Visual Long Term Memory and Learning Assessments

In terms of measuring learning and delayed recall, list learning tasks are the most common assessments in both research and clinical settings (Lezak et al., 2012). A learning task invariably consists of multiple trials that present the same stimuli, giving an individual the opportunity to familiarise themselves with the information, encode the stimuli, and develop a strategy for effective recall. To examine learning and whether material has been stored effectively, a free recall or recognition delayed recall trial is often incorporated into these assessments (Lezak et al., 2012). For verbal information, list learning tasks are considered to have good clinical utility, and are often used as they can gather much information about an individual's memory function in a brief amount of time (Strauss et al., 2006). In healthy participants, list learning tasks allow the measurement of short term retention and learning capacity (Brown & Craik, 2000). When the same stimuli are presented in the same order every time it allows the examiner to gain an understanding of the individual's learning strategies, thus, allowing a further qualitative examination of inquiry to be conducted. Encoding patterns can be observed as the initial trials yield evidence of primacy and recency effects, though these effects become less apparent in the later trials when the recall order becomes more indicative of the individual's strategies. By the final trial healthy participants with good learning capacity are generally able to recall the entire list in the order it has been presented to them (Strauss et al., 2006). List learning tasks when no context is given have been found to be the most sensitive as individuals are unable to use cues from the presentation to assist them in their recall (Campbell, Edwards, Horswill & Helman, 2010). More recently research has been conducted utilising visual list learning tasks to explore the serial position effect for visual information, however, these tests have not yet been standardised for use in clinical settings (Ginsburg et al., 2017).

Current list learning tasks are predominantly verbal, and although some visual list learning analogues exist these do not tend to be used routinely in clinical assessment (Ruff & Allen, 1999; Benedict, 1997). This is because the few visual list learning tasks are not as psychometrically robust as their verbal memory counterparts. With most visual list learning tasks being developed for research purposes predominantly or for use with patients who have severe deficits (i.e. L'Hermitte, four hidden objects) (Papageorgiou, Economou, & Routisis, 2013). While some other visual learning assessments exist, such as the Austin Maze, these assessments are better considered measures of executive function more so than memory due to the exploratory focus of the initial trial and the focus on measuring an individuals ability to self correct and plan the maze (Bowden & Smith, 1994). The Austin Maze is generally used clinically to determine frontal lobe dysfunction and Bowden and Smith (2007) assert the interpretation and administration of this assessment have evolved over time to accomodate this.

The Ruff-Light Trail Learning Test (RULIT) was designed as a multiple trial visuospatial learning task (Ruff & Allen, 1999). It was designed to measure visuospatial learning without the need to have good motor functions or even good eyesight. Unfortunately, despite their best efforts the RULIT lacked robust psychometric properties. The RULIT yields weak correlation coefficients for both IQ (r = .20) and education (r = .24) (Strauss et al., 2006). As stated earlier memory is known to have a strong relationship with both IQ and education attainment and these low scores suggest that the RULIT may not be a valid measure of memory. In terms of construct validity, total scores on the RULIT were identified to be weakly or moderately correlated with a number of other attention and memory subtests (e.g. Rey Complex Figure Test, Verbal Selective Reminding Test). Furthermore, there is no data exploring test-retest reliability or practice effects. There is also little research exploring the use of the RULIT with clinical populations as all of the data outlined above is derived from healthy samples. Subsequently, despite the developers best efforts this assessment is not routinely used in clinic or research work and no other visuospatial analogue similar has been developed besides the aforementioned test of executive function, the Austin Maze.

Considerations When Developing Visual Long Term Memory Assessments

While the same consistent limitations effect all components of visual memory. Long term visual memory and learning are particularly influenced by encoding strategies, motor requirements and recognition paradigms. Unfortunately as visual list learning tasks are more scarce than other visual memory tasks, pilot data was also limited. With only data about the RULIT, the Austin Maze and the Brief Visual Memory Test - Revised (BVMT-R) development being readily available. Ruff and colleagues (1996) acknowledged that although the Wechsler Memory Scale - Revised (Wechsler, 1988), the most recent version of the WMS at the time, provided a thorough examination of both visual and verbal short term and long term memory it lacked a learning component that was capable of assessing performance after the stimuli has been presented numerous times. At this point in time there was no current spatial visual list learning task for clinical use, though verbal list learning tasks had been widely established and were a routine part of most memory assessments. Ruff and colleagues (1996) stated that as short term and long term memory is typically assessed by modality, then learning should also be tested in this manner.

A Review of the Ruff-Light Trail Learning Test - (Ruff & Allen, 1999).

When developing the RULIT Ruff and Allen (1999) intended to incorporate five main conceptual considerations. They intended to avoid a paradigm that was based on drawing ability, keen eyesight, good motor functioning, refined visuospatial integration and the learning being evaluated primarily by recognition. As individuals presenting for a memory assessment generally also lack skills in one of the aforementioned areas this was important to ensure that the task was capable of providing an accurate measure of visuospatial performance. During the development of the RULIT they were able to address all five of their conceptual considerations. As participants are required to trace the path with their finger it did not depend on drawing ability. They were able to avoid the necessity for good motor control by eliminating a processing speed component for the task. The visual perceptual demand was low as the task only contained dots and lines. Finally, this assessment is a free recall task where participants are required to remember the path each time without seeing it drawn in front of them by the examiner. The ability to address the conceptual goals highlights the potential of mitigating the consistent limitations present in visual memory assessments. The instructions for this assessment are similar to the Austin Maze where the first trial is an exploratory trial as the participants are not shown the pathway initially. This does therefore imply that an element of executive functioning is required to complete the task.

A Review of the Austin Maze - (Milner, 1965).

The Austin Maze was originally developed for research purposes in 1965 as part of Milner's work exploring hippocampal and frontal bilateral lesions. It has since evolved and been adapted for use in both clinical and research settings (Tucker, Kinsella, Gawith & Harrison, 1987). The standard form of this assessment incorporates a 10 x 10 grid. Participants are required to find the correct path initially in trial 1 through trial and error. Once participants have successfully completed the maze they are required to complete the task until they are capable of finishing three error free performances. When administering the standard 10 x 10 Austin Maze, it has been identified that some healthy participants can take up to 50 trials to reach the criterion of three consecutive error free performances (Bowden et al., 1992). Due to the difficulty of this grid alternate forms of the Austin Maze also exist ranging from a 5 x 5 grid to the 10 x 10 grid. However, these assessments are used more routinely in research than in clinical settings. Within a clinical setting as mentioned in the previous section the Austin Maze is predominantly used to measure frontal lobe dysfunction highlighting the high degree of overlap present between cognitive functions and the difficulty in creating standardised measures that isolate function. Furthermore, the Austin Maze was one of the first neuropsychological assessments designed and developed for use on tablet devices (Walterfang & Velakoulis, 2016). This assessment allowed the participant to receive immediate feedback on whether they had selected the right square and allowed for automatic scoring. While the test can be described as a memory assessment, the exploratory nature of trial 1 hinders this. As participants are required to learn the correct path through trial and error, a number of executive functions are utilised, including; attention, planning, organising and working memory. Difficulties in one of these areas could lead participants to remember their errors more easily than they are able to rectify them, thus impacting on their memory score. This is an interesting notion as one could argue that the ability to recall errors, indicates that a level of both learning and memory are involved, however, the task does record these mistakes as errors. Removal of the exploratory trial could aid in the development of a more accurate measure of spatial learning as it would remove a number of the executive functions that are employed during the initial stage.

A Review of The Brief Visual Memory Test - Revised - (Benedict, 1997).

The Brief Visual Memory Test -Revised (BVMT-R) was developed as an object based visual list learning analogue to complement verbal counterparts (Benedict, 1997). This assessment yielded more promising psychometric results that its spatial counterpart. Normative data indicates that high rates of inter rater reliability (>.90) were observed and test - retest reliability ranged from low (.60 for trial 1) to high (.80 for trial 3) (Benedict, 1997). The BVMT-R also demonstrated good construct validity with verbal list learning tasks, with reliability coefficients ranging from (.65 - .80). Lower scores may be indicative that while both tasks are measures of learning the difference in modalities impacts on overall scores. Promisingly coefficients were higher when compared to other visual tests, such as the ROCF (r = .65) than with verbal fluency tasks (FAS, r = .24). Intelligence and education were both found to be moderately correlated with scores.

This indicates that current measures of object visual memory may be more reliable and valid than measures of spatial memory. Past research and assessments have suggested that developing abstract object based assessments is easier than dynamic spatial assessments and this is reflected in both the WMS-IV (Wechsler, 2009) and the WMTB-C (Gathercole & Pickering, 2001). The BVMT-R provides evidence that developing a psychometrically robust measure of object memory is possible (Benedict, 1997). While there are limitations within this assessment these can be easily rectified as this assessment provides a platform for other object based memory tasks to be modelled from.

Assessing the Two Streams of Visual Memory

As discussed in chapters 2 and 3 while it has been long established that there are dual streams for processing visual information, the influence of these two streams is not always present in visual memory literature and assessments. There is a paucity of assessments that have attempted to focus on the capacity of memory for spatial information and object information separately without the influence of other potentially confounding variables. There is also no assessment series or battery developed where visuospatial or object memory are assessed separately, that then would allow for direct comparisons to their counterpart to be made in an endeavour to investigate how each stream is functioning. More often, visual memory assessments include an amalgamation of both spatial and object components and invariably involve static stimuli only. Despite researcher's best efforts at acknowledging the complexity of visual memory and the range of variables that can impede or influence performance, assessments that pay homage to the two streams that are developed in a manner that would allow direct comparisons between the two simply do not currently exist. Similar to developing assessments that relate to the individual memory components (STM, WM and. LM), developing spatial and object memory assessments are confounded by similar limitations that influence all visual memory assessments.

Spatial Memory

Measuring spatial memory has always been more challenging than object memory (Nadel & Hardt, 2004; Lemay et al., 2004; Wood, 2010). Spatial memory generally processes dynamic information that utilises a system that has been described as the inner scribe (Logie, 1995). The inner scribe tracks information as it is presented and is used to recall movement, and spatial locations. A number of tests that claim to measure spatial processes do exist, however, these tests are not normally pure measures of spatial memory as they are confounded by other variables such as elements of object processing, the ability to verbalise stimuli and the involvement of executive processes. Difficulty in measuring spatial memory has also been largely due to the limitations of pen and paper administration, which impedes the ability to present movement in a standardised manner. More recently examiners have begun to incorporate computer based tasks in an attempt to include dynamic stimuli into their assessments, however, their ability to implement this successfully has been limited. Portability is an issue in many desktop oriented tasks as they often require an individual to come to a specific location that may be difficult or cumbersome for them to get to (Lezak et al., 2012). Due to standardisation these tasks are also limited in what computers they can be presented on as changes in size or resolution could yield potentially different findings. This difficulty in presenting dynamic movement is the predominant limitation hindering the development of spatial memory assessments.

Object Memory

Current measures of visual memory tend to involve assessments of object based memory (Benton, 1945; Benedict, 1997; Baddeley, Emslie & Nimmo-Smoth, 1994). Quantifying the capacity of object memory without the influence of a range of other variables has proven to be a difficult feat, due to the automaticity of language producing a spontaneous label for any known object. Any identifiable object (e.g. a cup, a table, a dog etc) has prototypical representations of it stored in long term visual memory (Strauss, 1979). This means that any stimuli that can be identified as an object that has previously been encoded and stored is also able to be verbalised. This is problematic for visual object memory as the influence of auditory encoding can effect the recall of the visual stimuli in a positive way, without the individual drawing deeply upon visual memory skills. This confounds the ability to obtain a pure measure of object memory as spontaneous naming may inflate performance.

The Benefits of Electronic Memory Assessments

Neuropsychological assessments are beginning to make a shift towards using electronic media for task administration with the most recent version of the Wechsler Memory Scale (WMS-IV) now adapted and released for iPads. This new version is reported to represent a simple conversion of the current pen to paper tasks directly to tablet devices, in order to reduce errors related to timing and administration, as well as to streamline the scoring process (Wechsler, 2016). While this represents an improvement compared to pen to paper versions in terms of visual memory, it may still be considered a missed opportunity in terms of harnessing all that is possible with electronic administration. In the past, visual memory tasks (including the WMS) have often relied on a motor component (drawing) or tasks in which information was unable to move. The use of electronic media can allow for greater flexibility and the reduction of these shortcomings. It can allow for paths to be presented dynamically in front of a client instead of being restricted to a static format, as well as movement to be shown in complex patterns, a method that is limited by pen and paper (Groth - Marnat, 2009).

The use of electronic media could also allow for flexibility in how participants can respond. The Western world is becoming more and more technologically driven and most current neuropsychological tests do not reflect this. The use of electronic media to deliver visual learning and memory tests may be more inherently appealing to the current generation and may represent greater ecological validity, thus, gaining a more valid measure of visual memory performance.

One of the dominant limitations that emerged consistently in the literature, was that the difficulty measuring visual memory capacity, was more often than not due to methodological limitations (Ciaramelli et al., 2010; Strauss et al., 2006; Lezak et al., 2012). At the time of the development, many prior assessments of visual memory acknowledged that the flexibility to express visual information dynamically, utilising a practical and portable approach, did not yet exist. While electronic media existed, developing assessments that utilised it tended to be cumbersome, non standardised and lacked portability. Memory tests tend to be hypersensitive to any variation in administration procedures (Lezak et al., 2012), therefore, utilising software to ensure all administration is standardised, can improve the reliability and the accuracy of the data collected.

The utility of incorporating portable tablet devices, in particular iPads, in hospital settings has been investigated since 2012 however, is not a universally adopted standard as most research focuses on using them for education or imaging purposes (Paddock, 2015). Nucog was one of the first companies to develop cognitive assessments for iPad devices in 2014 (Walterfang & Velakoulis, 2016). Each of the four developed tasks, incorporate standardised movement into the administration. The latest revision of these assessments was in 2016 and these assessments are still used in clinical and research settings in Melbourne Australia.

Summary of Visual Memory Assessments

Memory is one of the most well established cognitive domains, and subsequently memory assessments have been a key component of clinical assessment for a number of decades. Nonetheless verbal memory assessments are currently much more utilised, known and established in comparison to their visual memory counterparts. While a number of visual memory assessments exist and are used routinely, they are not as robust as verbal memory tasks. On the whole researchers understand what considerations should be accounted for when developing visual memory assessments, however, despite their best efforts this has not always been possible, due the aforementioned limitations. A number of visual memory assessments do exist and are used routinely in both research and clinical settings (Corsi, 1972; Benedict, 1997; Wechsler, 2009), however, both researchers and clinicians acknowledge their limited utility in comparison to measures of verbal memory. As described in the chapter there are a number of methodological constraints that limit visual memory assessments from being reliable and accurate measures. Due to pen and paper administration it is often difficult to display dynamic or 3D information in an engaging and standardised manner. Furthermore, pen and paper tasks are not reflective of the complex, ever changing visual world that we live in, thus limiting their ecological validity. A number of developers have acknowledge the potential of electronic administration and although some tasks are being adapted, the use of electronic tasks for neuropsychological assessments is still in its infancy. Moreover, due to the lack of development of specific spatial and object tasks that are not confounded by other variables, it is very difficult to discern differences between the two streams of perception. Being able to compare performance between the two streams on memory tasks has the potential to have profound clinical and research benefits.

CHAPTER 5

THE PRESENT THESIS

Rationale

It is clear from the research examined that visual memory is a complex process that incorporates many different components. While more and more research has begun to acknowledge the complexity of visual memory, a conclusive notion of capacity has yet to be developed. Research to date has tried to apply and understand visual memory by utilising a verbal memory paradigm, however, this has continuously produced inconclusive results. Upon examination of the literature it was identified that one of the main considerations potentially influencing the capacity of visual memory is the nature of the visual stimuli required to be remembered (e.g. spatial or object). It is well established that visual processing involves two key anatomical networks, the dorsal and the ventral streams and thus, it was necessary to explore these demarcations to determine if they have differing capacities within visual memory. Past literature was able to identify that there are not only key differences in the anatomical networks involved in each of these processes but also in the amount of attention required, cognitive load and complexity of these functions, it can therefore also be assumed that their capacity should be different. This notion formed the basis for the present thesis, which attempted to isolate each of these functions as much as possible, and test them individually in terms of span, working memory and learning and delayed recall to determine if capacity for each function, when not influenced by the other is different.

Aims of the Project

The present thesis aims to investigate the differences between spatial and object capacity by developing a series of visual memory assessment tasks that are hypothesised to reflect a pattern of performance consistent with existing memory theory and assessment paradigms. To this aim an electronic battery of visual assessment tasks was developed that was then implemented in a series of three experiments with the view to accomplish the following:

- Experiment 1 (Chapter 6) was undertaken with the purpose of developing and piloting a series of visual memory tasks to determine whether they were reliable and accurate measures of visual memory. These tasks would then be used in later experiments to evaluate the capacity of memory for each of the two streams. Experiment 1 consisted of two separate sections.
    - The first section took a novel approach to develop an electronic battery of visual memory assessment tasks. Based on the literature reviewed a series of tasks were developed that aimed to evaluate the capacities of spatial and object memory separately.
    - The second section involved pilot testing the developed tasks to ensure that they were reliable and valid measures of what they purported to measure.
- The purpose of Experiment 2 (Chapter 7) was to modify the assessment tasks that did not produce the expected results in the first study, as well as compare the participant's performance between spatial and object scores for span, working memory and learning and delayed recall. Experiment 2 consisted of three sections.
    - The first section involved revising the developed working memory tasks to attempt to rectify reliability and validity issues that arose in the first experiment.

    - The second section involved establishing the psychometric properties for each of the revised assessments.
    - Finally, the third section involved investigating whether differences in capacity were present for the developed spatial and object memory tasks.
- Experiment 3 (Chapter 8) involved developing additional tasks for the span and working memory components of each stream. Experiment 3 also consisted of three sections.
    - Similarly to Experiment 1, the first section of Experiment 3 took a novel approach to develop additional visual memory assessment tasks. These tasks intended to explore spatial and object memory function more comprehensively
    - Congruent with the previous experiments, the second section involved establishing the psychometric properties for each of the additional assessment tasks.
    - Finally, the third section involved investigating whether differences in capacity were present for performance on tasks within each of the two streams (e.g. allocentric processing compared to egocentric).

Each of the experiments extended upon the results and ideas that emerged from the previous findings. The same participants were utilised in Experiment 2 and Experiment 3 and thus, any new assessment tasks were tested using a repeated measures design. This allowed for direct comparisons to be made between individuals and subsequently reduced the likelihood of error. Further details are outlined in each chapter.

CHAPTER 6

EXPERIMENT 1 - THE DEVELOPED ASSESSMENT TASKS

The modal model of memory is one of the most widely utilised and established models of memory research and subsequently memory research is still guided by its principles. Figure 6.1 below depicts an adapted version of the modal model of memory (Atkinson & Shiffrin, 1968) that pays homage to the two streams hypothesis. This adapted model has informed the development process and subsequent investigation presented in this research. This model was adapted to assist in investigating whether the capacities of the visual memory system vary and are dependent on the nature of the information being remembered.

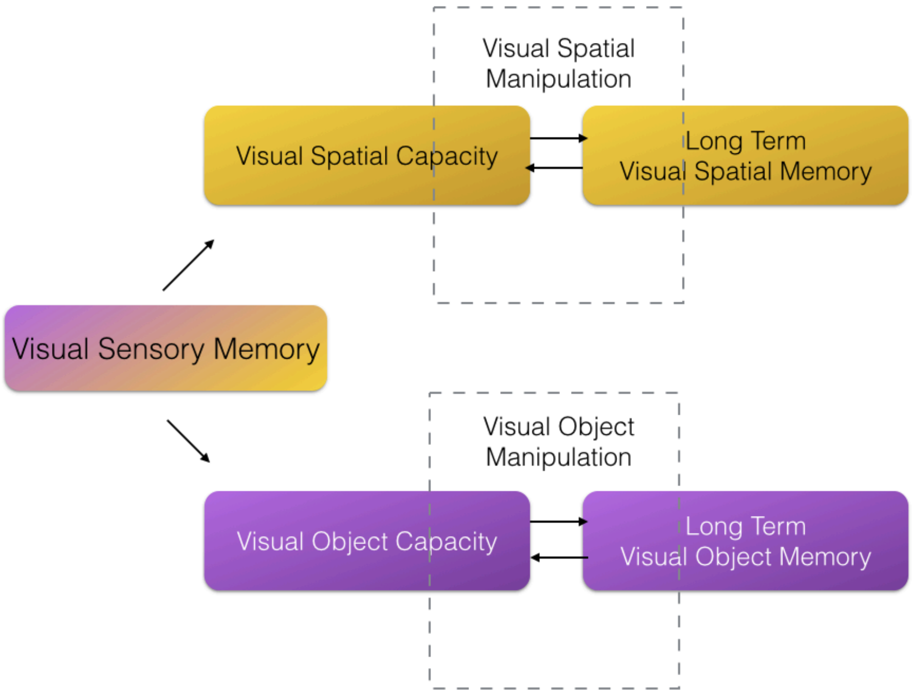

Figure 6.1. *The Proposed Model for the Development of Tasks in Experiment 1*

To be able to explore whether there are differences in the capacities for each of the pathways, it was essential to develop a series of tasks that measure each of the components highlighted in figure 6.1. These tasks are outlined in Table 6.1.

Table 6.1. Summary of the Developed Assessment Tasks

	Spatial Tasks	**Object Tasks**
Short Term Memory	Spatial Span	Object Span
Working Memory	Spatial Working Memory	Object Working Memory
Learning and Delayed Recall	Spatial Learning	Design Learning (Free Recall) Visual Pairs (Cued Recall)

Based on the research examined in the previous chapters, the preliminary phase of this experiment involved the development of tasks that could measure spatial and object memory separately. Therefore, prior to investigating capacity differences between spatial and object memory, Experiment 1 of this thesis involved the development and piloting of a series of visual memory tasks. The general considerations that were acknowledged during development will first be discussed, before introducing each of the developed tasks that were created.

General Considerations

One of the dominant limitations that emerged consistently in the literature was that the measurement of visual memory has been methodologically constrained (Ciaramelli et al., 2010; Strauss et al., 2006; Lezak et al., 2012). At the time of the development, many prior assessments of visual memory acknowledged that the flexibility to express visual information dynamically, utilising a practical and portable approach, did not yet exist. While electronic media existed, developing assessments that utilised it is in its infancy and past attempts on desktop devices tended to be cumbersome, difficult to standardise and lacked portability (Rensink, 2002). The tasks developed for use in Experiment 1 are hybrid tasks that involve electronic administration with pen to paper response sheets. It was beyond the scope of the project to develop an electronic scoring system. As scoring assessments often requires a degree of subjective human interpretation, the decision to incorporate pen to paper response sheets was made. All participants had their own 'participant pack' that consisted of scoring sheets for the examiner, response sheets for the examinee and a data collation sheet for collating raw scores to aid in efficient data entry and analysis (see Appendix A.)

The stimuli designed for use in Experiment 1 were developed for use on tablet devices. This allowed the researcher the freedom to use any mode of presentation for the stimuli (static or dynamic) as well as enhanced the reliability of task administration, as all the timing for the stimuli presentations were built into the program. Memory tasks tend to be hypersensitive to any variation in administration procedures (Lezak et al., 2012), therefore, utilising software to ensure all administration was standardised, aimed to improve the reliability and the accuracy of the data collected. As tablets are portable devices, to ensure standardisation among participants all tasks were developed and administered for use on an iPad Pro 10.5 inch tablet. The iPad Pro had attached to it an Apple Smart Cover that allowed it to stand independently at an angle of 120 degrees to the viewer. For all participants the iPad was located 30cm away from where the participant was seated.

Lezak and colleagues (2012) acknowledge that many tests of perception also measure other components of cognition, including but not limited to attention, spatial orientation, and memory. While tests of visual perception are generally better than tests of visual memory at acknowledging the spatial/object demarcation, most current tests of visual perception have not focussed on reducing verbalisation, which has been found to impact memory performance in the past (Brown et al., 2014). Tests of perception also highlight the necessity of the role of attention. As previously discussed, attention is the necessary precursor for all higher order cognition, as without attending to the necessary stimuli no further processing can take place. In the same way, an intact visual perception pathway is a necessary precursor to visual memory, as it ensures that all visual information is being processed and interpreted before being utilised by the higher order cognitive function. This reasoning gives rise to three predominant considerations.

First, the attentional demand required to comprehend and remember the instructions needed to be low, as in tests with difficult instructions, performance tends to be affected (Wechsler, 2009). This is potentially due to an individual's cognitive load dedicating substantial resources to remembering the instructions and subsequently being unable to devote the required attention to the task itself (Brown et al., 2014). In keeping with principles of test design, the tests designed in Experiment 1 included short, succinct instructions accompanied with practice trials, to ideally reduce the demand required to comprehend the instructions, similarly to many of the established memory tests (Wechsler, 2009; Benedict, 1997).

Secondly, when constructing an assessment task it is important to ensure that it is difficult for a participant to succeed based on chance alone (Martin & Schroeder, 2014). In memory tasks where participants are asked to recall what they saw based on a discrimination/recognition trial the chances of guessing the correct answer are higher than in free recall tasks and this is dependent upon the number of options available. This is most often observed in recognition trials that only have two response items e.g. The Faces subtest in the WMS-III utilised a yes/no response system to complete the task.

Many participants produced inflated results as guessing provided them a 50% chance of getting the answer right. While such tasks are useful for identifying malingering (Morgan & Sweet, 2009) in terms of accurately measuring an individual's memory performance, results may be inflated due to the ability for a participant to guess correctly 50% of the time. While it is not always possible to develop free recall only tasks, in an attempt to prevent the ability of chance to inflate performance no assessment tasks were developed that incorporated only two response items. Furthermore, the lowest amount of responses an individual can choose from in any one task is in the initial spatial span and working memory trials, where an individual must accurately select, two, two response items in succession. While this is unfavourable, the likelihood that an individual would successfully select the correct pathway by chance is less than 25% (when the direction of the path is also accounted for) and this difficulty is only present for the initial trials. By the third span the likelihood of participants drawing the correct sequence by chance is reduced to less than 12.5%. In the object tasks, participants in the initial trials must accurately select two correct items out of 8 possible responses. The likelihood of passing even the initial trials by chance is less than 1.7%. All assessments were designed to assess visual memory performance while controlling for a range of confounding variables, including performance inflation by chance.

Finally, one of the most important considerations involved stimuli design. As the tasks all involved visual stimuli it was important to develop a battery that encompassed a range of measures of visual memory, while also ensuring that the stimuli from one task did not interfere with the stimuli for another (Rademaker, Bloem, De Weerd & Sack, 2015). Thus, all abstract designs and the order of administration were carefully evaluated during this process to ensure that minimal interference between the tasks was present.

Based on the research examined and the general considerations above, Experiment 1 involved first developing a series of electronic assessment tasks that aimed to measure spatial memory and object memory function separately. While many measures of visual memory exist, cohesive measures that aim to provide a point of comparison for visual memory function are few and far between. It is with this notion that during development, known memory assessment paradigms were reviewed and where relevant applied to the visual memory tasks developed for this thesis. This process highlighted that individually many promising measures of visual memory exist, that are well designed and allow for investigation of memory function. A primary aim of this experiment was to adapt and combine current measures of visual memory to create tasks that can be administered utilising electronic media and incorporate what is known perceptually about the demarcation of spatial and object function.

The Developed Tasks

Note please find attached a quick reference guide for the developed tasks in Appendix B.

Where possible all span and working memory tasks were developed using the memory span paradigm i.e. consisting of a span task that aims to assess attentional control and capacity and a working memory task, that mirrors the span task in terms of stimuli design and task administration, however, contains an additional manipulation component. While the literature examined clearly highlights that visual memory assessments should be developed through their own lens, many standardised procedures that are incorporated in verbal memory assessments are applicable for visual information. All stimuli from the developed tasks are presented at a rate of one every two seconds. This is consistent with established measures of memory in both verbal and visual memory assessments (Wechsler, 2008; Milner, 1965). This allows a level of standardisation and consistency to be present throughout the developed tasks. Furthermore, all span and working memory assessment tasks consisted of two trials for each span. This ensures that participants are not penalised for a lapse in attention, and provides a more accurate depiction of an individual's memory capabilities. Furthermore, this allowed both scoring and discontinue procedures to mirror those utilised in the robust established span tasks (Wechsler, 2008) as well as ensured consistency among the developed tasks. Finally, the stimuli designed for use in the working memory tasks and the administration procedures directly mirrored the stimuli and administration utilised in the span tasks. As the only difference between tasks is the inclusion of a manipulation component in the working memory tasks, this allows for direct comparisons of performance to be made between the two tasks while controlling for variables related to stimuli design, and the perceptual demand for developing encoding strategies for new stimuli. Thus, any differences observed should be able to be attributed to differences in memory performance.

Furthermore, the developed learning tasks drew administration inferences from established list learning verbal assessments, however, provided unique stimuli designs implemented to measure the various components of visual memory (Rey, 1964).The free recall tasks both contain five trials, where stimuli are presented in the same order each time at a rate of one every two seconds. This design aligns with both the standardised procedures of the RAVLT and the developed span and working memory assessment tasks. No measure of interference was included in this series of tasks, this is due to this being a pilot study, and it was a greater priority to ensure that the tasks were capable of measuring the various components of visual memory in all stages of the learning process. The inclusion of an interference trial at this stage would have made identifying the causes of performance variance in the delayed recall tasks difficult to discern. The delayed recall trials proceeded a 30 minute wait period which also aligns with the RAVLT. Finally, the cued memory task drew administration inspiration from Verbal Paired Associates. Similar to the past tasks stimuli were presented at a rate of one every two seconds.

The following section will provide evidence of what the developed tests involve, acknowledging the components that overlap with existing assessments or those that have been advanced through the use of electronic media, as well as noting what makes the developed tasks unique. There will also be commentary for how the stimuli were developed and the scripts used in the administration of each of the assessment tasks.

Spatial Memory Tasks

Spatial Span and Working Memory

Historically memory researchers have not explored the capacity of spatial memory in detail. To account for a severe lack of a comprehensive visual working memory assessment in children Gathercole and Pickering (2001) developed a series of visual and verbal assessments that together, made up the Working Memory Test Battery for Children (WMTB-C). One of the subtests included in this battery was a measure of spatial memory called Mazes Memory. During the development of the Mazes Memory task a static version and a dynamic version of the task were proposed, developed and piloted (Gathercole & Pickering, 2001). Several problems were identified with the dynamic mode of presentation. Firstly, it was not possible for a human to replicate the same clear, crisp lines that electronic media was capable of. More importantly, often the clinician's arm and hand interfered with the child's ability to see and commit the emerging path to memory. Gathercole and Pickering (2001) reported that both versions showed promise, and thus, the final task became an amalgamation that incorporated both modes of presentation. The stimuli for this task involved a series of rectangles surrounding a stick figure stimulus in the centre. Each rectangle had two small sections of the shape missing. These informed the participant of the possible exits for that section of the maze. As performance increased so did task difficulty with extra rectangles (walls) being added. While this task demonstrated good psychometric properties for use with children (Gathercole & Pickering, 2001), adult norms were never developed. Similar to the RULIT and Corsi Blocks this task was also limited by the examiner's ability to present dynamic stimuli. Building from the strengths and weaknesses of this task the Spatial Span subtest was developed for use in Experiment 1.

Rather than have participants complete the Spatial Span task backward, the manipulation component for Spatial Working Memory instead involved rotating the maze. Visual information has the ability to be manipulated in a three dimensional space as Shepard and Metzler (1971) who conducted a series of studies exploring the effects of mental rotation and spatial processing highlighted. They asserted that mentally rotating stimuli was a more cognitively demanding task than simply recalling information in the same orientation. Neuro-imaging has also demonstrated that mental rotation tasks show activation in the prefrontal cortex indicating that some level of executive functioning (likely working memory) is involved (Shepard & Metzler, 1978). Based on the findings of their research in conjunction with the foundations established in the Mazes Memory task in the WMBT-C the Spatial Working Memory task was developed.

Stimuli Design

The stimuli design for this assessment was influenced from the design of the maze task in the WMBT-C (Gathercole & Pickering, 2001). When reviewing the stimuli utilised in the psychometrically sound Mazes Memory task it was found that components such as the length of the line, the rate at which the line was drawn and the number of turns involved were randomised rather than standardised. That is, different mazes included different line lengths, different turn directions and different amounts of 'door skips' (which is where the line goes past the initial door it reaches and bypasses to the second). While no pilot notes could be sourced on why these processes were not standardised it is suspected that this could possibly have occurred to prevent prediction based on previous trials. As the use of mazes is a long standing measure of memory e.g. the Morris Water Maze in animal research (Morris, 1984), Mazes Memory in children (Gathercole & Pickering, 2011) and the Groton Maze Learning Test in adults (Pietrzak et al., 2008), the standardised two dimensional, allocentric maze design was adapted and incorporated for use in this task. The image of the cat was selected for use to allow the user to orient where the top and bottom of the maze are located (this is particularly important in the working memory trial) (see in figure 6.2 and figure 6.3).

Spatial Span Outline

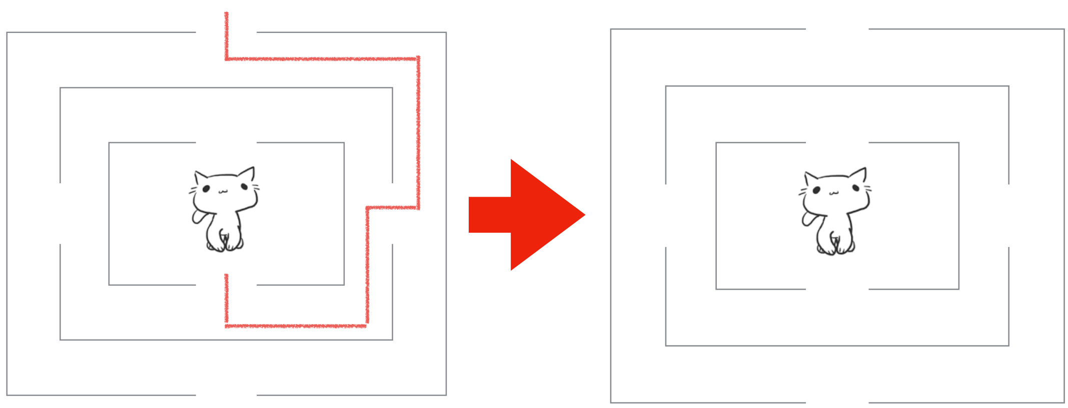

Figure 6.2. *The Spatial Span Stimuli*

The Spatial Span task is a dynamic task that measures aspects of basic attentional control as well as an individual's maximum spatial span when no manipulation is involved. This subtest involves a series of two dimensional mazes presented on a tablet device. Individuals are presented with a path that automatically appears from the centre of the maze outwards, on a tablet screen. The correct path is traced leaving a clear red line (6pt). Once completed the entire path remains on the screen for two seconds to allow for holistic consolidation before disappearing. Immediately following the disappearance of the path, the individual is asked to redraw it using on the response sheet that is given in pen and paper form. The maze, with the path removed remains on the tablet screen, mirroring the response sheet. Every two trials, the maze increases in size. Mirroring Gathercole and Pickering's (2001) maze task this involves another wall being added to the outside of the maze. While each maze has several possible routes participants are asked to draw the same path they saw presented to them for a trial to be considered correct. Each wall consists of two possible exits that the individual can elect to take and selection of the incorrect exit will result in the response being incorrect. This task requires individuals to utilise free recall to demonstrate the correct route that was shown to them. This task is not timed and accuracy is the only factor that is measured. When a participant incorrectly completes two consecutive trials the task is discontinued. This task produces two scores. One score summates the number of trials an individual successfully completes correctly when the task is discontinued. The second score provides a measure of span and is determined by the number of walls present in the last span that the individual successfully completed both trials of (for example if an individual got both span 3 trials correct but then only one of the span 4 trials before discontinuing they would have a span score of 3). This task consists of 14 trials ranging across 7 spans, thus, scores can range from 0 - 14 correct trials and 0-7 for span. (See Appendix C. for the examiners script)

Spatial Working Memory Outline

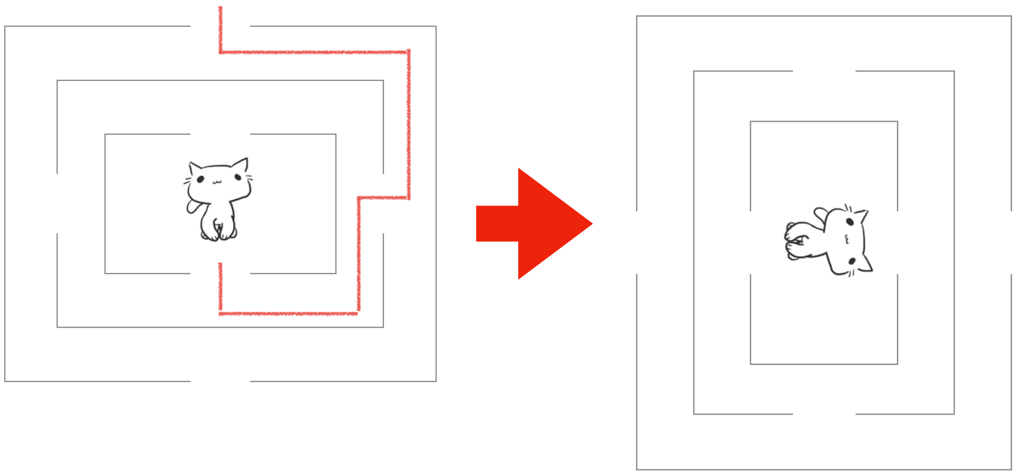

Figure 6.3. *The Spatial Working Memory Stimuli*

As highlighted above this task is a modified version of the span task that requires the use of spatial working memory skills. For this task the information is presented in the same manner as Spatial Span, however after seeing the pathway electronically drawn and vanish, this time the maze is rotated either 90 degrees, 180 degrees or 270 degrees and participants are required to draw the path that they saw in the original version on a rotated version of the maze stimulus. Using the same style of stimuli allows for direct comparisons in performance to be made, as this attempts to control for alternate variables which may interfere or affect memory performance. Response sheets presented to the participant correspond with the rotation that the mazes were presented in and participants are instructed not to change the orientation of the paper and attempt to complete the maze in its rotated form. This requires the participant to not only recall the path as they saw it, but also to mentally rotate it in the direction of the response sheet maze. This task is also not timed and only accuracy is recorded. The same stimuli design, discontinue and scoring procedures apply for this task. (See Appendix D. for the examiners script)

Spatial Learning

The Spatial Learning task was designed to build on the foundations laid down by the RULIT. Given the technological constraints at the time of the RULIT development, this task was developed for use using pen to paper instruments. While it demonstrated fair psychometric properties (Strauss et al., 2006) and addressed a number of conceptual considerations (Ruff & Allen, 1999) a number of methodological issues were identified. In particular, the RULIT was compromised by the ability to present the stimuli dynamically in a standardised manner, which in turn lowered the inter-rater reliability of the task. Maze learning tasks have a long history in neuropsychology (Milner, 1965). The Austin Maze (Walsh, 1978) is one of the more commonly used maze learning assessments and now incorporates electronic administration on tablet devices (McKay, Stolwyk & Ponsford, 2013). However, as highlighted earlier the Austin Maze measures multiple constructs of cognition and its first trial is exploratory in nature. For the development of Spatial Learning inferences were drawn from both the RULIT and the Austin Maze, to attempt to create a thorough and dynamic measure of Spatial Learning. Furthermore, the incorporation of five learning trials in congruent with research established regarding the list learning paradigm (Rey, 1964; Dellis et al., 2000).

Stimuli Design

The Spatial Learning assessment is a learning task with a cued component. Once each square in the pathway has appeared it does not disappear. This was designed to give participants the opportunity to develop a strategy that involved memorising the whole path holistically. The decision to make participants draw the path in order was designed to ensure that they remember each individual feature of the pathway. As participants could not rely on primacy and recency in the early stages and then subsequently guess the missing blank squares to complete the path, they were required to remember the path from a bottom up perspective, once the path was completed a top down perspective could allow them to check their work, however it could not be relied on as a strategy to complete the task. This was implemented with the aim that participants would use recall initially to complete the task, whereas if participants were able to complete the first squares and the final squares first they would be able to rely on recognition to fill in the missing squares. Thus, this may not have been an accurate measure of their spatial recall. Requiring participants to respond in the order that they saw the squares allows a level of control over the various strategies individuals may utilise when completing these tasks, potentially giving them an advantage.

Stimuli are presented at a rate of one every two seconds. This is in line with the standard administration for verbal list learning tasks, as it allows the participant time to encode information successfully and build a strategy without the information succumbing to decay too quickly (Carstairs, Shores & Myors, 2012). The stimuli colour for the path was green. Green is considered to be a positive colour and research suggests that participants have been found to demonstrate an increase in performance when the colour of the stimuli is considered to be positive, thus, by selecting green as the colour of the pathway participants potentially have a higher chance of success (Mammarella, Di Domenico, Palumbo & Fairfield, 2016).

The grid of the maze in Spatial Learning is 8x8. When administering the standard 10 x 10 Austin Maze, it has been identified that some healthy participants can take up to 50 trials to reach the criterion of three consecutive error free performances (Bowden et al., 1992). Due to the difficulty of this grid alternate forms of the Austin Maze also exist ranging from a 5 x 5 grid to the 10 x 10 grid. An 8x8 grid was selected for this task, as this task was interested in visual learning and memory rather than executive function, and the standard rate of learning on a verbal list learning task will show that participants will generally reach the maximum score by trials 4 and 5 (Lezak et al., 2004), an 8x8 grid will likely decrease the difficulty in comparison to a 10x10 and give participants a greater opportunity to complete the pathway successfully within the 5 trials.

The length of the path in Spatial Learning is 25 squares. In the standard 10x10 version of the Austin Maze the path is 28 squares. A reduction in squares was utilised to compensate for the smaller grid and to reduce the incidence of squares on the path being reconnected with one another diagonally as the path progresses. The choice to attempt to avoid a reconnection of the path is in keeping with the design of the original Austin Maze. Furthermore, the attempt to avoid the path reconnecting with a previous section aimed to reduce confusion among participants as they completed the Spatial Learning path on their response sheet. This attempt was unavoidable in one instance (see figure 6.4 below) where in the final 6 squares, the path diagonally reconnects with a section from the middle. This was necessary to ensure that the maze was complex enough in design.

Test Outline

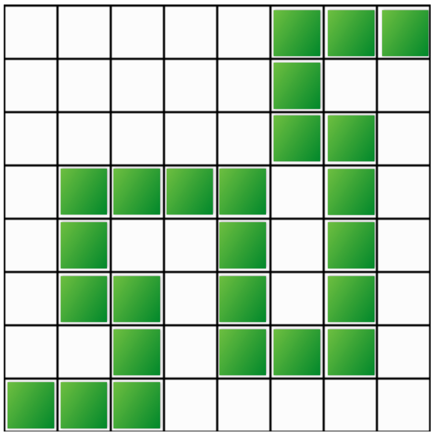

Figure 6.4. *The Spatial Learning Stimuli*

Spatial Learning is a dynamic, spatial learning task with a delayed component. By presenting the stimuli in a sequential fashion across five trials, Spatial Learning is structured similarly to verbal list learning tasks. Unique to Spatial Learning in comparison to other spatial learning tasks is the removal of the initial exploratory component. Instead, for all five trials individuals are presented with an empty grid on a white background on the tablet device. Once the task begins, green squares appear on the grid forming a path by lighting up adjacent squares one at a time. Once a square has appeared it remains on the screen until the completion of the path. Participants are asked to remember the path in the order that it appeared. After the entire pathway is shown, it lingers for three seconds and then the grid and the path disappear leaving a plain white screen. Participants are asked to record on the paper response sheet (that shows the initial empty grid) the path they saw in the order that it appeared by marking each square in the box with a number (e.g. the first box they write 1, the second box they mark 2 etc). Participants are informed prior to beginning the task, that the maze is long and that it is unlikely that they will be able to recall it all on the first trial. They are also informed that the task has five learning trials, thus, the exact same procedure is repeated five times. After the completion of trial five the participant does not see the completed path again. Unlike the Austin Maze corrections are not made after each trial and no feedback is given during the duration of the task. After a 30 minute delay participants are presented with another blank grid and asked to recall the same path that they were shown earlier, in the order that they saw it. This provides a measurement of delayed recall. The task is scored based on the number of correctly coloured in squares and produces four measurements. The immediate recall score is derived from the total squares coloured correctly in trial one. The total recall score is derived from adding the scores from all five initial trials together. The learning curve is calculated by subtracting the individual's trial one score from their trial five score. Lastly, the delayed recall score is derived from the total squares correct on the delayed trial. There are no penalties for incorrect components or errors. (See Appendix E. for the examiners script)

Object Memory Tasks

Object Span and Working Memory

The following object span and working memory tasks were developed to follow a similar structural design to the well established span paradigm (Kirchner, 1958). This task includes both forwards and backwards trials, to measure span and working memory respectively. In order to reduce the verbalisation of objects, stimuli that were inherently abstract in their design were created for this task. Inspiration for these stimuli was derived from the WMS - IV Symbol Span subtest, however were designed to be larger and slightly more complex as in this developed task stimuli are presented one at a time rather than all at once. These images are considered difficult to name and thus are considered to provide a more accurate measure of object memory as there is less likely to be influenced by the verbal pathway.

Stimuli Design

Object Span includes eight abstract designs as the stimuli. The decision to use eight stimuli instead of nine as per Digit Span, was to attempt to avoid pre cuing certain stimuli by orienting attention (Posner & Boies, 1971) to the centre of the grid array on the discrimination screen. Abstract stimuli were utilised to attempt to make verbalisation more difficult. Attempting to reduce verbalisation increases the likelihood that the task is measuring object capacity without the influence of auditory encoding as well (Ferdinand & Kray, 2017).

Each design incorporated two or three ‘components’ such as a two circles and a line. One of the eight stimuli incorporated two components, while seven had three components. These components were known shapes that were laid over one another to create a design that was abstract in nature (see figure 6.5 below). The shape that only included two components had a similar level of line overlap as those with three and was thus, not deemed to be any more simple or difficult to encode than those with three components. Each abstract design was created to be unique from all the others. The aim was not to have shapes interfere with the others that were part of the task, but instead encourage individuals to encode each design independently. The shapes were designed to limit the ease of verbal encoding, however it is acknowledged that it is impossible to completely halt this process.

The same stimuli were used for Object Working Memory as Object Span. This was decided as this task was designed to be a visual analogue to Digit Span Forwards/ Backwards which both incorporate the same stimuli (Numbers 1 -9).

Object Span Outline

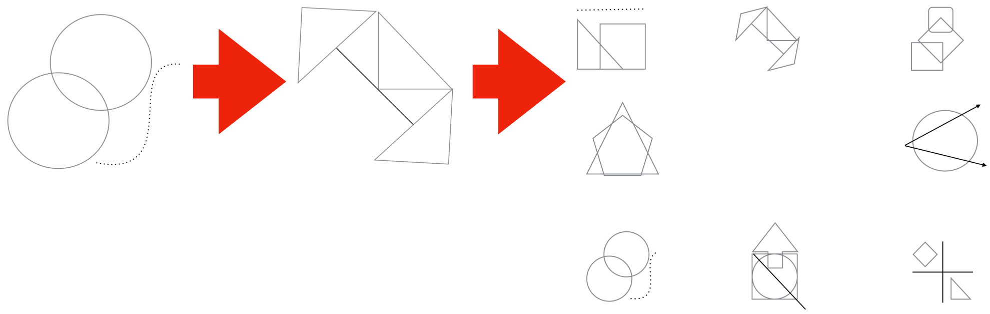

Figure 6.5. *The Object Task's Stimuli*

The Object Span task is a static, memory task that intends to measure basic attentional control and visual span when no manipulation is involved. In this task, object span is measured using a series of abstract designs presented in sequences of increasing length. Each of the stimuli are inherently different in design to assist in the encoding. Each design is represented by a single abstract shape or series of connected shapes. Stimuli are presented one at a time, at a rate of one image every two seconds. The designs that are selected for each sequence are derived from a possible 8 and during each sequence no single design is repeated. Sequences of increasing length are presented in a predetermined order and each trial is independent and unrelated to any previous trials. At the conclusion of each sequence, participants are presented with a grid array containing all the possible designs and are asked to point to the designs they were just shown in the order that they were presented. The locations of the designs on the grid change after each sequence, to ensure participants answers are not influenced by spatial contributions or locational cues. Trial one begins with two stimuli being presented, and every two trials the amount of stimuli increases by one. When a participant fails two consecutive trials the task is discontinued. The task produces two scores for each participant. The first score is derived from how many trials an individual completes correctly. The second score is the span score and this score is derived from the length of their last set of correct consecutive sequences (e.g. if both trials containing 3 stimuli were the last set recalled correctly, then the individual would have a span of 3). The object span task consists of 14 trials, allowing a maximum score of 14 and a minimum score of 0. Subsequently, the span score can produce a maximum of 7 and a minimum of 0. (See Appendix F. for the examiners script)

Object Working Memory Outline

To complete this task, individuals are again presented with a series of abstract designs one at a time. The objects used in this task are the same objects that are used in the span task. In this task the participant are asked to recall the designs (from the series presented on the grid) in the reverse order that they were shown. This task is scored in the same manner as its span task counterpart and utilises the same discontinue rules. (See Appendix G. for the examiners script)

Design Learning

List learning tasks are considered to have good clinical utility, and are often used as they provide substantial information about an individual's memory function in a brief amount of time. Benedict (1997), and Ruff and Allen (1999) both intended to develop a visual list learning task to compliment the established verbal ones. Benedict's BVMT-R is an object based list learning memory test. However, it has some limitations due to the scoring complexity, and motor requirements as discussed in Chapter 4. During the development of Design Learning inferences were drawn from the strengths and weaknesses of Benedict's (1997) assessment tool, in particular the scoring procedures.

Stimuli Design

The stimuli used in Design Learning were designed to be simplistic in nature, to avoid the need for advanced motor skills when drawing the answers on the response sheet. The designs used varied in the number of components, the shapes incorporated and the position in which they were oriented. Of the twelve designs there were two of every shape (squares, circles, lines, waves, dots, triangles). The BVMT-R includes 12 designs to be remembered. As this test is considered to have good validity and reliability as a visual memory test, the decision to also include 12 designs in Design Learning was derived from the design of the BVMT-R.

One of the critiques of the BVMT-R is the scoring procedure. While the BVMT-R includes separate scores for spatial and visual performance both these scores are combined to give an overall picture of performance. The purpose of this project was to separate spatial and object components of processing, therefore this form of scoring was not adopted. Design Learning does not include a spatial component, and participants are encouraged to recall the designs in any order. However, individual scores are given for correct orientation, shape and number of components. While these scores are combined to give an overall object score they can also be analysed separately, to further the understanding of how objects are encoded during a learning trial.

Test Outline

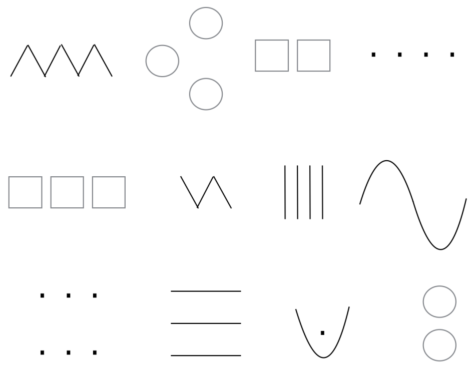

Figure 6.6. *The Design Learning Stimuli*

Design Learning is a free recall, object learning and memory task with a delayed component. In this task individuals are presented with a series of basic geometric designs. These designs appear and disappear on the screen one image at a time. After viewing the series of 12 images the individual is asked to recall as many of the designs by drawing them on the response sheet from memory. They are instructed to recall the designs in any order and they are informed that they will get to see the designs multiple times. The designs are presented in the same order each time. There are five initial learning trials that measure immediate recall, learning curve and total learning. After the fifth trial participants do not see the designs again. No corrections are made for incorrect images.

Thirty minutes later participants are presented with another blank piece of paper and once again are asked to recall the designs shown before to the best of their ability.

Similarly to the BVMT-R and Visual Reproduction, this task is scored using a point system. Individuals receive one point if the design is orientated correctly, one point if the design is drawn in the correct form and one point for all the correct components. This provides a maximum score of three for each design and 36 for each trial. This will show patterns of learning between individuals and will show if individuals are likely to learn aspects of an object in a specific way based on their pattern of performance. Once again, the immediate recall score is derived from the total points earned in trial one, the total recall score is derived from adding the scores from all five initial trials together, the learning curve is calculated by subtracting the individual's trial one score from their trial five score. Lastly, the delayed recall score is derived from the total points earned on the delayed trial. (See Appendix H. for the examiners script)

Visual Pairs

Designed to be a visual analogue to the Verbal Paired Associates task from the WMS - IV, Visual pairs is a cued object learning task, that also incorporates a delayed component. Verbal Paired Associates is a frequently used assessment clinically, due to the ability the examiner has draw inferences about memory for both associated (e.g. sky-cloud), and arbitrary information (e.g down-noise). In the verbal memory paradigm associative memory is arguably easier to recall as the word pairs already have semantic meaning attached to them, whereas a higher degree of encoding is required for the unrelated, arbitrary pairs. In terms of generating a visual analogue for this task, it was arduous to modulate what constituted as an 'easy' pair and a 'hard' pair. It was deemed that shapes that are known and are easily verbalised (e.g. star) would be more easily recalled as they are encoded verbally and visually which is likely to lead to deeper encoding similarly to how verbal associative memory is encoded more deeply due the extra semantic meaning. This however, does assume that verbalisation is occurring, and thus makes it difficult to determine whether recall is inherently verbal or visual in nature. Alternatively, hard pairs were abstract designs with multiple elements, that were designed to be difficult to verbalise. Thus, these shapes relied more heavily on an individual to utilise their visual object memory to encode the information successfully.

Stimuli Design

The Visual Pairs task was designed as a cued recall object memory task that included both easy and hard stimuli. Of the eight pairs, four are considered 'easy' pairs and four are considered 'hard'. The easy pairs consist of simple known geometric designs, whereas the hard pairs consist of complex abstract designs. The complex designs require higher levels of feature integration skills to recall successfully. Moreover, easy pairs can also be defined as pairs that are easily verbally mediated, as they are known objects. Hard pairs are abstract images that are difficult to verbally mediate and required a higher degree of associative memory as it is more difficult to impose meaning on the objects. Easy pairs were designed as single known shapes. Hard pairs incorporated 3 'components' which were over laid on one another to create an abstract design. These abstract designs were complex and difficult to verbalise and thus, relied more so on object memory alone.

As Visual Pairs was designed to be analogous with Verbal Paired Associates the order of presentation was derived from that assessment. Verbal Paired Associates changes the order in each of the four trials and thus, that method was also followed in Visual Pairs. To further mirror Verbal Paired Associates, Visual Pairs also consisted of four trials. The stimuli are presented at a rate of one every two seconds, which is the rate the words are read in Verbal Paired Associates.

Test Outline

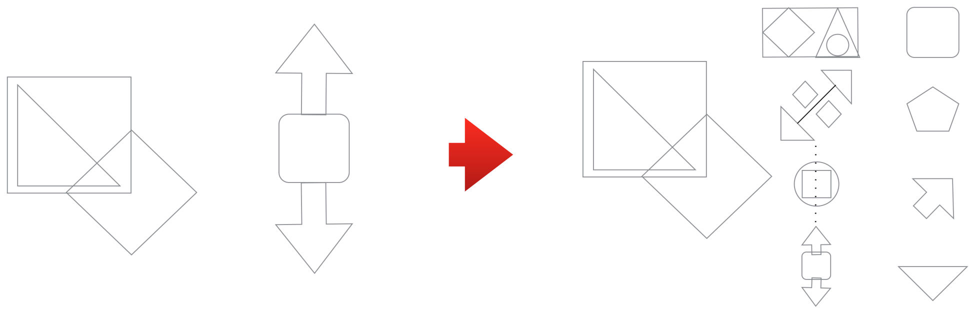

Figure 6.7. *The Visual Pairs Stimuli*

As Verbal Paired Associates is considered to be a reliable and valid measure (Wechsler, 2009) no need to alter the administration procedure during the development of the visual analogue was identified. In this task, individuals are presented with a series of paired images and are asked to remember them as a unit. All pairs were presented at a rate of 1 every 2 seconds. After being presented with all the pairs the participant is then presented with one image from the pair and is tasked with recalling its partner. This is a cued recall task, as individuals are presented with all the possible paired choices and asked to discriminate which image goes with the presented pair. Like Verbal Paired Associates, the task is repeated four times which allows the test to incorporate a measure of learning. The designs are presented in a different order each time. Following a 30 minute delay, participants are asked to complete the matching aspect of Visual Pairs without seeing the pairs again to incorporate a measure of long term memory within this task.

This task consists of separate scores for the Easy Pairs, the Hard Pairs and for both sets combined. A score of one for each correct pairing is given for a total score of eight for each trial. Like the previous two subtests, an immediate recall score is derived from the total pairs correctly identified in trial one. The total recall score is derived from adding the scores from all five initial trials together. The learning curve is calculated by subtracting the individual's trial one score from their trial five score. Lastly, the delayed recall score is derived from the total pairs correct on the delayed trial administered at the completion of the Design Learning. (See Appendix I. for the examiners script)

Piloting the Developed Visual Memory Assessment Tasks

Experiment 1 involved piloting the developed tests to investigate the validity and reliability of each to determine whether they were appropriate measures for understanding spatial and object memory performance.

Validity

Validity is the tool used to determine if a test is measuring what it purports to measure (Gravetter & Wallnau, 2012). Measuring validity generally involves using other tests that measure a similar function or past reviews to justify the scores produced by the test in question (Messick, 1995). Validity can be understood as a unitary concept that incorporates all the evidence that supports the intended meaning and subsequent interpretation of the measure. Validity in psychological measures consists of the four following main components that are then subdivided further (Kaplan & Saccuzzo, 2005).

- Face Validity
- Content Validity
- Criterion Validity
- Construct Validity

Until the late 1990’s the notion of validity consisting of distinct types was considered the norm. However there is a degree of overlap between the different types, in particular criterion and construct validity. Some psychologists now argue that construct related validity is considered enough evidence for a test to be considered valid and should be the only major type of validity researchers should be concerned with (Kane, 2006). In 1999 the standards of education and psychological testing no longer recognised the distinct components of validity, instead changing the description to different categories of evidence for construct validity. Hunter and Schmidt (1990) acknowledged that validity as a construct must always be defined by evidence and the other previous separate components of validity may be thought of as sub categories of evidence, if researchers still want to consider a demarcation. This is not a new idea, in 1980 Chronbach first suggested that all validation is unitary and can be considered under the construct validity umbrella.

Construct Validity - Convergent and Discriminant Validity

The use of construct validity was born out of a necessity to correct the aforementioned issues that arose through the use of content and criterion validity (Kaplan & Saccuzzo, 2005). There is no universally accepted best approach to measuring construct validity, instead a number of methods exist (Kane, 2006). These various methods acknowledge that not all tests are constructed the same and not all tests serve the same purpose hence, forcing them all into a unitary validity model may not best represent the test in question (Larrabee, 2003). For the purpose of this section a focus on construct validity in terms of cognitive testing will be utilised. It is acknowledged that a number of various measures exist though those that are not relevant will be excluded.

While there is no single, efficient method for determining construct validity, one of its strengths is that almost any data can be used to aid in establishing it (Kaplan & Saccuzzo, 2005). The more data that exists that supports the test, the greater the degree of confidence examiners will have when implementing it. For this reason alone construct validity is considered one of the most fundamental components to developing an assessment for both its strength and sophistication (Groth-Marnet, 2009). The strength of construct validity comes from the fact that it involves theoretical knowledge, hypothesis testing, and knowledge of other related variables. With this knowledge assertions regarding the relationships of the new test with established variables can be determined (Smith, 2005).

Construct validity involves the researcher defining a construct and then developing the instrumentation to measure it (Kaplan & Saccuzzo, 2005). This generally involves a number of stages and often a number of tasks, to ensure the researcher is being thorough and that the instrumentation is a representative measure of the construct. The degree of consistency of a test with other assessments that purport to measure the same construct is established by correlating the developed tests with related established tests or theory (Streiner, 2003). E.g. When establishing construct validity in a developed measure of verbal short term memory, a researcher may compare the test scores, to scores on the immediate trial of the 'Rey Auditory Verbal Learning Task' or they may compare test scores to the theoretical understanding that verbal short term memory is on average 7 items +- 2. While correlations can be made with other tests that appear to measure the same construct it is important to note that a test that correlates too highly with the pre existing test is unlikely to be unique or offer an additional advantage, as high correlations indicate too much similarity (Kaplan & Saccuzzo, 2005). Therefore, in most cases moderate correlations are deemed acceptable, as this indicates that a relationship is present however, the tests vary in some way. Every time a relationship is demonstrated it adds more meaning to the test. Construct validity in its entirety does not have to be fully established before a test is developed, in fact it is an ongoing process that will occur over the life time use of a test, as new researchers continue to find more meaning. The continuing development of construct validity is guided by specific hypotheses that researchers develop regarding the developed tests and established theoretical notions.

In 1959, Campbell and Fiske acknowledged that construct validity in its current form limited the evidence that was able to be used for items that were related to a test. They purported that knowing what does not work or what is not related can provide just as much meaning as knowing what is related. They argued that two distinguishing categories should exist and dubbed them convergent and discriminant validity. The more evidence a researcher has about both forms of construct validity the more meaning that can be given to a test (Kaplan & Saccuzzo, 2005; Groth- Marnet, 2009). Convergent validity mirrors the prior notion of validity and states that when a developed measure or score correlates moderately with pre established tests or theory then validity can be established. On the contrary, discriminant validity explores how and why tests are different from pre established tests or theories. Discriminant validity can assist in highlighting why the new test is necessary and what unique or novel advantages it offers over the previous ones.

Construct validity works off the notion of comparing test scores to scores on a related measure (Hymel, LeMare & McKee, 2011). However, construct validity can also be used when there is no well defined criterion in the construct being measured, therefore, the meaning can be derived from other variables or theories that it can be associated with. Convergent validity is not as limited as criterion validity as it acknowledges that no single variable, test or theory alone is representative of the test construct as a whole, instead it is a series of evidence gathered by many observations and testing sessions that slowly identifies what a test means. Convergent validity is generally established in one of two ways, by demonstrating that the developed test measures the same constructs as other like tests developed for the same purpose or by exploring the specific relationships that should be present if the developed test is really measuring what it claims to be measuring. Both methods demonstrate that the developed test is a similar construct that converges with previously established constructs and theories. On the other hand discriminant validity highlights that the measure does not represent any construct other than the one it has been developed for. To provide evidence for discriminant validity, low correlations are sought after between the developed test and unrelated constructs. This analysis provides further support for what the test does not measure.

In terms of memory research both theoretical knowledge and established assessments can be utilised to measure construct validity. There is a clear understanding of the relationships between the different components of memory e.g. short term memory capacity is generally greater than working memory capacity. This allows for comparisons between developed span and working memory assessments to be undertaken, even when no clear similar test is available. Furthermore, in terms of investigating relationships the Wechsler Memory Scale provides a comprehensive series of memory tasks that measure both auditory and visual memory. Correlating the developed assessments with these indices will assist in the confirmation that the developed tests are measures of memory, with a closer relationship with the visual memory index highlighting its relationship with this sense.

Reliability

Reliability refers to the consistency of a test and comprises both internal (the extent to which a measure is consistent with itself) and external (the extent to which a measure varies from one use to another) reliability. Most reliability coefficients are derived from correlations whereby the higher the reliability coefficient the more likely the test score can be attributed to individual differences in the domain of interest being measured. Any remainder is the amount of variance that is explained by chance. This highlights the necessity for a high degree of rigour in psychological assessments to ensure the assessments measure what they purport to measure.

Internal consistency investigates the different items that when combined make up a test and aims to determine if items that propose to measure the same construct and difficulty actually do (Kaplan & Saccuzzo, 2005). It is typically measured using correlations and/or within subjects analyses depending on the nature of the assessment. This is important during the development of psychometric assessments as it allows for an in depth analysis of the items within a test to be conducted, which can elucidate if specific items are too easy or too difficult.

Error can come from a number of different factors (Kaplan & Saccuzzo, 2005; Groth - Marnet, 2009). There are situational factors such as noise, distraction, and time of day that could influence results. There are also internal factors such as motivation, mood, hunger, and fatigue. Within the test it is possible that a number of items may not be representative of the domain that the assessment is purporting to measure (Strauss et al., 2006). While researchers can attempt to control for error to the best of their abilities, there are a number of ways that the internal consistency of test reliability can be measured to determine if the test is consistent with what it claims to measure. This can include comparing similar items to one another to determine if scores are consistent, it cal also include comparing performance scores on tasks that claim to measure similar constructs.

The Relationship Between Validity and Reliability

Validity and reliability, as psychometric test principles co-exist (Gravetter & Wallnau, 2012). Attempting to define the validity of a test is entirely pointless if the test is not considered to be reliable. Links between the expected validity coefficients based on the reliability of the test have been developed and it is acknowledged that validity coefficients do not have to be exceptionally high for a test to be considered valid (Kaplan & Saccuzzo, 2005). Sometimes a test may have strong reliability ratings however, have virtually no meaning. Therefore, it can be understood that reliability can exist without validity however, the same is not true for the inverse. A test cannot have established meaning if that meaning does not occur on a consistent basis. Once reliability has been established the researcher's focus should turn to the much more in depth component of validity, as to make any inference about an individual's performance, a researcher must have substantial evidence to support this claim. Cronbach and Meehl (1995), contend that once reliability is established there should be as many validity explorative studies as there are inferences about scores, this will ensure that every inference made is grounded in evidence. Landy (2003) reframed this notion by arguing that validity is more about the evidence that supports what can be understood by the produced test scores more so than what the tests themselves mean. Any time a researcher intends to infer something from a test score that differs from the norm or what is established, a new validity study should be conducted to provide further evidence for the interpretation (Kaplan & Saccuzzo, 2005).

Ceiling and Floor Effects

The ceiling effect is a methodological limitation that is present when the highest score on a measurement is reached, this indicates that it is possible that the test did not accurately measure the intended domain as it is likely that a participant (if more trials were present) would be able to continue. Alternatively, the floor effect occurs when most participants score near the minimum possible score. Little variance is likely the result of the test being too difficult and this results in a floor effect.

Experiment 1 : Aims and Hypotheses

Experiment 1 involved piloting the developed series of assessment tasks to determine if they were reliable and accurate measures of spatial and object memory. A purposeful effort was made to ensure that each task developed was founded on established theory, and drew from the strengths and weaknesses of past assessments as outlined in the first portion of this chapter. The idea of developing a series of separate spatial and object memory assessments for comparative use is novel, however, before they could be implemented in a practical sense or for use in investigative research they had to be established as psychometrically sound. Developing psychometrically sound assessments that acknowledge the demarcation between spatial and object information, was necessary to explore visual memory capacity and the role of each stream.

The aim of Experiment 1 was to create and pilot a reliable and valid series of spatial and object assessment tasks.

To demonstrate construct validity it was expected that:

- Performance on span tasks would be greater than working memory tasks

- Performance would increase across trials on the learning tasks
- Performance on delayed trials would be greater than immediate trials on the learning tasks.
- Performance on the developed tasks would demonstrate weak - moderate correlations with established measures of memory.

To demonstrate internal consistency it was expected that:

- Performance between trials on a single span would yield similar patterns of performance
- Performance would decrease as span number increased

To demonstrate internal validity it was expected:

- There would be no floor or ceiling effects on any of the developed span and working memory tasks.
- A ceiling effect would be present on the delayed trials of the learning tasks.

Method

Participants

Branmaier and colleagues (2013), identified that for a pilot study to be indicative of the population, the pilot sample should consist of 10% of an acceptable sample for normative data collection. Based on past research that generated normative data for other memory assessments that used samples of approximately 500 (Wechsler, 2009), a sample size ~ 50 for Experiment 1 was deemed adequate and appropriate to both represent the sample and conduct the analyses of interest.

Participants for Experiment 1 were recruited from the Northern and Western regions of metropolitan Melbourne, Victoria, Australia. These regions included a range of varying socio economic strata. Data was collected from 57 participants. All participants were aged between 18 - 45 years with a mean age of 25.67 years (*SD* = *6.86*). This age range was selected as most higher order memory skills are said to develop by the age of 15 (Gathercole & Pickering, 2001) thus, a minimum age of 18 would assume that all adults had developed the necessary skills to complete all tasks. The upper restriction was based on Salthouse's (2009) research that states cognitive decline does not generally occur until the age of 50-55 hence, the upper binding of 45 is a conservative measure to reduce the likelihood that participants would demonstrate significant age related deterioration. Table 6.2 displays descriptive nominal data about the sample group.

Table 6.2. Percentage of Participants Represented in Each Category for Nominal Demographic Data (N=57)

Category	Percentage of Participants in Each Group %					
Sex					Female	Male
					56.20% N = 32	43.80% N = 25
Employment				Unemployed	Casual / Part Time	Full Time
				28.10% N = 16	56.10% N =32	15.80% N = 9
Highest Level of Education	Year 11 Completion	High School Completion	TAFE Certificate	Diploma	Undergrad Degree	Postgrad Degree
	1.80% N = 1	50.00% N = 28	14.30% N = 8	7.1% N = 4	23.20% N = 13	3.60% N = 2

It can be seen from Table 6.2 that the participant group comprised of individuals with varied employment status and educational attainment. The higher percentage of casual/part time and unemployed individuals in comparison to full time employed individuals is likely due to many participants being sourced from university campuses and were subsequently more likely to be students who were studying full time. It is also worth noting that 50% of individuals had completed high school as their highest level of attainment and this is indicative of the general population.

Table 6.3 shows the means, standard deviation and ranges for the sample's performance on measures of IQ and established measures of memory.

Table 6.3. Descriptive Statistics for Index Scores on the WMS and WASI (N = 57)

Index	Mean *(SD)*	Range
Full Scale IQ	112.02 *(13.42)*	79 - 137
Verbal Comprehension Index	114.43 *(14.96)*	79 -1 38
Perceptual Reasoning Index	108.62 *(12.06)*	75 - 129
Auditory Memory Index	106.63 *(13.03)*	72 - 124
Visual Memory Index	101.06 *(13.68)*	72 - 124
Visual Working Memory Index	96.35 *(14.36)*	60 - 130
Immediate Memory Index	104.81 *(13.32)*	70 - 130
Delayed Memory Index	102.75 *(14.17)*	67 - 123

Skewness and kurtosis indicate that all variables fell within the accepted range (-3 to 3) to be considered normally distributed (George & Mallery, 2010). The Wechsler administration manual outlines that the mean for all indices in the WMS and WASI is 100 with a standard deviation of 15 (Wechsler, 2009; Psychological Corporation, 1999). It can be seen from the above table that the means of the sample all fall within one standard deviation for each index measured. Although IQ indices are somewhat elevated (likely due to the large presence of tertiary students) this data not only indicates that the scores produced by the sample are normally distributed but also that it is representative of the pattern of performance seen in the general population. The WMS index scores were more representative of the general population than IQ, as mean scores were more closely clustered around the standard mean of 100.

Exclusion Criteria

Participants were ineligible for inclusion if they were currently taking medication for any neurological/psychological or psychiatric illness, as many different medications are known to have an effect on cognition ranging from mild to profound (Obermann, Morris & Roe, 2013). Adults who had been diagnosed with a mood disorder within the last two years were excluded, as were adults who had any history of developmental or acquired brain injury, or neurological disease. Adults who were affected by vision impairment that was unable to be rectified through the use of corrective eyewear were also excluded. It was also required that all participants were proficient in conversational English to promote optimal understanding of test instructions and to minimise errors from this source.

Materials

Demographic Questionnaire.

Each participant was asked to provide basic demographic information, including variables such as sex, age, and education attainment. (See Appendix J.). The demographic questionnaire included 8 questions. For 4 of the questions (sex, employment status, education status and language spoken at home) participants were asked to circle the answer that best represented them. For age, occupation, country of birth and cultural background participants were asked to record the correct answer in the space provided.

Wechsler Memory Scale (WMS) (Wechsler, 2009).

The WMS is the most commonly used neuropsychological memory test battery for adults (Spedo et al., 2013). As outlined in Table 6.4 it consists of six core subtests (4 of which have an immediate and delayed component) and the results from performance on these subtests are categorised into five distinct indices.

Table 6.4. Summary of the WMS Indices and Respective Subtests

Indices	***Subtests***	
Auditory Memory Index	Logical Memory 1 and 2	Verbal Paired Associates 1 and 2
Visual Memory Index	Visual Reproduction 1 and 2	Designs 1 and 2
Visual Working Memory Index	Spatial Addition	Symbol Span
Immediate Memory Index	Logical Memory 1	Verbal Paired Associates 1
	Visual Reproduction 1	Designs 1
Delayed Memory Index	Logical Memory 2	Verbal Paired Associates 2
	Visual Reproduction 2	Designs 2

The aims of the current research relate to visual memory components specifically, however composite and index scores from both auditory and visual measures were collected to allow for analysis of both convergent and discriminant validity. The psychometric properties of the WMS-IV report good validity and reliability, with coefficients for the primary subtest scores ranging from 0.62 to 0.82 and those for the primary indices ranging from .70 to .88 (Wechsler, 2009). In terms of validity the highest interrelations are observed between related components of memory i.e. immediate auditory subtests with delayed auditory subtests (r = 0.88), and similar findings are observed for the visual assessments (r = 0.84). Thus, this battery of assessment forms a strong basis to compare the developed tests to determine whether they demonstrate evidence of convergent and discriminant validity. This battery was administered in full according to standardised procedures.

Wechsler Abbreviated Scale of Intelligence (WASI) (Psychological Corporation, 1999).

The four subtest version of the WASI was used to provide a brief measure of each individual's intelligence. Due to the relationship memory has with intelligence (Leeson et al., 2010), the WASI was included to ensure that the sample population demonstrated a normal IQ distribution. The WASI provides a valid estimate of full scale IQ, incorporating two subtests from the verbal comprehension index of the Wechsler Adult Intelligence Scale (WAIS-III) and two subtests from the perceptual reasoning index (titled the performance index on the WASI; Wechsler, 2011) as seen in Table 6.5.

Table 6.5. Summary of the WASI Indices and Respective Subtests

Indices	*Subtests*	*Measures*
Verbal Comprehension Index	Vocabulary	Test of : expressive vocabulary and verbal knowledge
	Similarities	Test of : abstract verbal reasoning ability and verbal concept formation
Perceptual Reasoning Index	Block Design	Test of : spatial visualisation, visual- motor co ordination and abstract conceptualisation
	Matrix Reasoning	Test of : non verbal fluid reasoning

As seen in Table 6.5 the four subtest scale incorporates alternate versions of the subtests Vocabulary, Similarities, Block Design and Matrix Reasoning from the WAIS - III (Psychological Corporation, 1999). The WASI was selected for use as it is a brief, reliable and valid measure that provides an estimate of intelligence, with reliability coefficients for FSIQ ranging from .96 to .98 in an adult population (Psychological Corporation, 1999). All subtests were administered according to standardised procedures.

Developed Visual Memory Assessment Tasks.

As outlined at the beginning of this chapter assessment tasks were developed for the purpose of this pilot study and are displayed in Table 6.6. These assessments aim to measure short term, working and long term memory capacity for each pathway.

Table 6.6. Summary of the Developed Tasks Separated by their Respective Visual Pathway

Domains	***Subtests***		
	Aim of Assessment	**Key Features**	**Maximum Score**
Spatial			
Spatial Span	• Measure of spatial span and basic attentional control	• Two dimensional static maze with a dynamic pathway • Maze increases in size with accurate performance • The size of the maze (number of walls) is representative of the participants span • Discontinue after two incorrect trials	Trials Correct = 14 Total Span = 7
Spatial Working Memory	• Measure of spatial working memory span	• Identical design and administration to spatial span • Includes a manipulation component where after the pathway has been drawn the maze will rotate either 90,180 or 270 degrees. • Discontinue after two incorrect trials	Trials Correct = 14 Total Span = 7
Spatial Learning	• Measure of immediate spatial span, total learning over a period of 5 trials, spatial learning and delayed spatial recall	• Allocentric 8x8 grid maze • Squares are highlighted one square at a time and remain highlighted • Required to remember the maze in the order it was presented.	Immediate recall = 25 Total recall = 125 Learning = 25 Delayed recall = 25
Object			
Object Span	• Measure of object span and basic attentional control	• Abstract objects are presented one at a time in a predetermined order. After each sequence participants are required to select the objects that they saw in the order that they saw them • Difficult increase by one object every two trial • Discontinue after two incorrect trials.	Trials Correct = 14 Total Span = 7
Object Working Memory	• Measure of object working memory span	• Identical design and administration to object span • Manipulation component involves recalling the objects in the reverse order than they were presented. • Discontinue after two incorrect trials	Trials Correct = 14 Total Span = 7
Design Learning	• Measure of immediate object span, total learning over a period of 5 trials, object learning and delayed spatial recall • Measure of free recall	• 12 abstract features are presented one at a time • Required to draw all the features remembered after each trial • Score of 1 for the correct form, orientation and number of components for each feature	Immediate recall = 36 Total recall = 180 Learning = 36 Delayed recall = 36

Visual Pairs	• Measure of immediate object span, total learning over a period of 4 trials, spatial learning and delayed object recall • Measure of cued recall	• 4 easy and 4 hard pairs are presented in a randomised order for each trial • Participants are presented with one of the images that makes the pair and are asked to select the correct partner	Immediate recall = 8 Total recall = 32 Learning = 8 Delayed recall = 8

Procedure

This project was approved by the Victoria University Human Research Ethics Committee (See Appendix K). Participants were recruited by the use of flyers placed on social networking websites and community bulletin boards, promoting the project at undergraduate lectures and through word of mouth. Any person interested in taking part in the experiment was asked to contact the student researcher. They were provided with the opportunity to ask any questions and if they were interested in participating were sent the Information to Participants sheet and Consent Form via email (See Appendix L). They were also sent the demographic questionnaire at this time and asked to complete this documentation prior to the testing session. A meeting time for testing was also scheduled over email at this time. Participants completed the testing session at a Victoria University campus. They were asked to turn their mobile phone off during testing. All testing was undertaken in a quiet room free from distractions.

The testing session was approximately 90-120 minutes duration, and the order of administration was counterbalanced, as seen in Figure 6.8 below.

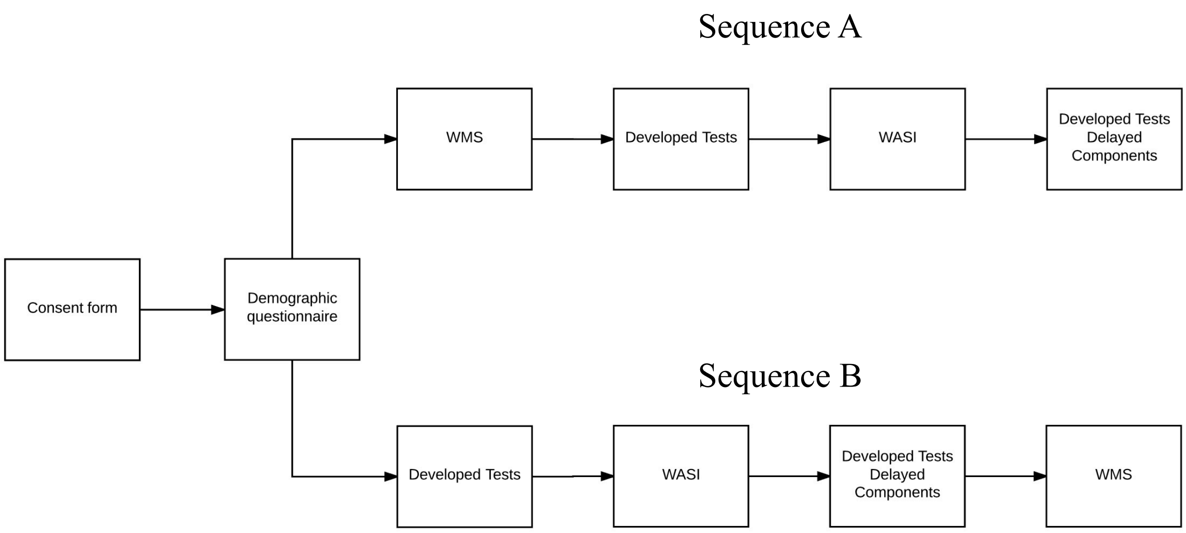

Figure 6.8. *Administration Order for Experiment 1.*

Note. All participants completed the first two steps and then one of the two sequences.

Counterbalancing between participants was implemented to reduce the influence of order effects. This order was determined as the WMS and the other three components take approximately the equivalent time to administer. Both the WASI and the WMS were administered as per standard administration guidelines. As per WASI and WMS guidelines, no feedback was given during the session unless specified in the test manual. At the conclusion of testing participants were not informed of their task performance.

In order to account for the timing of the delayed memory tasks, the developed assessments were presented in a standardised order, regardless of whether the participant completed the tasks before or after the WMS. Figure 6.9 shows the standardised order for the developed tasks that was utilised for all participants.

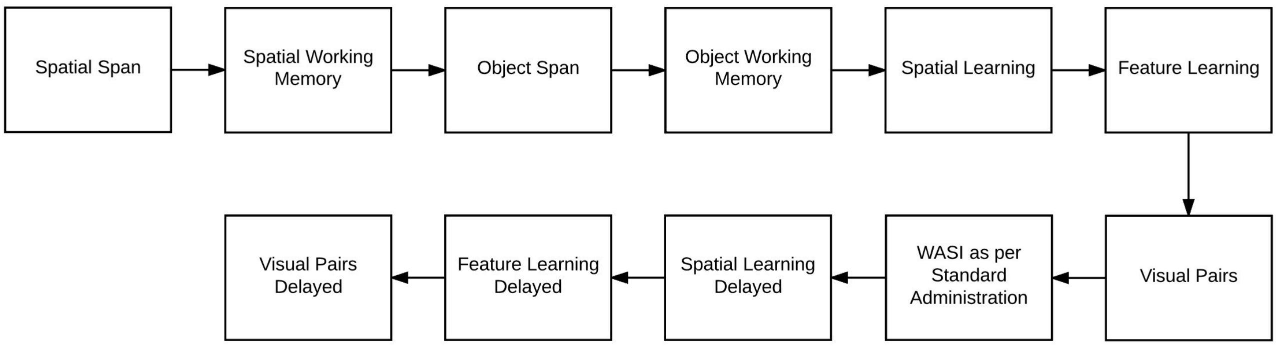

Figure 6.9. *Administration Order for the Developed Tasks.*

Figure 6.9 illustrates that all the span and working memory tasks were completed prior to beginning the learning assessments to avoid any interference between object stimuli. As all the object assessments utilised abstract designs it was necessary to ensure that stimuli from one task did not interfering with stimuli from the other assessments. The WASI was used during the delay for all learning tasks as the standard administration is 20 - 30 minutes.

The WASI and the WMS were administered and scored according to standardised procedures and all raw scores were converted to scale scores for the purpose of analyses. All scaled scores were used to derive their respective index scores, along with full scale IQ. All of the developed assessments were scored as described earlier.

Data Analysis

All tasks had the same number of trials per span and maximum scores therefore, raw scores were considered appropriate for all analyses. All data was then collated and analysed using SPSS Version 22 (IBM Corp, 2013).

When investigating the presence of differences between scores on two different tests, paired samples t-tests were utilised. For all analyses the alpha value was set at .05. The assumptions of paired samples t-tests are as follows:

- The dependent variable must be continuous (interval/ratio).
- The observations are independent of one another.
- The dependent variable should be approximately normally distributed.
- The dependent variable should not contain any outliers.

To investigate the presence of outliers skewness and kurtosis were checked and all trials correct and span scores fell between the accepted -+ 3.29.

When comparing the whether trials within a span yielded similar levels of performance as one another (as they should be of equal difficulty) Friedman Test's were utilised. As this data was ordinal (the participant completed the trial correctly, incorrectly, or did not attempt) it did not meet the assumptions of the paired samples t-test. The Friedman test is the non parametric alternative to the paired samples t-test. It can be used for data that has violated the assumptions of the paired samples t-test.

The assumptions of the Friedman Test are as follows:

- One group that is measured on two or more occasions
- Group is a random sample
- Variables should be ordinal or continuous (ordinal can include likert scales, in the case of the present study yes, no, did not attempt)
- Samples do not need to be normally distributed.

As the Friedman test is generally utilised when the assumptions of parametric assessments have been violated, there are no analyses that are conducted prior to implementing this procedure. All assumptions are based on the methodological design and thus, are examined qualitatively prior to selecting this assessment.

Finally in the investigation of the relationships between established tests of memory and the developed assessments Pearson Correlation's were utilised, as correlation analyses do not require standardisation of the variables used in the analyses and are considered a robust measure for evaluating relationships between variables.

The assumptions of a Pearson Correlation are as follows:

- Every variable must be continuous
- Each participant should have a pair of values
- No outliers should be present for either variable
- Linearity and homoscedasticity

Outliers, linearity and homoscedasticity were checked by creating and analysing a scatterplot of all variables on SPSS. For Experiment 1 all values fell within the accepted ranges.

Results

For simplicity the following results have been subdivided into two sections. The first section aimed to assess the construct validity of the developed assessment tasks to determine whether the results regarding the overall constructs of the developed tasks were in accordance with already established notions of memory e.g. are span scores larger than working memory scores. It also aimed to evaluate convergent and discriminant validity by investigating the relationships between the developed assessments and the relevant WMS indices. The second section aimed to determine if there were any immediate methodological constraints present in the developed assessment tasks. This involved reviewing the internal consistency of the items within each task. To do this an item analysis of each of the developed tests was conducted to determine that all items within a span produced similar results, and that the trajectory of the tests became progressively harder as span trials increase. This section also investigated if any floor or ceiling effects were present.

An Investigation of Construct Validity

The Span and Working Memory Assessment Tasks

To assess the construct validity of the developed tasks, paired samples t-tests were first conducted for the span and working memory assessments for each pathway. Each task generated two scores; number of trials correct (calculated by the sum of every trial that the participant correctly answered in each test) and overall span score (determined by the highest span where the participant answered both trials correctly). As each task included the same number of trials per span, raw scores were considered appropriate for all analyses and standardisation was not undertaken. Table 6.7 displays the descriptive statistics and whether statistical differences were present between the span and working memory tasks for the spatial and object measures.

Table 6.7. Means, Standard Deviations and Paired Samples T-Test Results Comparing Span and Working Memory Assessments Tasks (N = 57)

	Trials Correct Mean (SD)	T *(df)*	p Value	Span Mean (SD)	T *(df)*	p Value
Spatial Span	9.13 *(2.32)*	14.75 *(54)*	< .001	5.35 *(1.14)*	12.41 *(54)*	< .001
Spatial Working Memory	4.29 *(2.01)*	-	-	2.85 *(1.53)*	-	-
Object Span	4.96 *(1.95)*	-0.88 *(54)*	.38	3.20 (*1.09*)	-0.90 *(54)*	.37
Object Working Memory	5.18 *(2.14)*	-	-	3.32 *(1.24)*	-	-

Analysis of the descriptive statistics for the spatial tasks indicates that performance was higher for Spatial Span on both trials correct and span scores, compared to Spatial Working Memory. Contrary to expectations, Object Working Memory scores were actually slightly higher than those on Object Span.

It can be seen from Table 6.7 that a significant difference was present between the two spatial memory tasks for both trials correct and span, with span performance significantly exceeding working memory performance. Alternatively, there was no significant difference observed between the object memory tasks for either score. As the results of this test are not as expected this indicates that the object span and working memory assessments may not be valid measures of visual object span and working memory.

To investigate convergent validity, correlation analyses were conducted between the developed tasks and the relevant WMS indices to determine whether a significant relationship was present. The findings of these analyses for the span and working memory tasks are depicted in Table 6.8.

Table 6.8. Pearson Correlations Between Established WMS Indices and the Developed Span and Working Memory Assessment Tasks (N = 57)

	Spatial Span	Spatial Working Memory	Object Span	Object Working Memory
Auditory Memory Index	.19	.15	.21*	.48**
Visual Memory Index	.33 **	.34**	.36**	.38**
Visual Working Memory Index	.41**	.46**	.50**	.45**
Immediate Memory Index	.30**	.24*	.35**	.49**

* denotes p < 0.05

** denotes p < 0.01

It can be seen from Table 6.8 that two relationships were not significant; Auditory Memory Index/Spatial Span and Auditory Memory Index/Spatial Working Memory. All other relationships were considered weak to moderate. Contrary to expectations a significant relationship was observed between the two object measures and the Auditory Memory Index.

The Learning and Delayed Recall Assessment Tasks

To determine if the developed learning and delayed tasks demonstrated good face and construct validity the learning trajectories of each task were reviewed. Figure 6.10 shows the mean scores for each trial of Spatial Learning and Design Learning respectively

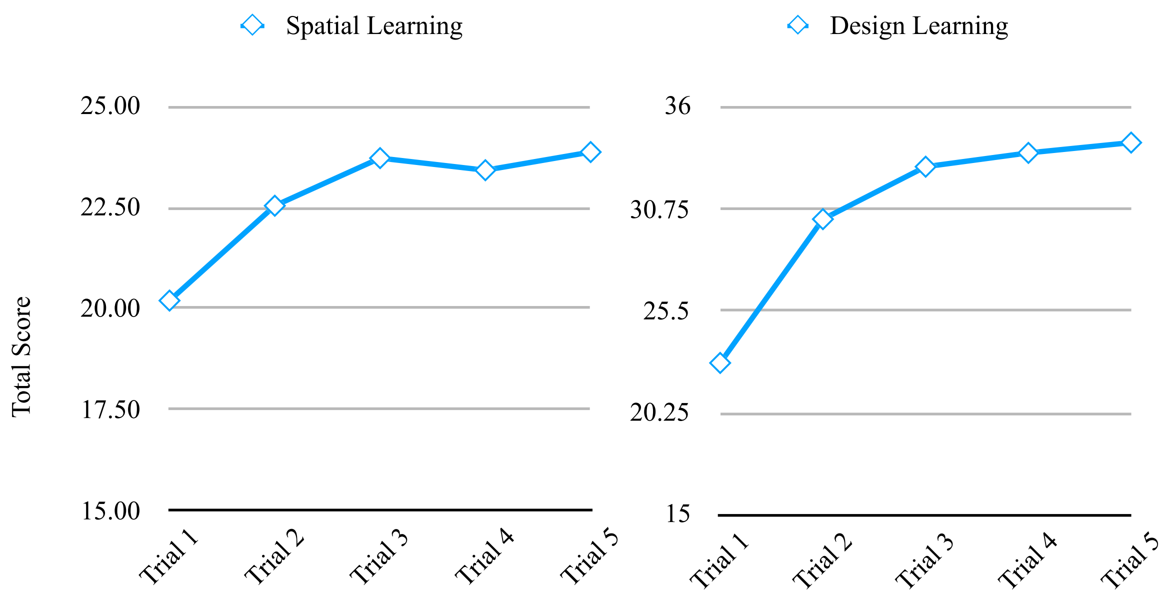

Figure 6.10. *Learning Trajectories for Spatial Learning and Design Learning Respectively. (N = 57)*

It can be seen from the above figures that scores in general are indicative of a normal learning curve. In Spatial Learning scores increase between trials 1 and 3 before a slight decline in performance is seen on trial 4 (0.37). The values obtained in trial 3 and 5 are similar however, indicating that peak learning performance is likely achieved by trial 3. Design Learning shows a normal learning curve with scores showing the most increase between trials 1 and 3 before gradually plateauing in the final 2 trials.

The following figures show the learning trajectories for Visual Pairs. This task produces a score for the easy trials, the hard trials and a combined score. Thus, to determine the rate of learning, a figure was developed showing the pattern of performance for the aforementioned three scores. These trajectories are depicted below in Figure 6.11.

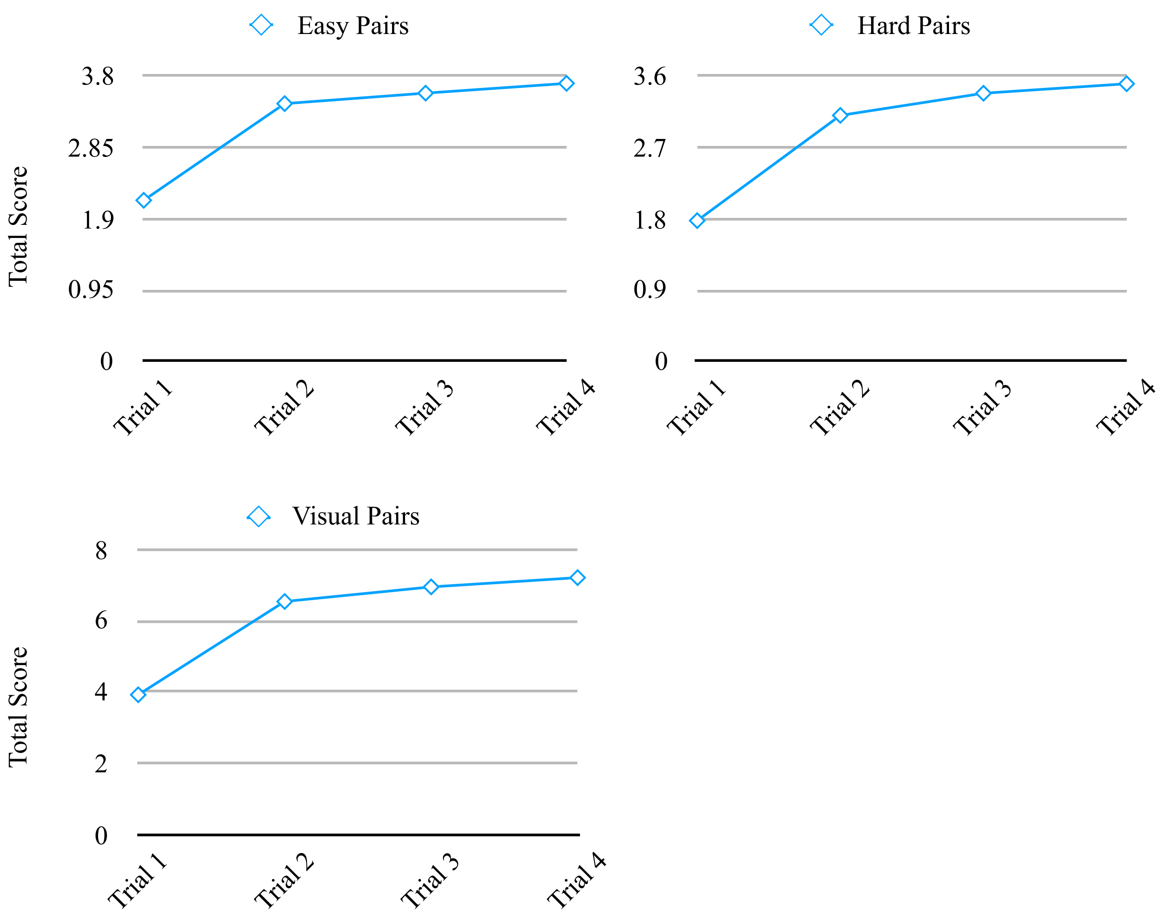

Figure 6.11. *Learning Trajectories for the 3 Components of Visual Pairs : Easy Pairs, Hard Pairs, and Overall Score Respectively. (N = 57)*

It can be seen from Figure 6.11 that a normal learning curve is present in all three conditions with scores initially rising between trials 1 and 2 and then plateauing. A paired samples t-test was conducted to determine whether there was a significant difference for the overall number of easy pairs remember compared to the overall number of hard pairs. Results indicated a significant difference was present, t (56) = 3.42, $p < 0.001$, with participants remembering significantly more easy pairs than hard pairs over the duration of the task. Interestingly when investigating the performance on the easy and hard pairs by each trial only trial 2 produced a significant difference in performance, $t(56) = 2.75$, $p < .001$. This suggests that on all other trials differences between the pair difficulties were relatively similar. These findings can be corroborated by examining the means present in Figure 6.11.

Finally, it was expected that a significant difference would be present between participants' immediate score on the learning tasks (Trial 1) and their delayed score that is derived after a series of learning trials followed by a 30 minute delay.

To investigate whether there were differences between the immediate and delayed trials on each of the learning tasks, paired samples t-tests were conducted. The results of these analyses are depicted in Table 6.9.

Table 6.9. Means, Standard Deviations and Paired Samples T-Test Results Comparing Immediate Recall and Delayed Recall for the Three Learning Assessment Tasks (N=57)

	Immediate Trial	Delayed Trial		
	Mean *(SD)*	Mean *(SD)*	T *(df)*	p Value
Spatial Learning	20.25 *(5.38)*	23.84 *(3.12)*	-5.64*(54)*	< .001
Design Learning	22.24 *(5.86)*	33.56 *(3.02)*	-14.32 *(54)*	< .001
Visual Pairs	3.96 *(1.74)*	6.93 *(1.67)*	-9.57 *(54)*	< .001

It can be seen in all three assessments that performance is higher on the delayed trial that it is on the immediate trial. This indicates that learning has occurred. Furthermore, it can also be seen from Table 6.9 that a significant difference was present in all three assessments between the immediate score and the delayed memory score, with the delayed task having a significantly higher mean score than the immediate task in all three tests.

Table 6.10 shows the correlation results for the learning and delayed tasks with the relevant WMS indices.

Table 6.10. Pearson Correlations Between Established WMS Indices and the Developed Learning and Delayed Memory Assessment Tasks (N = 57)

	Spatial Immediate Span	Spatial Delayed Span	Design Immediate Span	Design Delayed Span	Visual Pairs Immediate Span	Visual Pairs Delayed Span
Auditory Memory Index	.32**	.24*	.35**	.29**	.40**	.42**
Visual Memory Index	.55**	.38**	.33**	.53**	.28**	.29**
Visual Working Memory Index	.39**	.42**	.17	.53**	.06	.24*
Immediate Memory Index	.55**	-	.42**	-	.37**	-
Delayed Memory Index	-	.34**	-	.49**	-	.39**

* denotes p < 0.05

** denotes p < 0.01

It can be seen from Table 6.10 that only two relationships were again not significant; Visual Working Memory Index/Design Immediate Span and Visual Working Memory Index/Visual Pairs Immediate Span. All other relationships were considered weak to moderate.

Reliability Analysis of the Developed Assessments : An Investigation of the Item and Test Design

Span and Working Memory

To determine whether the developed tests were considered reliable (with good internal consistency), analyses were conducted to explore the task difficulty by comparing the individual trials within each of the developed subtests to investigate if when span increases performance will decrease. This section also aims to investigate whether the trials within each span yield a similar pattern of performance, indicating that they are of equivalent difficulty.

Table 6.11 shows the pattern of performance for the sample on Spatial Span.

Table 6.11. Percentage of Participants in Each Category For Performance on Spatial Span. (N = 57)

	Span 2		Span 3		Span 4		Span 5		Span 6	
Trial No.	1	2	3	4	5	6	7	8	9	10
Correct	89.50%	91.20%	91.20%	91.20%	84.20%	80.70%	80.70%	43.90%	56.10%	42.10%
Incorrect	10.50%	8.80%	8.80%	8.80%	7.00%	10.50%	5.30%	42.10%	29.80%	24.60%
Discontinue	-	-	-	-	8.80%	8.80%	140%	140%	14.10%	33.40%

It can be seen from table 6.11 that excluding trial 1, performance decreased gradually between trials 2 and 8 before an increase in performance was observed in trial 9. Performance remains quite high and stable between 1 and 7. Within spans 2 - 4 the percentage of participants who got the trial correct is relatively similar. Within trials 7 and 8 a difference was observed. A non parametric Friedman test of differences among repeated measures was conducted and rendered a chi square value of 23.00 which was significant $p < .001$. This indicates that trial 8 was significantly more difficult than trial 7.

Table 6.12 shows the pattern of performance for the sample on Spatial Working Memory.

Table 6.12. Percentage of Participants in Each Category For Performance on Spatial Working Memory. (N = 57)

	Span 2		Span 3		Span 4		Span 5		Span 6	
Trial No.	1	2	3	4	5	6	7	8	9	10
Degree of Rotation	90	180	90	270	180	90	270	180	90	180
Correct	71.90%	59.60%	70.20%	66.70%	21.10%	52.60%	12.30%	5.30%	5.30%	3.50%
Incorrect	28.10%	40.40%	7.00%	10.50%	56.10%	19.30%	36.80%	47.40%	10.50%	5.30%
Discontinue	-	-	22.80%	22.80%	22.80%	28.00%	50.80%	47.30%	84.20%	91.20%

Note : 90/270 degree rotation refers to a quarter turn to the right (90 degrees) or the left (270 degrees) and 180 degree rotation refers to a complete inversion of the original pattern.

It can be seen in Table 6.12 that there is a clear difference between performance on the 90/270 degree rotation and the 180 degree rotation. A non parametric Friedman test of differences among repeated measures was also conducted and rendered a chi square value of 2.88 which was not significant $p > .05$ for the span 2 trials. This indicates that while a difference is present between the 90 and 180 degree trials this difference was not statistically significant. However, a non parametric Friedman test of differences among repeated measures was also conducted and rendered a chi square value of 10.71 which was significant $p < .001$ for the span 4 trials. This indicates that by span 4 the 180 degree trial is significantly more difficult than the 90 degree trial. The decline in performance occurs much more rapidly for this Spatial Working Memory task compared to Spatial Span, with 84% of people discontinuing by, or during, the 6th span.

Table 6.13 shows the pattern of performance for the sample on Object Span.

Table 6.13. Percentage of Participants in Each Category For Performance on Object Span. (N = 57)

	Span 2		Span 3		Span 4		Span 5		Span 6	
Trial No.	1	2	3	4	5	6	7	8	9	10
Correct	100%	92.30%	80.40%	82.70%	48.10%	48.10%	21.60%	26.90%	5.80%	3.80%
Incorrect	-	7.70%	19.60%	15.40%	48.10%	40.40%	49.00%	30.80%	28.80%	23.10%
Discontinue	-	-	-	1.90%	3.80%	11.50%	29.40%	42.30%	65.40%	73.10%

A steady decline in performance between each span trial can be observed. It can also be observed that within each span there is little difference between performance on the two trials. This infers that there is little difference in the difficulty of the trials for each span.

Table 6.14 shows the pattern of performance for the sample on Object Working Memory.

Table 6.14. Percentage of Participants in Each Category For Performance on Object Working Memory. (N = 57)

	Span 2		Span 3		Span 4		Span 5		Span 6	
Trial No.	1	2	3	4	5	6	7	8	9	10
Correct	86.00%	98.00%	69.20%	70.60%	66.70%	40.40%	26.90%	26.00%	6.00%	5.80%
Incorrect	14.00%	2.00%	30.80%	29.40%	17.60%	40.40%	44.20%	30.00%	30.00%	19.20%
Discontinue	-	-	-	-	15.70%	19.20%	28.20%	44.00%	64.00%	75.00%

As with Object Span a steady decline in performance can be seen after the initial trial across all six spans. It can also be observed that the differences between trial scores for each of the spans were small in all spans excluding span 4. A non parametric

Friedman test of differences among repeated measures was conducted for this span and rendered a chi square value of 9.80 which was significant $p < .05$. This indicates that this span lacked internal consistency as trial 6 was significantly more difficult than trial 5. However, excluding this span all other trials for each span were of similar difficulty which overall suggests a high level of internal consistency.

Learning and Delayed Recall

Design Learning is unique when compared to the other developed learning and delayed recall assessments as it includes a multi-faceted scoring component. When scoring Design Learning each design is scored out of three, with one point each dedicated to the correct form, orientation and the correct number of components. Table 6.15 depicts the delineation of the three scoring components. It also highlights how many designs were accurately depicted and scored the maximum amount of points. For all components the maximum score is 12 and the minimum score is 0.

Table 6.15. Means and Standard Deviations For Design Learning According to Overall Scores, Stimuli Orientation, Form and Number of Correct Components (N = 54)

	Orientation	Form	Component	Perfect Score (All components correct in a single figure)
Trial 1	7.00 *(2.12)*	8.41 *(2.19)*	7.00 *(2.16)*	5.83 *(2.08)*
Trial 2	9.53 *(1.87)*	10.89 *(1.55)*	9.70 *(2.09)*	8.67 *(2.28)*
Trial 3	10.56 *(1.36)*	11.55 *(0.94)*	10.75 *(1.66)*	9.77 *(1.96)*
Trial 4	10.83 *(1.40)*	11.70 *(0.92)*	11.29 *(1.20)*	10.49 *(1.64)*
Trial 5	11.21 *(1.32)*	11.81 *(0.86)*	11.21 *(1.75)*	10.63 *(1.68)*

It can be seen in Table 6.15 that initially participants display a slight tendency to encode the form (shape) of the object before the other components. By trial 3 there was a smaller variation in the differences between scores. To determine if the differences observed between mean scores for orientation, form and component were consistent a non parametric Friedman test of differences among repeated measures was also conducted and rendered a chi square value of 50.22 which was significant $p < .001$. Means show that initially participants displayed a significantly higher performance on the form component than the other two. This difference was still present at the completion of the final trial with the chi square value produced by Friedman's test equalling 22.03 which was also significant $p <.001$.

Ceiling and Floor Effects

Performance has been plotted to determine whether a ceiling or a floor effect was present for each of the developed assessments. Unless otherwise specified all the figures were considered to be normally distributed with skewness and kurtosis scores falling within the acceptable ranges (-3 and 3). Figure 6.12 shows the number of participants that discontinued on each trial for the spatial and object span assessments.

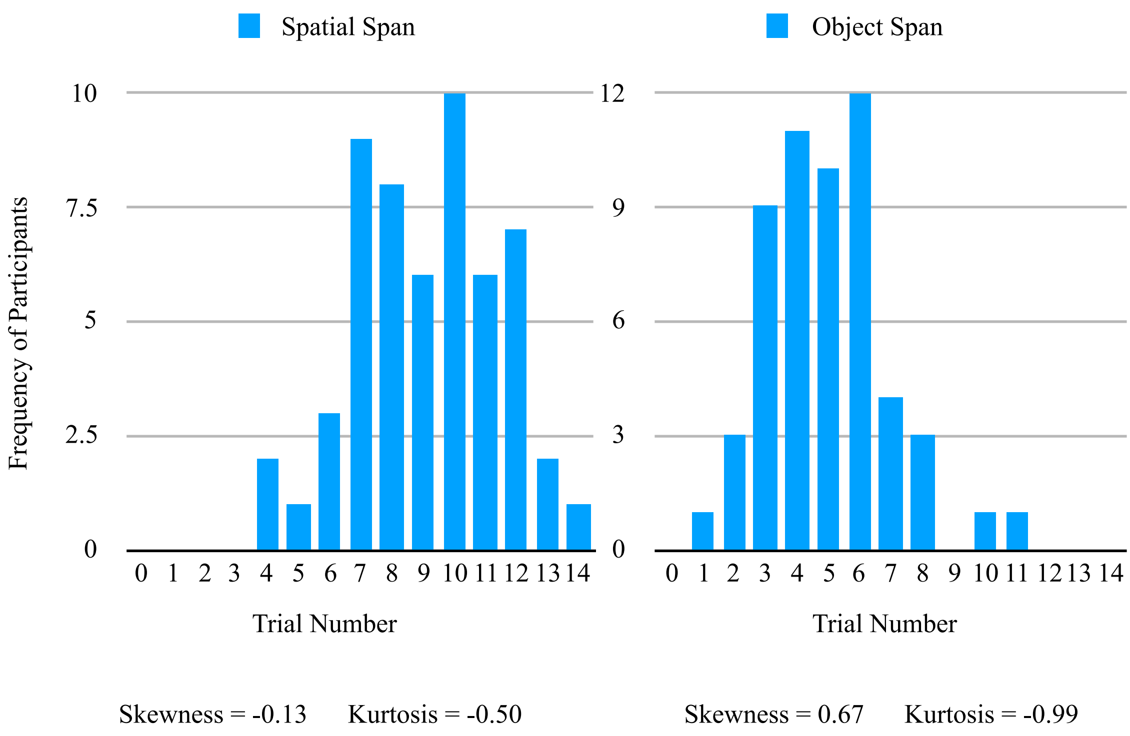

Figure 6.12. *Frequency of Participants who Discontinued on Each Trial for the Number of Trials Correct on Span Tasks (N = 57)*

It can be seen that no ceiling or floor effect appears to be present for either Spatial Span or the Object Span tasks.

Figure 6.13 shows the number of participants who discontinues at each trial on the working memory assessment tasks, to determine if a floor or ceiling effect was present.

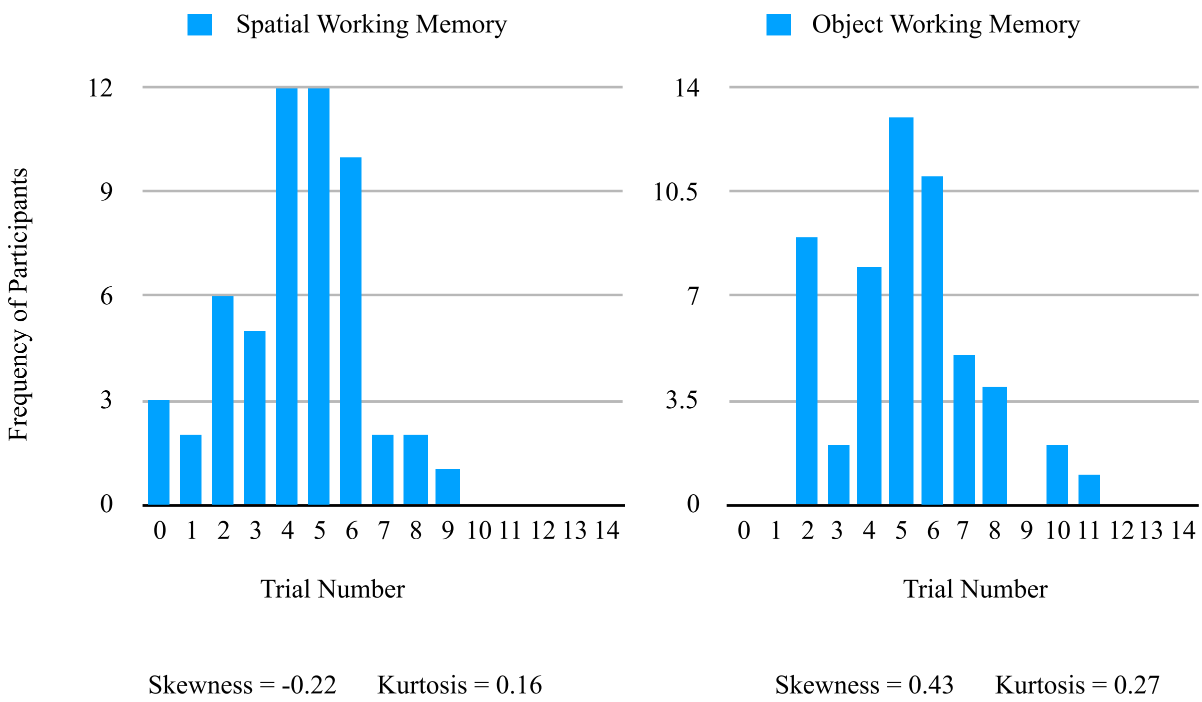

Figure 6.13. *Frequency of Participants who Discontinued on Each Trial for the Trials Correct on Working Memory Tasks (N = 57)*

Similarly to the span figures, no ceiling or floor effect appears to be present in the two working memory assessments despite a more dramatic decline in performance being observed.

Figure 6.14 shows the distribution of participant's scores for the immediate trial of Spatial Learning, Feature Learning and Visual Pairs.

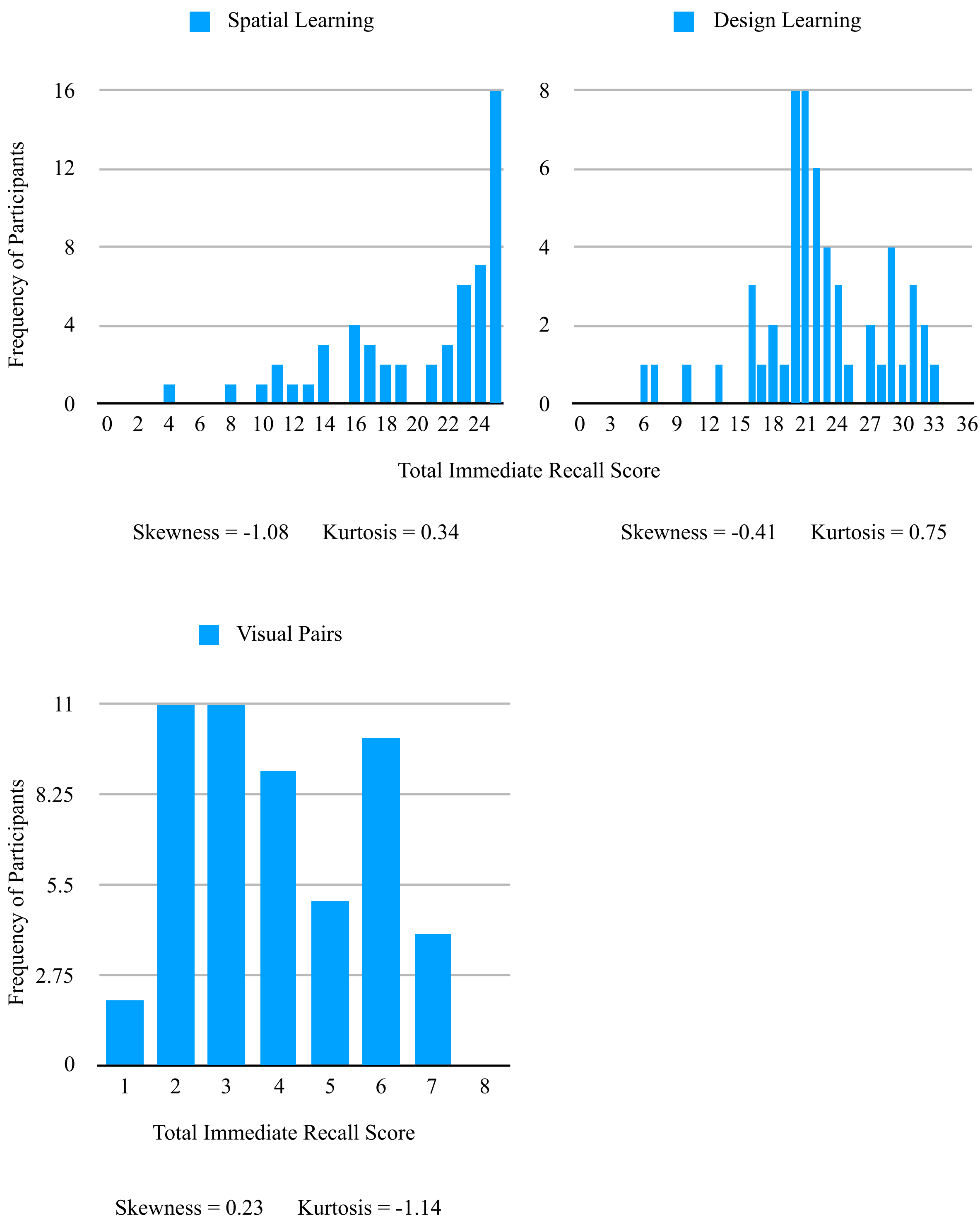

Figure 6.14. *Mean Scores for Participants Performance on the Immediate Trials for the Three Learning and Delayed Tasks (N = 57)*

Despite the negative skew present in Spatial Learning, skewness and kurtosis values indicate that this data is still normally distributed and thus, no floor or ceiling effect is present. The Design Learning and Visual Pairs immediate trials indicate that there is likely no ceiling or floor effects present.

Figure 6.15 shows the shows the distribution of participant’s scores for the delayed trial of the three learning/delayed tasks.

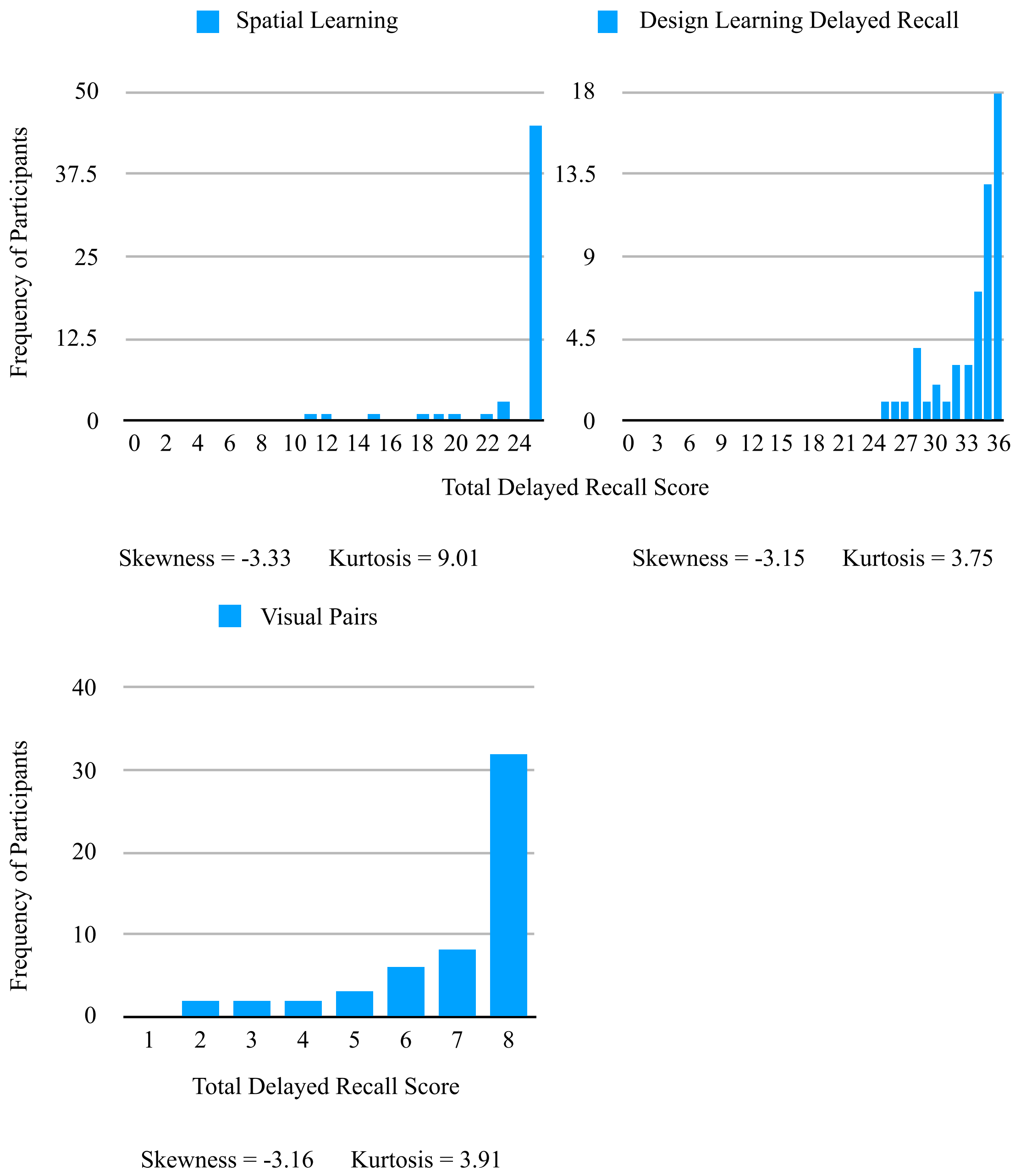

Figure 6.15. *Mean Scores for Participants Performance on the Delayed Trials for the Three Learning and Delayed Tasks (N = 57)*

From the figures above a ceiling effect is likely present in the delayed component of all three learning assessments. As expected a negative skew can be observed in all 3 of the figures depicted in Figure 6.15. This data is considered to be statistically skewed with skewness and kurtosis values falling outside the -3 - 3 range for all values.

Discussion

Experiment 1 was a pilot study that aimed to determine whether the developed assessment tasks were reliable and valid measures of visual memory. To do this construct validity was analysed in light of the developed assessments in comparison to both established theoretical notions of memory as well as in comparison to pre-existing assessments. This pilot study also included an item analysis for each of the developed assessments to evaluate the test design and the internal consistency of each of the developed tasks.

A Discussion of the Construct Validity Findings

On the tasks measuring spatial memory, performance was higher on the span task than on the working memory one. This finding is in line with Atkinson and Shiffrin's (1968) modal model of memory and Baddeley and Hitch's (1978) working memory model. Surprisingly, this finding was not observed in the object domain. No significant differences were observed between performance on the span and working memory tasks. It is possible that the lack of difference was due to the fact that the same stimuli were utilised in both object tasks. During the span task, participants were required to encode, develop a strategy for recall and complete the span task. This would have increased the participants' perceptual load and the attention demand required during the task. Once the Object Working Memory task commenced, it is likely that the stimuli was familiar to the participants as a stored representation had been generated during the earlier span task. This would allow the images to be more easily recognised and recalled (Delvenne & Bruyer, 2004) and thus the task load for object encoding was decreased when compared to the demand required for the span component. Hence, the more difficult aspect was in object encoding rather than span or working memory. The stimuli used in Digit Span (which follows the same methodological paradigm as the developed object tasks) are known numbers there is no secondary level of encoding where participants are required to develop a strategy for learning not only the order of the stimuli, but also the stimuli themselves. As the developed abstract shapes are not know this secondary level of encoding requires a greater perceptual demand of the participants when they are first exposed to the stimuli. Working memory tasks are traditionally significantly more difficult than span tasks (Allen et al., 2014), thus, this task yielding a higher performance in the working memory component indicates that it is likely not a representative measure of the system.

In keeping with established list learning tasks, all learning tasks demonstrated an increase in performance over the learning trials. This finding is similar to research conducted by Rushby, Barry and Johnston (2002) and Wiswede, Russeler and Munte (2007) who state that in the initial trials a steady increase in performance will be observed, before plateauing to a more steady performance in the later trials. On both Visual Pairs and Design Learning this pattern of performance was observed. Spatial Learning yielded similar results with one difference. In the fourth learning trial (out of 5) a drop in performance was seen. Blachstein and Vakil (2016) contend that a single drop in performance is not considered unusual as often individuals spend most of their attentional demand focusing on the items that were previously missed. In doing so, often previously learned information decays and is forgotten due to not being maintained in the visual cache. It is also important to note that this slight decrease in performance was less than .4 between the means for trials 3, 4, 5 and is therefore, not considered noteworthy.

The multifaceted scoring system utilised for Design Learning also indicated that participants displayed a consistent preference for learning the form of the object before the orientation or number of components. This suggests that encoding shapes may be the most efficient way of remembering objects, and that other details such as orientation or the number of components are secondary features that are encoded later, it is possible that this occurs as shapes are easily verbally encoded. Importantly, the perfect score column reflects that while participants showed consistent improvement in all three components over the five trials, they were not necessarily perfecting each design before moving on. This suggests that when recalling the designs participants tend to adopt a holistic approach where fluctuations in scores are observed across the 12 designs rather than individuals focusing on each design specifically.

Also in line with established learning and delayed research performance was found to be significantly better in the delayed recall trial of the task than the immediate recall trial. This was observed in all 3 learning tasks. This finding mirrors the normative data for the RAVLT, HVLT and CVLT (Strauss et al., 2006). As the delayed trial occurs after a period of learning it allows participants the opportunity to not only encode but also consolidate the information they have learnt, which allows it to be more readily recalled at a later date.

The final hypothesis for this section aimed to assess the construct validity (convergent and discriminant) of the developed tests compared to the established WMS indices. All correlations were as expected with the exception of Object Span and Object Working Memory yielding a significant relationship with the Auditory Memory Index. As the Auditory Memory Index is a measure of verbal memory performance (Wechsler, 2009; Strauss et al., 2006) and thus, does not share the same cognitive processes or anatomical regions as the object memory task, no relationship was expected. It is possible that individuals were able to develop a phonological encoding strategy to remember the shapes (despite best efforts), and thus, utilised verbal memory processes. All other measures demonstrated weak to moderate relationships with the Visual Memory Index, Visual Working Memory Index and the Immediate Memory Index. These weak to moderate relationships indicate that it is likely that the developed tests are measuring a similar construct as the aforementioned indices however, the strength of the relationships also suggests that they are also measuring different components of memory. These findings were expected as the developed tests aimed to measure varying facets of visual memory in a novel manner that deviates from established measures of visual memory. Only two relationships were not significant when comparing the relationships between the immediate and delayed components on the three learning tasks. The Visual Working Memory Index did not yield significant relationships with the immediate span of feature learning or the immediate span of visual pairs. This provides evidence of discriminant validity, as both the immediate recall components are measures of span where as the VWMI measures working memory which is an inherently different subsystem of memory. All other correlations were significant indicating that the developed tests show good convergent validity with the WMS indices. This is promising as the WMS is considered one of the most robust measures of memory. Thus, the significant positive relationships that were present in nearly all analyses reflects that the developed tests are valid assessments of visual memory.

A Discussion of the Item and Test Design

Similarly to performance data on established memory assessments it was found that all measures of span and working memory showed a decrease in performance as span increased. This finding is similar to those found in the other cognitive assessments that increase the number of items over time. Most assessments aim to slowly increase the number of items in a span to measure a participants capacity to perform on a particular task. Small increases (in the case of the present study, an increase of 1) offer the researcher the best opportunity to accurately measure a participant's capability on a particular subtest. Healthy participants will invariably perform better on the earlier tasks before a consistent discontinue rate is observed as task difficulty increases. This was also evident in the present 's findings. Spatial Span, in particular demonstrated high performance for the initial spans before seeing a decline in performance during span 5, trial 8. The fact that these tasks show a similar pattern of performance to the performance trajectory of established measures further demonstrates the construct validity.

When investigating the similarity between trial scores between items on the same span a small number of spans that yielded significant differences between trials indicating that one trial was more difficult than the other. However, the general pattern of performance observed in the trial scores for each span in the Spatial Span, Object Span and Object Working Memory tasks demonstrated high levels of internal consistency. The tests were designed to have two trials for each span and this was implemented as it allowed participants to demonstrate consistency while providing a more accurate measure of an individual's performance than a single trial would. Sometimes an incorrect score is not the result of an individual's capacity being exceeded, but is rather due to a lapse in attention. Allowing two trials for each span gives participants the opportunity to rectify a potential lapse in attention. Capacity is likely exceeded when a participant fails to answer both trials correctly on a single span and that is why the span score is derived from the last span where both trials were considered correct. However, when the findings indicate that a significant portion of people fail to complete a trial correctly it is likely due to the difficulty of the trial more so than a lapse in attention.

Contrary to the findings of the other tests, Spatial Working Memory did not provide stable evidence of internal consistency. On closer evaluation a decrease in performance was seen in the 180 degree rotation conditions in comparison to the 90 degree rotation and 270 degree rotations. It is possible that the 180 degree rotation condition is more difficult than the other two as a higher degree of rotation is required to be conducted, encoded and stored. Shepard and Metzler (1971) in their work on mental rotation identified that the greater the degree of rotation, the lower the individual's performance was in accuracy and speed. The reason why this decrease in performance is not seen in the 270 degree rotation condition may be due to the fact that 270 degrees is equivalent to 90 degree if the image is rotated counter clockwise instead of clockwise, thus, requiring the same degree of rotation, but in a different direction. This is also evident in the trial analyses as the single trial that contained both a 90 and a 270 degree rotation showed little difference in performance.

The ceiling effect is a methodological limitation that is present when the highest score on a measurement is reached, this indicates that it is possible that the test did not accurately measure the intended domain as it is likely that a participant (if more trials were present) would be able to continue. Alternatively, the floor effect occurs when the minimum standard score does not distinguish between participants who may have performed differently albeit low. It was hypothesised that there would be no floor or ceiling effects present in any of the span and working memory tests. This was supported. Atkinson and Shiffrin (1968) identify in their modal model of memory that repetition of information is the key to encoding memories into one's long term memory successfully. Subsequently, it was also hypothesised that a ceiling effect would be present in the delayed recall component of the three learning tasks as the population consisted of healthy adults, who after a series of learning trials should be able to demonstrate high rates of recall. At the completion of the delayed recall component most participants were able to complete this task successfully. This finding provides evidence for both bottom up and top down processing. It is possible that successful completion of the task is due to the stimuli being encoded individually initially from a feature or bottom up perspective. However, as the task progresses participants get a holistic view of what they are required to remember as a whole and begin to apply top down processes such as identifying patterns and reviewing the shapes as a set rather than individuals. This combined with the five learning trials allows participants (even after the delay) to inadvertently check their answer (as they know what the path should look like, or what the object patterns in Design Learning contain) and make corrections where necessary. This dual encoding process likely enhances memory and improves performance on this task. Lezak and colleagues (2004) acknowledge that in a healthy population participants should be able to readily recall most items from a learning task after a delay period of 30 minutes.

Conclusion

Experiment 1 identified that while most of the developed tasks were working as intended, performance on the two developed working memory tasks appeared to have some developmental problems. No differences were present between the Object Span and Object Working Memory tasks. As discussed previously this is potentially due to the same stimuli being used in both tasks. Based on these findings prior to beginning the Experiment 2 the stimuli for the Object Working Memory task were altered to ensure that they are different than those used in the Object Span task. This change was designed to prevent the participant from drawing on the stored representations from the span task when undertaking the working memory task. This should ensure that the Object Working Memory performance will be lower than span performance in Experiment 2 as each task will now require the same amount of perceptual load to encode the stimuli and performance differences can now be attributed to memory function.

A methodological issue arose in the Spatial Working Memory task. The item by item analysis indicated that participant's performance was worse on the 180 degree trials than the 90/270 trials. While the structure of this test was based off the the standard span assessment paradigm that includes two trials for each span, the findings of Experiment 1 identify that this may not demonstrate an accurate portrayal of the participants performance. Prior to commencing Experiment 2 of the present research the Spatial Working Memory task was altered to include all three trials at each span, one for each rotation. This was implemented to ensure the trials of each span share the same difficulty (in terms of degree of rotation) and would thus, ideally generate a more accurate portrayal of participants performance. As all other tasks were functioning as intended no further changes will be included. Finally, in individual spans where discrepancies were observed minor changes were made to the stimuli to ensure that they were both of equal difficulty.

CHAPTER 7

EXPERIMENT 2 - AN INVESTIGATION OF CAPACITY DIFFERENCES FOR SPATIAL AND OBJECT INFORMATION

Spatial Working Memory

Spatial Working Memory was a developed task that aimed to measure one's ability to mentally rotate and recall dynamic spatial information. This task was presented in the form of a maze with a cat in the centre. Participants viewed a dynamic line drawn from the centre of the maze out. Once the line disappeared the maze rotated 90, 180 or 270 degrees and participants were required to recall the correct path in the new orientation. The revision for Spatial Working Memory was born from inconsistent findings in the item analysis. All the developed span and working memory tasks were designed to follow the format of the reliable and valid span assessment paradigm (Strauss et al., 2006; Wechsler, 2008). The span assessment paradigm involves the presentation of two trials at each level of difficulty (span). The Spatial Working Memory task was initially designed to exactly mirror this presentation, with two presentations of rotated mazes at each span, however, three types of rotations were possible (90, 180 and 270 degrees). These three orientations were randomised to be presented in pairs across trials. The randomisation aimed to ensure that the participant would be unable to identify a pattern of rotation, and thus make accurate predictions about what rotation would be presented next, potentially inflating their Spatial Working Memory score. In an attempt to remediate this error and to ensure that every trial was of equal difficulty, each span on the revised Spatial Working Memory assessment was expanded to three trials, with each span containing one trial for each rotation (90, 180 and 270 degrees). Within each trial the three rotations would be presented in a predetermined, randomised order. This means that all participants would receive the same trials presented to them in the same order however, this order was not be based on any pattern and therefore, the participant is unable to predict what stimuli will be presented next which may have had the ability to enhance their spatial working memory score.

Object Working Memory

Object Working Memory was a developed task that aimed to measure one's ability to manipulate and recall static, object information. The item analysis from the Object Working Memory task yielded expected findings, with scores within spans producing similar results and as span increased a decline in performance was observed. The issue that arose in this task regarded the construct validity being questioned, as findings did not conform sufficiently to the established theoretical notions of working memory. Unexpectedly, no differences were found between the forwards (span) and backwards (working memory) presentations of the stimuli. The decision to incorporate the same stimuli in both the span and working memory tasks was a notion derived from the Digit Span subtest of the WAIS-IV (Wechsler, 2008). Digit Span, whose design and administration follows the same theoretical underpinnings as the developed tasks, uses the numbers from 1 - 9 in both the forwards and backwards trials. The manual highlights that numbers were chosen as the stimuli for this task as they carry no context or semantic meaning to individuals. As reiterated numerous times, it is known that verbal and visual information are inherently different, and this finding highlights that mirroring the stimuli design of a verbal memory task may not be appropriate when attempting to measure visual memory. Similar to Digit Span, the stimuli chosen for presentation in this task included abstract components designed to limit contextual or semantic meaning. Despite attempts to limit context or meaning for the stimuli presented, seeing the same stimuli presented in the span version of this task, may have allowed the individual to encode the different objects effectively (by creating verbal analogues) and to generate stored representations in their long term memory. Thus, by the time Object Working Memory was administered using the same stimuli, rather than having to hold the information, encode it and manipulate it, the individuals were likely able to recognise the object from their stored representations. As a result, the working memory component of this task possibly required reduced cognitive demand when compared to the span component. This notion of object familiarity aiding in recall has been established in the literature. Xie and Zhang (2017) identified that participants were readily able to recall objects that were familiar to them much more swiftly than unfamiliar objects. This lead to participants demonstrating a greater capacity for objects that were known to them compared to unknown.

Based on this review, Object Working Memory was redesigned using different stimuli than Object Span. Therefore, each task should now involve the same perceptual processes where a participant is required to observe, develop an encoding strategy and hold the individual objects as they are presented, thereby attempting to standardise cognitive load across both tasks, asides from the additional manipulation component in the working memory component. Despite threats to construct validity arising from the design, Object Span had demonstrated fair internal consistency. In order to maintain this, each stimuli developed for use in the revised Object Working Memory task was matched to a stimulus in the original Object Span task, in terms of the number of features to be encoded (see Appendix M). Some studies contend that once an object is bound the number of features becomes irrelevant (Luck & Vogel, 1997), while more recently it has been found that an increase in the number of features makes an object more difficult to bind (Taylor et al., 2012). To control for these inconclusive findings an attempt to standardise the number of features present in each object was made. Similarly to Object Span, an effort was made to allow each stimulus designed to be easily identifiable as a stand alone object that was not able to be easily confused with any other objects that are presented.

Investigation of Performance Between the Spatial and Object Memory

The primary purpose of Experiment 2 was to investigate if differences in performance exist between spatial and object memory. The notion that differences would be present within these two visual memory functions is based off the two streams hypothesis understanding of visual perception (Milner & Goodale, 1992). Past research that has investigated visual memory has consistently produced varied findings (Brady et al., 2011; Corsi, 1972; Pickering, 2001). Researchers have reported that there are profound difficulties with replicating findings in scenarios where the stimuli are slightly altered (Humphreys, 2016). Furthermore, there is longstanding significant research that indicates how an individual processes and stores information pertaining to a visual scene (Green & Oliva, 2009) varies substantially to how an individual encodes specific objects (Brady et al., 2008). Moreover, many studies that have produced these findings have done so by incorporating both spatial and object stimuli (e.g. tasks exploring how object locations are stored) (Alvarez & Oliva, 2008). While understanding how the spatial and object information are processed together has high ecological validity, as in reality they often work in conjunction with one another, to understand the visual memory system as whole, investigating how memory for spatial and object information is stored independently is also vital for discovering the influence that each stream has on visual memory function. Past research has investigated the functions independently

(Humphreys, 2016; Luck & Vogel, 1995; Ishikawa & Montello, 2006; Poirel et al., 2011), however, research that incorporates methods that isolate each domain, while designed in a manner that allows for direct comparison is scarce. Subsequently, after reviewing the psychometric properties that aimed to isolate spatial and object memory functioning, analyses were undertaken to determine whether a difference in capacity was present between the two streams.

Aims and Hypotheses

Experiment 2 aimed to investigate whether there were capacity differences between spatial and object memory. The aims, results and discussion for this experiment will be presented in two distinct sections - piloting the revised working memory assessment tasks followed by an investigation of the capacity differences between the developed spatial and object memory tasks.

Experiment 2 involved piloting the revised working memory tasks. With that notion the psychometric properties (construct validity, internal consistency and internal validity) of these tasks was measured using the same construct parameters as outlined in Chapter 6.

Furthermore, based on the promising results of Experiment 1, a more exhaustive analysis of convergent and discriminant validity was conducted utilising specific exemplar tests that model the memory assessment paradigms incorporated into the developed tests. Specifically;

- Performance on the developed span and working memory tasks would yield weak - moderate correlations with Digit Span.
- Performance on the developed learning tasks would yield weak - moderate correlations with the RAVLT.

Experiment 2 also involved investigating whether there were capacity differences between spatial and object memory.

It was therefore hypothesised that:

- Performance differences will be present between spatial and object tasks.

Method

Participants

Experiment 2 involved the recruitment of a new sample of participants. As the present study incorporated revised versions of the working memory tasks as well as all other developed tasks, to reduce the impact of practice effects and task familiarity and to increase the likelihood of meaningful, unbiased results a new sample was required. To maintain integrity and consistency between the findings established by the former sample and the newly recruited sample, participants for Experiment 2 were recruited from the same regions of metropolitan Melbourne, Victoria, Australia using the same methods as those recruited in Experiment 1. Data was collected from 63 individuals, aged between 18 -45 (mean = 29.19, SD = 8.09). Table 7.1 displays a summary of the demographic data about the sample recruited for Experiment 2.

Table 7.1. Percentage of Participants Represented in Each Category for Nominal Demographic Data (N=63)

Category			Percentage of Participants in Each Group %		
Sex				Female	Male
				55.60% N = 35	44.40% N = 28
Employment			Unemployed	Casual / Part Time	Full Time
			20.60% N = 13	34.90% N = 22	44.40% N = 28
Highest Level of Education	Year 11 Completion	Tafe Certificate	High School Completion	Tafe Diploma	Undergrad Degree
	7.90% N = 5	6.30% N = 4	44.40% N = 28	20.60% N = 13	20.60% N = 13

The sample sourced for Experiment 2 were of a similar demographic to those who participated in Experiment 1. The proportion of participants from each biological sex category was nearly the same. In terms of employment, more participants from this sample were full time workers which is contrary to the sample from Experiment 1 that saw a higher proportion of participants in the casual/part time category (likely due to the higher proportion of university students present in Experiment 1). In terms of level of education the present sample indicated that they were slightly less educated than the initial. While they has slightly less high school graduates and more individuals with a TAFE diploma, they had a smaller proportion of undergraduate degree holders and no one with a post graduate degree.

Table 7.2 shows the means, standard deviation and ranges for the sample's performance on measures of IQ and established measures of memory.

Table 7.2. Descriptive Statistics for Index Scores on the WMS and WASI (N=63)

Index	Mean *(SD)*	Range
Full Scale IQ	104.87 *(12.68)*	79 - 140
Verbal Comprehension Index	104.52 *(13.43)*	79 -140
Perceptual Reasoning Index	105.80 *(13.24)*	77 - 131
Auditory Memory Index	103.75 *(14.05)*	80 -136
Visual Memory Index	97.84 *(15.76)*	57 - 134
Visual Working Memory Index	87.72 *(10.87)*	60 - 120
Immediate Memory Index	102.88 *(13.97)*	80 - 132
Delayed Memory Index	103.14 *(17.98)*	67 - 141

Skewness and kurtosis indicate that all variables fell within the accepted range (-3 to 3) which indicates that the sample is normally distributed (George & Mallery, 2010). The Wechsler administration manuals outlines that the mean for all indices in the WMS and WASI is 100 with a standard deviation of 15 (Wechsler, 2009; Psychological Corporation, 1999). It can be seen from the above table that the sample means and SDs fall within range for all indices, excluding the standard deviations for the Visual Working Memory Index and the Delayed Memory Index. Standard deviations for these variables fell outside the expected range, indicating high rates of variability, however, mean scores were as expected. Somewhat concerning are the low scores observed in the Visual Memory Index and the Visual Working Memory Index, in particular mean scores for the Visual Working Memory Index are lower than would be expected in comparison to other scores. Nonetheless these scores still fall squarely within one standard deviation of the mean. In comparison to the initial sample, in general this sample scored half a deviation lower on measures of intelligence and memory. This indicates on most subtests the present sample yielded slightly lower scores. While this slight difference is present, this data indicates that the sample is normally distributed and representative of the pattern of performance seen in the general population.

Materials

As highlighted in the test revision section, Spatial Working Memory and Object Working Memory were revised prior to the commencement Experiment 2. Based on the findings of Experiment 1 Spatial Working Memory has been adapted and now includes an extra trial for each span (making three trials total) to ensure each span is equivalently difficult in terms of stimuli rotation. Also based on the findings of Experiment 1 Object Working Memory now incorporates different stimuli than Object Span (as seen in Appendix M.). All other materials were unchanged from Experiment 1 and thus, details of each measure can be found in Chapter 6.

Experiment 2 while presented in sequence, utilises the same sample as the future Experiment 3. During Experiment 3, some methodological changes were implemented to provide a more exhaustive analysis of construct validity. Namely, the inclusion of two assessment tasks that align with the same administration paradigms utilised in the development of the spatial and object tasks. While a verbal memory task, Digit Span incorporates the well established span paradigm, that involves the inclusion of two trials to measure each span, and similar start and discontinue rules as the developed span and working memory tasks. Similarly the RAVLT is considered to be an exemplar assessment that incorporates the list learning paradigm. Again, while verbal in nature it incorporates the same administration procedures as the developed learning tasks. While verbal memory is inherently different from visual memory they are both components of the same construct. While differences in capacity between these tasks are expected, relationships are also expected. Similarly, to how IQ is associated with memory, it would be expected that verbal memory performance would have a relationship with visual memory performance (e.g. if you perform well in one you will likely perform well in the other, due to your cognitive capabilities). Subsequently, while this data was collected as part of Experiment 3, this data will be incorporated retrospectively in analyses pertaining to the developed tasks incorporated in this chapter.

Rey Auditory Verbal Learning Test (RAVLT) (Rey, 1964).

The RAVLT is a list learning task designed to assess verbal learning and memory. The RAVLT is a commonly used assessment as it is brief, easy to administer and provides an accurate measure of immediate memory span, new learning, delayed memory and susceptibility to interference. This task consists of a list of 15 nouns that are read in the same order to a participant five times, at a rate of one word every two seconds. After each reading of the list, the participant is asked to recall as many words as they can in any order. Participants are not penalised for repeating words or for including words not on the list. Once the participant is unable to recall anymore words the list is read again. After the 5th time the participant is presented with a new list of 15 words. Immediately after recalling the new list they are asked to recall words from the original list. They do not hear the original list again. Following this recall trial there is a 30 minute delay before participants are asked to recall the original list one final time.

In terms of scoring, immediate recall is derived from the participant's score on the first trial. To measure total acquisition the scores from the first five trials are summed to produce a measure of overall total recall. The learning curve score is acquired by subtracting the trial 1 score from the trial 5 score. Finally, the delayed recall score is derived from the score in the final trial that occurs after the 30 minute delay.

Besides from the ease of administration and the potential to yield substantial information about an individual's memory function in a brief period of time, the RAVLT is also a commonly used measure due to its robust psychometric properties. With internal reliability coefficients of $r = 0.90$ (Van den Burg & Kingma, 1999) and the availability of numerous robust alternate forms ($r = 0.60$) (Crawford, Stewart & Moore, 1989) the RAVLT is considered to be a reliable measure with the potential to be used multiple times in quick succession without the risk of practice effects due to the variety of available, standardised versions. Van den Burg and Kingma (1999) also identified that the RAVLT displays high rates of internal validity, with scores for each measure correlating highly with one another ($r > .75$). This demonstrates that people with high short term memory capacity are also likely to have high delayed memory scores etc. Furthermore, the RAVLT produces moderate correlations with other commonly used list learning tasks as well as the WMS.

Digit Span (Wechsler, 2008).

Digit span is a subtest of the Wechsler Adult Intelligence Scale that loads on to the working memory index (Wechsler, 2008). It provides a measure of both short term memory and working memory capacity. Digit Span is a particularly robust measure of short term and working memory as it utilises the same stimuli and administration for both tasks, the only exception being the manipulation component involved in the working memory task. This means that the task controls for a number of potentially confounding variables and it can be assumed that generally a difference in performance is a result of memory function. This subtest is considered both reliable and valid, with test - retest reliability consistently yielding coefficients >.85 and validity values >.79 with other measures of verbal span and working memory (Sung, 2011).

The short term memory component is known as Digit Span Forward and the working memory component is known as Digit Span Backward. In both tasks participants are read a series of numbers at a rate of one every two seconds. Once the series has been completed, in the forward trials participants are asked to recall the numbers in the same order that they heard them. In the backwards trial they are required to recall them in the reverse order. The sequences start small with each series containing two digits and becomes progressively more difficult with successive correct answers. Each span contains two trials that are sequences containing the same number of digits. The task discontinues when both trials within a span are answered incorrectly. This task can provide two scores for both the forward and backward conditions. The first score is the number of sequences the participant was able to successfully recall. The second score is the span score. The *span score* refers to the number of items in the last span where the participant successfully recalled both trials.

Procedure

The procedure for Experiment 2 was unchanged from Experiment 1. The two revised working memory tasks were administered in place of the previous ones. The testing session remained approximately 90 -120 minutes. In order to account for the timing of the delayed memory tasks, the developed tasks were presented in the same standardised order as seen in Experiment 1.

As in Experiment 1 all subtests of the WMS and WASI were scored according to standardised procedures. A new scoring procedure was adopted for the redesigned Spatial Working Memory. A score of 1 was given for every trial correct. A span score of 1 was given if all three trials within a span were answered correctly. The task was discontinued if participants scored incorrectly on two trials in a given span, regardless of their rotation. All other developed tasks were scored as described in Chapter 6.

As noted above the data from the RAVLT and Digit Span was collected as part of Experiment 3 (that utilised the same participants) and this data was analysed retrospectively where relevant to the developed tests as part of this experiment.

Data Analysis

Similarly to Experiment 1, Experiment 2 utilised paired samples t-tests and Pearson correlations and all assumptions were checked using the procedures outlined in Chapter 6.

Standardisation.

The redeveloped Spatial Working Memory task contains scores for three trials for every span. This was to be compared to the Spatial Span task, that only contains two trials for each span. Therefore, scores for these tasks were standardised for comparative purposes. As the current task intended to compare means, z scores were not appropriate for this method. Instead individual scores for the spatial span and working memory tasks were standardised to the grand mean. To determine the grand mean, the mean scores for each task were first derived. The overall mean of these two scores was then generated to produce the grand mean. Individual scores for both tasks were then standardised to the grand mean using SPSS Version 22 (IBM Corp, 2013). This allowed for an investigation of mean differences to be undertaken.

A limitation of the grand mean is that its accuracy is dependent on there being little variance in minimum and maximum scores produced by the scores being standardised. As participants in this sample had a maximum Spatial Span score of 14 and Spatial Working Memory a maximum score of 13, the grand mean was considered appropriate. In the learning assessments which also had varied maximum scores and thus, required standardising for mean differences to be compared, there was much greater variability in the score range. As Spatial Learning has a maximum score of 25, Design Learning 36 and Visual Pairs 8, the grand mean would not have provided an accurate manner of standardisation. Subsequently, parametric tests were unable to be conducted for comparisons among the learning assessments.

Raw scores were considered appropriate for all other analyses. All data was collated and analysed using SPSS Version 22 (IBM Corp, 2013).

Results : Piloting the Revised Working Memory Assessment Tasks

For simplicity the results section for the review of validity and reliability has been subdivided into two sections. The first section aimed to assess the construct validity of the revised working memory tasks to determine whether the results regarding the overall constructs of the revised tests were in accordance with already established notions of memory e.g. are span scores larger than working memory scores. Construct validity was also explored through correlation analyses between the results of the developed tasks and established measures of memory. (This included re-evaluating the validity of the developed tasks in Experiment 1 in relation to Digit Span and the RAVLT.) The second section aimed to investigate if there were any immediate methodological concerns present in the developed tasks. This involved reviewing the internal consistency of the items within each task as well as determining if any floor or ceiling effects were present. This was conducted via an item analysis of each of the revised tasks to determine that all items that should result in similar scores did, and that the performance trajectory of the tasks decreased as span trials increase.

A Further Investigation of Construct Validity

The Span and Revised Working Memory Tasks.

To assess the construct validity of the developed working memory tasks, paired samples t-tests were first run between the span and working memory tasks for each pathway. Each task generated two scores; number of trials correct and overall span score. The results of the analyses evaluating the construct validity between the developed span tasks and the revised working memory tasks is displayed in Table 7.3 below.

Table 7.3. Means, Standard Deviations and Paired Samples T-Tests Results Comparing Span and Working Memory Tasks. (N = 63)

	Trials Correct : Mean (SD)	T Statistic (*df*)	p Value	Span : Mean (SD)	T Statistic (*df*)	p Value
Spatial Span Scores can range from 0-14	9.13 *(2.32)*	15.18 *(61)*	<.001	4.48 *(1.13)*	13.59 *(61)*	<.001
Spatial Working Memory (revised) Scores can range from 0 -21	4.29 *(2.01)*	-	-	1.74 *(1.38)*	-	-
Object Span Scores can range from 0 - 14	5.35 *(1.14)*	5.02 *(61)*	<.001	2.73 *(1.22)*	2.93 *(61)*	.01
Object Working Memory (revised) Scores can range from 0 - 14	2.85 *(1.53)*	-	-	2.13 *(1.30)*	-	-

It can be seen from Table 7.3 that a significant difference was present between the span and working memory tasks on the standardised scores generated for the spatial pathway. Perusal of Table 7.3 indicates that performance was higher for the Spatial Span task for the number of trials correct and for the overall span score. With the changes made between Experiment 1 and Experiment 2, there was now a small but significant difference observed between the scores for Object Span and Object Working Memory. With performance on the Object Span task was now significantly higher than performance on the Object Working Memory task for both scores.

To check for convergent and discriminant validity, Pearson correlations were conducted between the developed span and revised working memory tasks, the relevant WMS indices and Digit Span to determine whether a significant relationship was present. As the span tasks were analysed during Experiment 1 only the revised working memory tasks were compared to the WMS indices. The results of these analyses are displayed in Table 7.4.

Table 7.4. Pearson Correlations Between Established Memory Assessments and the Developed Span and Working Memory Tasks (N = 63)

	Spatial Span r =	Spatial Working Memory (revised) r =	Object Span r =	Object Working Memory (revised) r =
Auditory Memory Index	-	.28	-	.52**
Visual Memory Index	-	.39**	-	.41*
Visual Working Memory Index	-	.33*	-	.50**
Immediate Memory Index	-	.24*	-	.51**
Digit Span Forwards (n = 54)	.48**	.53**	.55**	.52**
Digit Span Backwards (n = 54)	.29	.50**	.28	.37**
RAVLT Immediate Trial (n = 54)	.56**	-	.48**	-

* denotes $p < 0.05$

** denotes $p < 0.01$

Contrary to expectations, it can be seen from Table 7.4 that the Auditory Memory Index demonstrated a significant relationship with Object Working Memory. As expected Digit Span Backwards yielded no significant relationship with the span tasks. All other scores demonstrated moderate significant relationships, indicating that they are similar, likely due to them all being measures of memory

The Learning and Delayed Recall Tasks.

To further demonstrate convergent and discriminant validity correlation analyses were conducted between the learning and delayed tasks and the RAVLT during Experiment 2. As the learning tasks were designed utilising a list learning paradigm similar to the RAVLT the inclusion of the test as a measure of validity aimed to provide further evidence for the construct validity of the developed learning and delayed tasks. It is important to note that while these tasks all follow the principles of list learning tasks as the RAVLT is a verbal measure of memory and the developed tasks are visual, weak-moderate correlations were considered sufficient. The results of the correlation analyses between the developed learning tasks and the established RAVLT are depicted in Table 7.5 below.

Table 7.5. Pearson Correlations Between the RAVLT and the Developed Learning and Delayed Recall Tasks (N = 54)

	RAVLT			
	Immediate Recall r =	Total Recall r =	Learning Curve r =	Delayed Recall r =
Spatial Learning				
Immediate Recall	.23	-	-	-
Total Recall	-	.44**	-	-
Learning Curve	-	-	-.05	-
Delayed Recall	-	-	-	0.22
Design Learning				
Immediate Recall	0.10	-	-	-
Total Recall	-	.53**	-	-
Learning Curve	-	-	-.26	
Delayed Recall	-	-	-	.50**
Visual Pairs				
Immediate Recall	.29*	-	-	-
Total Recall	-	.47**	-	-
Learning Curve	-	-	-0.13	-
Delayed Recall	-	-	-	.28*

* denotes $p < 0.05$

** denotes $p < 0.01$

It can be seen Table 7.5 that Spatial Learning yielded a significant relationship with the RAVLT on the total recall component. Design Learning yielded significant relationships on the total recall and delayed recall components. Finally, Visual Pairs yielded significant relationships on the immediate recall, total recall and delayed recall components.

Reliability Analysis of the Revised Tasks : An Investigation of the Item and Test Design

To determine whether the revised tests are considered reliable (with good internal consistency), analyses were conducted to explore the task difficulty by comparing the individual trials within each of the revised tests to investigate whether as span increases, performance decreases, and to measure if performance between trials on a span yield similar patterns of performance

Table 7.6 shows the pattern of performance for the sample on the Spatial Working Memory task.

Table 7.6. Percentage of Participants in Each Category For Performance on Spatial Working Memory. (N=63)

	Span 2			Span 3			Span 4		
Trial No.	1	2	3	4	6	5	8	7	9
Degree of Rotation	90	180	270	90	180	270	90	180	270
Correct	88.30%	65.60%	93.30%	65.60%	13.60%	58.30%	18.60%	8.30%	5.20%
Incorrect	11.70%	34.40%	6.70%	27.90%	67.80%	36.70%	42.40%	20.00%	13.80%
Discontinue				6.60%	18.60%	5.00%	39.00%	71.70%	81.00%

Note : 90/270 degree rotation refers to a quarter turn to the right or left respectively and 180 degree rotation refers to a complete inversion of the original pattern.

* Trials are presented out of sequence to allow for direct comparisons between the rotations

It can be seen in Table 7.6 that there is a difference between performance on the 90/270 degree rotations and the 180 degree rotation. The decline in performance occurred at a steadier rate with the introduction of the third trial. Performance was similar between 90 and 270 for all 3 spans. In spans 2 and 3 performance was lower on the 180 degree rotation however this did not hold for span 4. However, it is noteworthy that a substantial number of people had discontinued by the completion of span 4.

Table 7.7 shows the pattern of performance for the sample on the Object Working Memory task.

Table 7.7. Percentage of Participants in Each Category For Performance on Object Working Memory. (N=62)

	Span 2		Span 3		Span 4		Span 5		Span 6	
Trial No.	1	2	3	4	5	6	7	8	9	10
Correct	96.70%	72.10%	42.40%	56.70%	19.00%	25.00%	12.30%	3.40%	-	-
Incorrect	3.20%	27.90%	54.20%	23.30%	46.60%	38.30%	26.30%	28.80%	16.70%	6.80%
Discontine	-	-	3.40%	20.00%	34.50%	36.70%	61.40%	67.80%	83.30%	93.20%

With the changes made to the Object Working Memory task a steady decline in performance was now observed. The amended task appeared to be more difficult than Object Span with no one completing span 6 successfully. Within each span there were some differences in performance indicating that each trial may not have even difficulty levels.

Ceiling and Floor Effects

Figures and skewness and kurtosis values were used to determine whether a ceiling or a floor effect was present for each of the revised tests. Figure 7.2 shows the frequency of participants who discontinued on each trial of the revised working memory tasks to determine the distribution of results and establish if a floor or ceiling effect was present.

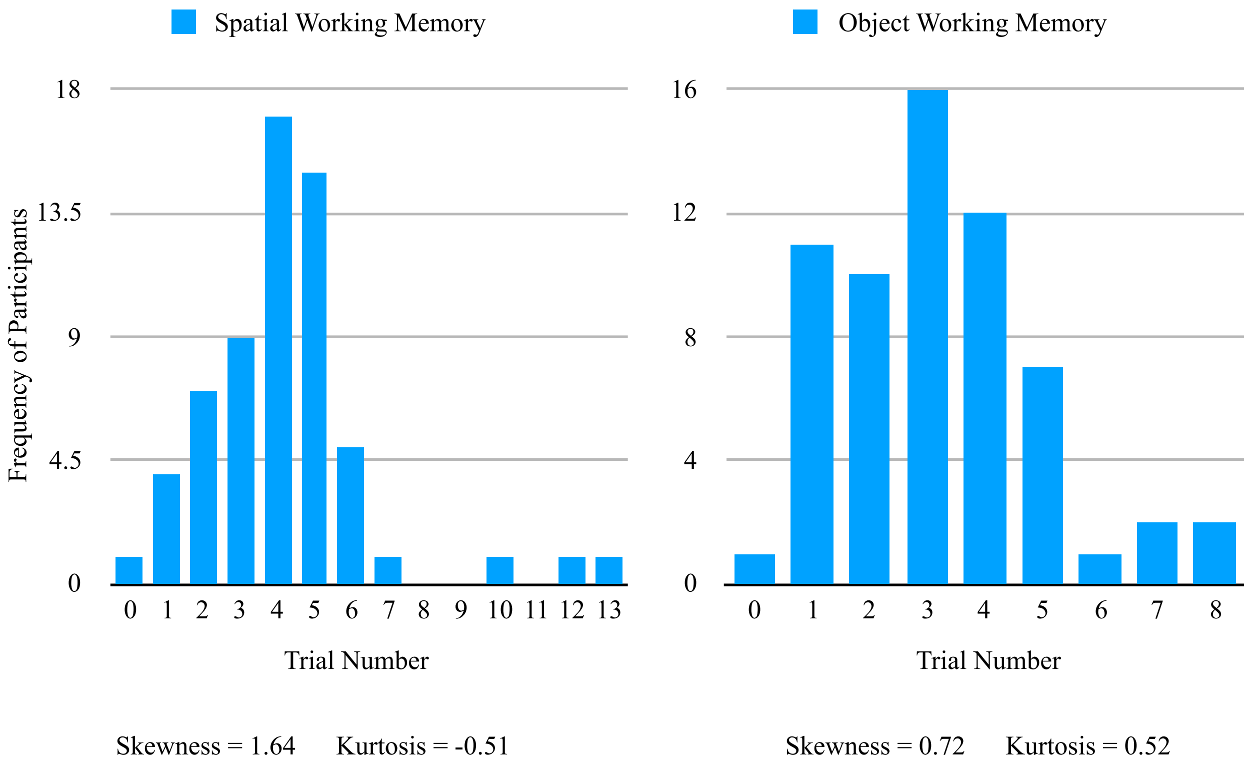

Figure 7.2. *Frequency of Participants who Discontinued on Each Trial for the Trials Correct on the Revised Working Memory Tasks (N = 63)*

No ceiling or floor effect appeared to be present in the two working memory tasks.

Results : Analysis of Capacity Differences Between the Two Streams

Based on the results produced in the above pilot section, the developed tasks were identified as promising measures of visual memory in terms of their reliability and validity. Due to these findings the current section aimed to determine if there were significant differences between the capacity for spatial and object information on span, working memory and learning and delayed tasks.

The results for the investigation into differences between the spatial and object span and working memory tasks are depicted in Table 7.8 below.

Table 7.8. Paired Samples T-Test Results Comparing Spatial and Object Tasks for Span and Working Memory (N=63).

	Mean (SD)	T Statistic *(df)*	p Value
Spatial Span	4.48 *(1.13)*	9.58 *(61)*	<0.001
Object Span	2.73 *(1.22)*	-	-
Spatial Working Memory Span	1.74 *(1.38)*	-2.08 *(60)*	0.04
Object Working Memory Span	2.13 *(1.30)*	-	-

It is clear from Table 7.8 that there were significant differences between the spatial and object domains for both span and working memory. As indicated by the descriptive statistics, performance on the Spatial Span task was better than on the Object Span task. Interestingly, the opposite was observed with the working memory tasks, with participants performing significantly better on the Object Working Memory task than the Spatial Working Memory task.

As described in the data analysis section, parametric comparisons of the learning tasks were unable to be made due to the inability to standardise the range of values. Figure 7.3 shows the mean scores for each trial on each of the developed learning tasks.

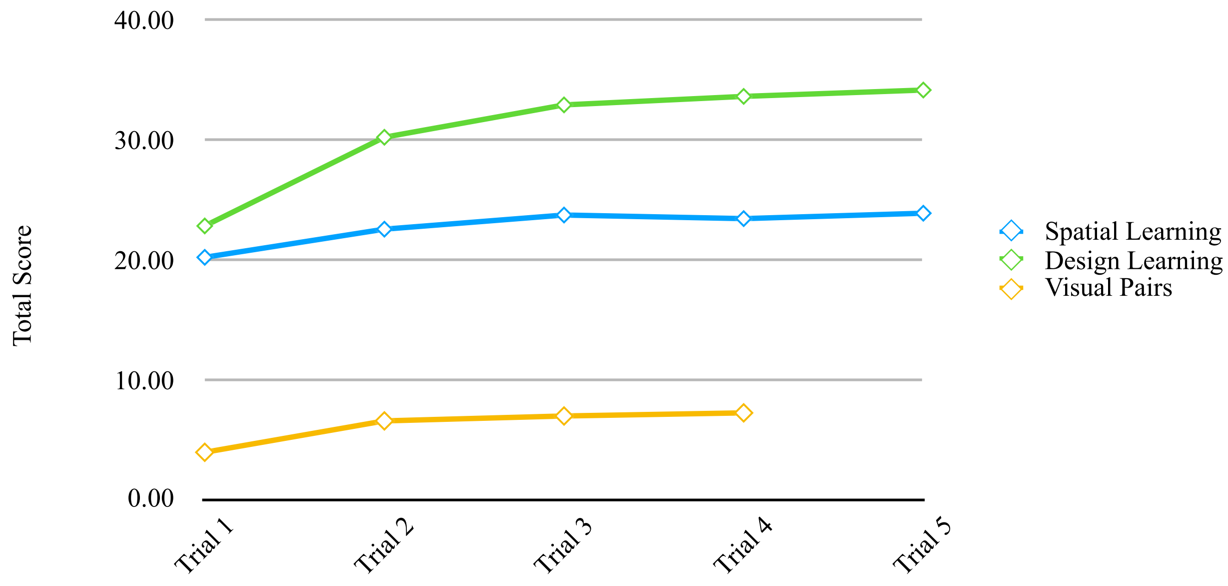

Figure 7.3. *Learning Trajectories for the Developed Learning Assessment Tasks*

It can be seen from figure 7.3 that the learning trajectories for each of the developed learning tasks were similar. While Design Learning (a free recall, object learning task) demonstrated more rapid improvement between trials 1 and 2 no significant differences in the rate of learning were immediately apparent.

Discussion : Piloting the Revised Working Memory Assessment Tasks

The initial aim of Experiment 2 was to ensure that the revised developed tasks were reliable and valid. To do this construct validity was analysed in light of the developed tests in comparison to the established tasks and theoretical notions of memory. Similar to Experiment 1, Experiment 2 also included an item analysis for each of the revised tests to evaluate the new test design and the internal consistency.

A Discussion of Construct Validity

With the changes made to the developed tasks the same hypotheses regarding the test constructs were included in Experiment 2 as were in Experiment 1. In light of the amendments made to both the Spatial Working Memory task and the Object Working Memory task all hypotheses were now supported. That is, performance was significantly better on the span tasks for each domain than on working memory tasks. These findings are in line with the modal model of memory (Atikinson & Shiffrin, 1968), Baddeley and Hitch's (1974) model of working memory, and the normative data for span and working memory tasks as outlined by Strauss and colleagues (2006).

Performance on the developed tasks were not significantly correlated with performance on all established measures of memory. Object Working Memory demonstrated significant relationships with all the WMS indices and Digit Span Forward/Backwards. Spatial Working Memory demonstrated significant relationships with Digit Span Forward/Backwards and all WMS indices excluding the Auditory Memory Index. This may further highlight the demarcation of verbal and visual processing. During the development of the object tasks, abstract stimuli were utilised to attempt to minimise the ability to verbalise the stimuli. Nonetheless it remains possible, that participants had developed a strategy that allowed for the verbalisation of the presented stimuli, accounting for the relationship between the Object Working Memory task and the Auditory Memory Index. It may also indicate that object information is more easily verbalisable than spatial due to either the mode of presentation (static vs dynamic), or that an individual has a greater ability to spontaneously name or pose meaning on an object in comparison to a path.

Finally, the two span tasks yielded significant relationships with Digit Span Forwards but not Digit Span Backwards. This provides further evidence for construct validity as while the Digit Span tasks are verbal and the developed tasks are visual the theoretical and administrative underpinnings are similar as both draw from the well established span paradigm. This finding further highlights that while visual and verbal memory are likely different, as indicated by the weak - moderate correlations, relationships between the memory construct as a whole likely exist. Furthermore, this idea was further solidified when investigating the relationships between the learning and delayed tasks and the RAVLT. Similarly to the span tasks, both the developed learning tasks and the RAVLT share a theoretical, administrative underpinning. The weak - moderate correlations observed once again indicate that while capacity differences are present for verbal and visual information, a shared relationship likely exists as they are both components of the overall memory construct. This notion is consistent with research that suggests that a healthy individual who has a high memory capacity in one domain is likely to also have relatively high memory capacity in the others (Lezak et al., 2012). This finding demonstrates that regardless of the network the information is encoded in, maximum performance is related.

A Discussion of the Reliability for the Revised Working Memory Tasks

With the changes made to the developed tasks the same hypotheses regarding the item and test design were included in Experiment 2 as were in Experiment 1. That is it was hypothesised that to demonstrate internal consistency, performance on trials within each span would yield similar results, as these trials should be similar difficulties. This was evident for both the revised working memory tasks. In terms of the test design the hypothesis stated that to demonstrate construct validity performance on the revised measures of working memory would decrease as the number of items presented in a span trial increased. This hypothesis was supported as both working memory tasks showed a decrease in performance as span increased. Finally, it was expected that to demonstrate internal validity there will be no floor or ceiling effects present on either of the revised working memory tests. This hypothesis was completely supported with neither of the developed tests indicated that a ceiling or a floor effect was present.

Discussion : Analysis of Capacity Differences Between the Two Streams

As the developed assessment tasks showed promise as valid and reliable measures of visual memory, the aim of the second section of Experiment 2 was to investigate whether differences in performance were present between spatial and object tasks.

A Discussion of Spatial and Object Capacity

A significant difference between the span scores for the spatial and object tasks was found. These findings support the notion that the two streams hypothesis extends past perception and into other higher cognitive functions. This finding suggests that the reason spatial and object span were found to differ in capacities is as a result of them being processed by two different anatomical regions (Schneider, 1969; Milner & Goodale, 1992). Baddeley and Hitch (1974) suggested that this demarcation may be present in working memory, within the visuospatial sketchpad however, the findings from Experiment 2 indicate that this may be present in span as well. Similarly to Baddeley and Hitch’s (1974) findings, a significant difference between the capacity for Spatial Working Memory and Object Working Memory was also present. These findings suggest that the capacity for spatial information is larger than the capacity for object information. This could potentially be due to spatial memory being a more practiced and ecologically valid task. The spatial information presented was dynamic in nature and thus, individuals were cued to use their inner scribe and track the information as it was presented to them (Logie, 1995). This cues them to encode the information in a specific manner. The object information was presented without context and required individuals to bind each object using their visual cache for later recall. In reality object information relies on both contextual cues and its spatial location to be processed accurately (Oliva & Torralba, 2007). These findings suggest that when object information is isolated and abstract in nature it is less efficiently stored than spatial information (that also lacks context and object cues).

Interestingly, the inverse was seen for the working memory tasks, where object working memory capacity was found to be greater than spatial working memory. Realistically, in the current era, a person is less likely to be required to manipulate spatial information than object information (especially with the advent of electronic GPS systems that present the allocentric map in the correct orientation). Thus, manipulating object information may be a more practiced task in day to day life. There is also evidence that a degree of verbalisation may have been present during the object working memory task (as seen by the relationship between this task and the Auditory Memory Index) which potentially could explain the higher capacity for object information when compared to the Spatial Working Memory task as individuals would be capable of encoding information via both verbal and visual pathways.

In terms of the learning and delayed tasks, less concrete conclusions were able to be drawn due to inability to standardise the scores. However, inferences were still able to be made. Based on the data examined it appeared that regardless of whether the information was spatial or object in nature it followed a similar learning trajectory. While initially performance was relatively lower in the object free recall task than the spatial learning task, this difference was mitigated by trial 2 and scores on all tasks showed little increase between trials 2 - 5. This difference in the immediate scores mirrors the findings of the span tasks that highlight spatial capacity is likely greater than object capacity in terms of span. As Experiment 2 utilised healthy individuals, a learning trajectory that plateaued in the final trials was to be expected (Lezak et al., 2012)

Theoretical Limitations and Future Research

Mixed findings on which capacity is greater were present throughout Experiment 2. It is difficult to discern however, why these differences are inconsistent, as there was only one task developed for each memory construct within the two streams. It is possible that perhaps there are not only differences present between these two pathways but also for information within, as eluded to by the findings of the object learning tasks, where Design Learning is more feature based and Visual Pairs incorporates bound objects. The findings of Experiment 2 clearly highlight that the capacity of visual memory is dependent on the kind of information being observed. Based on the promising findings of Experiment 2, future research may want to further explore these differences by incorporating more tasks that measure different kinds of information that are processed within each of the streams. This could further elucidate how dependent capacity is on the kind of information being presented, and could shed further light on the link between visual perception and memory theory. It is also noteworthy that this sample also had on average an IQ that was 8 points less than the initial sample, this slightly lower IQ may have contributed to variation in scores.

Conclusion

The findings suggest that the storage capacity for spatial and object information differs. However, only one spatial and one object task was given for each component of memory (span, working memory and learning/delayed recall). Visual information is complex and each of the two pathways are capable of processing a wide variety of information. While these findings establish that it is likely that differences are present within each pathway, it would be foolish to assume that this data was representative of the entire visual information system. As it has been ascertained that differences are present, further experimentation may be interested in exploring whether there are differences for the storage capacity for information within each pathway as well. As it is known that spatial information can be encoded via two main frames of reference (allocentric and egocentric) (Tu et al., 2017) and object information can be encoded via bottom up (feature) or top -down (bound object) processes (Brady et al., 2008) it is possible that these factors may influence the storage capacity within each of the pathways. Exploring each pathway in more depth would allow researchers to further understand both, how each stream processes and stores their respective visual information as well as how different the capacity for that information is between the two pathways. Within the object domain the notion that the lack of context resulted in lower scores, piques interest. As suggested by Craik and Lockhardt (1972) the depth of encoding can influence retention of information. Perhaps in a situation were more context was provided a deeper understanding of its influence could be determined. It is with these notions discussed that additional tasks were developed and piloted in Experiment 3 to allow these ideas to be investigated in detail.

CHAPTER 8

EXPERIMENT 3 - AN INVESTIGATION OF CAPACITY DIFFERENCES WITHIN THE TWO STREAMS

Test Development

Experiment 1 aimed to develop spatial and object memory assessment tasks, that provided an accurate measure of memory performance while differentiating between the spatial and object pathways. After some adjustments in Experiment 2 to account for problems with test design, validity and reliability, this was largely achieved. Although these results constitute an advancement in the conceptualisation of the assessment of visual memory, by investigating differences in the capacities for spatial and object information, they do not acknowledge that spatial and object information can be multifaceted and subsequently may influence visual memory functioning in markedly different manners. Experiment 3 will involve further bifurcation of spatial and object processing, and through the use of additional assessments will investigate whether performance differences are also present within each of the two streams. The first section of Experiment 3 involved the development of additional visual memory tasks. The second section involved piloting the additional tasks and held them to the same psychometric construct parameters as all other tasks developed for this project. Finally, the third section investigated whether there were capacity differences for information within the spatial and object streams respectively.

The Development of the Additional Tasks

Based on the findings of Experiment 2 and established research from the visual perception and memory fields, Experiment 3 proposes a more comprehensive model of visual memory to be investigated. This is displayed in figure 8.1 below.

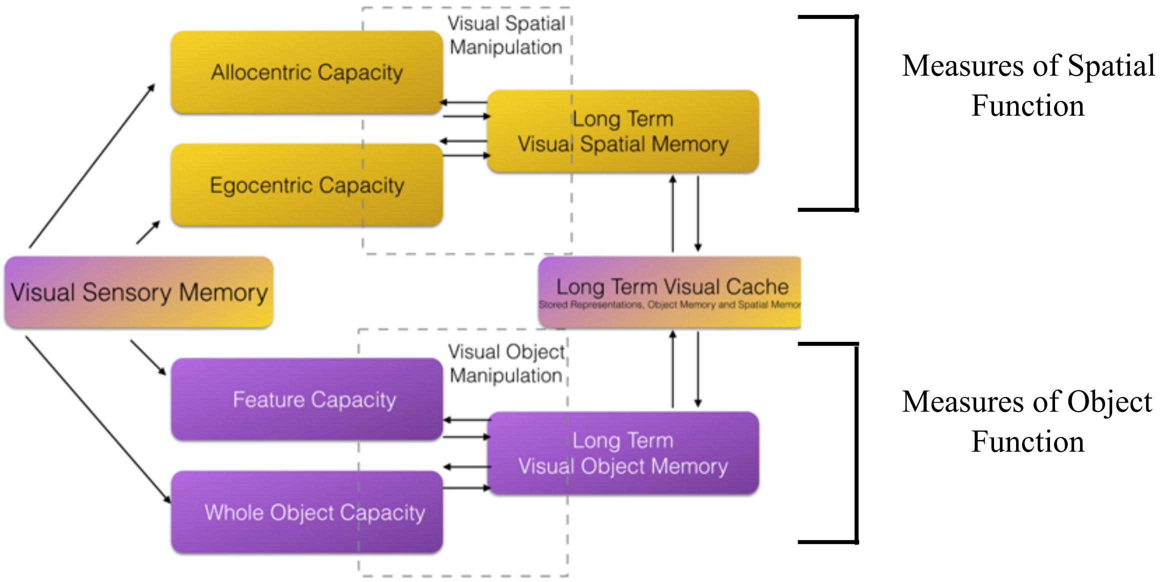

Figure 8.1. *A More Comprehensive Model of Visual Memory Representing the Stimuli Type and Used in the Developed Tests*

Building off the original framework presented in Chapter 6, that depicted the serial nature of spatial and object memory, Figure 8.1 presents a further bifurcation of each stream to create a framework for a more thorough investigation. Traditional neuropsychological measures of memory tend to incorporate measures of allocentric processing when investigating spatial memory functioning and bound object (including both known and unknown stimuli) measures when investigating object memory (Milner, 1965; Wechsler, 2009). The initial tasks developed for the present thesis conformed to these traditional standards. Thus, to extend the findings of this thesis and provide a more comprehensive investigation of visual memory, Experiment 3 investigated the not traditionally assessed components of spatial and object memory (i.e. egocentric memory tasks and feature based memory tasks). Furthermore, there has been much contention in the literature surrounding the capacity differences of memory for feature information compared to whole objects (Luck & Vogel, 1997; Delvenne & Bruyer, 2004; Wheeler & Treisman, 2002; Humphreys, 2016) and some studies have outlined that the influence of context and association impact upon any observed differences (Schurgin & Flombaum, 2017; Grubert et al., 2017). Thus, to allow a more comprehensive investigation, when developing the feature tasks both a contextual task and a non-contextual task were developed.

Egocentric Learning and Working Memory

Visual perception theory highlights that spatial information can be processed using two distinct frames of reference; allocentric and egocentric (Lemay et al., 2004). During cognitive assessment most spatial tasks utilise an allocentric frame of reference, as it is difficult to incorporate an egocentric frame into standardised pen and paper assessment tasks. While measures of perception exist that present stimuli using an egocentric frame of reference (Ciaramelli et al., 2010), in terms of memory assessments no commonly used task currently exists and several limitations have arisen in studies that have attempted to incorporate egocentric stimuli (Van der Ham, 2015; Ruddle et al., 2013). While past researchers have attempted to incorporate desk top assessments to measure egocentric functioning these tests have often lacked validity and reliability, as egocentric processing is related closely to movement, and desk top applications are disconnected from the individual and require participants to be stationary (Kearns et al., 2002; Van der Ham, 2015; Ruddle et al., 2013). In tasks that utilised desk top computer methods, the absence of physical motion lead to participants producing poorer results and more frequent reports of feeling ‘lost’ in the virtual environment (Kearns et al., 2002). In tasks that incorporated physical motion, participants response times produced minimal delay and were more indicative of performance in reality (Riecke et al., 2007). However, incorporating movement into a psychological assessment of a cognitive function, which requires that all participants experience the same stimuli and conditions, has been difficult to achieve in the past. Recently, Tenbrink and Salwiczek (2016) have highlighted the utility of incorporating virtual reality when assessing spatial functions.

Virtual reality has the potential to provide researchers with greater insight into cognitive processes and will allow them to investigate the strategies that are utilised to maintain orientation in space (Tenbrink & Salwiczek, 2016). This is a vital component, as problem solving through an egocentric frame of reference is substantially different from an allocentric frame of reference (Teel et al., 2016). When a participant is completing a task that utilises an allocentric frame of reference (such as a maze task) they are often able to navigate the task and problem solve from a holistic ‘birds eye’ perspective (Ruddle et al., 2013). Once they have drawn their path in a maze, or viewed a map from a ‘birds eye’ view, they are able to check their answers against the prototypical answer in their mind for accuracy. Alternatively in egocentric tasks participants do not have the ability to view the entire problem (e.g. maze) as they are actively in it (Ruddle et al., 2011). Therefore, they must progress through the maze sequentially and are not able to ‘zoom’ out to alter their performance or rectify mistakes. Thus, these two frames of reference adopt different processes to complete (Desmurget et al., 2000). Furthermore, egocentric tasks put a greater demand on an individual’s memory, as it is constantly forced to update information as the individual moves through the environment (Teel et al., 2016). For these reasons it has been suggested that performance on egocentric memory tasks are more sensitive than allocentric tasks when it comes to distinguishing between different forms of dementia (Tu, Spiers, Hodges, Piguet, & Hornberger, 2017). The incorporation of virtual reality could also allow participants, through the use of a headset, to view and physically navigate through a virtual environment. It is with these notions that the Egocentric Learning and Egocentric Working Memory tasks were developed.

Stimuli Design

Due to the complexities of programming a virtual reality task, designing and developing an assessment task was not within the scope of the present thesis. Nonetheless, a number of apps available on the Apple store were reviewed to determine whether a task that involves the completion of a virtual reality maze without the presence of features existed. Maze Walk is a virtual reality task developed by MyPad3D. This app consists of a number of virtual reality mazes of varying difficulty. After thorough examination of the mazes that were on offer it was found that the level 3 and 4 mazes were of almost equal difficulty, in terms of length, complexity and number of turns. Permission was sought from this United States of America based company and was granted (see Appendix N). MyPad3D provided the researcher with design plans of each map to analyse and ensure that the selected mazes would meet the requirement for use in psychometric testing.

Egocentric Learning Outline

Figure 8.2. *The Egocentric Stimuli Viewed Through A Virtual Reality Headset.*

Note: When the headset is on no border is present.

Prior to beginning this task participants were shown a video on the iPad of the egocentric perspective of an individual walking though the maze. This was viewed from a first person perspective which allowed the participant to view the maze as though it was them walking through it. This video showed the first person point of view of an individual walking from the starting position in the centre of the maze, navigating turns and culminated with them reaching the end of the maze. Immediately after watching the video of the maze, the participant put the VR headset on, and attempted to move through the same maze that they just viewed on the video. Participants were required to walk in place to navigate the maze, and were able to look around the maze by moving their head. The VR headset was connected to the researcher's computer, to allow the researcher to have a headset view of the participant, thereby allowing real-time tracking of performance. All participants were given a practice trial on a simplistic maze to allow them time to familiarise themselves with the task and the equipment.

This task contained two forms of errors; look errors and move errors. A look error was counted when a participant looked in the incorrect direction, but based on what they could see continued down the correct path. Look errors are exploratory in nature as they allow an individual to evaluate what is currently in their visual field and through recognition make a decision about whether they have seen the pathway before or not. These errors allow individuals to self correct the mistake of looking in the incorrect direction, and proceed through the maze accurately. A move error was counted when an individual physically moved in the wrong direction. These errors are also exploratory but did not involve the same level of self regulation as look errors. An individual who commits to moving in the wrong direction is likely to have not recognised the pathway as incorrect, as they have made a purposeful effort to move in the mistaken direction. A move error most often naturally occurs after a look error. If an individual made a look error and then pursued the incorrect path, this error was only counted as a move error. Participants received a score of one for each look error they made, and a score of one for each move error. The researcher recorded the number and category of errors and the time in seconds that it took the participant to move from the beginning of the maze to the end successfully. Timing commenced as soon as the individual made purposeful movement through the maze.

This task incorporated a learning component and was completed three times. While all other learning tasks involved four to five learning trials, virtual reality tasks are known to make a proportion of people feel nauseous. To ensure the integrity of the data and also to ensure the head set was not worn for an extensive period of time the number of trials was reduced to three.

Egocentric Working Memory Outline

In an attempt to measure egocentric working memory, a backwards component was also developed for this task. In the backwards component participants were asked to watch a video of a maze being completed from the end of the maze to the maze's starting point. As the app only allowed a participant to move forward from the starting location, filming the maze from the end to the beginning was a necessary step for the inclusion of a working memory trial. This time, when they placed the headset on, they were required to reverse the directions they just saw on the video to complete the maze from start to finish. As this was a working memory task, there was no learning component and only one trial was undertaken. All other scoring and administration procedures were the same as the forward component. (see Appendix O for the task's scripts).

Feature Span and Working Memory

Much of the research investigating divisions within the object stream has focussed on differences between encoding features and objects (Luck & Vogel, 1997; Delvenne & Bruyer, 2004; Wheeler & Treisman, 2002; Hardman & Cowan, 2015). As previously outlined, Luck and Vogel's controversial findings (1997) suggested that when it comes to memory, no differences are present between the two, contending that a single feature and an object that has been bound take up the same amount of space in one's cognitive load. This finding has ben controversial as since their work, many researchers have tried to replicate their findings to no avail (Delvenne & Bruyer, 2004; Wheeler & Treisman, 2002; Hardman & Cowan, 2015). Discrepancies in the research are dependent on the nature of the features and the objects being presented. Some research has suggested that recalling objects is easier than features, as objects are generally more easily verbalisable and can be encoded holistically taking into account multiple features (Humphreys, 2016). Alternatively, other papers identified that isolated features are easier to recall than objects, as an object is essentially a series of bound features (Wheeler & Treisman, 2002; Delvenne & Bruyer, 2004). These researchers suggested that objects require greater perceptual demand. This inconclusive evidence indicates that there are likely other variables that impact on one's ability to encode object related information.

From a perceptual level research by Wheeler and Treisman (2002), contends that learning and recall of features is a more primitive task than recalling objects, and relies on bottom up processing. While this is true, most studies that explore feature processing in relation to bottom up processing are tests of perception rather than tests of memory. Many memory theories (Schurgin & Flombaum, 2017; Grubert et al., 2017; Souza et al., 2013) have suggested that information processing theories highlight the need to consider context and association when measuring capacity for object related information. Familiarity and context are known to enhance memory for known/ verbalisable objects (Xie & Zhang, 2017; Schurgin & Flombaum, 2017), however, there has been little research that has investigated the role of context when binding features as part of a memory task. Research investigating the importance of context from a perceptual level highlights, that due to Gestalt principles individuals are able to visually perceive known objects, even when only minimal information is present, by binding features together (Spelke, 1990). Similar studies are yet to be conducted that comprehensively investigate the impact of context on memory and feature bindings, however these preliminary explorations of the role of context in visual perception necessitate further investigation, to highlight whether feature encoding occurs more efficiently with the presence of context, and how this influences the capacity for ventral stream related information.

Based on the aforementioned research, Feature Span was developed as a feature based analogue to the previously developed Object Span task. Structured identically to Object Span in terms of number of trials and span structure, Feature Span differs, as it requires participants to remember only one feature of a larger image. Like in Object Span, participants were then required to recall the sequence of features that were presented to them from an array. There are two versions of Feature Span: contextual and non-contextual. The decision to incorporate two components to this task was to try and demonstrate definitive evidence regarding the role of context when remembering visual information.

Stimuli Design

The development phase for this task was two-fold, as to provide a more exhaustive investigation of feature capacity both a contextual and non-contextual span and working memory task were developed. In the development of the non-contextual stimuli the array was designed to minimise the possibility of verbalisation and the presence of visual cues. From the array of features, many which only had slight variations in size and orientation, nine were selected as potential stimuli that would activate during the course of the spans. Each of the selected features were distinct enough in shape for discrimination to be possible, but were similar enough to ensure the specifics of each feature had to be noted. While there was no pre-cuing in this task, participants were instructed in the script (see Appendix P) that they would have to visually scan the entire screen to ensure they attended to all stimuli. This task also incorporated two practice trials with a different array of images to allow them experience with the task.

The development of the stimuli for the contextual task underwent a similar process. The predominant difference between the non-contextual task and the contextual task was the image that the stimuli were encoded from. Where the non-contextual task included a complex array of abstract figures, for the contextual task a geometric face of a girl was developed. While lacking fine detail, from the information provided any activated features could easily be encoded as a portion of the face and were subsequently verbalisable. Similarly to the non-contextual task, nine features were selected as the stimuli for this task. The discrimination array presented the stimuli in a different order for every trial, to ensure that participants were unable to rely on learning the locations of features and subsequently match them.

In an attempt to investigate the influence of context, the features selected for use as stimuli in the two tasks were designed to be as similar as possible (consisting of either simple curved or straight lines). This developmental decision to was undertaken with the hope that any substantial differences in performance observed could be contributed to the presence or absence of context.

Feature Span Outline

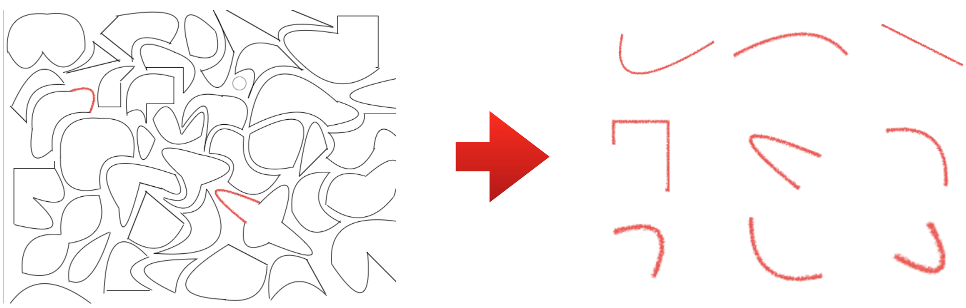

Figure 8.3. *The Non-Contextual Feature Span Stimuli.*

The non contextual task as depicted in Figure 8.2 shows the abstract presentation of various unnameable shapes. The participant was presented with the total abstract design and one individual target line within the image flashed red for a period of two seconds and then disappeared before the next target line appeared after a period of 0.5 seconds. Features flashed in red one at a time until the maximum number of stimuli for that span was reached. Participants were then presented with an array (showed on the right of figure 8.3) and asked to point to the features that flashed in red in the order that they were presented.

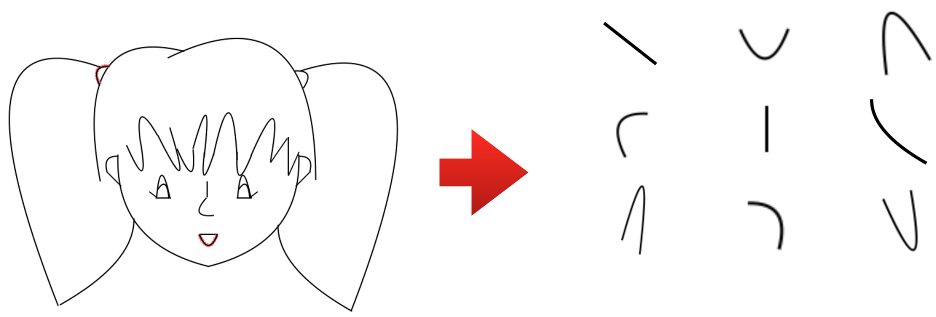

Figure 8.4. *The Contextual Feature Span Stimuli.*

The contextual component used a face to provide a meaningful percept as the background for the task. The notion was that using a face would provide both spatial and object cues to facilitate encoding and promote recall. For example a curved shape that previously had no context may now be encoded as a mouth as depicted in Figure 8.4. The non-contextual and contextual tasks were administered separately and each contained their own set of scores.

To be consistent with the other object measures, span increased by one every two trials and two consecutive incorrect scores discontinued the task. The task produced two scores for each participant. The first score was derived from how many trials an individual completed correctly. The second score was the span score and this score was derived from the length of their last set of correct consecutive sequences (e.g. if both trials containing three stimuli were the last set recalled correctly, then the individual would be awarded a span of three). The feature span tasks each consisted of 14 trials, allowing a maximum trials correct score of 14 and a minimum score of 0. Subsequently, the span score could produce a maximum of 7 and a minimum of 0.

Feature Working Memory Outline

The working memory components utilised the same stimuli and presentation rules as both feature span tasks (contextual and non-contextual). However, as with the Object Working Memory task, in Feature Working Memory participants were required to recall the features presented to them in the reverse order.

Aims and Hypotheses

Experiment 3 aimed to further investigate spatial and object memory by exploring performance differences within each of these the two areas through the use of additionally developed tasks. The aims, results and discussion for this experiment will be presented in two distinct sections - piloting the newly developed assessment tasks followed by an investigation of the capacity differences within the two streams (allocentric capacity compared to egocentric capacity, and object capacity compared to feature capacity).

Similarly to Experiment 1 and Experiment 2, the initial aim of Experiment 3 was to first ensure that the additional tasks were psychometrically valid and reliable measures. Subsequently, construct validity, internal consistency and floor and ceiling effects were investigated using the same construct parameters as the previous experiments.

After establishing the validity and reliability of the developed tasks, the second section of analysis involved investigating if there were differences in capacity for information within the spatial and object pathways respectively. It was hypothesised that:

- Performance on the developed egocentric and allocentric tasks would demonstrate weak - moderate relationships.
- Performance on the object span and working memory tasks would be greater than on the feature span and working memory tasks respectively.
- Finally, performance would be greater on the contextual tasks than on the non-contextual tasks.

Method

Participants

Of the 63 participants who completed Experiment 2, 54 individuals, returned for participation in Experiment 3. Participants were invited to return for further testing via email. Invitations to participate were sent out approximately one year after the participants had engaged in Experiment 2. The 54 individuals in Experiment 3 aged between 18 – 45, had a mean age of 26.67 years (*SD = 7.89).* As Experiment 3 utilised participants from the Experiment 2 sample, with an attrition rate of 15%, this sample represents a subsection from Experiment 2 and subsequently further demographic analyses were not conducted. As this was the final experiment an analysis of sex differences for the present sample was also undertaken to investigate if any differences were present. Independent samples t-tests were conducted for each of the developed tests and performance between the sexes was found to be equivalent, with no noteworthy results (the table of independent t-test comparisons can be viewed in Appendix Q.).

Materials

As described above new tasks were developed to measure egocentric memory and memory for feature information. Due to Experiment 3 utilising participants who also completed Experiment 2, their scores from the previously developed tests were also incorporated into the analyses, though they were not re-administered. For simplicity and accuracy the previously developed spatial assessments that represented stimuli from an allocentric frame of reference were renamed Allocentric Span/Working Memory and Learning. A summary of the additional developed tasks and changes can be seen in Table 8.1 below.

Table 8.1. Summary of the Additional Developed Tasks and Previous Task Adaptions

Domains	***Subtests***		
	Aim of Assessment	**Key Features**	**Maximum Score**
Spatial			
Spatial Span - Now Allocentric Span	-	-	-
Spatial Working Memory - Now Allocentric Working Memory	-	-	-
Spatial Learning - Now Allocentric Learning	-	-	-
Egocentric Learning	• Measure of immediate egocentric span and egocentric learning.	• Virtual reality task using the MazeWalker 3D app • Participant navigates the same maze three times to measure learning • Requires participants to view a virtual maze being completed in first person view and then replicate the pathway in a virtual environment • Contains two forms of error: Look errors involve the participant looking in the incorrect direction and then rectifying their error. Move errors involve the participant actively moving in the incorrect direction.	This is a timed task, and each trial records the time to complete the maze in seconds Look errors - a score of one is given for each error Move errors - a score of one is given for each error.
Egocentric Working Memory	• Measure of egocentric working memory	• Virtual reality task using the MazeWalker 3D app • Includes a different map of the maze to be completed • Only one trial. • Participants are shown a video of the maze being completed from the end of the maze to the centre. They are then asked to complete the maze from the centre outwards (the opposite to what they viewed.	This is a timed task, and each trial records the time to complete the maze in seconds Look errors - a score of one is given for each error Move errors - a score of one is given for each error.
Object			
Feature Span	• Measure of feature span and basic attentional control	• Has a contextual and non contextual component • Stimuli are presented are presented one at a time in a predetermined order. After each sequence participants are required to select the features that they saw in the order that they saw them • Difficulty increased by one feature every two trials • Discontinue after two incorrect trials.	Trials Correct = 14 Total Span = 7
Feature Working Memory	• Measure of feature working memory	• Has a contextual and non contextual component • Identical design and administration to object span • Manipulation component involves recalling the objects in the reverse order than they were presented.	Trials Correct = 14 Total Span = 7

Virtual Reality Headset

The egocentric measures involved the use of a virtual reality headset and an iPhone 6S as depicted in Figure 8.2 below.

Figure 8.5. *The Virtual Reality Headset Utilised in the Egocentric Tasks. (Typo-VR-Headset Mini)*

This headset was placed over the eyes of the participant and one strap was tightened around the circumference of their head horizontally. To ensure that the headset did not move and to reduce the onset of nausea the headset also utilised a strap that attached to the goggles and then went over the top of the head to connect to the horizontal strap. The iPhone was placed in the gap between the plastic on the front of the headset and the lens area. This allowed the individual to view the screen through the headset and complete the task.

Established Measures of Memory

The present study consisted of individuals who had previously participated in Experiment 2. Due to this their past WMS and WASI results were utilised in Experiment 3 analyses however, they were not re-administered. As part of Experiment 3 both Digit Span and the RAVLT were administered to individuals who returned for this study. These measures were used to provide a more comprehensive assessment of construct validity as they were both developed using the same structural paradigm as the developed span/working memory assessments and learning and delayed assessments respectively. As outlined previously this data was used retrospectively in Experiment 2.

Procedure

This project was approved by the Victoria University Human Research Ethics Committee (See Appendix R). Participants were recruited using the contact details that they supplied during recruitment for Experiment 2. Participants who were interested in being involved in Experiment 3 were given the opportunity to ask any questions of the student researcher. If they were interested in participating they were sent the new Information to Participants sheet and Consent Form via email (See Appendix S). Participants completed the testing session at Victoria University, Footscray Park or St Albans campus. They were asked to turn their mobile phone off during testing. All testing was undertaken in a quiet, private room free from distractions. The testing session was approximately 45 - 60 minutes.

In all cases the RAVLT was the first task administered as it included a delayed recall trial. The developed tests were then presented in a counterbalanced order to account for order effects whereby some participants completed the egocentric tasks and Digit Span first, and others completed the feature memory tasks first (see Appendix T). The RAVLT and Digit Span were administered and scored using standardised procedures.

To set up the virtual reality utilised in the egocentric tasks, participants were asked to stand in an area of the room that was free from furniture and other potential hazards. They were required to place the straps of the VR headset over their head and the student researcher secured them in place. The iPhone app was then set up and placed in the viewing section at the front of the headset. The headset was connected via a five meter long cable to the researcher's MacBook Pro which allowed them to see what the participant was currently viewing and record their performance using Quicktime. The cord was secured above the participant to ensure that they were unable to trip. Participants were instructed that to move they were required to nod their head and walk in place. All administration instructions are described in the previous egocentric tasks outline. Timing commenced as soon as the participant began to navigate their way through the maze.

The feature based tasks were administered using a 10.5 inch iPad Pro. Participants were asked to sit in a chair with the iPad positioned approximately 30cm from them. They were given a pen to point and select their answers with. All feature tasks were administered following the procedure outlined previously in this chapter.

All data was collated and analysed using SPSS Version 22 (IBM Corp, 2013).

Data Analysis

Experiment 3 utilised paired samples t-tests, and Pearson correlations and all assumptions were checked using the procedures outlined in Experiment 1.

Standardisation.

To establish construct validity for the additional tests paired samples t-tests and Pearson Correlations were utilised. The egocentric memory tasks recorded the time to complete in seconds. Raw scores were considered appropriate for all paired samples t-tests conducted between span and working memory for the developed egocentric and feature based tasks.

As the feature tasks followed the same administration and scoring format as the previously developed object memory tasks raw scores were also considered appropriate for all paired samples t-tests conducted between these tasks.

Pearson correlations were conducted to determine whether a relationship was present between the egocentric and allocentric tasks. Due to substantial variation in administration and scoring these tasks were unable to be standardised and subsequently paired samples t-tests were unable to be conducted.

Finally, a comparison of the object learning tasks was not conducted as the feature based Design Learning is a measure of free recall and the object based Visual Pairs is a cued recall task. Thus, any observable differences are likely due to the nature of the task more so than the stimuli utilised.

All data was collated and analysed using SPSS Version 22 (IBM Corp, 2013).

Results: Piloting the Egocentric and Feature Memory Assessment Tasks

To evaluate the psychometric properties of the egocentric and feature based tasks, this section of Experiment 3 will investigate the construct validity, internal consistency and floor and ceiling effects. Following the previous structure (Seen in Experiment 1 and 2) this first section will first review the construct validity of the developed tasks. This was conducted by comparing the developed tasks to the currently established theoretical notions of memory and cognition, as well as running Pearson Correlation analyses to further examine construct validity in terms of the developed tasks in relation to currently established measures of memory. The next component involved an item analysis to review the internal consistency of the developed tasks and an investigation of floor and ceiling effects.

An Investigation of Construct Validity for the Additional Tasks

As with the previous experiments to assess the construct validity of the developed tasks, paired samples t-tests were first run for the tasks of each pathway.

Evaluation of the Egocentric Tasks.

Table 8.2 shows a summary of the descriptive statistics derived from the egocentric virtual reality tasks to evaluate whether a difference was present between the immediate trial of the learning task and the working memory component. This table also allows examination of the learning trials.

Table 8.2. Means and Standard Deviations for the Time to Complete the Egocentric Learning and Working Memory Tasks in Seconds (N = 54)

	Trial 1	Trial 2	Trial 3
	Mean Time in Seconds *(SD)*	Mean Time in Seconds *(SD)*	Mean Time in Seconds *(SD)*
Egocentric Span	90.63 *(19.82)*	67.59 *(23.48)*	54.31 *(19.39)*
Egocentric Working Memory	109.15 *(24.27)*	-	-

Table 8.2 shows that for Egocentric Learning the time to complete the maze decreased over the three trials indicating that participants became more skilled at recalling and completing the task each time. A paired samples t-test was conducted to determine if a significant difference was present for the time it took to complete the first trial of Egocentric Learning compared to Egocentric Working Memory. A significant

difference was observed, *t*(53) = -11.70, *p* = 0.00, with participants performing trial 1 of the Egocentric Learning task almost 20 seconds faster than the Egocentric Working Memory task.

Table 8.3 shows the results investigating whether one form of error was more common the other for each component of the egocentric tasks.

Table 8.3. Summary of the Error Means, Standard Deviations and Paired Samples T-Tests Results Comparing the Errors During the Egocentric Tasks. (N = 54)

	Look Error Mean *(SD)*	Move Error Mean *(SD)*	T (*df*)	p Value
Span				
Trial 1	2.67 *(1..79)*	1.56 *(2.33)*	3.20 *(53)*	0.02
Trial 2	1.26 *(1.15)*	0.22 (*0.42)*	7.05 *(53)*	<0.001
Trial 3	0.44 *(0.72)*	0.06 *(0.30)*	4.55 *(53)*	<0.001
Working Memory	4.09 *(1.91)*	0.69 *(0.82)*	14.93 *(53)*	<0.001

Note: Look error denotes a participant purposely looking in the wrong direction before correcting themselves. A move error refers to a purposeful movement in the incorrect direction.

As expected a decrease in both look and move errors was seen over the course of the three span trials. Paired samples t-tests were conducted to determine whether the differences between the incidence of errors was significant. It can be seen that participants were significantly more likely to make a ‘look error’ than a ‘move error’. This finding is consistent across all the trials for both the span and working memory components.

A final investigation was conducted to see whether participants who took longer to complete the maze were likely to make less errors (of either type). The Pearson Correlations can be seen in Table 8.4.

Table 8.4. Pearson Correlations Between the Time to Complete and the Number of Errors for the Egocentric Tasks (N=54)

	Look Errors	Move Errors
Egocentric Learning Trial 1	0.60**	0.31*
Egocentric Learning Trial 2	0.58**	0.37*
Egocentric Learning Trial 3	0.18	0.01
Egocentric Working Memory	0.56**	0.65**

* denotes $p < 0.05$

** denotes $p < 0.01$

Note: Errors only included for the specific trial in question. E.g. Error relationships for trial 1 are for errors that occurred during trial 1.

The findings seen in Table 8.4 indicate that as the time to complete the egocentric learning and working memory tasks increased so did the incidence of errors. This was true for all trials excluding trial 3 in Egocentric Learning.

To further demonstrate construct validity the egocentric tasks were compared to established measures of memory in Table 8.5 below.

Table 8.5. Pearson Correlations Between the WMS Indices and the Egocentric Tasks (N=54)

	Egocentric Learning Trial 1 r =	Egocentric Learning Trial 2 r =	Egocentric Learning Trial 3 r =	Egocentric Working Memory Trial 1 r =
Auditory Memory Index	.16	.31	.43	.09
Visual Memory Index	.04	.00	.16	-.03
Visual Working Memory Index	.02	.01	.08	-.02
Immediate Memory Index	.16	.20	.40	.13
Digit Span Forwards	.05	.22	.23	-
Digit Span Backwards	-	-	-	.01
RAVLT Immediate Trial	.05	.01	.11	-

Table 8.5 shows that there were no significant relationships present between the egocentric tasks and any of the established WMS indices, Digit Span or the RAVLT. While not significant it can be observed that as the trials progressed an increase in the relationship between Egocentric Learning and Auditory Memory Index was present. This indicates that there may be some degree of verbal encoding occurring. Furthermore, this relationship is also seen to a similar extent with the Immediate Memory Index which also has contributions from verbal memory assessments.

Evaluation of the Feature Memory Tasks.

Table 8.6 displays a summary of the descriptive statistics and paired t-test results for the Feature Span and Feature Working Memory tasks. These will be used to inform construct validity.

Table 8.6. Means, Standard Deviations and Paired Samples T-Tests Results Comparing the Feature Span and Working Memory Tasks. (N = 54)

	Trials Correct: Mean *(SD)*	T (*df*)	p Value	Span: Mean *(SD)*	T (*df*)	p Value
Contextual Feature Span	4.31 *(1.90)*	9.48 *(53)*	<0.001	2.77 *(1.20)*	1.38 *(52)*	<0.001
Contextual Feature Working Memory	2.52 *(1.93)*	-	-	1.41 *(1.38)*	-	-
Non Contextual Features Span	2.43 *(1.82)*	5.55 *(53)*	<0.001	1.50 *(1.37)*	3.78 *(53)*	<0.001
Non Contextual Feature Working Memory	1.39 *(1.54)*	-	-	0.80 *(1.12)*	-	-

It can be seen from Table 8.6 that in both the contextual and non-contextual tasks span scores were significantly greater than working memory scores.

The influence of context when remembering feature based information was explained using paired samples t-tests. Results are displayed in Table 8.7 below.

Table 8.7. Paired Samples T-Tests Results For Performance on Feature Tasks when Context is Present Compare to Not Present (N = 54)

	T *(df)*	p Value
Contextual Span vs Non Contextual Span	7.94 *(52)*	<0.001
Contextual Working Memory vs Non Contextual Working Memory	3.89 *(53)*	<0.001

Observing the means displayed in Table 8.6 participants performed significantly better on feature based tasks when context was given. This was evident for both the span and working memory tasks.

To further demonstrate construct validity the feature tasks were compared to established measures of memory in Table 8.8 below.

Table 8.8. Pearson Correlations Between the WMS Indices and the Feature Based Tasks (N=54)

	Contextual Feature Span r =	Contextual Feature WM r =	Non Contextual Feature Span r =	Non Contextual Feature WM r =
Auditory Memory Index	.15	.26	.23	.20
Visual Memory Index	.22	.28	.02	.29
Visual Working Memory Index	.37*	.37**	.34**	.49**
Immediate Memory Index	.18	.14	.09	.29
Digit Span Forwards	.52**	.57**	.52**	.64**
Digit Span Backwards	.42*	.25	.30	.58**

It can be seen from Table 8.6 that all tests demonstrated a significant, positive, moderate relationship with the Visual Working Memory Index and Digit Span. Furthermore, a moderate relationship was observed between Non-Contextual Feature Working Memory and Digit Span Backwards. All other relationships were not significant.

Reliability of the Additional Tasks : An Investigation of the Item and Test Design

To determine whether the developed tests could be considered reliable, analyses were conducted to explore the difficulty by comparing the individual trials within each task. This analysis wills whether each span becomes progressively more difficult, and will assess whether the trials between each span are of similar difficulty.

Table 8.9 shows the pattern of performance for the sample on Contextual Feature Span Forwards.

Table 8.9. Percentage of Participants in Each Category For Performance on Contextual Feature Span (N =54)

	Span 2		Span 3		Span 4		Span 5	
Trial No.	1	2	3	4	5	6	7	8
Correct	96.90%	96.90%	78.10%	75.00%	37.50%	34.40%	21.90%	21.90%
Incorrect	3.10%	3.10%	21.90%	25.00%	50.00%	46.90%	25.00%	18.80%
Discontinued (Cumulative)	-	-	-	-	12.50%	18.80%	53.10%	59.40%

As expected a reduction in performance was seen across each of the spans. Also as expected performance within each span was relatively similar.

Table 8.10 shows the pattern of performance for the sample on Contextual Feature Working Memory.

Table 8.10. Percentage of Participants in Each Category For Performance on Contextual Feature Working Memory (N =54)

	Span 2		Span 3		Span 4		Span 5	
Trial No.	1	2	3	4	5	6	7	8
Correct	84.40%	75.00%	31.30%	46.90%	21.90%	18.80%	0.00%	6.30%
Incorrect	15.60%	25.00%	28.10%	28.10%	31.30%	31.30%	28.10%	12.50%
Discontinued (Cumulative)	-	-	12.50%	25.00%	46.90%	50.00%	71.90%	81.30%

A greater degree of variation was seen within the Contextual Feature Working Memory task than its span iteration. A gradual decline in performance was still observed across the spans however, within each span there was a greater degree of variation with correct scores fluctuating between 3% and 15%.

Table 8.11 shows the pattern of performance for the sample on Non-Contextual Feature Span.

Table 8.11. Percentage of Participants in Each Category For Performance on Non-Contextual Feature Span (N =54)

	Span 2		Span 3		Span 4		Span 5	
Trial No.	1	2	3	4	5	6	7	8
Correct	81.80%	81.80%	40.90%	45.50%	18.20%	13.60%	9.10%	0.00%
Incorrect	18.20%	18.20%	45.50%	36.40%	36.40%	31.80%	18.20%	18.20%
Discontinued (Cumulative)	-	-	13.60%	18.20%	45.50%	54.50%	72.70%	81.80%

It can be observed from table 8.11 that performance between each span decreased. It can also be observed that in span 2, 3 and 4 performance within the span was relatively stable.

Table 8.12 shows the pattern of performance for the sample on Non-Contextual Feature Span Working Memory.

Table 8.12. Percentage of Participants in Each Category For Performance on Non-Contextual Feature Working Memory (N =54)

	Span 2		Span 3		Span 4		Span 5	
Trial No.	1	2	3	4	5	6	7	8
Correct	50.00%	54.50%	27.30%	4.50%	9.10%	-	-	-
Incorrect	50.00%	45.50%	36.40%	54.50%	18.20%	9.10%	9.10%	-
Discontinued	-	-	36.40%	40.90%	72.70%	90.90%	90.90%	100.00%

Table 8.12 shows that performance on the Non-Contextual Feature Working Memory task was relatively low. A decrease in performance was observed across the

first 2 spans, however, no participants made it past trial 5 successfully, thus limiting the interpretation of the results. Within span 2 performance was relatively stable whereas in span 3 a large amount of variation was observed.

Ceiling and Floor Effects

Figures were used to determine whether a ceiling or a floor effect was present for each of the developed tasks. Unless otherwise specified all figures were considered to be normally distributed with skewness and kurtosis scores falling within the acceptable ranges (-3 and 3). Figure 8.6 shows the frequency of participants who discontinued on each trial for the contextual feature span and working memory tasks to determine if a floor or ceiling effect was present for each task.

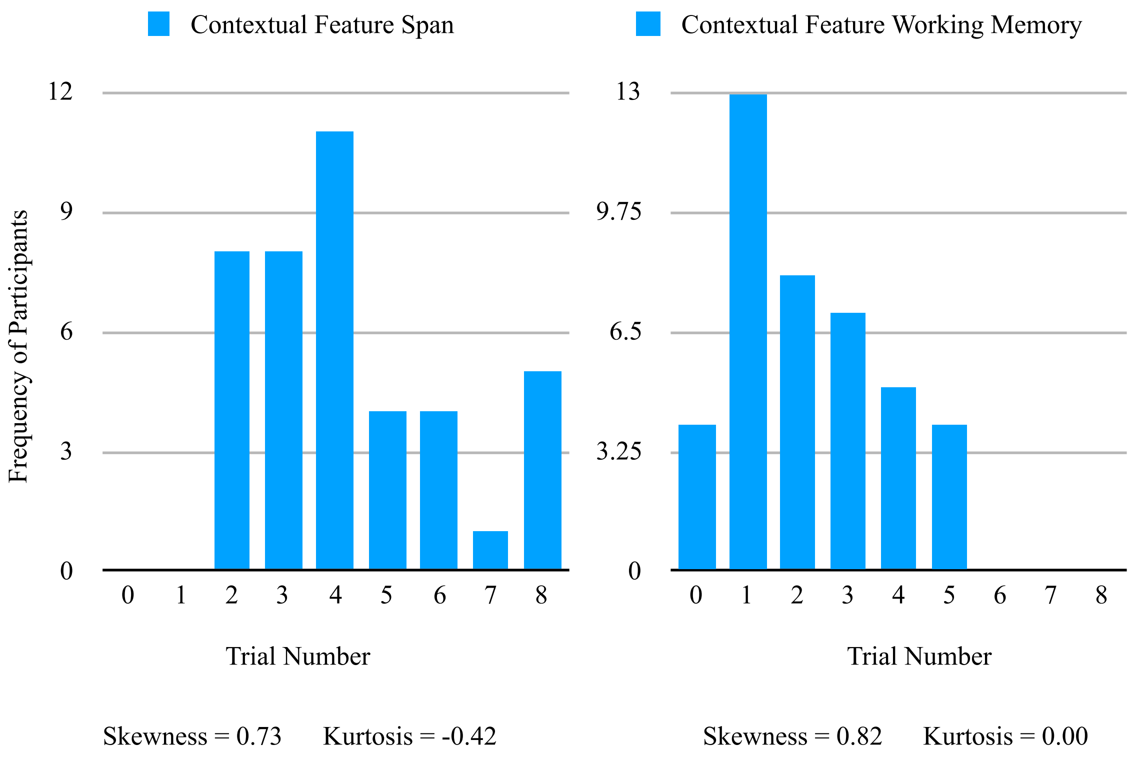

Figure 8.6. *Frequency of Participants who Discontinued on Each Trial for the Trials Correct Score on the Contextual Feature Trials (N = 54)*

It can be seen that no ceiling or floor effect appeared to be present.

Figure 8.7 shows the shows the frequency of participants who discontinued on each trial for the non contextual feature span and working memory tasks

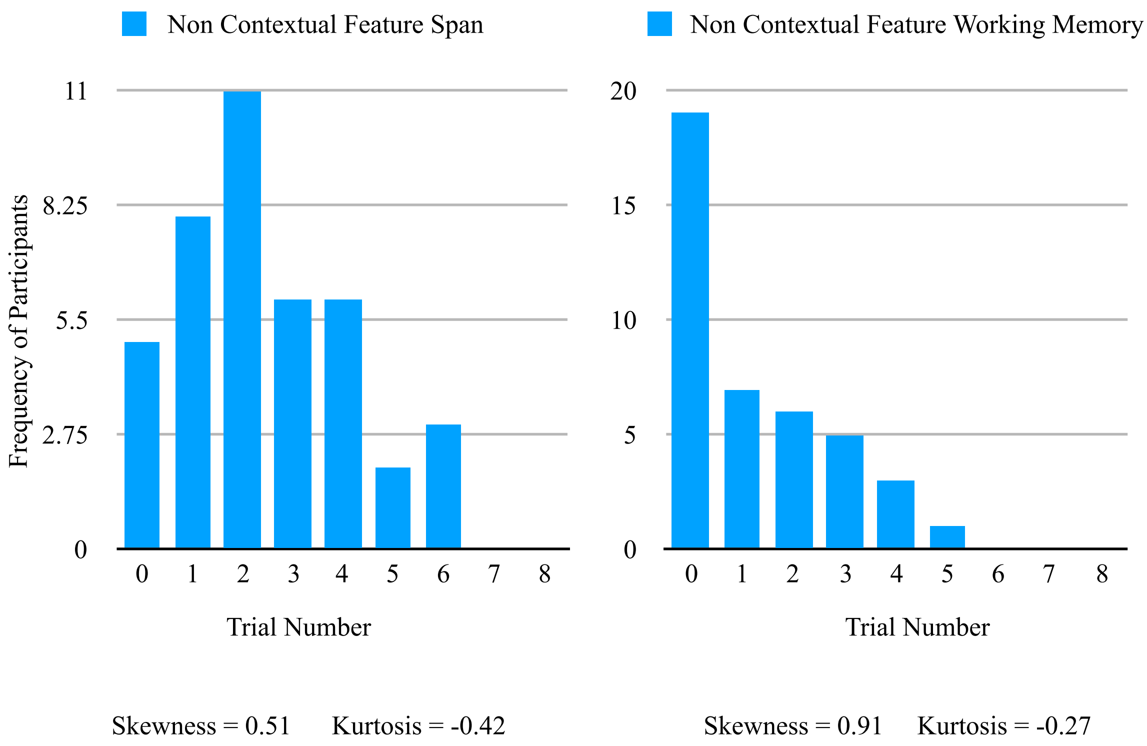

Figure 8.7. *Frequency of Participants who Discontinued on Each Trial for the Trials Correct Score on the Non Contextual Feature Trials (N = 54)*

Similarly to the contextual tasks the Non-Contextual Feature Span task did not show evidence of a ceiling or floor effect. Despite the apparent positive skew present for Non-Contextual Feature Working Memory, skewness and kurtosis values fell in the accepted ranges.

Figure 8.8 shows the completion time in seconds it took participants to finish each of the trials on Egocentric Span.

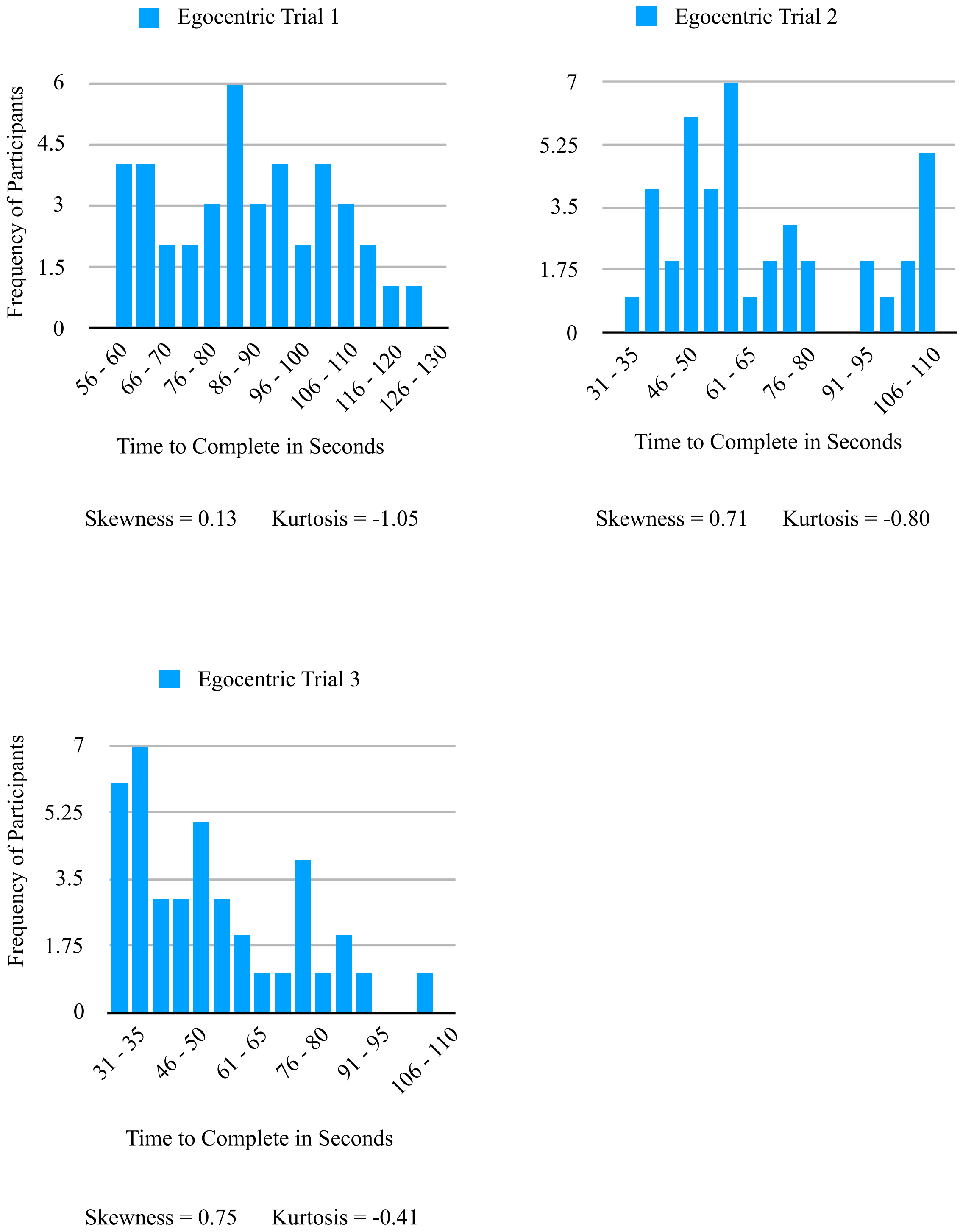

Figure 8.8. *Completion Times for Participants Performance on the Egocentric Span Trials (N = 54)*

Figure 8.8 indicated that no ceiling or floor effect appeared to be present. Trial 3 appears to display a slight positive skew however, skewness and kurtosis were still considered to be within the acceptable ranges.

Figure 8.9 shows the completion time in seconds it took participants to finish Egocentric Working Memory.

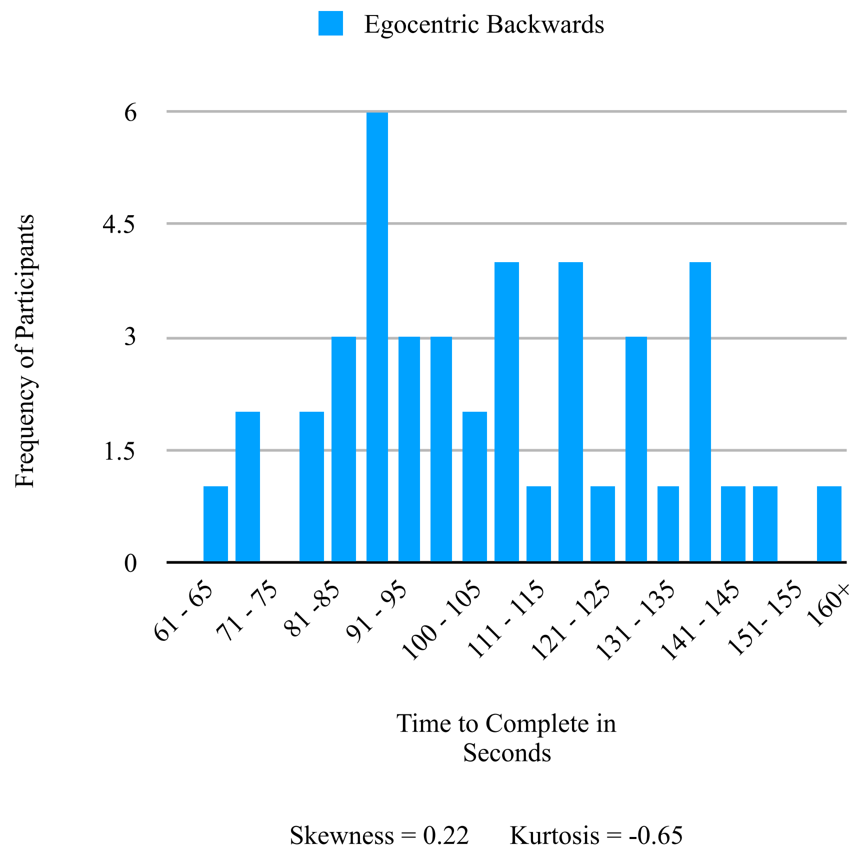

Figure 8.9. *Completion Times for Participants Performance on the Egocentric Working Memory Task (N = 54)*

Figure 8.9 also indicated that no ceiling or floor effects were present.

Results: Analysis of Capacity Within the Two Streams

Analysis of the Spatial Stream

The main purpose of Experiment 3.3 was to investigate whether capacity differences were present for information within both the spatial and the object streams. Due to an inability to standardise the allocentric and egocentric tasks, as one was scored by the number of squares correct and the other by the time taken to complete the task, Pearson correlation analyses were conducted to investigate the relationship between the two spatial tasks. Egocentric Learning contained three learning trials and Allocentric Learning contained 5 trials, therefore, only the first three trials of Allocentric Learning were used for analyses. The Egocentric Working Memory task was compared to the Allocentric Working Memory span score. The results of these analyses can be seen in Table 8.13 below.

Table 8.13. Pearson Correlations Between the Allocentric and Egocentric Tasks (N=54)

	Allocentric Learning Trial 1 r =	Allocentric Learning Trial 2 r =	Allocentric Learning Trial 3 r =	Allocentric Working Memory Span r =
Egocentric Learning Trial 1	.28	-.09	-.07	-
Egocentric Learning Trial 2	.15	-.12	-.04	-
Egocentric Learning Trial 3	.13	-.12	-.014	-
Egocentric Working Memory	-	-	-	-.09

It can be seen from Table 8.13 that no significant relationships were observed between any of the developed allocentric and egocentric tasks. This indicates that they are measuring inherently different constructs.

Analysis of The Object Stream

In terms of the object stream, Experiment 3.3 aimed to explore whether there was a significant difference in capacity for features, when compared to bound objects. A paired samples t-test was conducted to investigate whether significant differences were present for scores on the Object Span task and the Feature Span tasks. Results for the contextual component yielded no significant differences for the number of trials correct *t* (53) = 1.91, *p* = 0.06, or for span scores *t* (53) = 0.34, *p* = 0.74. Contrary to this, a significant difference was observed between Object Span and the Non-Contextual Feature Span task for both trials correct, *t (*53) = -5.29, *p* <0.001 and span scores *t* (53) = -6.22, *p* < 0.001. Inspection of means indicated that performance was significantly higher for performance on the Object Span (mean number of trials correct = 4.45, mean span score = 2.73) task in comparison to the Non-Contextual Feature Span task (mean number of trials correct = 2.44, mean span score = 1.51).

Paired samples t-tests were also conducted to investigate whether differences were present between the Object Working Memory task and the Feature Working Memory tasks. Results for the contextual component yielded significant differences for both trials correct *t (*53) = -8.13, *p* < 0.001 and span scores *t* (53) = -6.64, *p* < 0.001. Inspections of the means indicated that performance was significantly higher for the Object Working Memory task (mean number of trials correct = 3.19, mean span score = 2.13) in comparison to the Contextual Feature Working Memory task (mean number of trials correct = 2.29, mean span score = 1.22). Congruent with these findings significant differences were also observed between Object Working Memory and Non-Contextual Feature Working Memory for both trials correct *t* (53) = -9.10, *p* < 0.001 and span *t* (53) = -9.77, *p* < 0.001. This indicates that performance was higher in the Object Working Memory task (mean number of trials correct = 3.19, mean span score = 2.13) than in the Non- Contextual Feature Working Memory task (mean number of trials correct = 1.24, mean span score = 0.71).

Discussion: Piloting the Egocentric and Feature Memory Assessment Tasks

A Discussion of the Psychometric Properties for the Developed Egocentric Memory Measures

In keeping with robust and long held memory theory (e.g. Atkinson & Shiffrin, 1986; Baddeley & Hitch, 1974) it was hypothesised that short term memory capacity would be significantly larger than working memory capacity. This was supported. A significant difference was also found between the first trial of the Egocentric Learning and the Egocentric Working Memory task. This finding is in keeping with established literature evaluating span and working memory tasks, that indicate that performance on span tasks generally is higher than on working memory tasks (Wechsler, 2009; Brady, 2016). Most studies investigating differences between visual short term and working memory, explore the construct in terms of memory for objects (Brady, 2016; Cabbage et al., 2017; Luck & Vogel, 2017) and while there are some that investigate spatial memory (Woodman & Chun, 2006) these papers have predominantly explored allocentric memory. Research investigating egocentric memory is scarce, and many studies that do explore this function do so in relation to allocentric processing and through a visual perception paradigm, rather than a memory paradigm (Lester & Dassonville, 2014; Wood 2010). Literature investigating egocentric memory is limited, and at the present time, measures of egocentric memory that are developed for assessment using a span paradigm are non-existent. Nonetheless, the findings of this experiment suggests that egocentric memory is also governed by the same principles as other facets of memory, and it is likely that participants find completing the working memory task more difficult than the span. This finding aligns with other memory assessments that utilise the span paradigm such as Digit Span (Wechsler, 2008) and Corsi Blocks (Corsi, 1972).

Participants' performance on the Egocentric Learning task showed evidence of improvement, with the completion time to navigate the maze reducing across each of the three trials. While reaction times decreased over the three trials it is difficult to determine whether this difference was solely due to improvements in learning the maze, or improvements using the equipment. It is likely that the observed improvements were a result of the combination of both factors. However, as the number of errors was seen to decrease across the trials, it is evident that regardless of any methodological factors some learning was taking place. Furthermore, the working memory task was administered after the completion of the learning trials and performance on this task was significantly lower than trial one of Egocentric Learning. This provides further evidence that performance was influenced by memory improvements more so than familiarity with the equipment. The increase in performance across the learning trials is in keeping with data that is obtained relating to all list learning tasks. This finding supports that of Rey (1964) and Delis and colleagues (2000) who found in the development of learning tasks (the RAVLT and CVLT respectively) that performance will improve with each subsequent trial. Normative data from these assessments suggest that the incidence of errors also decreases as the task progresses and the findings of Egocentric Learning task mirror this notion.

Finally, the egocentric tasks yielded no significant relationships with any of the established memory measures. This could potentially be due to the drastic difference in the methodological design of the task and administration, as it is the only task that utilised virtual reality. All other tasks used for comparative purposes were designed to be administered using pen to paper format or via electronic media (in the case of the developed assessments). Interestingly, while not significant, correlation analyses suggest that with each trial the relationship between the Egocentric Learning task and the Auditory Memory Index increased. This suggests that despite best efforts to minimise verbalisation, individuals utilise an internal dialogue to complete the task successfully. This could be because following directions is a heavily verbally mediated task in real world settings. Despite the absence of object cues participants may still have been able to verbalise, 'take the second left, at the end of this row turn right', and used the maze itself as a visual cue. This finding highlights that although navigating through a maze from an egocentric perspective is conceptually a visual memory task, egocentric processing is likely verbally mediated and thus, warrants further investigation.

Despite limitations, as an independent measure of egocentric memory, this task did offer insight into how individuals learn when negotiating a virtual reality maze in a forward and backward direction. Look errors were significantly more common than move errors among all trials. The ability to look around the maze adds an element of recognition to the task. Most memory research has established that recognition tasks are simpler than free recall tasks as a participant simply has to determine whether they have seen stimuli before or not (Freund, Brelsford & Atkinson, 1969), thus, the ability to look and recognise one's surroundings likely decreased the complexity of the egocentric tasks. This strategy allows participants to adopt an exploratory and recognition approach to complete the task, and it allows for individuals to self correct their errors by recognising that they had not previously seen the environment they were looking at in the video. Furthermore, move errors provide evidence that suggests an individual failed to recognise their environment and subsequently self correct their error, as they pursue the incorrect path despite having been shown the correct path previously. It is more likely then to suggest that a look error could be considered a failure of recall and move errors a failure of recognition. However, this should be interpreted with caution as some individuals may have chosen to utilise looking at their surroundings as a strategy to enhance their memory, thereby weakening the link to failed recall.

A further caveat in relation to the interpretation of the egocentric task results, is that this task utilised a pre-existing app that was not developed for research purposes. While prototypical development data was provided by the company that produced the app (MyPad3D) and the overall maps provided were extensively reviewed to ensure that the two maps selected for the learning and working memory trials were as similar as possible in terms of length, number of turns and complexity, experimental control still restricted to an extent by the availability of the maps provided. Nonetheless, the findings of Experiment 3.2 indicate that incorporating virtual reality tasks into psychometric assessment batteries offers a new perspective and a novel way to measure performance that was previously not possible. The findings also suggest that the development of virtual reality tasks for this purpose, that are standardised cognitive measures, will likely be a worthwhile endeavour that would aid in our understanding of both spatial processing and spatial memory performance.

A Discussion of the Psychometric Properties for the Developed Feature Memory Measures

Within the object stream performance on the span tasks was significantly better than performance on the working memory tasks. This was seen in both the contextual feature tasks and the non-contextual feature tasks. This finding suggests that all four of these tests (contextual feature span/working memory and non-contextual span/working memory) display sound construct validity.

Furthermore, Experiment 3.2 was interested in investigating if the addition of a contextual component in span and working memory tasks would result in higher levels of recall, in comparison to a task that had no contextual component. Experiment 3.2 found evidence of this in both the feature span and working memory tasks with participants performing significantly better in the tasks that provided contextual cues. Tasks that provide context equip a participant with a stronger framework to encode information using multiple pathways (Delvenne, Cleeremans & Laloyaux, 2010). Memory tasks that provide contextual cues are often more easily verbalisable (Xie & Zhang, 2017), contain high measures of ecological validity (Jung, 2015), and allow individuals to use their associative memory to encode the stimuli more deeply, as the context often provides semantic meaning. Stimuli that is easily verbalisable is more relevant to how visual memory is processed in reality, as the visual and verbal systems work in conjunction with one another to aid in effective encoding and retrieval within the visual world (Brandimonte et al., 1997). However, in clinical and research settings it is often necessary to isolate functions to develop a greater understanding of their capacity, provide information about how systems function, as well as aid in the diagnoses of various disease and illnesses.

While the results of the contextual tasks and the non-contextual tasks indicate that they are clearly both measures of memory functioning, there are also clear distinctions within them. The contextual task likely has greater ecological validity, as in reality features of an object are rarely presented in isolation in a manner where they are unable to be bound due to an inherent lack of context. Feature binding in itself is a multifaceted complex process that relies on attention, recognition, bottom up processes and top down contextual cues. When identifying an object in reality, these processes work in conjunction with another to make an almost immediate decision about what is being viewed. Alternatively, the non-contextual tasks are less representative of data in the real world. As highlighted above, rarely is an object displayed in isolation. However, the non-contextual tasks are able to provide greater meaning about how individual features are encoded and recalled as an isolated process. This can allow the exploration of memory function when no other cues are present. In a visual memory task, known contextual cues also facilitate a participant's ability to bind the features into components of an object (Luck & Vogel, 1997). This can aid in the recall of features as they are tied to a meaningful object, and can be viewed more holistically. Context allows encoding to occur from a predominantly top down perspective, as the individual features are not as crucial to overall performance. E.g. If you remember the first feature as mouth and the second as nose, rather than remembering the exact shape the participant is able to discriminate against the presented stimuli and select the one most similar to a mouth then nose. The present findings indicate that performance on the contextual tasks was higher than the non-contextual tasks and this provides further evidence for strong construct validity between these two tasks, as these findings mirror that of the established literature that has also identified that when information is presented in a contextual scene, recall increases exponentially (Haney & Lukowiak, 2001).

When investigating relationships between the developed feature tasks and the pre-existing measures of memory to establish convergent and discriminant validity, a significant, moderate relationship was observed between all the developed feature tasks and the Visual Working Memory Index. It was unexpected that this result would be seen with the Visual Working Memory Index rather than the Visual Memory Index. It is possible that this is due to the Visual Working Memory Index including a task (Symbol Span) that is more akin to tasks developed using the span paradigm, than those tasks that load on to the Visual Memory Index. As the relationship was moderate, this indicates that the tasks are not entirely the same, and thus, it is likely highlighting the similarities in structure and administration. Furthermore, in terms of the feature tasks developed for this thesis, these may place a greater demand on an individual's cognitive load, similarly to the visual working memory tasks included on the WMS. When processing information that is feature based an individual will generally try and bind features in a meaningful way to aid in recall (Luck & Vogel, 1997; Wagner, 1974; Makovski et al., 2008), therefore, it is possible that this added binding process also increases the perceptual resources required to complete the task. As the predominant difference between a a working memory task and a span task is the additional manipulation component, the additional binding component observed in the feature span task may require the same amount of resources as a bound object working memory task. Working memory capacity is believed to be met when an individual is unable to recall and manipulate any more information correctly. Performance for the feature working memory tasks (regardless of the presence of context) was invariably low, and this may be due to an added binding process taking place.

In keeping with robust and long held memory theory regarding visual assessment (e.g. Wechsler, 2008; Gathercole & Pickering, 2001) it was hypothesised that all measures of span and working memory would show a decrease in performance as the number of items presented increases. This hypothesis was supported for all span and working memory tasks developed for use in Experiment 3.2. This finding supports the item analysis data from a range of memory assessments (Wechsler 2009; Wechsler 2008; Benedict 1997; Gathercole & Pickering, 2001). This indicates that as the number of items increase the ability to recall them all successfully is reduced. As the number of items within a trial increases so does the cognitive demand of the participant to complete the task correctly (Sweller, 1988). Once somebody has reached the capacity of their cognitive load they will no longer be able to encode and subsequently recall the information presented to them.

It was also expected that performance on trials within each span would yield similar results. This hypothesis was supported for the two feature span tasks. However, greater variation was observed in the feature working memory tasks. In the Contextual Feature Working Memory task variation was seen between span 2 and 3 before stabilising by span 5. It is possible that this task was difficult for some people and thus, their inconsistent results influenced the mean data, however as they discontinued early their scores did not influence the later spans. In the Non-Contextual Feature Working Memory task similarities were only observed within span 2 with all other spans producing inconsistent results. It is important to note though that by span 5 in Non-Contextual Feature Working Memory all participants had discontinued. Thus, the inconsistent findings are likely due to the task being too difficult for most people.

Finally, it was hypothesised that there would be no floor or ceiling effects on any of the developed tests. This hypothesis was supported. No floor or ceiling effects were observed on any of the tests. However, despite no presence of a floor effect on the Non-Contextual Feature Working Memory task, it is important to be mindful of the low performance on the initial trials. This indicates that many healthy adults had difficulty completing this task, and calls into question the usefulness of this task for individuals with clinical memory difficulties. Furthermore while the data was considered to be normally distributed the item analysis demonstrated that not a single participant progressed past span 4. This provides evidence that the Non-Contextual Feature Working Memory task may be too difficult, however, it also could be due to this task not having high ecological validity, as remembering a series of abstract lines in isolation is not a practiced function because in reality an individual is rarely asked to remember any features with no presence of contextual cues. Thus, this skill may be underdeveloped in most people.

Discussion: Analysis of Capacity Within the Two Streams

A Discussion of Spatial Memory

The lack of relationship between the allocentric and egocentric tasks observed further supports the notion that despite both being measures of spatial memory, they are underpinned by inherently different constructs. As both the allocentric tasks were scored using a point system and the Egocentric Learning task was scored using time it was not possible to standardise these assessments for comparison using parametric analyses. However, Pearson Correlation analyses were conducted to determine whether a significant relationship was present between the tasks measuring memory performance for each frame of reference. No significant relationships were observed between the relevant allocentric and egocentric tasks. This suggests that these tasks are inherently different from one another. However, as these tasks were both designed to be measures of spatial memory, a weak to moderate relationship was still expected to be present.

Past research investigating dysfunctions of perception within the two frames of reference, e.g. neglect, have suggested that allocentric and egocentric processing share many similarities and a dysfunction or deficit in one will invariably involve a dysfunction or deficit in the other (Rorden, 2012). However, research that investigated whether the distinction between egocentric and allocentric deficits could be related to the modality of the presented stimuli, found evidence to suggest that dysfunction can be isolated to either visual or tactile modalities (Marsh & Hillis, 2008). While this research was exploring the relationship between allocentric and egocentric processing in terms of hemispatial neglect rather than memory function, the findings suggest that there is strong evidence that egocentric and allocentric neglect are distinct syndromes, that often dissociate and most likely reflect atrophy in different regions of the brain. Studies exploring the two frames of reference in terms of memory function are scarce, but it is possible that no relationship was found between the two tasks due to the marked differences that can be present in functioning. As memory is considered a higher order task in comparison to perception (Mapou & Spector, 1995), it is possible that the distinctions between the two frames of reference become more apparent when completing spatial memory tasks. Furthermore, the findings support the research of Ishikawa and Montello (2006) and Poirel, Zago, Petit and Mellet (2010) who also stated that from a perceptual point of view allocentric and egocentric information are encoded in different ways. This was further supported by Hartley and colleagues (2003) who used neuro-imaging to demonstrate that allocentric and egocentric frames of reference are also processed by two different regions of the brain.

A Discussion of Object Memory

It was hypothesised that participants would perform significantly better on object based tasks than feature based tasks. Past research suggests individuals are able to remember objects more easily than features (Grubert et al., 2017), as they are often more readily verbalisable and can be encoded holistically. A significant difference was observed between performance on Non-Contextual Feature Span and Object Span. This indicates that an individual tends to have a larger capacity for objects than they do for non contextual features. This finding supports the work of Schurgin and Flombaum (2017) who found that object recognition is generally performed with a high degree of accuracy even when the objects are unfamiliar. Interestingly no significant difference was present between Contextual Feature Span and Object Span. This finding opposes the work of Grubert and colleagues (2017) who investigated the notion that memory for objects tended to be higher than features due to the complex template matching system that exists, that allows for an individual to draw on their stored representations to accurately and swiftly identify a whole object.

Alternatively, this finding is similar to that reported by Luck and Vogel (1997) who stated that there was no difference between the capacity for objects and features. The difference between the findings of the present experiment and past research is that rather than presenting features in isolation for recall, contextual cues were provided, which changed the task from being inherently a bottom up process, where the task relied solely on efficient feature binding, to a top down one where an individual could incorporate context and verbalisation into their encoding strategy. Studies that have aimed to replicate the findings of Luck and Vogel (1997) have often had difficulties and this is likely due to the influence of context. Research that was undertaken recently by Hardman and Cowan (2015) aimed to measure the capacity of features and objects, however, the feature stimuli used in this research were basic lines and edges with no contextual aids, more similar to the non-contextual feature tasks developed for use in Experiment 3. Past research coupled with the findings this experiment may highlight that context may be the definitive factor in encoding object based information. As both contextual features and whole objects facilitate an individuals ability to verbalise or encode the information more deeply, this may be the explanation for why the capacity differences between these two tasks were negligible.

In terms of working memory, performance on both the Contextual Feature Working Memory task and the Non-Contextual Feature Working Memory task was significantly worse than performance on the Object Working Memory task. This indicates that in working memory tasks the capacity for bound objects is significantly larger than the capacity for features. This is also similar to the findings that suggest that the ability to template match and recall objects, that may previously have had no context but due to the binding mechanisms during encoding are given context can further aid in the ability to recall the item (Grubert et al., 2017). Furthermore, due to the perceptual demand required when completing working memory tasks, it is possible that while the contextual cues aided in performance in comparison to the non-contextual task, when demand is increased an individual's cognitive load becomes too full for the contextual features to have an advantage over bound objects. Brandimonte and colleagues (1997; 2008) found that when the demand of a task is too high verbal overshadowing can occur. Verbal shadowing is when verbalisation is found to be a hinderance to a task due to the increase in cognitive load it takes to encode. It is possible that participant's found the working memory tasks so demanding that in the contextual task verbalisation and the binding of the features was found to be too much in comparison to the object working memory task.

Limitations

The egocentric tasks were limited by the use of established mazes on the VR Maze app. While the two mazes selected for measuring egocentric memory were chosen due to their similarities, same number of turns and approximately same distance, they were inherently part of an unstandardised app that was not designed to be used for psychometric testing. The findings derived from these tests do suggest that egocentric memory is inherently different from allocentric memory and suggest that the development of virtual reality egocentric assessment tasks is a worthwhile endeavour.

Furthermore, with the developed Feature Span tasks two factors may have impacted on and limited the results. Firstly, the non contextual tasks presented stimuli as part of an abstract design that was more complex than the contextual task counterpart. At the time of test development this was a purposeful decision to ensure that the non contextual tasks were ambiguous, unclear, and difficult to impose meaning on. However, in undertaking this, the final presentation featured more components that the contextual tasks, and these components were present across the entire tablet display rather than having a clear centralised focus point. This may have contributed to the significant differences that were observed between the feature tasks. While the findings still indicate differences are present, future research may adapt the present tasks to ensure that the designs for each task which highlight features contain similar levels of complexity in reference to the number of features, lines, curves and shapes.

Finally, it should be noted that a face was selected for use in the contextual task. This was chosen as past research indicates that faces tend to be processed holistically, rather than feature by feature (Tanaka & Farah, 1993). Tanaka and Farah (1993) do however, comment in their research that features when presented in a contextual environment, whereby the stimuli is generally encoded holistically, tend to be poorly recalled. While this provides further evidence for the rationale of this experiment, to gain a comprehensive understanding of the influence of context, completing a contextual feature task where the objects are part of a scene (that includes many objects) may provide different results than when ‘context’ is represented by a unitary construct (such as the use of a face in the present experiment).

Conclusion

The findings of Experiment 3 suggest that the capacity of visual memory does not only differ between spatial and object information but that differences also exist within each stream. Furthermore, the analysis of the findings indicate that an individual’s capacity for feature based information is highly influenced by the presence or absence of context within a task. The findings of Experiment 3 also provide further evidence that suggests that capacity for visual information is highly dependent on both the type of information being remembered and the pathway utilised to process it. It also highlights the necessity when investigating visual memory performance to take a holistic approach and account for the various forms of information, as deficits on one visual memory task may not necessarily be indicative of deficits in another task. The findings of the additional assessment tasks highlight the complexity of visual memory and provide further evidence that the comprehensive assessment of visual memory must acknowledge the established findings from current visual perceptual theories (Grubert et al., 2017; Hardman & Cowan, 2015; Rorden, 2012).

CHAPTER 9

GENERAL DISCUSSION

Summary of the Overall Findings

The current project was undertaken with a view to combine knowledge regarding both visual perception and memory, to develop a series of electronic visual memory tests that would overcome past limitations for measuring dynamic stimuli, in an attempt to determine whether differences in both performance and capacity exist between and within the spatial and object streams. The specific purpose was to add to the current body of knowledge about the serial nature of visual memory, as well as the dual stream nature of visual processing, to confirm that there is unlikely one global capacity for visual memory but rather capacity and performance are entirely dependent on the kind of information being remembered. Healthy adults with no history of neurological or psychological illness were studied. It was hoped that the developed series of tests could identify potential differences in visual memory capacity for information that was spatial or object in nature.

An examination of the literature surrounding visual perception theories, memory theories and the development of tasks assessing visual memory was undertaken. This examination identified that anatomically the two streams hypothesis is the most widely understood and accepted theory of visual perception. The key finding that emerged was that visual perception is a multifaceted, complex cognitive process and that much of what is known about visual memory has been gleaned through the lens of a verbal memory paradigm. That is, it simply follows the serial process as outlined in the modal model of memory (Atkinson & Shiffrin, 1968). While this has provided a strong foundation, visual memory is arguably more complex than verbal. Visual memory relies on intact perceptual systems to interpret and remember visual information.

Subsequently, investigating visual memory through the integration of the modal model of memory with the established two streams hypothesis of visual perception underpinned the test development and experiments of this thesis. During test development and Experiment 1, information from both perception and memory theories was integrated to develop a novel series of tasks that acknowledged the dual nature of visual processing and its relation with the serial nature of memory. The influence of context both on one's ability to process and encode visual information, was highlighted throughout both the perception and memory literature. Thus, the test development endeavoured to limit the influence of context as much as possible in Experiment 1 in attempt to reduce verbalisation which can allow participants to rely on a verbal strategy to recall visual information.

In Experiment 1 a series of tasks were developed to measure spatial and object short term, working and long term memory respectively. These tasks were designed by analysing the strengths and weaknesses of numerous current established measures of visual perception and memory, as well as the theoretical underpinnings that guided their development. Tests were designed to be structurally similar to one another to aid in the analysis of scores. Span and working memory tasks were designed to use similar stimuli and test design, with the only different component being the 'manipulation' aspect. The aim of this was to ensure that any differences in scores could be assumed to be the result of memory function, rather than potentially confounding variables. In keeping with established measures of long term memory and learning, learning and delayed recall tasks consisted of identical stimuli being repeated four to five times sequentially to aid in strategy development and encoding. This gave participants an opportunity to thoroughly learn the information before being asked to recall it at a later time.

As a result of the test development seven tasks were created and piloted as part of Experiment 1. Pilot testing of the new tasks aimed to investigate their validity and reliability in relation to established measures of visual memory. The span and learning/ delayed measures demonstrated good construct validity and internal consistency. The two working memory tasks however yielded less than ideal results. Spatial Working Memory demonstrated poor internal consistency from the item analysis, as some items were found to be more difficult than others. Alternatively, Object Working Memory demonstrated poor construct validity as there was no significant difference between working memory and span scores in this domain. Based on the findings of Experiment 1 these two tests were revised to address the identified issues. The revised version of Spatial Working Memory (which utilised a rotated maze) incorporated an extra trial for each span (one at each rotation; 90, 180 and 270 degrees), designed to mitigate the internal consistency error, as now all degrees of rotation were present for all trials. New stimuli were developed for the Object Working Memory task to ensure recalling the stimuli in this task would be of equal difficulty to the first task and that participants were not able to utilise the familiarity of stimuli from the span task to cue recall and enhance their scores.

The next step in fulfilling the purpose of the overall project was to examine the psychometric properties of the revised tests and conduct analyses to determine whether there were differences present in scores between the spatial and object domains. The sample for Experiment 2 consisted of a new population of healthy adults, to ensure that practice effects and prior knowledge of the tasks would not influence performance in any way. The psychometric properties of the revised working memory tasks demonstrated good construct validity and internal consistency and were thus deemed appropriate for use in further analysis. As was expected significant differences were found between memory for spatial and object information for span, working memory and learning tasks. These results have important clinical implications for those who are measuring visual memory function, as this identifies that the capacities of the components of visual memory are significantly different. Thus, the results imply that clinicians should seek to consider each stream separately when selecting tasks to measure visual memory, and when considering the implications of the results. This is especially important when profiling strengths and weaknesses. This has the potentially to implicate patients undertaking clinical assessment, whose deficits or strengths may not be successfully identified. It also has implications for researchers, as it highlights the need for investigative studies exploring visual memory to select precise methods related to the pathway that they are interested in exploring. While Experiment 2 did identify that the capacity differs between the streams, this experiment cannot claim to have developed measures that exhaustively measure spatial and object information. To do this additional assessment tasks that advance the developed measures would be necessary. Nonetheless, these findings clearly identify that capacity differences are present for spatial and object information.

Based on the promising findings from Experiment 2 that indicated that there were clear differences between the capacity for spatial and object information, additional tasks were developed and piloted to determine whether there were also differences present for capacity within the two streams. The newly developed object tasks demonstrated good psychometric properties. These tasks were designed to measure memory for unbound features, and a contextual and non-contextual version were developed. Significant differences in capacity were observed for all three object measures (Object Working Memory, Contextual Feature Working Memory and Non-Contextual Feature Working Memory). Significant differences were also observed between the Non-Contextual Feature Span task with the other measures of span. Surprisingly, no differences were observed between Contextual Feature Span and Object Span. This was expected to have occurred due to both tasks having a contextual component, as by definition an object, even abstract in nature, carries context. Furthermore, research suggests that in the presence of context, where there is an ability to verbalise, no differences in capacity will be present (Luck & Vogel, 1997). To further investigate memory for spatial information, a virtual reality measure was incorporated to investigate egocentric memory. The findings of this task were consistent with past research with performance on the Egocentric Working Memory task being worse than on the first trial of the Egocentric Learning task. When investigating capacity differences within the spatial stream, the egocentric tasks were found to yield no relationships with the allocentric tasks, indicating that they likely measure two entirely different constructs.

The findings of this thesis indicate that a global, unified capacity for visual memory does not exist. Rather, visual memory capacity/performance is dependent upon the kind of visual information being presented, and that different anatomical regions are implicated in the processing of each type as would be predicted by the two streams hypothesis (Milner & Goodale, 1992). Furthermore, demarcations were also found to be implicated within each stream. Differences in capacity were found for spatial information in terms of whether information was presented from an egocentric or allocentric frame of reference, and differences in capacity were present for objects related to features compared to whole objects. Thus, the key finding of this thesis suggest that the capacity for visual information is not just derived from what stream the information is processed in, but also that different capacities for information exist within each stream as well. The findings of this thesis also suggest that visual memory likely requires a more exhaustive and detailed model to encapsulate the multifaceted and complex nature of visual memory function. Figure 9.1 shows a more comprehensive conceptualisation of the modal model of memory in reference to the dual streams that was put forth in Experiment 3.

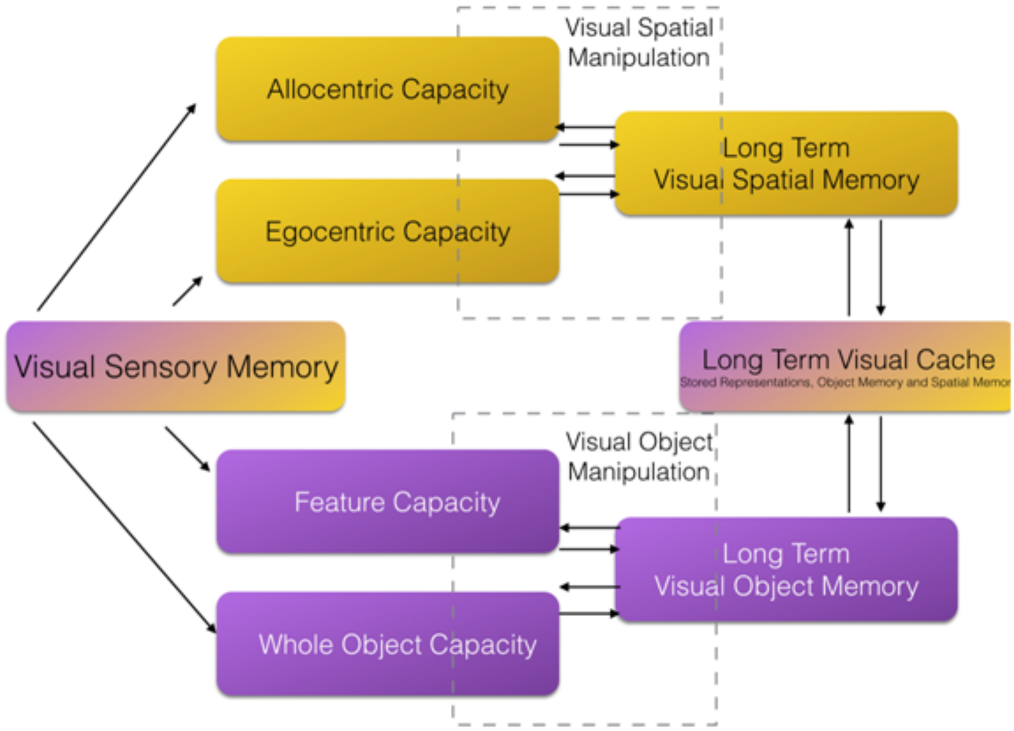

Figure 9.1. *A Conceptualisation of the Visual Memory System in Relation to Memory and Perceptual Theories*

This conceptualisation extends the modal model of memory defined by Atkinson and Shiffrin (1968) to demonstrate that visual memory, while still linear, is a multifaceted cognitive function. This model integrates the modal model of memory with the two streams hypothesis to demonstrate the demarcation of spatial and object processes while still acknowledging that differences exist within each pathway as identified by the findings of Experiment 3.

Implications of the Spatial Memory Findings

Spatial memory assessments in the past have been more limited in number than their object memory counterparts. While tasks such as Corsi Blocks and Spatial Addition are routinely used in clinical assessments, spatial assessments do tend to be less common due to the difficulties in measuring dynamic information (Ciaramelli et al., 2010; Strauss et al., 2006). The present thesis aimed to develop dynamic spatial tasks that were standardised in administration by incorporating electronic media. As a perceptual concept how spatial information is processed is widely understood (Valentinos et al., 2015; Wokke et al., 2014; Undgerleider & Mishkin,1982; Goodale et al., 1991). The original spatial subtests (renamed Allocentric subtests in Experiment 3) required participants to remember spatial information presented to them from an allocentric frame of reference. This frame of reference has dominated test design in the past due to the ease of developing measures that can assess this skill, and its high ecological validity (Van der Ham, 2015). Despite some of the complications that arose, the methods used and the findings generated by the developed allocentric and egocentric tasks in the present thesis highlight the notion that these two processes are inherently different functions.

Moreover, the incorporation of both an allocentric and egocentric memory measure provided insight into how individuals encode information presented to them to navigate their way through a task. As allocentric tasks are presented in a manner that allows individuals to view the entire image at once (e.g. a top down view of a maze) it allows participants to process the maze holistically (Ruddle et al., 2013) in reference to both the start and the end point, and allows them to problem solve using the length and shape of the lines within the maze, as well as by being informed by the completed pathway. Alternatively, when completing a task from an egocentric frame of reference participants are only capable of processing what is directly in front of them (Tenbrink & Salwixzec, 2016). In these tasks participants are more likely to adopt an exploratory approach to problem solving, where they can view all the current aspects within their visual environment, and make decisions about what turn to make based on the recognition of information within the field. These two vastly different approaches to task completion further indicate that their is strong evidence to suggest that allocentric and egocentric memory are vastly different from one another, and subsequently measures investigating how spatial information is processed should aim to ensure that each frame of reference is being thoroughly considered, to provide a comprehensive analysis of spatial memory functioning.

The present thesis identified that electronic media enables a number of the methodological limitations of visual memory assessment to be overcome, and the developed tasks demonstrate that dynamic measures of spatial span, working memory and learning can be created and implemented. The allocentric spatial tasks produced promising findings with the ability to remember complex, rotated mazes being much more difficult than the standard, static versions. The ability to create stimuli that was presented in a dynamic way, requiring the participant to utilise their inner scribe (Logie, 1995), made these tasks useful from an ecological standpoint, as when viewing a map many people will trace and remember a dynamic path to determine what direction to go. However, difficulty arose when identifying a method to accurately measure egocentric memory. In the past researchers had been limited in their ability to accurately egocentric memory in a laboratory environment that was portable and allowed them to view what the participant was seeing from first person point of view. The utilisation of virtual reality equipment in this thesis aimed to address these issues. As virtual reality is a relatively new form of electronic media, only becoming available for consumer use in

2016, (Verge, 2016) there were limitations surroundings its use in cognitive assessment (further addressed in the limitations section of this chapter). The present thesis notes the potential of incorporating virtual reality measures into spatial memory assessments, however, further investigation into its utility and the development of specific egocentric memory tasks is warranted.

Implications of the Object Memory Findings

The main findings of Experiment 3 highlight the importance of context when processing object related information. The addition of two feature based assessments to Experiment 3 has elucidated profound findings in relation to object memory functions. While a significant difference was observed between memory for bound object and non contextual features, when the features were presented in context this difference was not present. Luck and Vogel (1997) in their seminal work identified that there is no difference in one's ability to remember features or bound objects, as bound objects are seen as a unitary entity just as an individual feature is. Attempts have been made to replicate these findings since, and this endeavour has been largely unsuccessful. For example Hardman and Cowan (2015) has reported that significant differences are present between the two, with participants consistently reporting higher scores for objects when compared to features. The difference between an object and a feature is that it is often simpler to impose meaning or context to a whole object than it is an individual feature (which may consist primarily of a line) (Luck & Vogel, 1997). This notion is evident in the findings of Experiment 3, whereby, object performance exceeds feature performance except when context is provided to encode a feature. When a feature is presented in context and is able to be verbalised it can be encoded via both visual and verbal memory pathways (Schurgin & Flombaum, 2017). This allows for a deeper level of encoding and will improve ones ability to recall information at a later date. Thus, supporting both the opposing findings of Hardman and Cowan, (2015), Delvenne and Bruyer (2004) and Wheeler and Treisman (2002), and Luck and Vogel (1997), the findings of Experiment 3 indicated that whether a difference is present between features and objects is conditional on how much context is given. The presence or absence of context may be why studies such as Hardman and Cowan (2015) and Delvenne and Bruyer (2004) observed significant differences. Features presented without context are more difficult to recall than both contextual features and bound objects. Alternatively, the presence of context during the presentation of features, aids in the binding process, and thus may explain why no differences are observed in these trials.

The findings of the present thesis align with other phenomena that is present in the verbal memory literature. Chunking is known to enhance verbal memory capacity (Capaldi, Nawrocki, Miller & Verry, 1986), and essentially an object can be seen as a 'chunk' of features. Furthermore, chunks that have meaning applied to them are encoded and recalled more efficiently than those that lack context (Nassar, Helmers, & Frank, 2018). This is further established in the findings of Experiment 3 whereby, objects are recalled more readily than features presented with no context, whereas the presence of context aids in recall due to providing a meaningful chunk. Moreover, it does also offer insight to areas that may warrant further investigation. The notion of phonological similarity contends that, words that are phonologically similar are more difficult to recall than phonological dissimilar words (Copeland & Radvansky, 2001). It is possible, if a visual analogue to this phenomenon exists, that may explain poor performance on the feature based tasks, as all stimuli included were either curved or straight lines, and thus, low scores may have been due to the stimuli being too similar to distinctly recall. Further evidence, for the idea of a visual similarity analogue may be evident in the stimuli developed for the object tasks. As these abstract objects were designed to be complex but still distinct from one another, this may have attributed to higher scores. It is clear that there are likely other variables that are influencing capacity however, in what manner and to what degree warrants further investigation.

Furthermore, the findings of Experiment 3 may address the long standing controversy that has existed that has aimed to investigate the 'slot model of memory'. Zhang and Luck (2008) proposed the slot model of visual memory and this model implies that visual memory has a predetermined number of slots (like verbal memory), each able to maintain one item and this idea is analogous with span capacity. Based on the findings of Luck and Vogel (1997) and the findings Zhang and Luck (2008), a single feature and a bound, multi feature object both take up the same amount of space within these slots. However, other studies (Wheeler & Treisman, 2002; Delvenne & Bruyer, 2004; Hardman & Cowan, 2015)) noted differences in performance between feature based tasks and object based tasks. It is possible that the influencing factor in visual memory is the presence of context. When a feature is present in a contextual environment an individual will bind that feature to the overall object. This enables the participant to encode the information more efficiently. For this reason a feature present in context occupies the same number of 'slots' as a whole object. When multiple features are present the perceptual demand is not as high as features in isolation because the individual already has the overall object represented in their mind and is just required to add detail. For example, in the Contextual Feature task, the use of a geometric face provided a point of reference for all features. Participants were able to encode stimuli as 'nose', 'mouth' etc, and then when presented with the discrimination array, rely on recognition of each facial feature to select the correct geon. When no context is present the cognitive load is raised and every individual feature requires a greater level of cognitive demand to store even the most basic of features. In the Non-Contextual Feature task, participants were unable to anchor the geons presented to them in any meaningful way and this impacted their ability to recall significantly. Features in isolation are difficult to encode efficiently, as adopting a strategy that makes them meaningful invariably requires them to be bound to other features, therefore, the cognitive demand to remember these stimuli is much greater, and subsequently far less information is able to be remembered. Reviewing the concept of the 'slot' model of memory in light of the findings of Experiment 3, it can be inferred that visual information does not fit neatly into the 'slot model', but rather the amount of cognitive demand involved in remembering the stimuli is a greater predictor of memory recall.

Based on the findings of Experiment 3, the notion of ecological validity can be evaluated. While no statistical floor effect was observed for the Non-Contextual Working Memory Task, participant's scores ranged from zero to four, indicating that in general performance was poor. As the sample utilised healthy individuals the practical applicability of incorporating a non-contextual assessment task with clinical populations may be questioned. The inclusion of the non-contextual tasks was important as it has informed researchers not only on the impact of context, but also on the difficulties encoding feature based information in isolation. Nonetheless, these low scores highlight the difficulty of encoding and recalling non-contextual features, and provide further evidence that the type and context of visual information impact on capacity.

Therefore, the findings of Experiment 3 suggest that to obtain an accurate and pure measure of an individual's object memory, abstract, difficult to verbalise, non contextual shapes should be utilised, regardless of whether the task is evaluating memory for bound objects or features. This will reduce the ability for participants to spontaneously name the objects presented to them which generally results in the participant encoding information verbally or via both the verbal and visual network, potentially enhancing their performance. It also may result in participants' scores being more reflective of their verbal memory skills, as they may be able to compensate for their visual skills by applying context and language skills to aid in recall. However, these suggestions are not necessarily relevant when evaluating everyday memory skills. It is therefore, also suggested that while the incorporation of a contextual component may be limited by confounding variables, it likely has high ecological validity, and performance on a contextual task is more indicative of every day functioning. Thus, depending on the question being investigated, the nature and design of the object information analysed should be carefully considered based on the findings in the present thesis.

Contribution to Knowledge

The Pursuit of Visual Memory Capacity

The current thesis aimed to investigate the longstanding contention surrounding the capacity of visual memory. This contention was born from established verbal memory research that was able to confirm that the standard capacity for verbal memory was seven plus/minus two. While it is known that specific factors can enhance or diminish performance, this value was able to be established as the units utilised in verbal memory are always the same (auditory bites of information e.g. phonemes, numbers, words, non-words) (Zhang & Luck, 2008). However, perception theory highlights that visual information is not unitary in its structure or its function (Macko et al., 1982;). Depending on the nature of the information it can even be processed by two entirely different regions of the brain (Milner & Goodale, 1992). For a number of years memory researchers have attempted to identify the universal capacity for visual information and their research has been hindered by methodological limitations (Gathercole & Pickering, 2001) and difficulties in replicating the findings of past research (Humphreys, 2016; Schurgin & Flombaum, 2017). The present thesis intended to take a holistic approach to investigating visual memory that incorporated findings of past perceptual and memory research, and address through the use of electronic media, a number of longstanding limitations. Similarly to past research (Mercer, 2014; Sperling, 1963; Sewell et al., 2014; Wagner, 1974), the findings of the present thesis were also unable to encapsulate a universal capacity for visual memory. Rather, it proposes a new perspective, and based on the findings derived suggests that a universal capacity for visual memory may not exist. It is by nature elusive. Perceptual theory dictates that visual information is not unitary. Rather it is complex and ever changing, and thus, we are required to encode, process and recall this information in a more complex way than verbal information.

In terms of span the present thesis found that depending on the nature of visual information being processed capacity may be significantly different. Furthermore, results from all tasks indicate that memory performance is functioning as it should as per Atkinson and Shiffrin's (1968) model of memory i.e. span performance is greater than working memory performance, performance increases over learning trials. Thus, we can accept that the visual memory construct aligns with the same outcomes that are observed in the assessment of verbal memory. While future research is needed to firmly establish the capacity of each component, the current findings are enough to suggest that each component does measure a distinct function, that has its own strengths, weaknesses and capabilities that are separable to other visual memory functions.

Perceptual theory dictates that our ability to provide meaning to the world is impacted by our level of intelligence (Tadin, 2015), our sex, our age (Norman, et al., 2018), and our occupation (Laxton & Crundall, 2018). So given that, the pursuit of visual memory capacity will continue to be a complex research endeavour. The present thesis, does provide a foundation for investigations moving forward. It offers a standardised, consistent and thorough measure of visual memory that will aid in further understanding the role of the two streams of perception. If this series of assessment tasks is further standardised and normed, and coupled with neuro-imaging data then this will provide a platform for the development of a formal visual memory model. The foundations that this thesis lays, by developing a standard way of measuring memory for a broad range of visual information, will have the ability to aid in the pursuit of a thorough understanding of visual memory.

Practical Contributions to Knowledge

The practical contribution to neuropsychology is the introduction of a series of visual memory assessment tasks for adults, that demonstrates promising psychometric properties and that builds on the developed theories of visual processing and the serial nature of memory. The pilot data of the developed tasks indicates that they show promise, and with further investigation of their psychometric properties and subsequent establishment of norms may allow clinicians to hone in and clearly identify specific strengths and weaknesses within their client's visual learning and memory function. This could lead to more relevant interventions that target problems within the dorsal and ventral streams specifically rather than visual memory generally. A more detailed assessment of visual memory will equip clinicians to talk to their clients who have visual memory problems specifically and tailor interventions that acknowledge what facets of visual memory are intact and which are relative weaknesses. This should improve the ability to target intervention strategies and has the potential to reduce the chance of emotional problems developing as a result of a negative diagnosis.

This thesis also piloted assessment tasks designed and implemented for tablet devices, that investigate the dual nature of visual processing. The promising findings suggest that this may be a possible avenue for test development in the future. Utilising electronic media can allow neuropsychologists more freedom with how they approach visual memory assessments as they are no longer restricted by the limitations of pen to paper or desktop tasks (Groth-Marnet, 2009). For example, the developed tasks allowed for visual stimuli to be presented in motion in a standardised format, which is not presently possible in pen to paper form. Currently, most cognitive neuropsychological tests are pen to paper tasks. One of the primary implications of the development of this battery of tests in electronic format is the potential that it will lead to an increase in efficiency (Paddock, 2015), accessibility and client engagement (Walterfang & Velakoulis, 2016) during the often arduous assessment process.

Limitations and Methodological Concerns

While the findings of the present thesis were able to yield a substantial number of significant results indicating that there are performance differences in tasks that measure various aspects of visual information, some methodological issues did arise. Firstly, the implementation of the grand mean to standardise the Spatial Span and revised Spatial Working Memory task was the most robust measure available, however, it is not as accurate as standardisation that utilises z scores derived from the population mean. The grand mean has the potential to not be entirely representative of the data however, was a necessary method to incorporate to allow for comparisons of mean scores to be undertaken.

The use of the virtual reality headset and Maze VR app was a prototypical investigation that yielded promising results. It was beyond the scope of the current project to purposely develop a new application for the egocentric maze task, thus a pre-existing app was selected for use. The app was also developed as a game for any individual to download on to their iPhone, and was not designed for use as a psychometric assessment task. The two mazes selected for the span and working memory task were selected to be as similar as possible within the confines of existing maps. Mazes that had been standardised may yield more consistent and representative results.

Electronic media allows information to be presented dynamically and it also allows for the timing and administration of tasks to be standardised and programmed into the test. The present research was limited however, as participants were required to respond using pen to paper response sheets. With tablet devices becoming more advanced in what they are able to do, future research may be able to produce more accurate results by allowing participants to view the information on the tablet device and then respond on the same device. The recent adaption of the WAIS and WMS to tablet devices has incorporated this, however at the time of this thesis they utilise one tablet device for stimuli presentation and another separate tablet for the participant to respond on (Pearson, 2013). This adds considerably to the expense of these test batteries, and was beyond the scope of the current project. Having the ability to respond to stimuli on the same device it is presented on will potentially provide a more efficient assessment experience. Similarly to other tasks that have been developed for tablet use, the developed tasks will also allow the incorporation of computer scoring which will in turn reduce the likelihood of experimental error (Walterfang & Velakoulis, 2016), Unfortunately addressing these concerns was not within the scope of the present thesis.

All the experiments conducted as part of this thesis were pilot or exploratory in nature. The samples were of a sufficient size for statistical differences to emerge ($p<.05$) and for findings to be declared as accurate. However, future research is needed to substantiate these claims before further conclusions are attained. Furthermore, while the findings investigating the psychometric properties were substantial enough for use in pilot investigations, before incorporating them into future investigations or clinical settings more substantiative investigations should be undertaken to further establish the psychometric properties and develop normative data.

Directions for Future Research

Based on the findings of this thesis the following areas for future research are proposed. In relation to the developed tests incorporated in this thesis, it may be worthwhile to consider standardising those that showed promise for potential use in clinical settings. Furthermore, from a research perspective it may be worthwhile investigating the results of the developed assessments on a range of individuals who have clinical diagnoses that effect either visual perception or memory.

The present thesis aimed to investigate whether the capacity for visual information was dependent on the nature of the information being remembered. While the findings conclusively suggest that this was true, further research may be interested in replicating these studies with other samples to investigate the consistency of the findings. Comparing each function and finding similar results with samples that vary in terms of age, education attainment, mental health conditions and neurological conditions would further suggest that there are specific capacities for visual memory and that each specific component must be treated as its own individual function. Thus, investigating whether a standard capacity for each component is present with varied individuals, would further highlight the need to view visual memory as a more complex serial process as Figure 9.1 suggests. Future research would also allow for further investigation for the influence of context, perceptual demand, verbalisation and mode of presentation on visual memory performance for both the spatial and object domains. Subsequently, a deeper understanding of factors that influence visual memory capacity could also be undertaken.

Conclusions

Overall this thesis aimed to both develop a comprehensive, electronic visual memory battery as well as breakdown and investigate the various components of spatial and object memory. The following general conclusions can be drawn from the series of experiments:

Visual Memory

- The results of this thesis suggest that there is not a global capacity for visual information but instead visual memory capacity is dependent on the kind of information being remembered. E.g. Results from Experiment 2 indicate that the capacity for spatial information is greater than object information for span, but this is reversed for working memory.
- Differences in capacity are not solely limited to the two streams process but rather differences for information processed within both the dorsal and the ventral streams also exists.

- For a memory model to be representative of visual memory it must acknowledge not only the established serial model of memory put forward by Atkinson and Shiffrin (1968) but also must incorporate established visual perceptual models, such as the two streams hypothesis (Milner & Goodale, 1992) to provide a more accurate and comprehensive understanding of the nature of visual memory

Test Design

- A series of electronic visual memory assessments that demonstrate sound construct validity in relation to both the theoretical notions of memory and current established assessments of memory can be developed. These tests when administered to a healthy population demonstrated good internal consistency between items and with no presence of a ceiling or floor effects (unless it was expected as observed in the delayed memory trials).
- Results of Experiment 3 support the use of virtual reality as a valid measure that can be incorporated into psychometric assessment tasks. However, this warrants further development and exploration.

This thesis was unique in that it adopted a theoretically-driven approach to visual memory assessment that paid homage to both visual perception and visual memory theories. Performance on the electronic visual memory assessment tasks that were developed and inspired by the two streams hypothesis of visual perception were explored among samples of healthy adults. The findings make a unique contribution to the literature and offer a potentially new way of conceptualising and investigating visual memory. Such experiments are critical in further understanding complex cognitive functions and developing appropriate assessments that encapsulate this function, based on past research in all fields relevant to the specific skill. Further work is however, necessary in determining whether an exact capacity exists for visual memory function in each of the conceptualised areas. This will allow the gap to be bridged between various perceptual and memory models, and will have impact on research and the implications for clinical practice. Moreover, further investigation is also warranted when it comes to standardising electronic batteries to large samples of adults for potential clinical use. This may improve both the research and clinical experience for clinicians, patients, researchers and participants. Electronic batteries may increase the efficiency of conducting cognitive assessments and aid in an overall more accurate and standardised method of assessment.

In summary, the present thesis was undertaken with the intent to investigate the visual memory system by integrating theoretical concepts and assessment paradigms from two different cognitive domains. By utilising the two stream hypothesis of visual perception (Milner & Goodale, 1992) and the modal model of memory (Atkinson & Shiffrin, 1968), the present thesis was able to identify that clear capacity differences exist for spatial and object information. An extension of these findings that involved components of visual information that are not traditionally assessed (egocentric memory and feature memory) provided further evidence of these differences. While a conclusive understanding of visual memory has eluded researchers for decades, these findings can provide the foundations to understand this system through a theoretical lens that pays homage to perceptual and memory theory, thus providing a greater understanding of how we comprehend, and remember our complex visual world.

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Appendix A

Visual Memory Scale

Examinee Name Sample

Examiner Name Sample

Total Scores

	Spatial Memory		Object Memory	
Index	Total Score	Span Score	Total Score	Span Score
Short Term Capacity				
Manipulation				

	Spatial Learning	Object Learning
Immediate Recall		
Total Recall		
Learning Curve		
Delayed Recall		

	Easy Pairs	Hard Pairs	Total Scores
Learning Trial 1			

Learning Trial 2			
Learning Trial 3			
Learning Trial 4			
Delayed Trial			

Weschler Memory Scale

Raw Score to Scaled Score Comparisons

Subtest	Raw Score	Scaled Score
Logical Memory 1		
Logical Memory 2		
Verbal Paired Associates 1		
Verbal Paired Associates 2		
Designs 1		
Designs 2		
Visual Reproduction 1		
Visual Reproduction 2		
Spatial Addition		
Symbol Span		

Sum of Scaled Scores to Index Conversion

	Auditory Memory	Visual Memory	Visual Working Memory	Immediate Memory	Delayed Memory
Sum of Scaled Scores					
Index Score					
Percentile Rank					
Confidence Interval 95%					

Weschler Abbreviated Scale of Intelligence

Subtest Scores

Subtest	Raw Score	T Score
Vocabulary		
Block Design		
Similarities		
Matrix Reasoning		

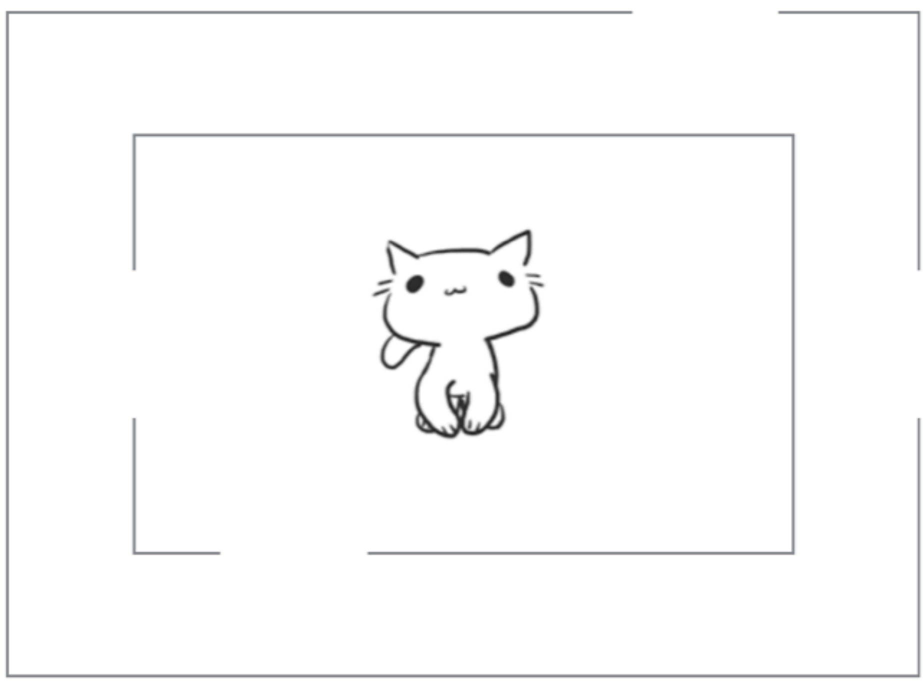
Sum of T Scores

	Sum of T Scores	IQ	Percentile	95% Confidence
Verbal Scores				
Performance Scores				
Full Scale IQ				

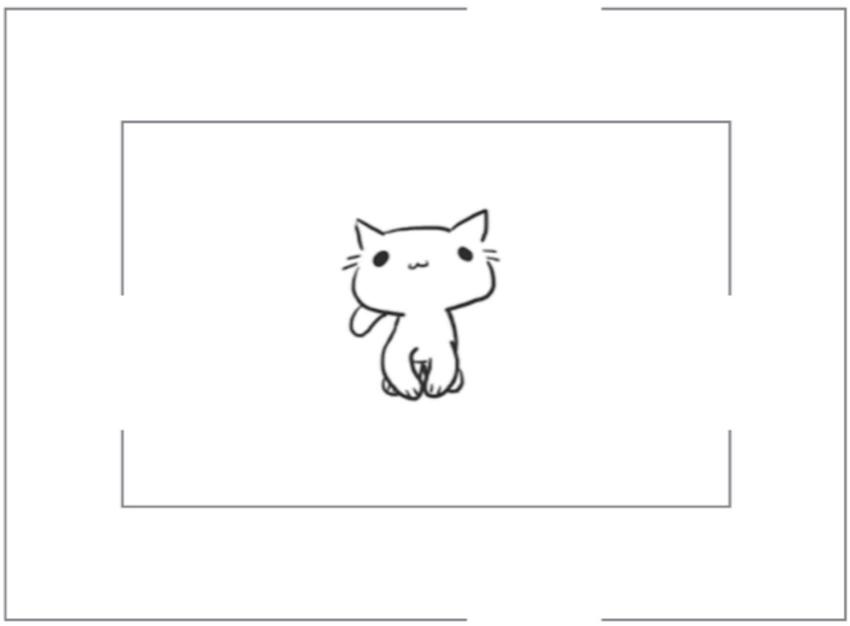
Maze Escape Response Booklet

Practice Trial 1

Practice Trial 2

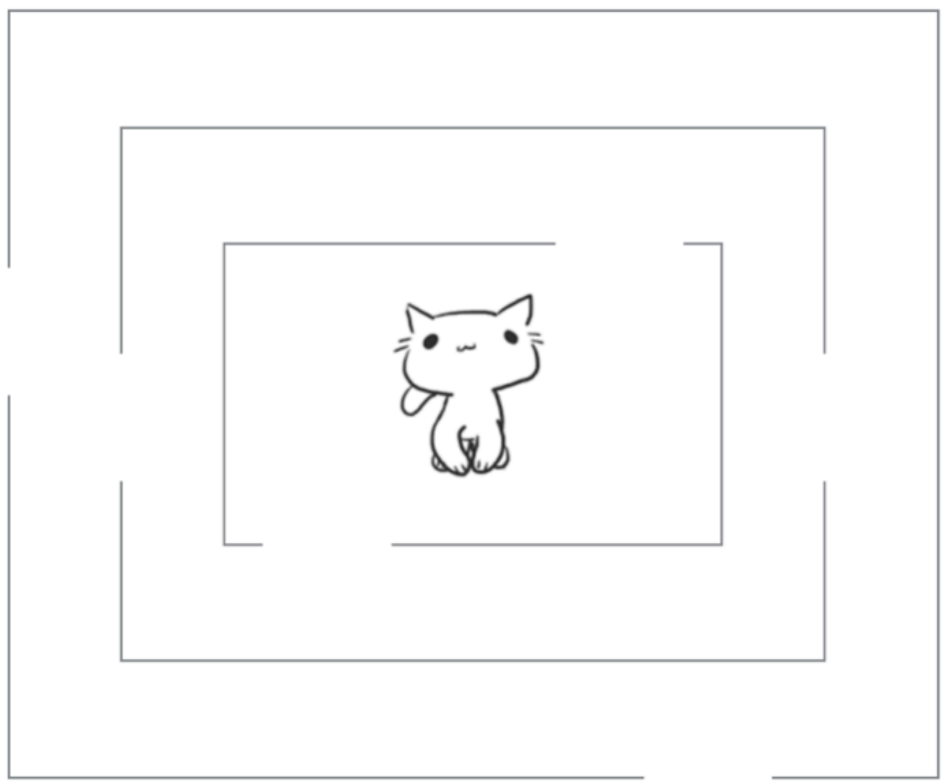


Trial 1

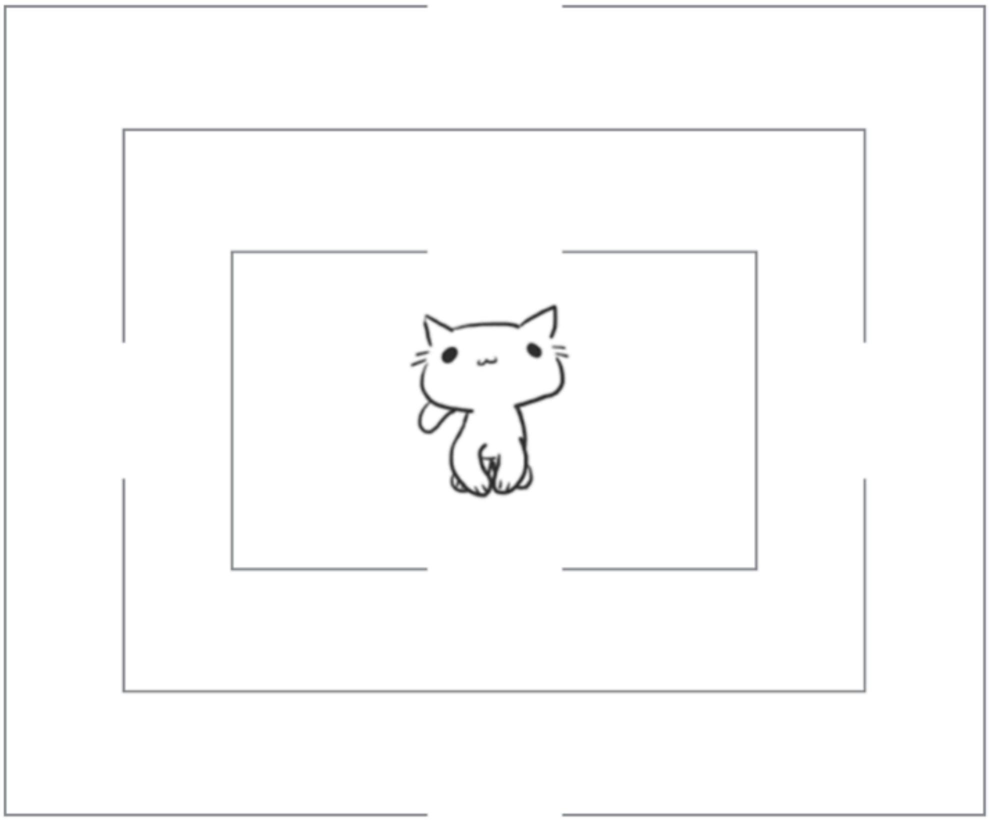


Trial 2

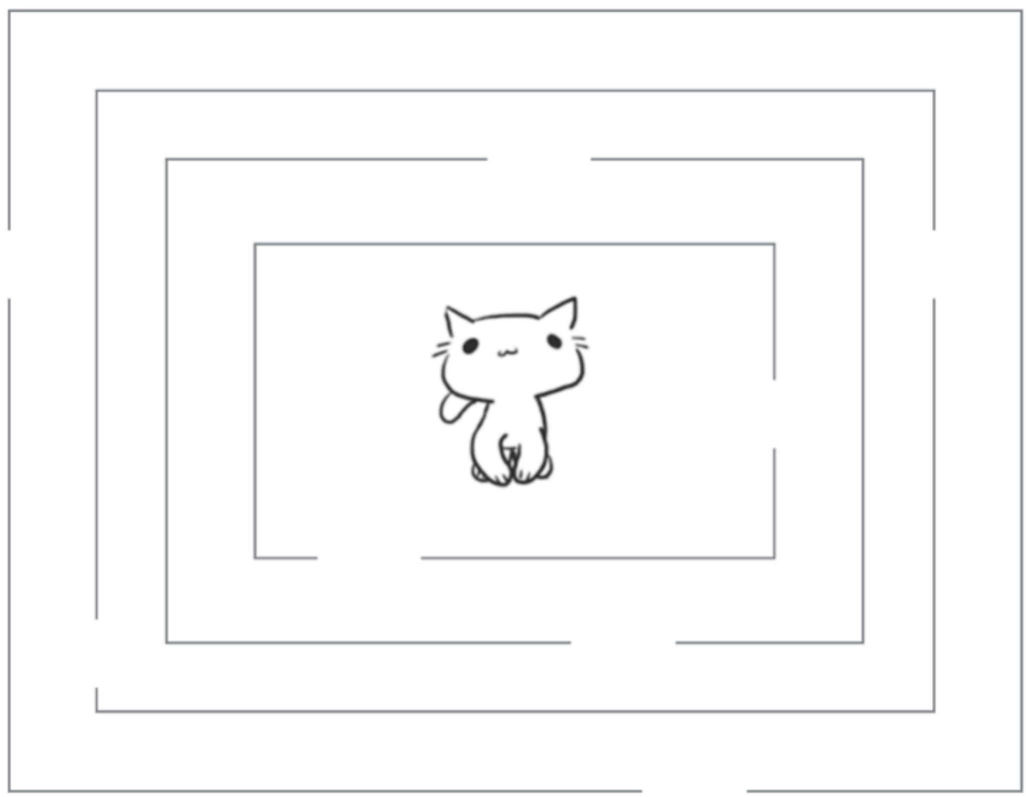
Trial 3



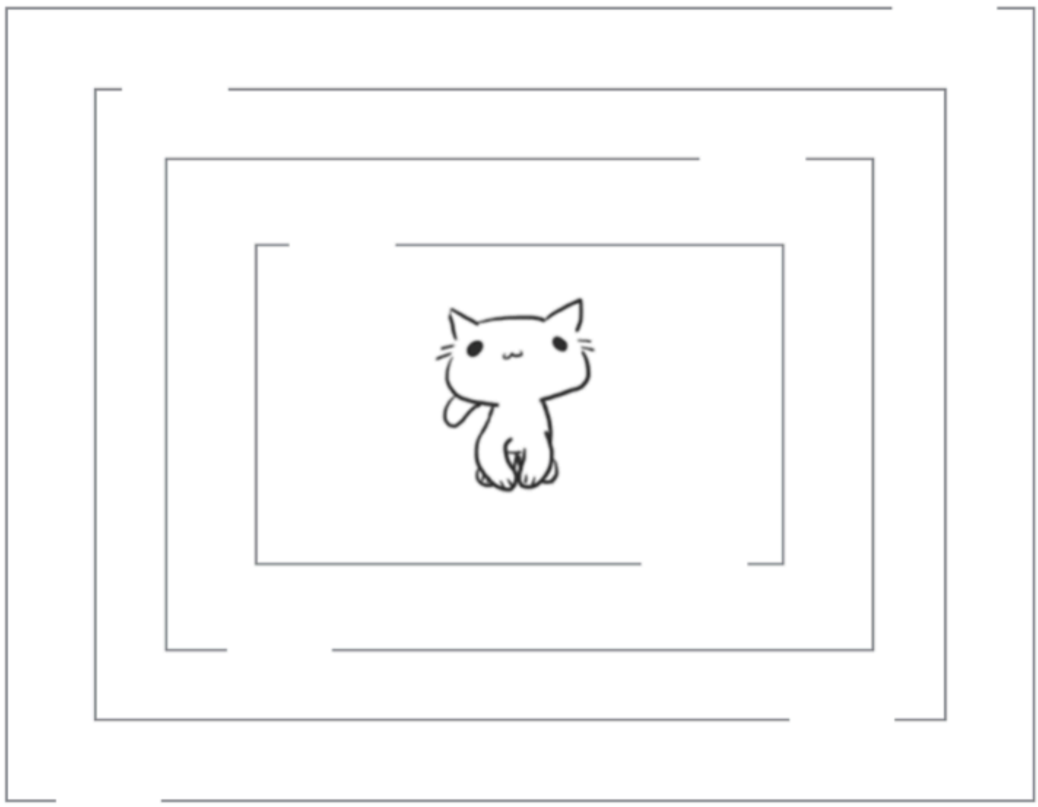
Trial 4



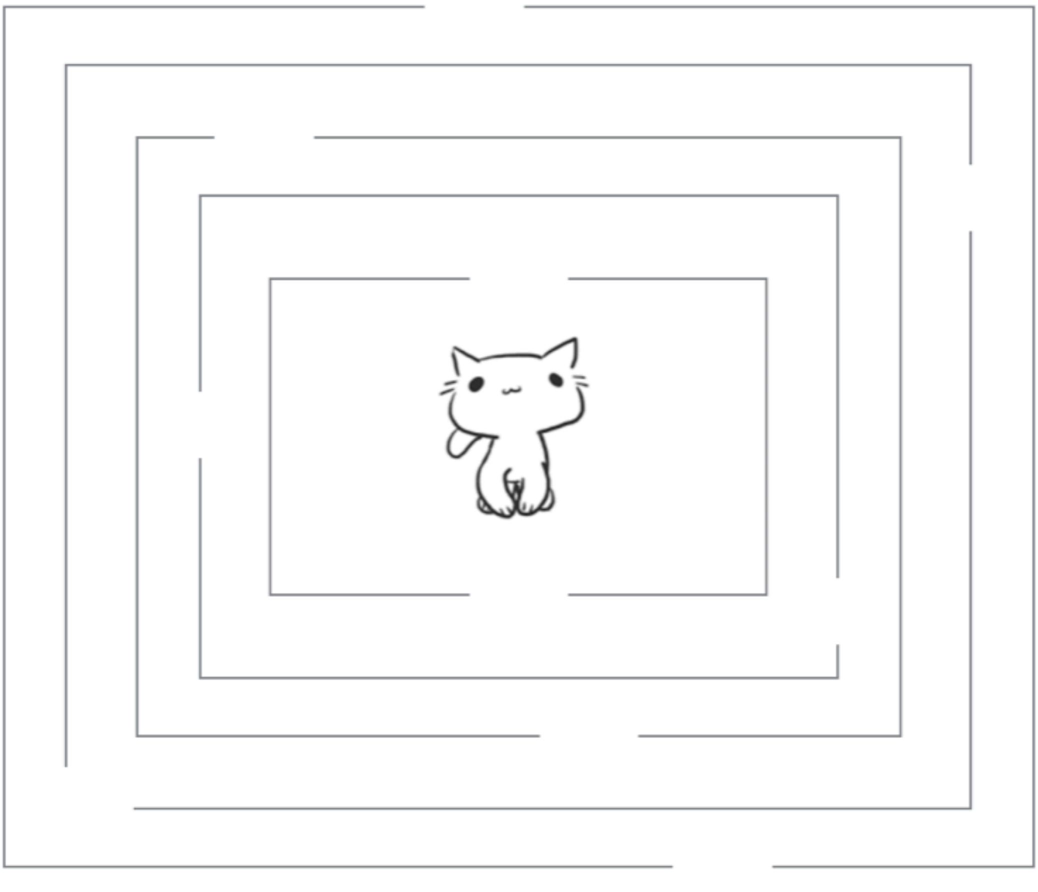
Trial 5



Trial 6

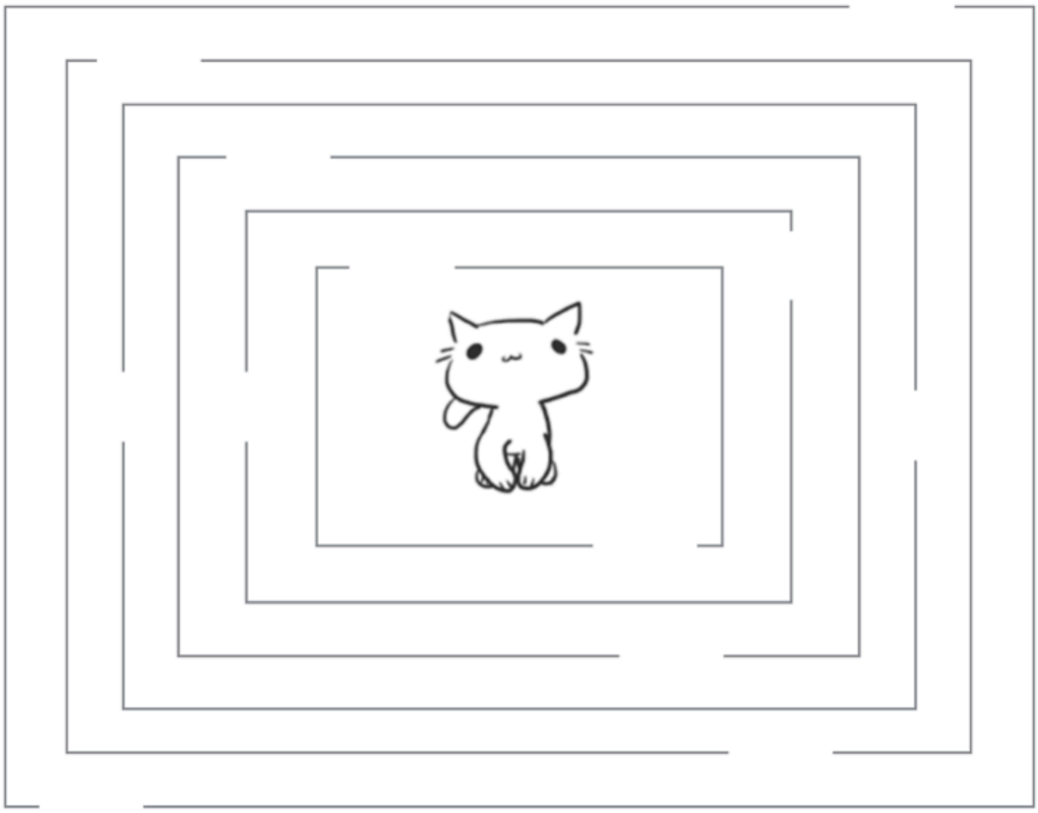


Trial 7

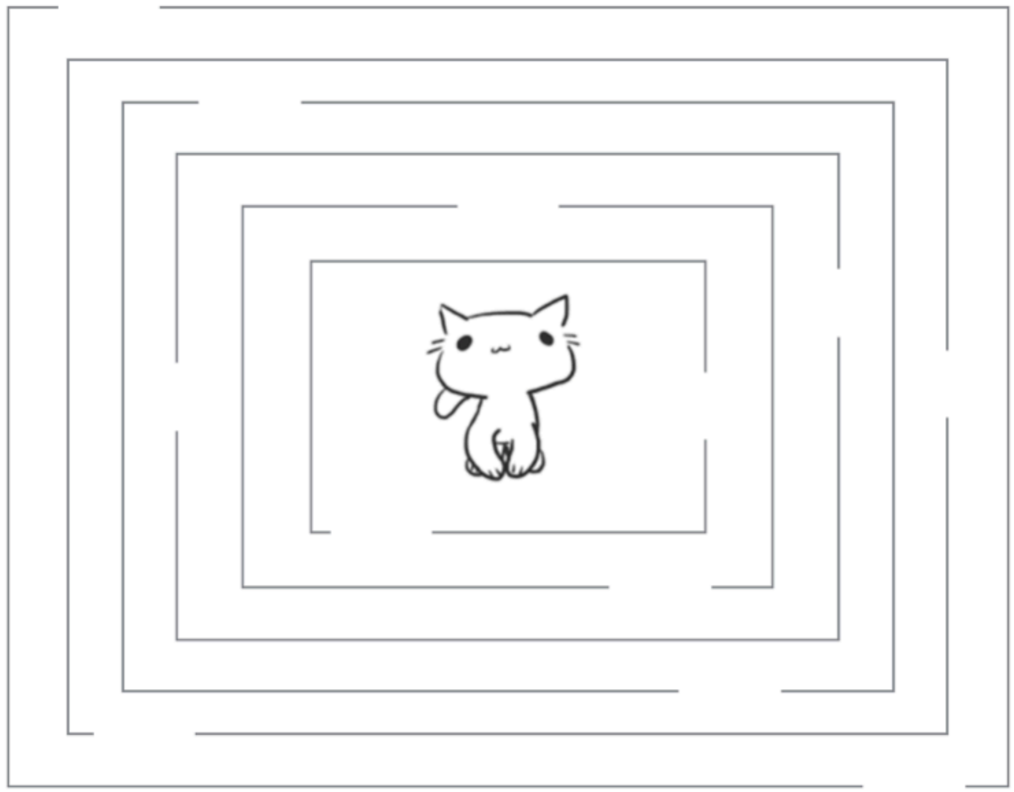


Trial 8

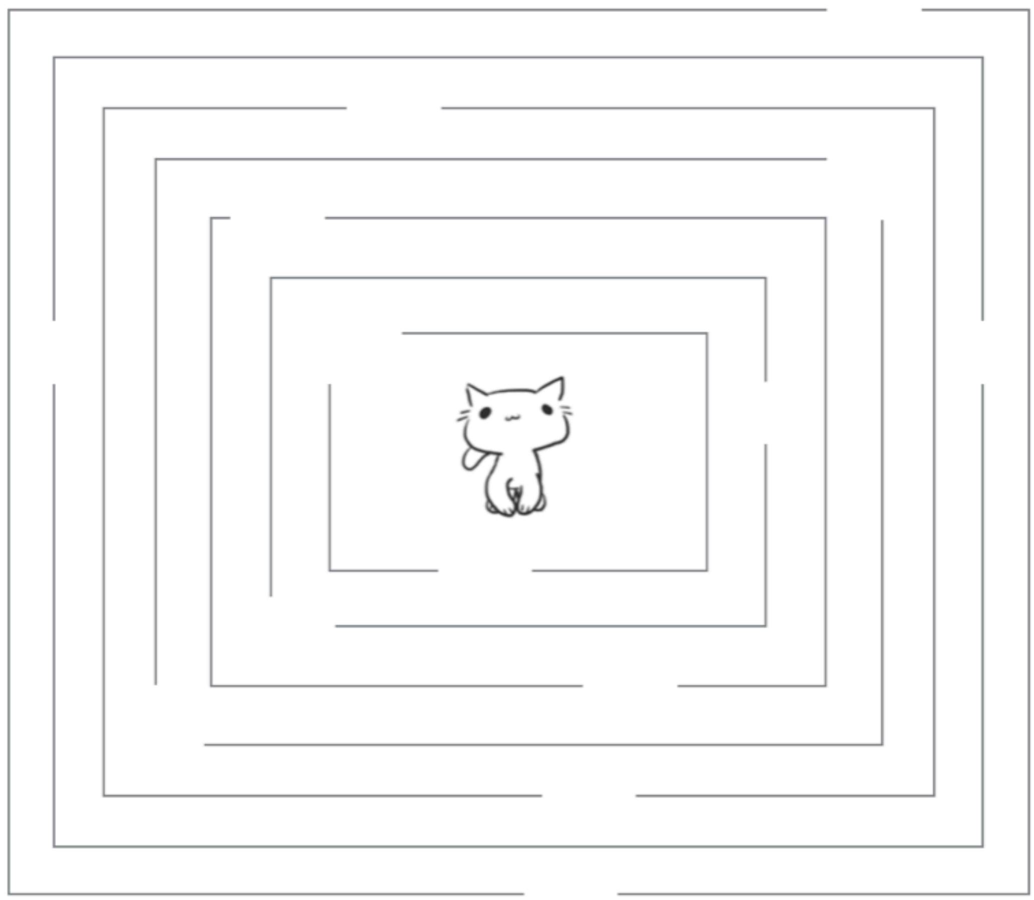
Trial 9



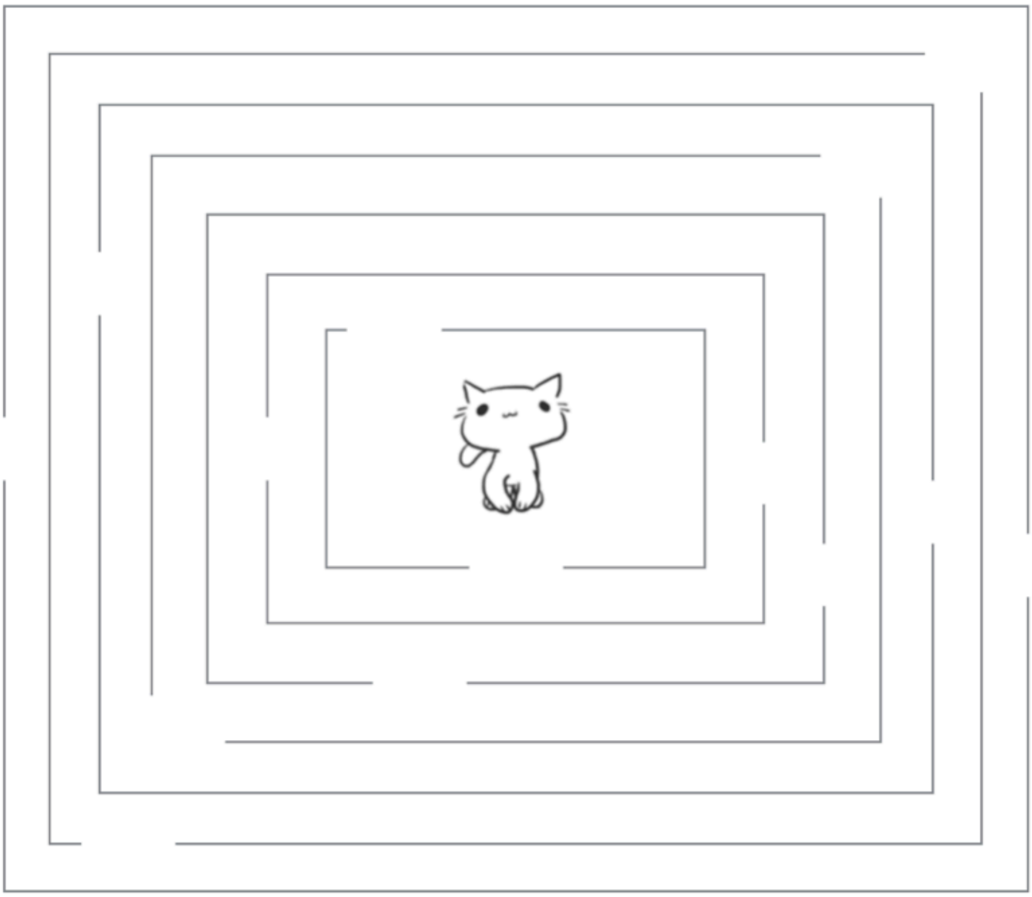
Trial 10



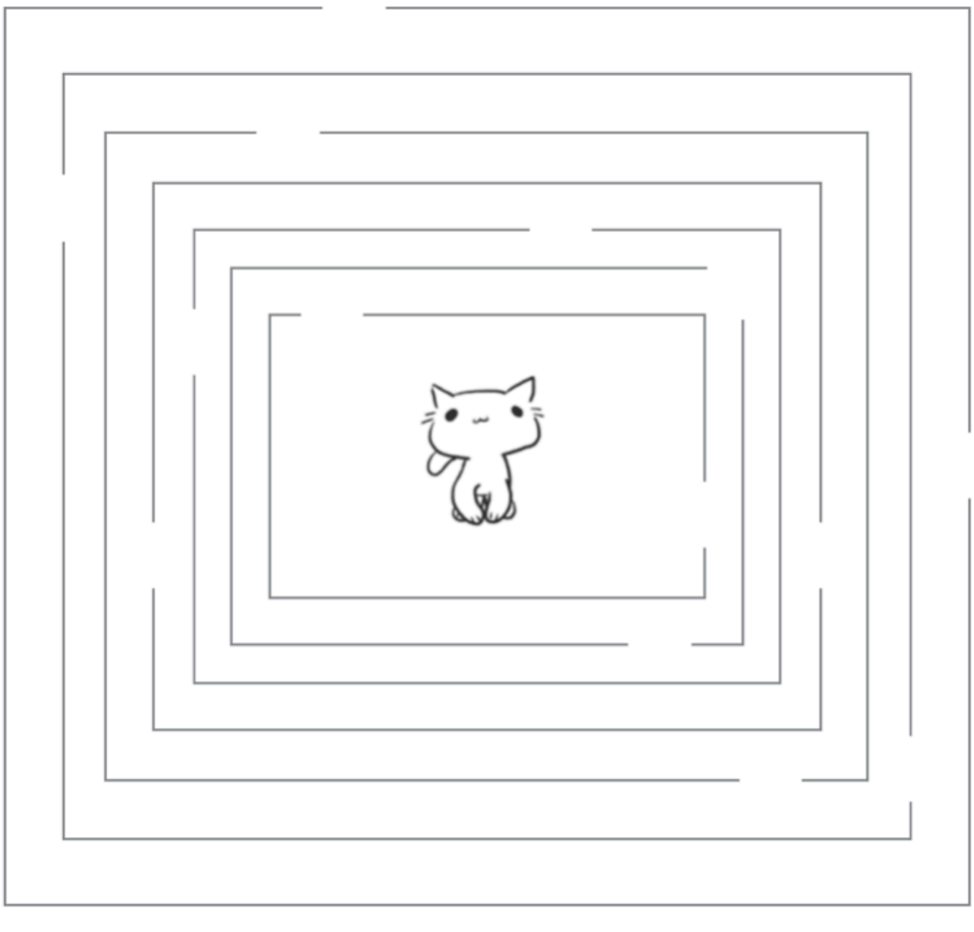
Trial 11



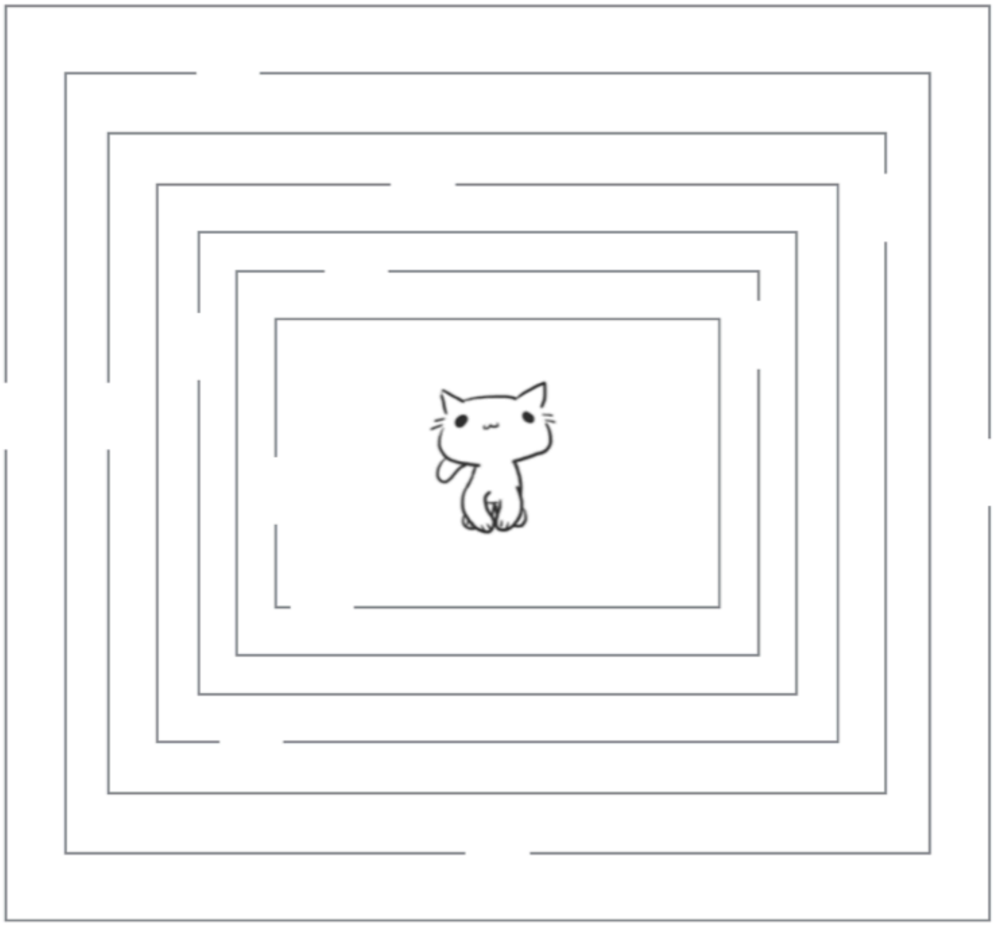
Trial 12



Trial 13

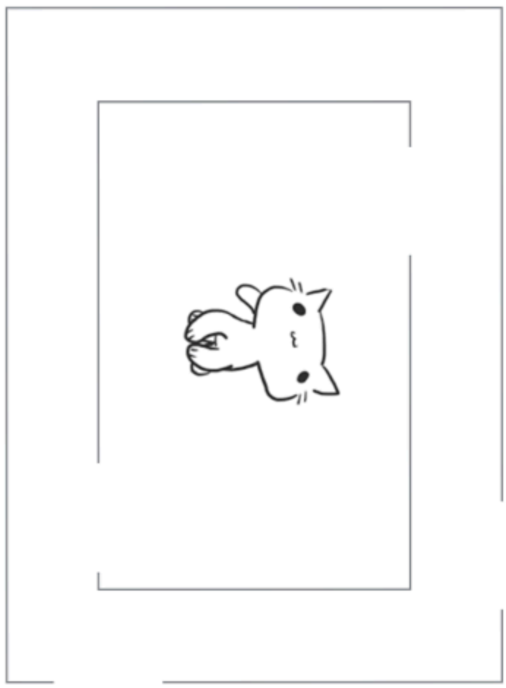


Trial 14

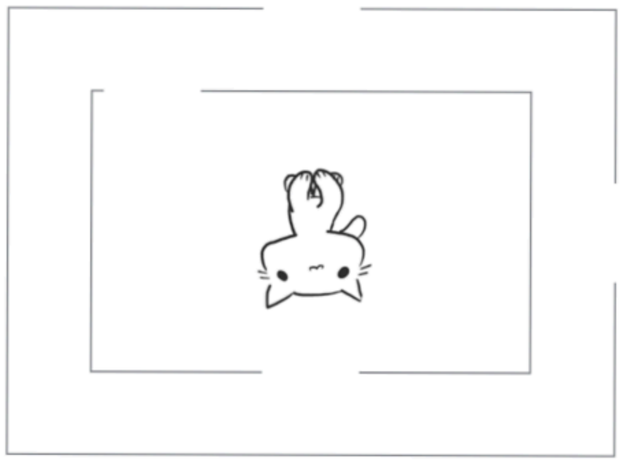


Mazes Response Booklet 2

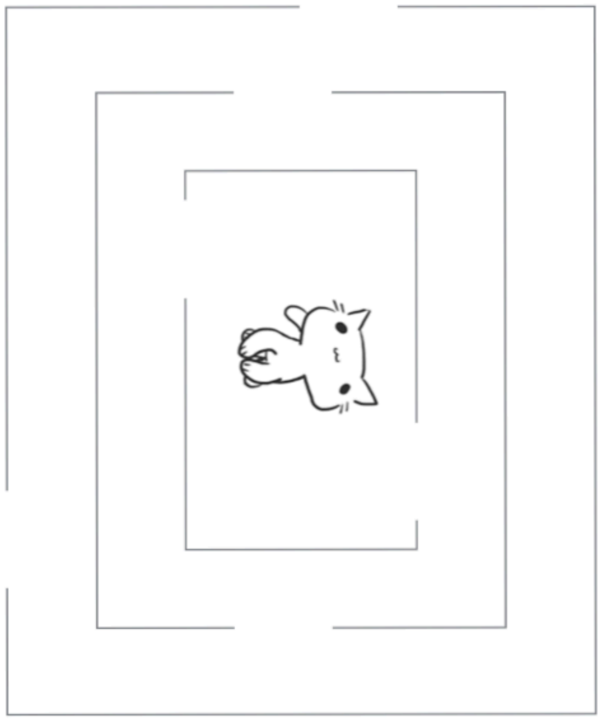
Trial 1



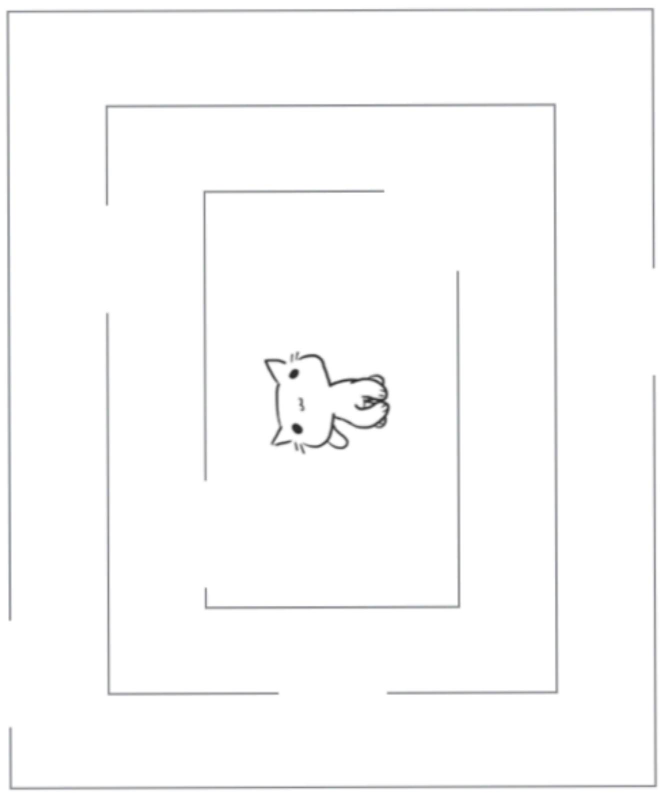
Trial 2



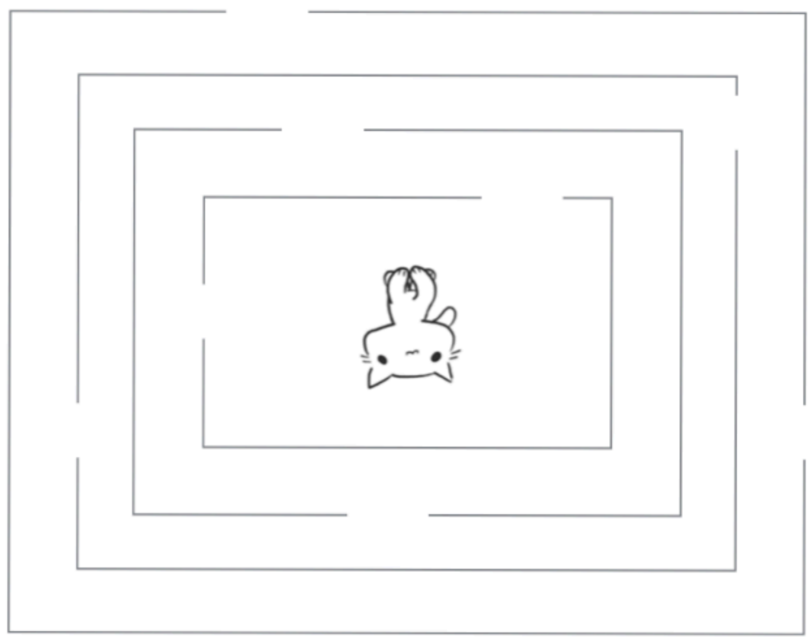
Trial 3



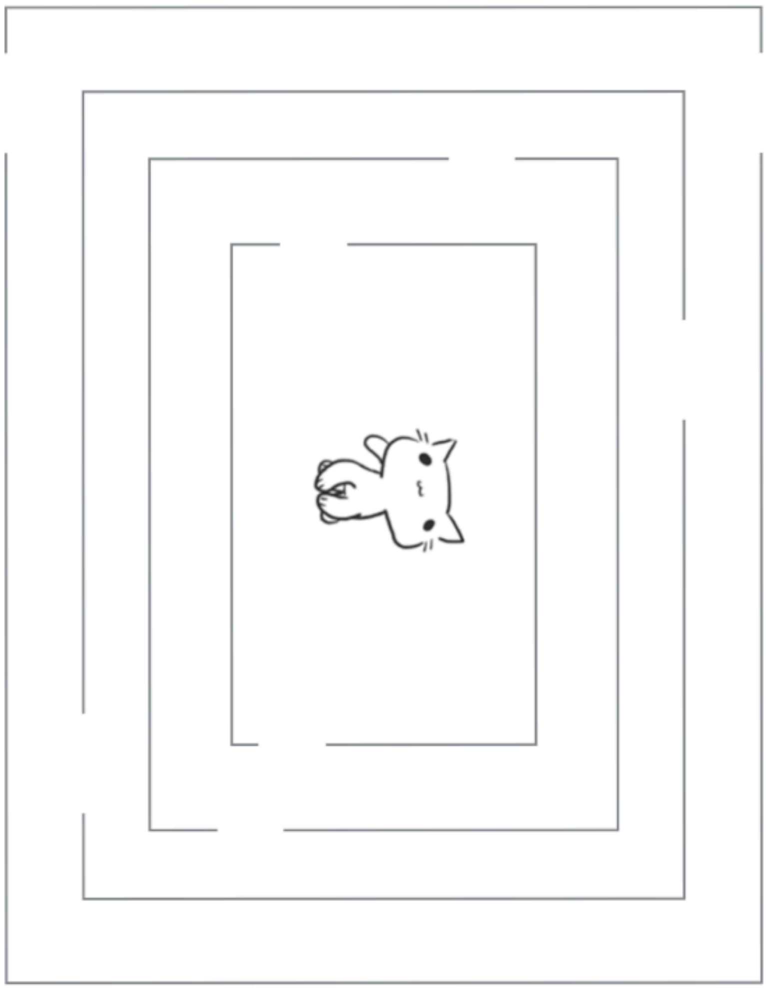
Trial 4



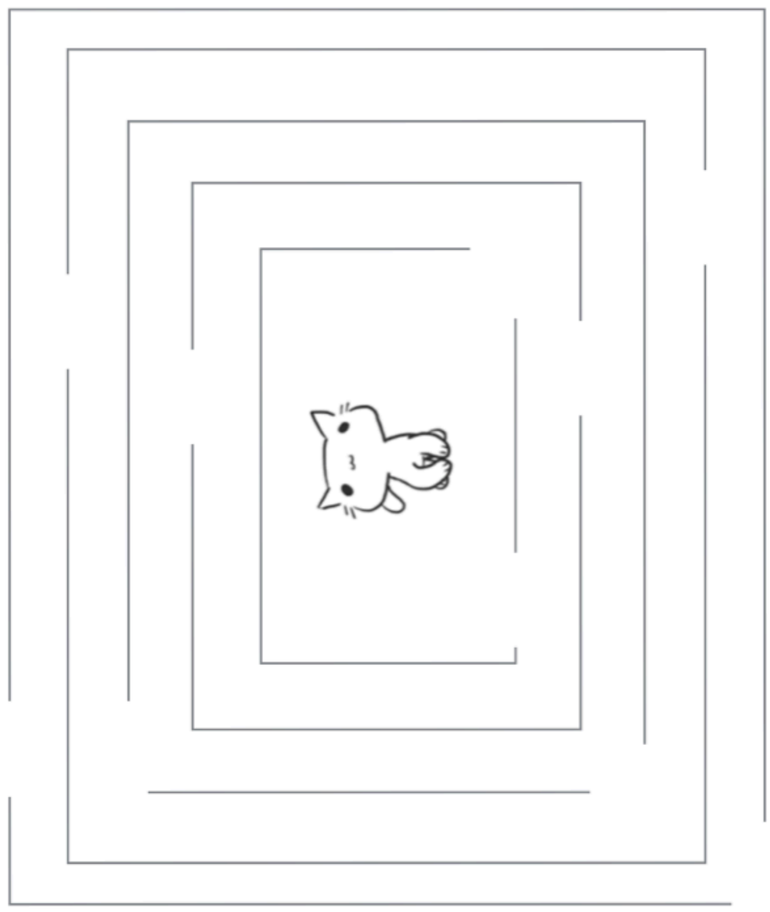
Trial 5



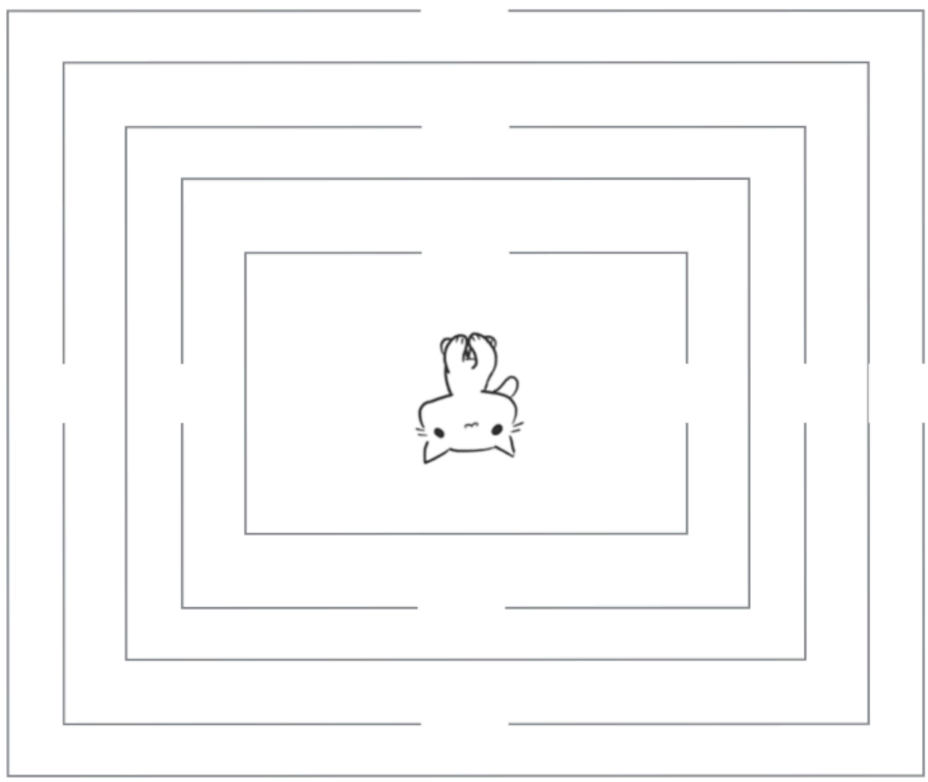
Trial 6



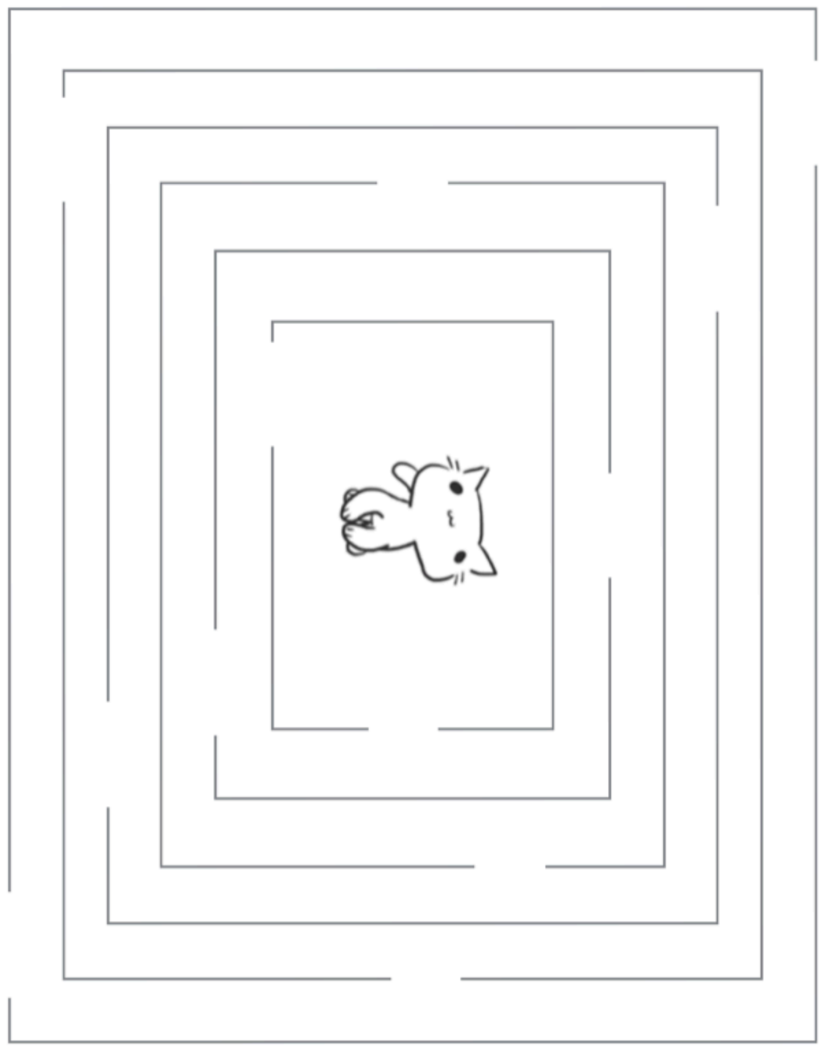
Trial 7



Trial 8



Trial 9



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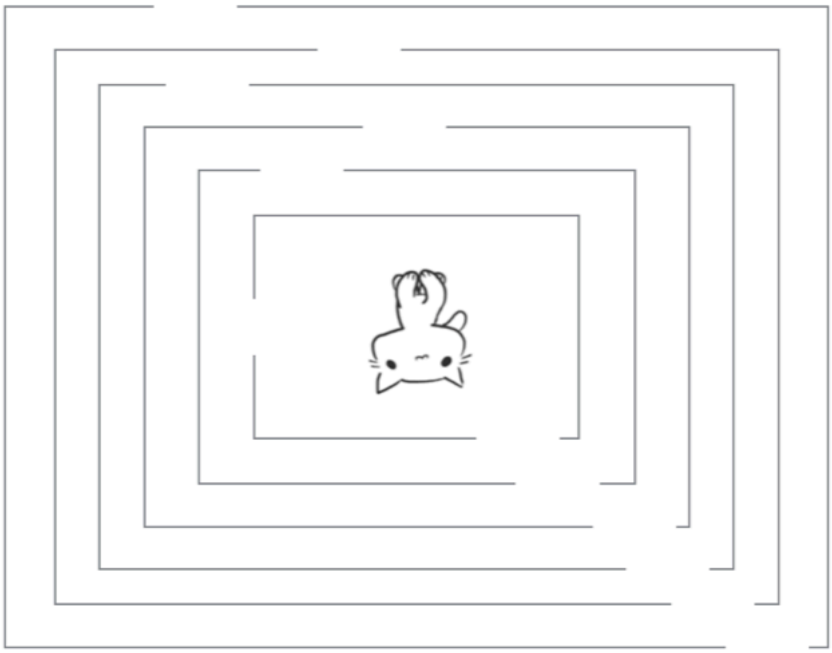
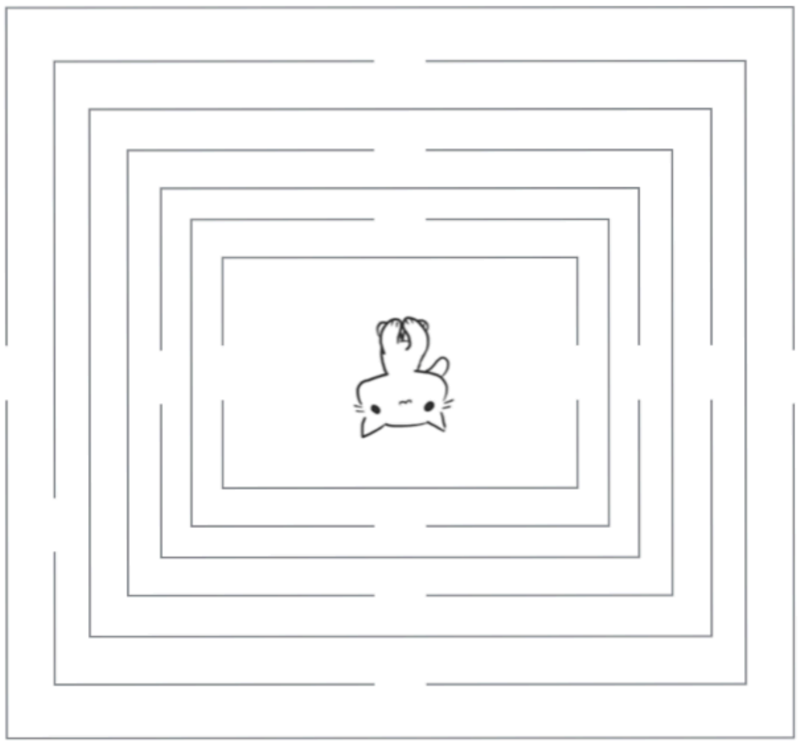
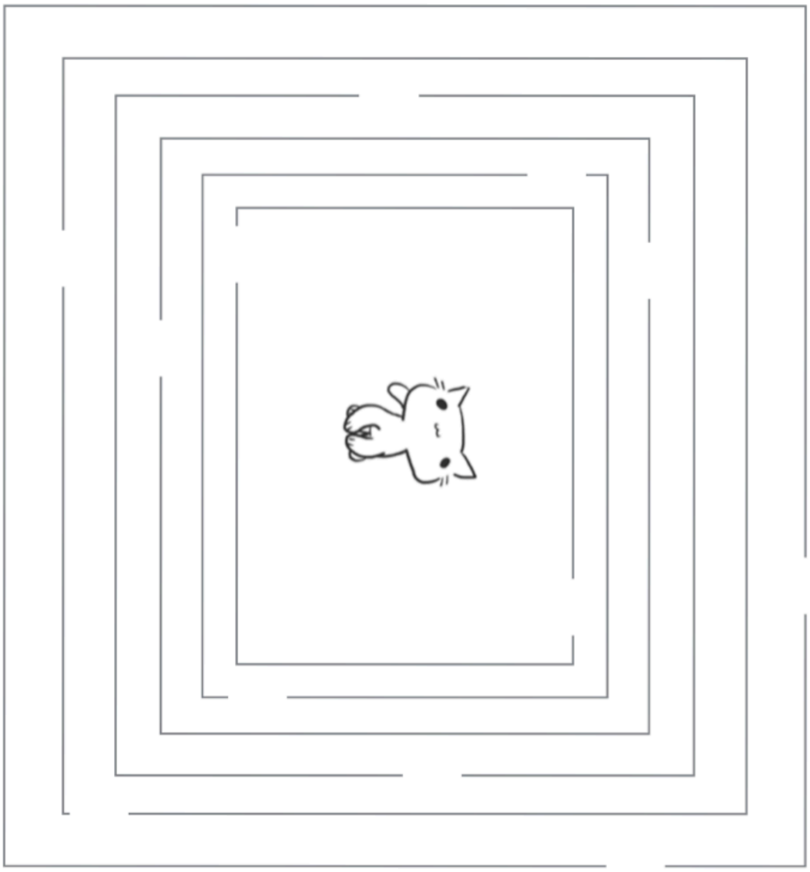


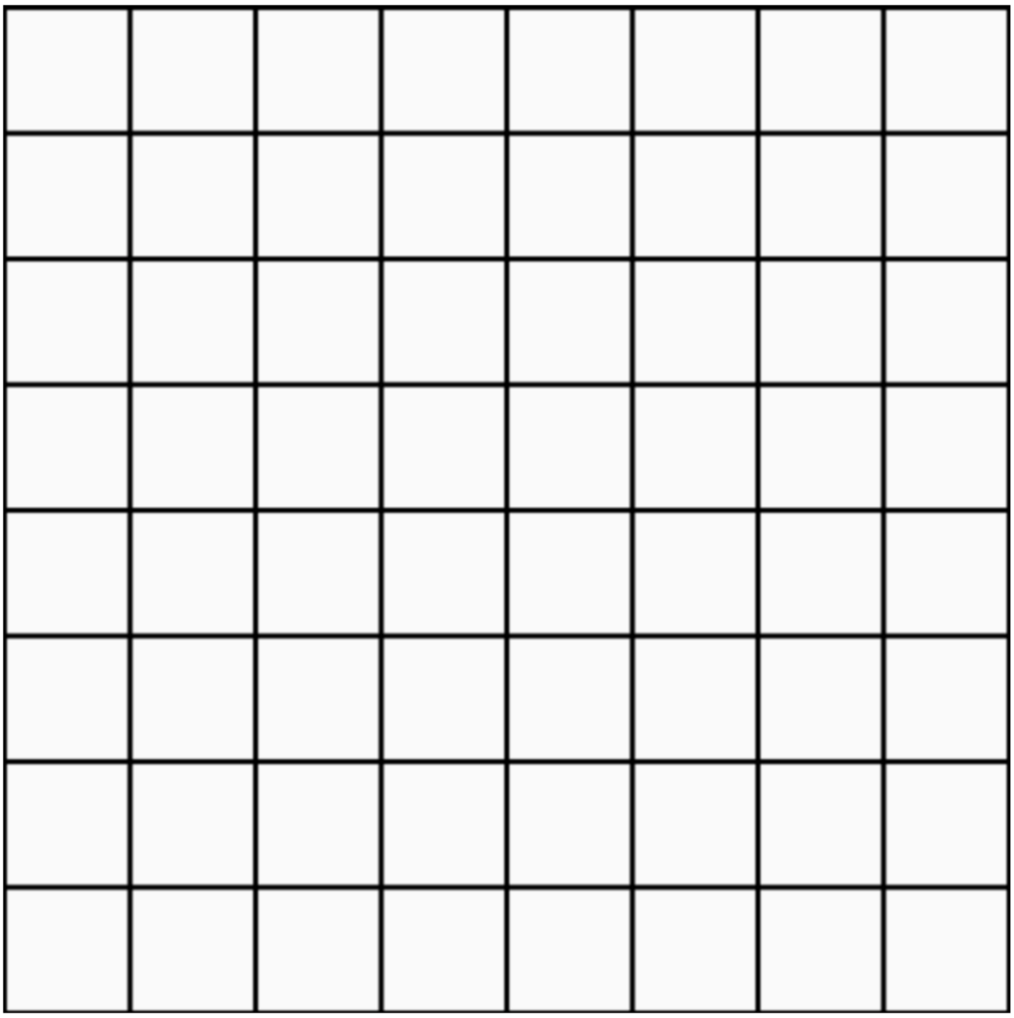
Trial 11



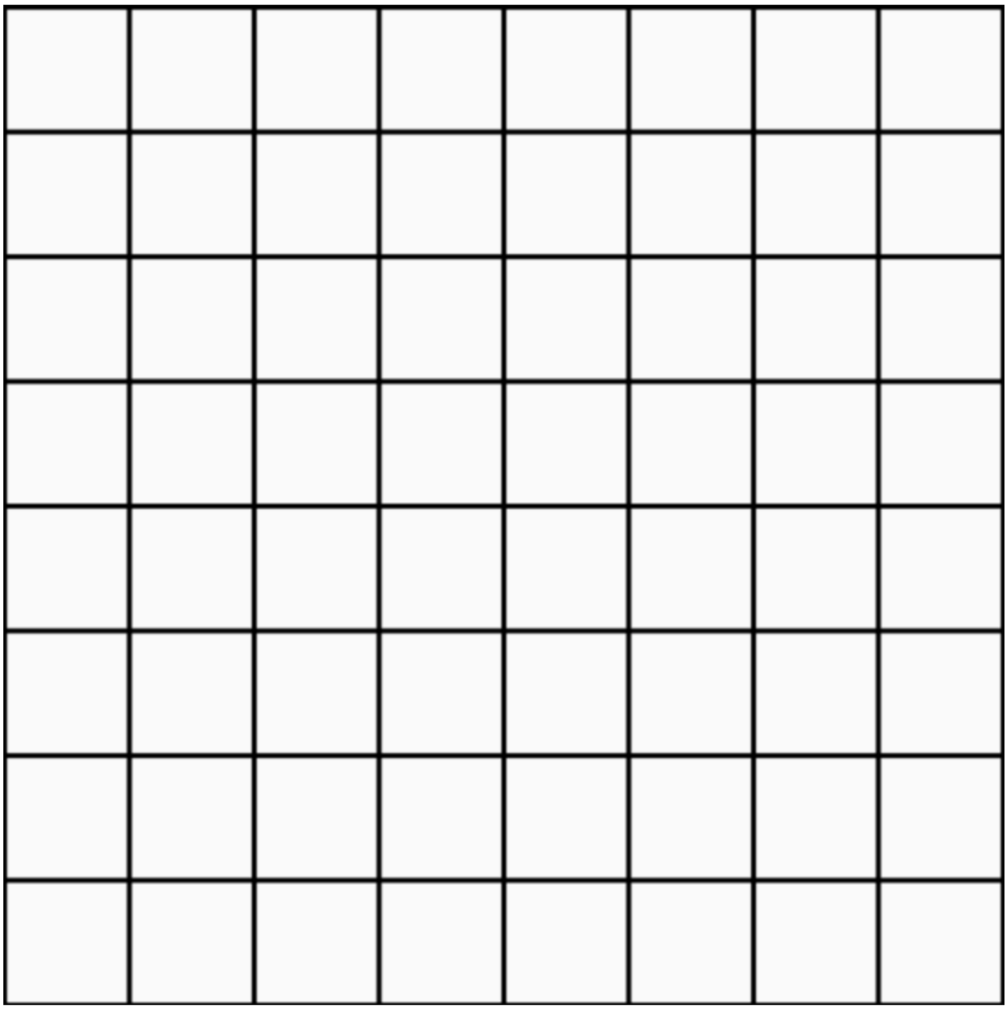
Trial 12



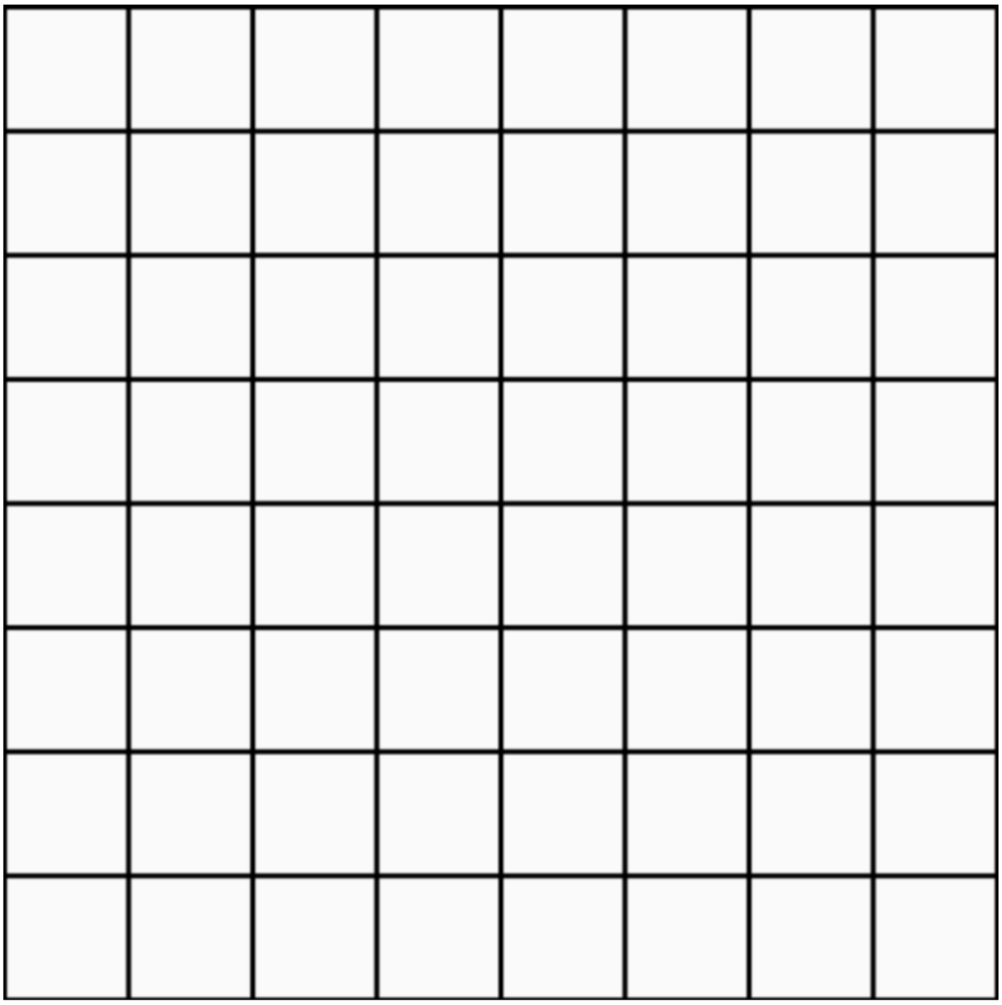
Mazes Learning Trial 1



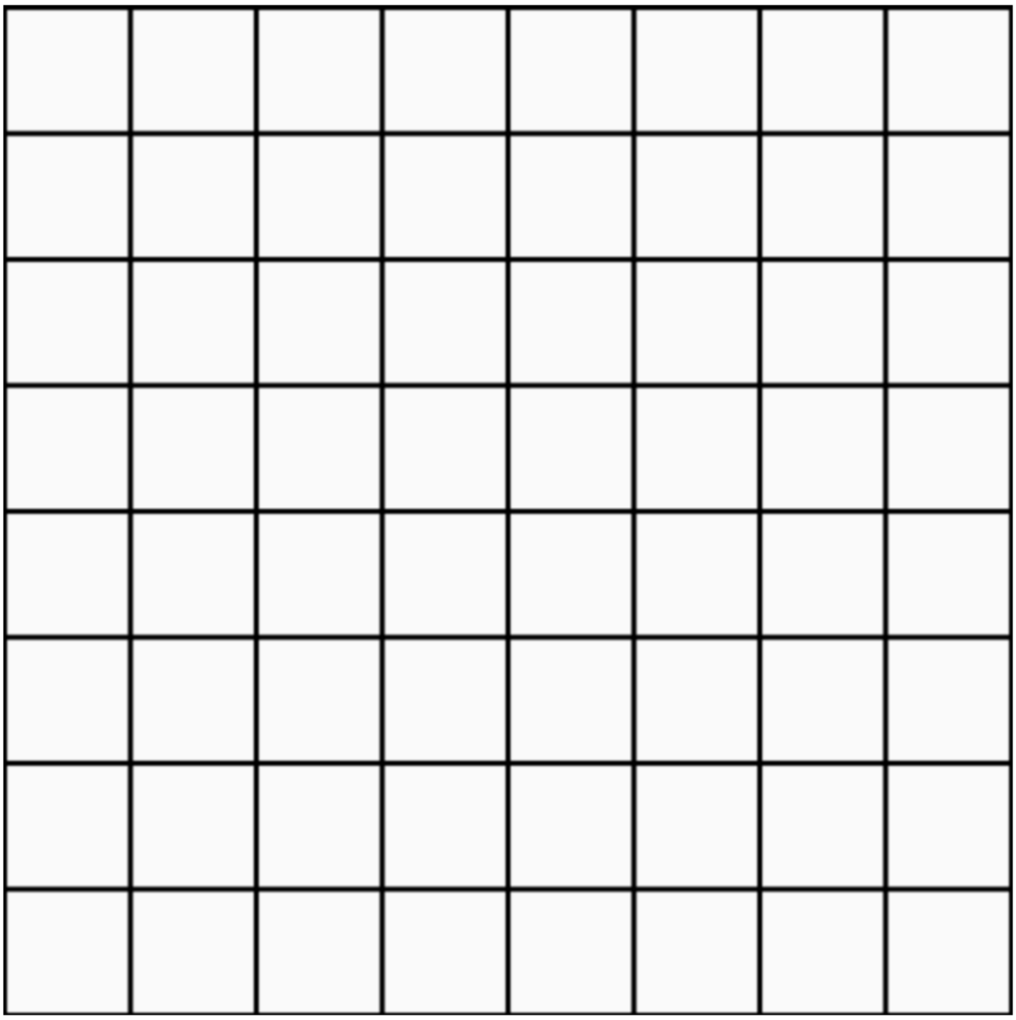
Mazes Learning Trial 5



Mazes Learning Trial 3



Mazes Learning Trial 4



Design Learning Trial 1

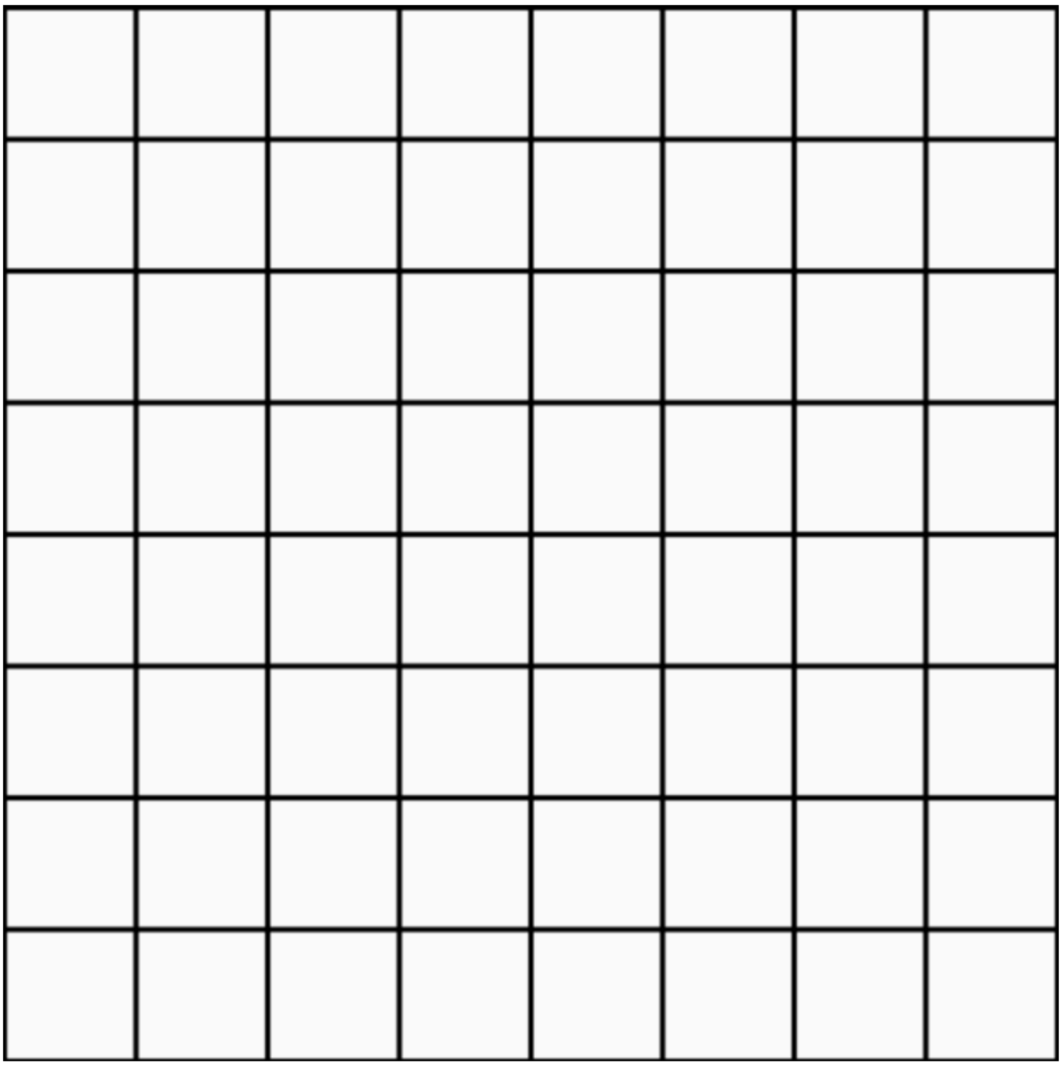
Design Learning Trial 2

Design Learning Trial 3

Design Learning Trial 4

Design Learning Trial 5

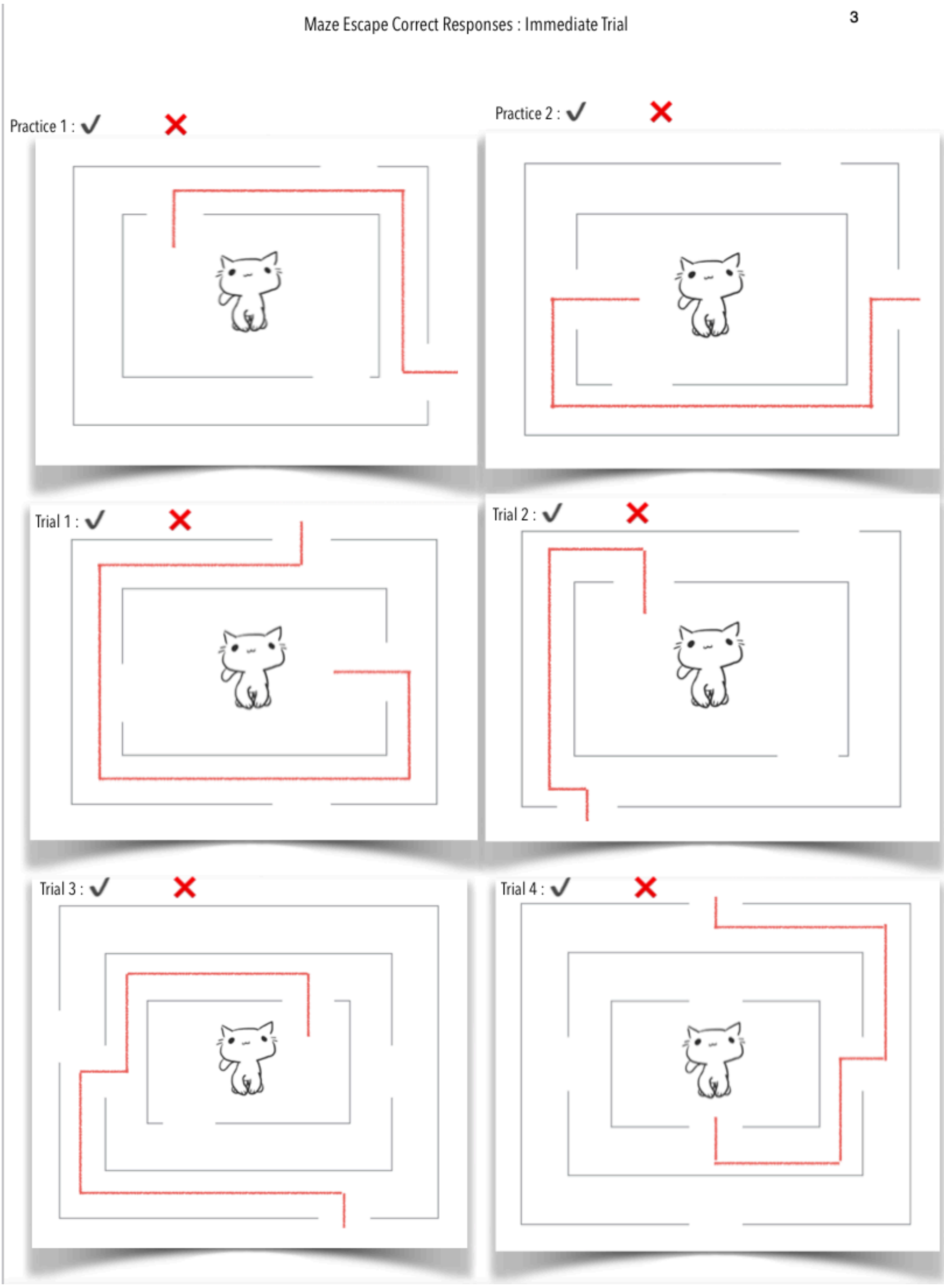
Mazes Learning Delayed Trial

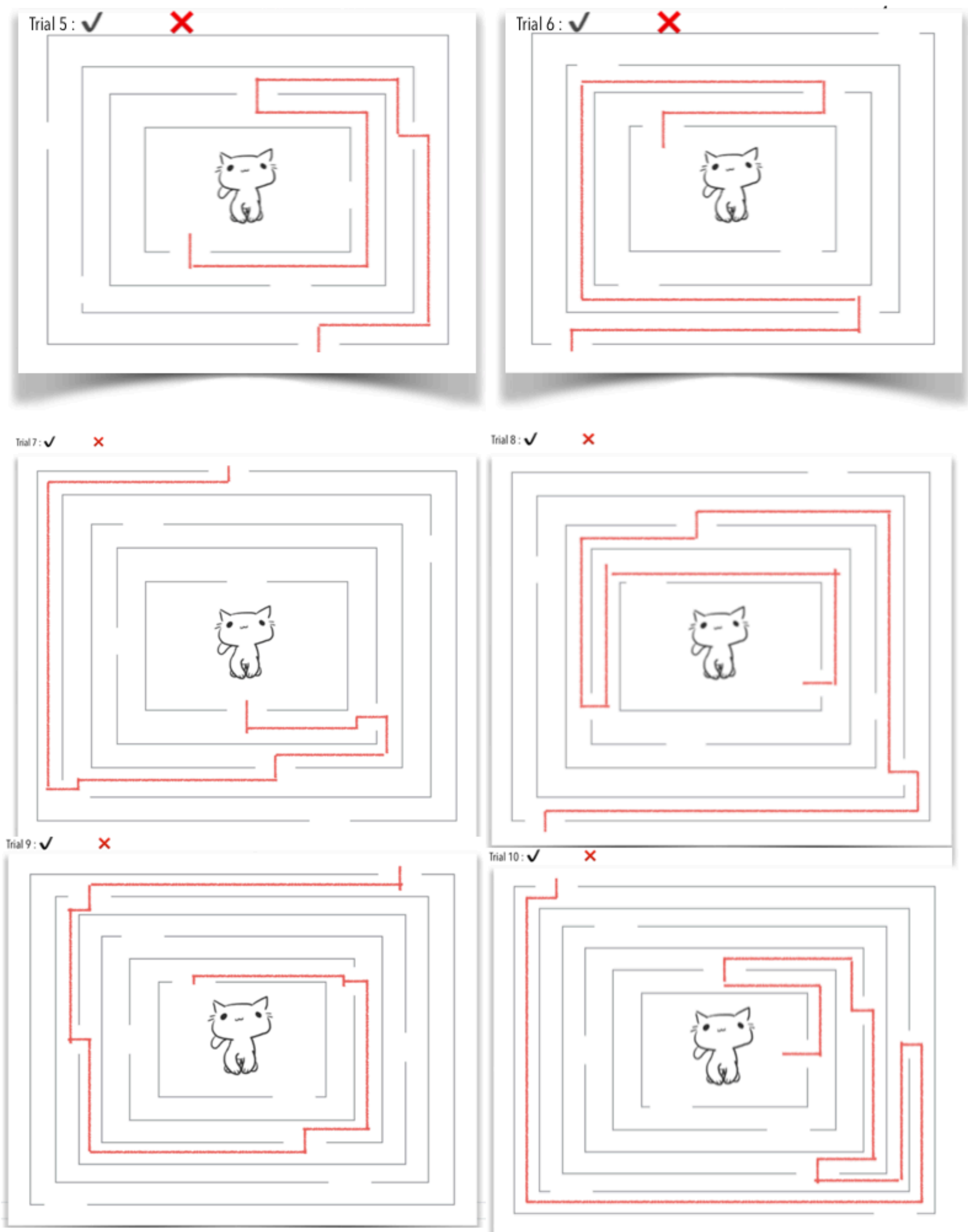


Design Learning Delayed

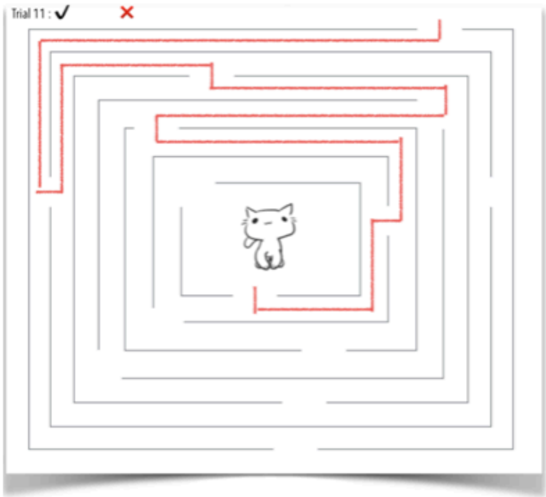
Visual Memory Scale

Examiner's Booklet

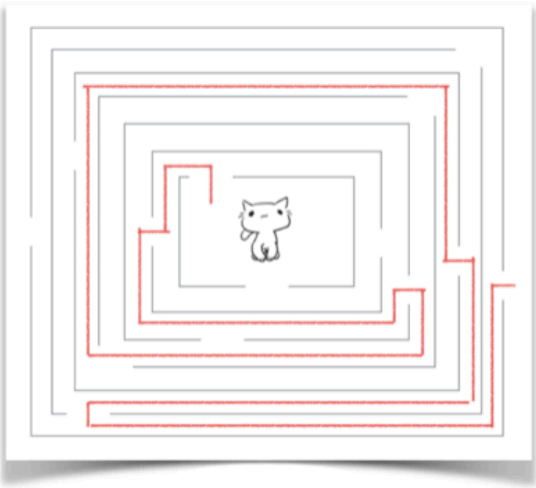

3
Maze Escape Correct Responses : Immediate Trial
Practice 1 : ✓ ✗
Practice 2 : ✓ ✗
Trial 1 : ✓ ✗
Trial 2 : ✓ ✗
Trial 3 : ✓ ✗
Trial 4 : ✓ ✗


Trial 5 : ✓ ✗
Trial 6 : ✓ ✗
Trial 7 : ✓ ✗
Trial 8 : ✓ ✗
Trial 9 : ✓ ✗
Trial 10 : ✓ ✗

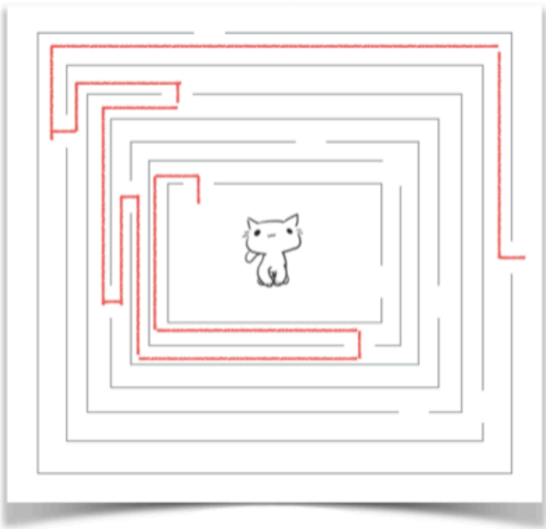
Trial 11 : ✓ ✗

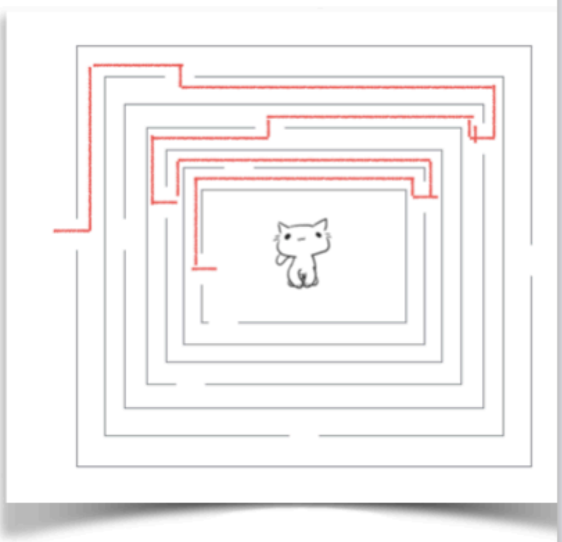


Trial 12 : ✓ ✗



Trial 13 : ✓ ✗



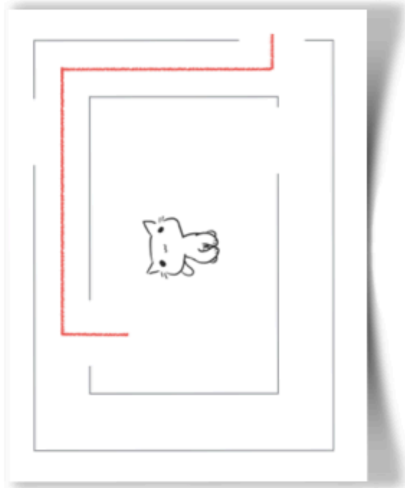


Total Score : ______________________________

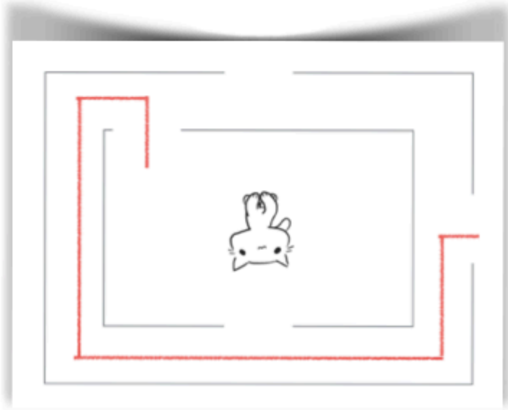
Span Score : ______________________________

Maze Escape Correct Responses : Working Memory Trial

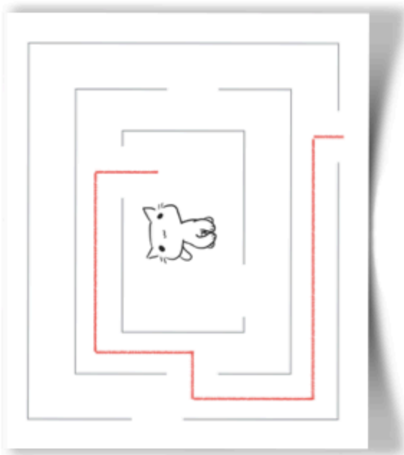
Trial 1 : ✓ ✗



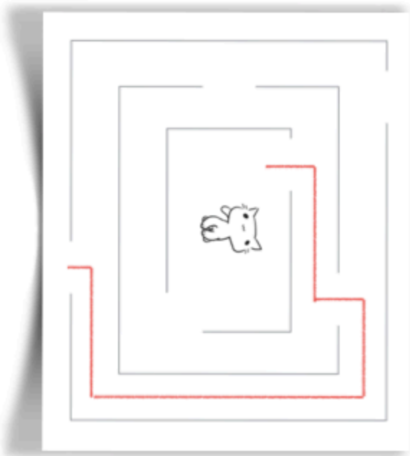
Trial 2 : ✓ ✗



Trial 3 : ✓ ✗

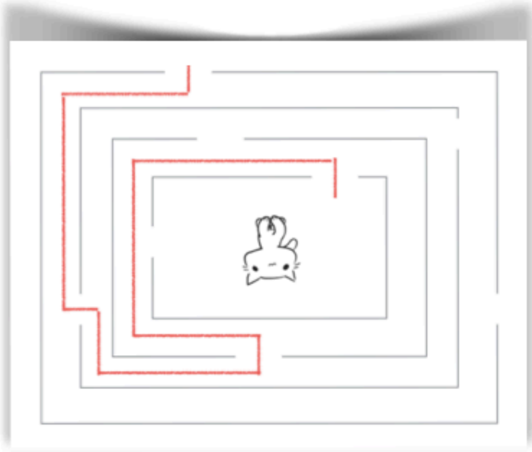


Trial 4 : ✓ ✗

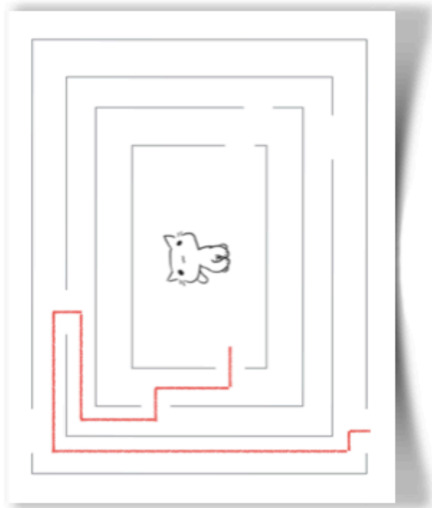


8

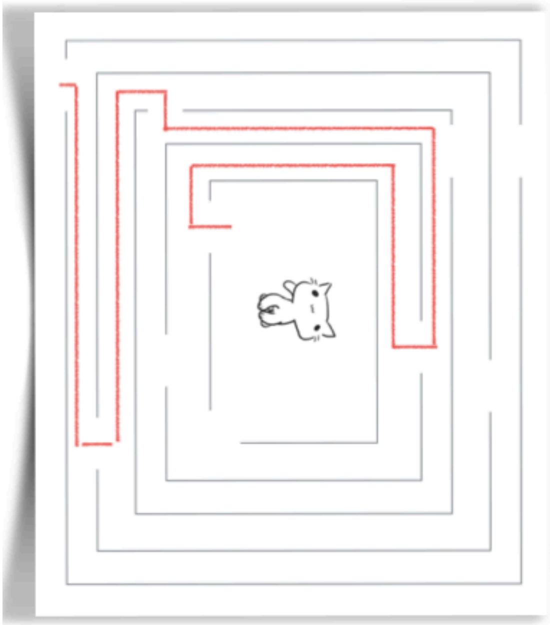
Trial 5 : ✓ ✗



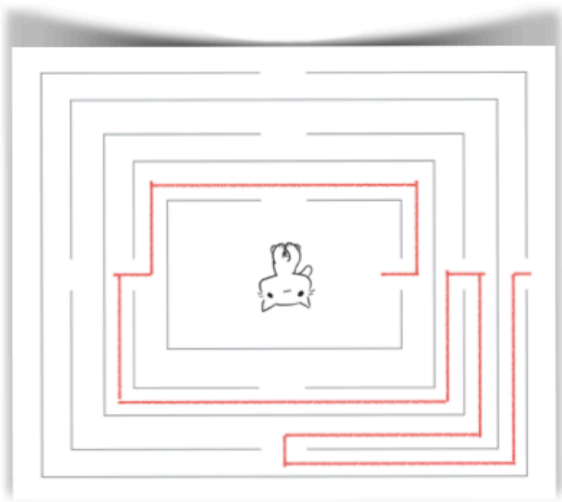
Trial 6 : ✓ ✗



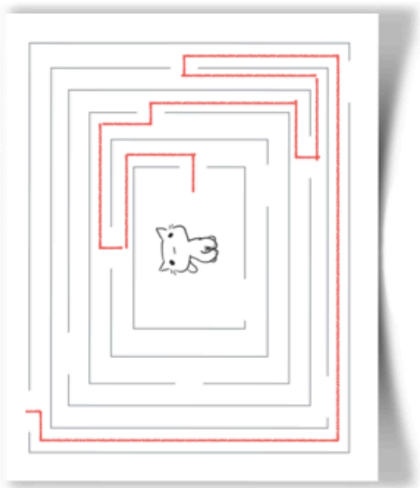
Trial 7 : ✓ ✗



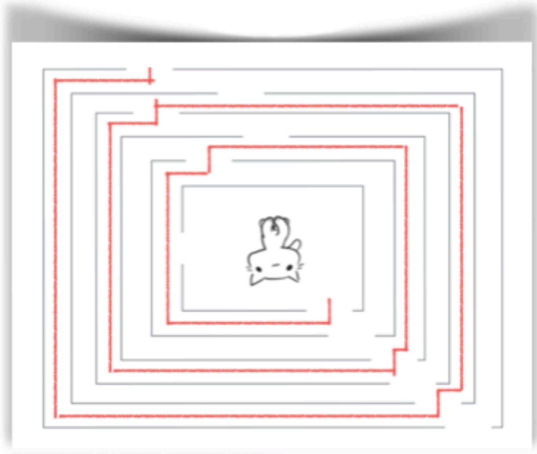
Trial 8 : ✓ ✗



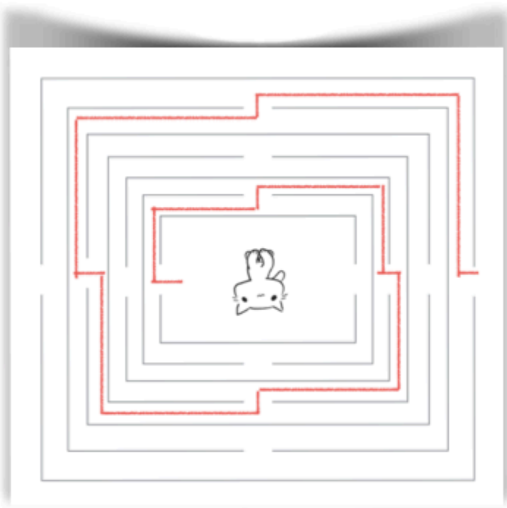
Trial 9 : ✓ ✗



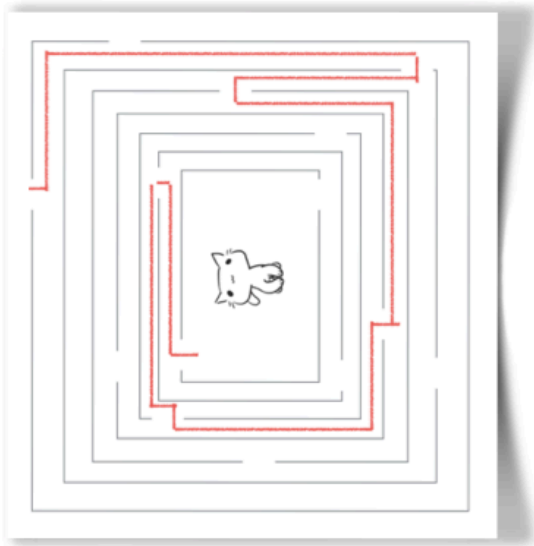
Trial 10 : ✓ ✗



Trial 11 : ✓ ✗



Trial 12 : ✓ ✗



Total Score ______________________________

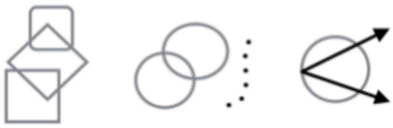
Span Score ______________________________

Abstract Span Forwards : Correct Responses

Trial 1

Trial 2

Trial 3



Trial 4

Trial 5

Trial 6

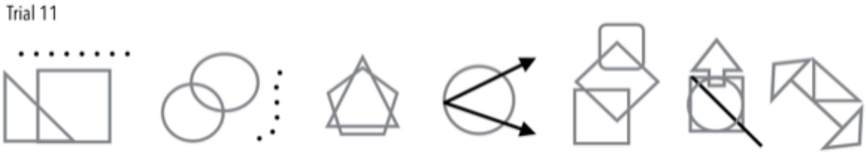
Trial 7

Trial 8

Trial 9

Trial 10

Trial 11



Trial 12

Trial 13

Trial 14

Total Score ___________________________

Span Score ___________________________

Abstract Visual Span Backwards : Correct Response

Trial 1

Trial 2

Trial 3

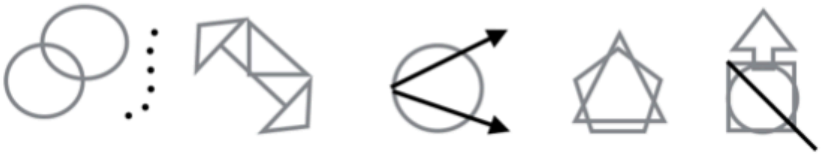
Trial 4

Trial 5

Trial 6

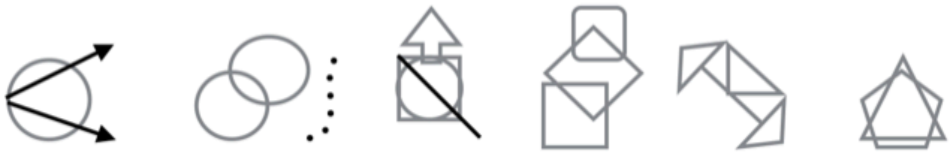
Trial 7

Trial 8



Trial 9

Trial 10



Trial 11

Trial 12

Trial 13

Trial 14

Total Score ______________________________

Span Score ______________________________

Maze Learning Answer Grid

					23	24	25
					22		
					21	20	
	8	9	10	11		19	
	7			12		18	
	6	5		13		17	
		4		14	15	16	
1	2	3					

Trial 1 Score ___________________________________

Trial 2 Score ___________________________________

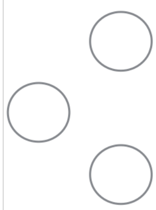
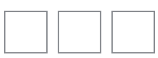
Trial 3 Score ___________________________________

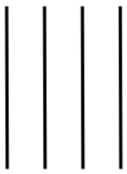
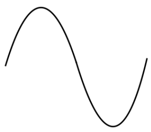
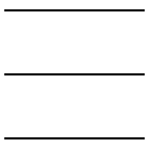
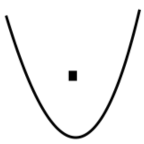
Trial 4 Score ___________________________________

Trial 5 Score ___________________________________

Delayed Score ___________________________________

Learning Curve ___________________________________
(Trial 5 - Trial 1)

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Delay
	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component
	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component
	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component
	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component
	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component

	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐
	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐
	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐
	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐
	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐
	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐	Orientation ☐ Form ☐ Component ☐

	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component	Orientation Form Component
Total	/ 36	/ 36	/ 36	/ 36	/ 36	/ 36

Trial 1 Score ______________________

Trial 2 Score ______________________

Trial 3 Score ______________________

Trial 4 Score

Delayed Score ______________________

Learning Curve ______________________
(Trial 5 - Trial 1)

Visual Pairs Response Sheet

Learning Trial 1

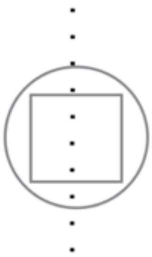
1.

2.

3.

4.

5.



6.

7.

8.

Easy Pairs ______________________________

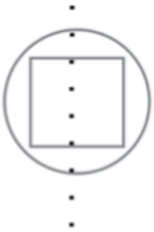
Hard Pairs ______________________________

Total Score ______________________________

Learning Trial 2

1.

2.



3.

4.

Easy Pairs ____________________________

Hard Pairs ____________________________

Total Score ____________________________

5.

6.

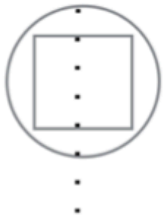
7.

8.

Learning Trial 3

1.

2.



3.

4.

Easy Pairs ______________________________

Hard Pairs ______________________________

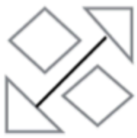
Total Score ______________________________

5.

6.

7.

8.



Learning Trial 4

1.

2.

3.

4.

5.

6.

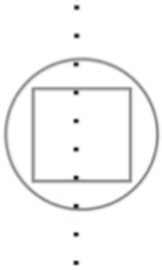
Easy Pairs ______________________________

Hard Pairs ______________________________

Total Score ______________________________

7.

8.



Trial 1 Score ________________________________

Trial 2 Score ________________________________

Trial 3 Score ________________________________

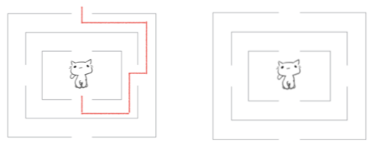
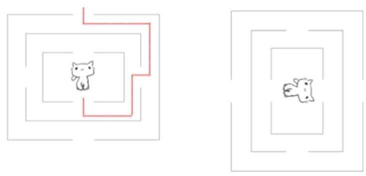
Trial 4 Score ________________________________

Overall Easy Score ______________________________

Overall Hard Score ______________________________

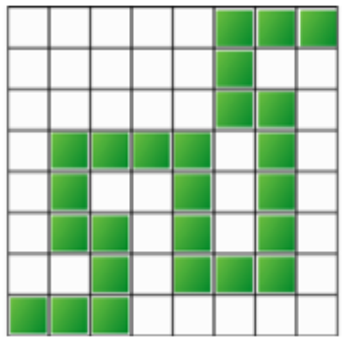
Delayed Score ________________________________

Appendix B

Tests Outlined in Chapter 6 : Test Development	Brief Description	Image
Spatial Span [Allocentric Span in Chapter 9 and 10}	- Measure of allocentric spatial span - Participants are presented with a static maze with a cat in the centre - A line is drawn from the centre of the maze out electronically - Once the line has been drawn it will linger for a few seconds and then disappear. Participants are then asked to replicate the pathway they saw - Every two trials the maze increases in size - Two consecutive errors results in the task being discontinued	
Spatial Working Memory [Allocentric Working Memory in Chapter 9 and 10]	- Stimuli presentation is identical to Spatial Span - Once the path disappears the maze will rotate either 90, 180 or 270 degrees. - Participants are presented with a response sheet that contains the maze post rotation. Participants are required to redraw the pathway on the maze that has been rotated - In Exp 1 every two trials the maze increases in size In Exp 2 and 3 every three trials the maze increases in size - Two consecutive errors results in the task being discontinued	
Object Span and Working Memory	- Measure of whole object memory - Participants are presented with a series of abstract shapes on the table device - Each image appears for 2 seconds before progressing to the next - Once the number of images in the span has been met participants are presented with an array of abstract figures. - For the span trial they are asked to select the ones that they saw in the order that they saw - For the working memory trial they are asked to select the ones that they saw in the reverse order that they saw them. - A score of one is given for each correct trial - Two consecutive errors results in the task being discontinued	

Spatial Learning

- Measure of allocentric learning
- Participants are presented with a blank grid
- Squares appear coloured one at a time to form a pathway (once the square has appeared it remains present on the screen)
- Once the path is complete the whole path will remain present for 2 seconds before disappearing
- Participants are asked to colour the square in on a grid of paper. They are instructed to begin the path from the beginning and colour to the end
- This task is repeated 5 times and produces a measure of immediate memory, total recall, learning curve and delayed recall.
- After 20 minutes participants are presented with a blank grid and are asked to recall the path that they were previously shown.

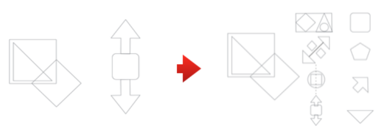


Design Learning {Feature Learning in Chapter 9 and 10]

- Measure of feature learning
- Basic shapes appear on the screen one image at a time. Each image will appear for two seconds before disappearing
- Once each image has been displayed the participant is asked to recall the images that they remember (in any order) on a blank piece of paper
- This task is repeated 5 times and produces a measure of immediate memory, total recall, learning curve and delayed recall.
- Presentation occurs in the same order each time
- After 20 minutes participants are presented with a blank piece of paper and are asked to recall as many images as they can that they were previously shown.

Visual Pairs

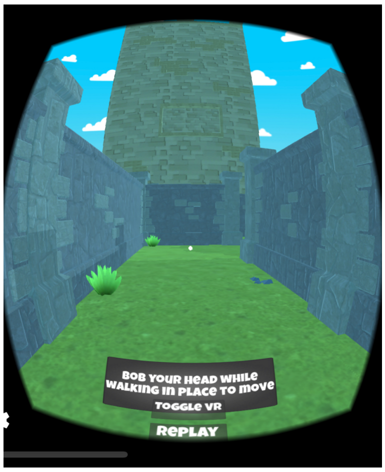
- Measure of whole object learning
- Participants are presented with 8 pairs of images on the tablet device. Each pair is presented for 2 seconds before disappearing and the next one appearing
- After viewing all 8 pairs participants are show one of the images associated with the pair on the left side of the screen and an array of images on the right side.
- They are asked to discern which image from the array was paired with the original shape.
- The presentation of stimuli occurs in a different order on each trial
- This task is repeated 4 times and produces a measure of immediate memory, total recall, learning curve and delayed recall.
- After 20 minutes participants are asked to match the pairs one final time without reviewing them.



Tests Developed for Experiment 3

Egocentric Span/ Learning

- Measure of egocentric span and learning
- This is a virtual reality task.
- Participants are shown a video (filmed in first person) of an individual completing a maze.
- They then place the headset on and attempt to complete the pathway out of the maze that they just observed
- This task is repeated 3 trials
- This task produces 3 scores : time to complete in seconds, look errors (when the participant looks the incorrect way but corrects their mistake), and move errors (when the participant actively walks in the wrong direction)

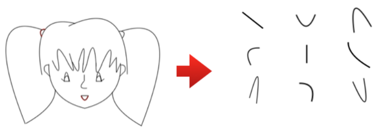


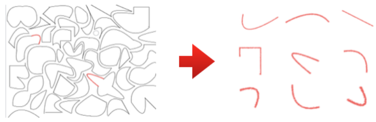
Egocentric Working Memory

- Measure of egocentric working memory
- This is a virtual reality task.
- Participants are shown a video (filmed in first person) of an individual completing a maze.
- They then place the headset on and attempt to complete the maze that they just observed backwards
- This task produces 3 scores : time to complete in seconds, look errors (when the participant looks the incorrect way but corrects their mistake), and move errors (when the participant actively walks in the wrong direction)

Contextual Feature Span and Working Memory

- Measure of contextual feature memory
- Participants are presented with a face on the tablet
- One feature of the face will flash red for 2 seconds before progressing to the next
- Once the number of features in the span has been met participants are presented with an array of features.
- For the span trial they are asked to select the ones that they saw in the order that they saw
- For the working memory trial they are asked to select the ones that they saw in the reverse order that they saw them.
- A score of one is given for each correct trial
- Two consecutive errors results in the task being discontinued



Non Contextual Feature Span and Working Memory	- Measure of non-contextual feature memory - Participants are presented with an abstract design on the tablet - One part of the design will flash red for 2 seconds before progressing to the next - Once the number of features in the span has been met participants are presented with an array of features. - For the span trial they are asked to select the ones that they saw in the order that they saw - For the working memory trial they are asked to select the ones that they saw in the reverse order that they saw them. - A score of one is given for each correct trial - Two consecutive errors results in the task being discontinued	

Appendix C

Spatial Span Script

*Let's begin with the first task. Remember that I just want you to do your best. There is no pass or fail on any of these tests we just want to get an idea about how you remember the things that you see. To start off with I am going to show you a series of mazes on my iPad. I will show you a blank maze and you will see a pathway drawn from the centre of the maze out. I want you to try and remember this path. After the path has been drawn it will linger for a few seconds and then disappear. Once it is gone I would like you to draw the path you just saw here *Hand them the sheet marked practice trial 1* The mazes will start off simple and get more and more complicated, I just want you to try your best. It doesn't matter how long it takes you, just be as accurate as you can. Do you have any questions?*

Answer any questions, if no continue to

'Let's start with a practice round. Are you ready?'

**Proceed to practice trial 1 if any errors are made provide feedback to ensure the participant understands the task* 'Good job let's try one more practice'*

Hand them practice trial 2. Use the same procedure as before, provide feedback if an error is made.

'Great, we are going to begin the actual trials now. They will start off at the same difficulty, do your best and good luck.'

- *At the conclusion of each trial take their response sheet and place it upside down next to you and hand the participant the next response sheet. Do not give any further feedback until the discontinue rule comes into effect. If the participant asks for feedback just reiterate that they continue trying their best.**

Appendix D

Spatial Working Memory Script

*Now we are going to do a similar task, however, this one is slightly different. I still want you to try your best. There is no pass or fail on any of these tests we just want to get an idea about how you remember the things you see. Like before I am going to show you a series of mazes on my iPad. I will show you a blank maze and you will see a pathway drawn from the centre of the maze out. I want you to try and remember this path. After the path has been drawn it will linger for a few seconds and then disappear. This time once the path is gone the maze will then rotate. I would like you to draw the path you just saw here *Hand them the response sheet for trial 1*. This time it will be a little trickier as you will have to mentally rotate the pathway to fit into the maze. As before the mazes will start off small and get larger and larger, I just want you to try your best. It doesn't matter how long it takes you, as the task is not timed, what is important is your accuracy. Do you have any questions?*

Answer any questions, if no continue to

'We are going to begin the actual trials now. They will start off at the same difficulty as before, do your best and good luck.'

*∗ As before at the conclusion of each trial take their response sheet and place it upside down next to you and hand the participant the next response sheet. Do not give any further feedback until the discontinue rule comes into effect. If the participant asks for feedback just reiterate that they continue trying their best. Score each answer by checking your booklet.**

Appendix E

Spatial Learning Script

*'The next task we are going to do is slightly different. What you will see on the screen is a grid. *Gesture at the screen*. When the task begins you will see different squares light up to make a path. I want you to not only remember the path but remember the order that the path was shown to you in. When the full path has finished it will linger for a few seconds and then you will see a blank grid. I want you to fill in the same path on your grid here *Hand them the trial 1 page*. When you are filling in your grid I want you to write the number that the square appeared in, in the square. For example if you saw this square first *Gesture at the top left square* You would write the number 1 it in then this one you would write 2 and this one 3 etc. Make sure you fill all the squares in order without skipping any. The maze is long and it is unlikely that you will be able to remember the maze without any mistakes, you will get to see it multiple times so do not worry just do your best. Do you have any questions?'*

** Answer any questions**

'Alright well let's begin with the first trial'

**After the first trial, take their page and turn it upside down so they cannot see their previous answer. Then hand them the next sheet* 'I am now going to show you the same path as before. The instructions are exactly the same, after you have seen the path complete I want you to fill in your grid here *Gesture to the new blank grid*.*

Repeat the above for Trials 3 - 5

Delayed Recall Script

*'Awhile ago I showed you a grid a number of times and asked you to remember the path that the grid showed. When you filled in the grid yourself you will remember that I asked you to colour in each square in the order that the path was created in. If you look here *Hand them the delayed recall response sheet* you will see a blank grid. I would like you to colour the path one final time. Just do your best.'*

Appendix F

Object Span Script

*‘ We are now going to begin a new task. In this task on the screen you will see some abstract designs one at a time. I want you to remember these designs as best as you can. After you have seen a couple you will see a screen with lots of different designs, I want you to point with this pen to the ones you saw in the order that you saw them. So for example if I showed you circle, square I would want you to point to * Gesture at them to encourage them to answer* Exactly. As with the last task as the task goes on the number of designs for you to remember will get bigger. As always just do your best. Do you have any questions?’*

*∗ Answer any questions**

‘Alright well let’s begin with the first trial’

Appendix G

Object Working Memory Script

‘ We are now going to do a similar task. Like before in this task on the screen you will see some abstract designs one at a time. I want you to remember these designs as best as you can. After you have seen a couple you will see a screen with lots of different designs. This time instead of pointing to them in the order you saw them I want you to point them in reverse order. So if I was to show you a triangle and then a square, I would want you to point to the square first and then the triangle. As with the last task as the task goes on the number of designs for you to remember will get bigger. It is important that you just do your best. Do you have any questions?’

∗ *Answer any questions**

‘Alright well let’s begin with the first trial’

Appendix H

Design Learning Script

*'We now have another different task. This time you are going to see some different designs again one at a time they will highlight across the screen in a row. I want you to do your best to remember each design. After the last design disappears here *Gesture at the bottom right corner* and you see a blank screen I am going to get you to draw them on this page here. *Hand them the trial 1 page of Design Span* The designs are not hard so do not worry about your drawing ability. You can draw the designs in any order. Like before it is unlikely you will get all the designs your first try, you will have the opportunity to do the task over again, so just do your best each time. Do you have any questions?**

** Answer any questions**

'Alright well let's begin with the first trial'

**After the first trial* 'Alright now I am going to show you the designs again. As before after the last design has disappeared I will get you to draw them on this page. Draw as many designs as you can remember EVEN if you drew them last time."*

Repeat the above for Trials 3 - 5

Delayed Recall and Recognition Script

*'Awhile ago I showed you a series of different designs a number of times and asked you to remember them. On this page *Gesture at the response booklet, turn to the correct page if necessary* I would like you to draw as many as of the designs as you remember one final time.'*

After they have drawn as many as they can

'I am now going to show you a series of designs. I just want you to say yes if you remember seeing the design previously or no if you do not.'

Appendix I

Visual Pairs Script

*'We are now going to move on to the final task on the iPad. In this task you are going to see a series of design pairs flash on the screen. I want you to do your best to remember which designs go together. You may find some designs easier to remember as they are more basic and you may find some pairs more difficult. After you have seen all the pairs I will show you one design and I will ask you to point with this pen to what design is its pair. As with the last few tasks you will get a couple of tries to remember as many as you can. As always just do your best. Do you have any questions?**

** Answer any questions**

'Alright well let's begin with the first trial'

**After the first trial* 'Alright now I am going to show you the pairs again. As before after the last pair has been shown I will show you one shape and ask you to point to its partner. The designs will be in a different order from last time. "*

Repeat the above for Trials 3 - 4

Delayed Recall Script

'This is the last task of the tests that we will be doing with the tablet. You will remember awhile ago I showed you a series of designs that were paired together. I am going to show you an individual design and I would like you to point with this pen to its corresponding pair. Do you have any questions?'

Appendix J

Demographic Questionnaire

Gender Female Male

Age ___________

Occupation____

Cultural Background ____

Country of Birth ____

Do you speak a language other than English at home Yes No

If Yes please specify____

Employment status ? (Circle as many as applicable)

Unemployed Part - time/ Casual work Full time work

Part-Time student Full - time student

Highest level of education obtained ?

Year 10 Secondary School Year 11 Secondary School Year 12 / VCE / HSC Completion

TAFE certificate TAFE diploma Bachelor degree

Post-graduate degree

Thank You

Appendix K

Dear DR MICHELLE BALL,

Your ethics application has been formally reviewed and finalised.

» Application ID: HRE15-133
» Chief Investigator: DR MICHELLE BALL
» Other Investigators: MS Kate Kelly, MR SAM HUMPHREY, MS ERIN SMITH, MRS EMRA SULEYMAN
» Application Title: THE DEVELOPMENT OF A VISUAL LEARNING AND MEMORY TEST BATTERY: A PILOT STUDY
» Form Version: 13-07

The application has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)' by the Victoria University Human Research Ethics Committee. Approval has been granted for two (2) years from the approval date; 15/06/2015.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date or upon the completion of the project (if earlier). A report proforma may be downloaded from the Office for Research website at: http://research.vu.edu.au/hrec.php.

Please note that the Human Research Ethics Committee must be informed of the following: any changes to the approved research protocol, project timelines, any serious events or adverse and/or unforeseen events that may affect continued ethical acceptability of the project. In these unlikely events, researchers must immediately cease all data collection until the Committee has approved the changes. Researchers are also reminded of the need to notify the approving HREC of changes to personnel in research projects via a request for a minor amendment. It should also be noted that it is the Chief Investigators' responsibility to ensure the research project is conducted in line with the recommendations outlined in the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007).'

On behalf of the Committee, I wish you all the best for the conduct of the project.

Secretary, Human Research Ethics Committee
Phone: 9919 4781 or 9919 4461
Email: researchethics@vu.edu.au

Appendix L

Consent Form For Participants Involved in Research

Information to Participants :

We would like to invite you to be a part of a study looking at developing an electronic visual learning and memory battery of tests.

The ability to learn and remember information is an integral aspect of every day life (Anderson, Lajoie & Bell, 1997). Learning and memory skills underpin all cognitive functioning during development and remain of critical importance during adulthood. Within current learning and memory assessment visual memory is often neglected in comparison to its verbal counterpart. Visual memory is intertwined with visual processing skills in a number of ways. Based on the 'two streams hypothesis' visual processing is divided into two key components : Where (consisting of path and pattern skills) and what (consisting of object recognition skills). While this theory is widely accepted in visual processing tests and forms the basis for most current assessments, this is not replicated in visual memory tasks.

Memory is a vast cognitive domain and to reduce testing times and burden on the participant visual processes are often combined into one or two 'visual memory tests' which can increase the difficulty and reduce the accuracy of interpretation. The present study aims to combine visual processing theories with well established memory theories to develop a series of visual memory tests that can be analysed in a domain specific manner. This index approach to psychological testing is considered best practice as it provides detailed information that can be analysed not only as a whole, but also on sub levels to see how functions differ across the domain. Current test batteries for learning and memory have attempted to provide a full index approach, however, these batteries are often limited in their visual memory assessments. Thus, the present study aims to not only develop an electronic visual learning and memory series of tests, but it also aims to incorporate an index style approach to allow exploration into immediate, working and long term memory in the visual domain. This will provide context to the developed tests that will assist in providing recommendations to individuals and carers.

Participants in this experiment will complete a series of tablet based visual learning and memory tests which will be used to measure different components of visual processing within the memory domain. Participants will also complete a short demographic questionnaire.

Certification By Subject

I, ____ (Enter full name)

of ____ (Enter street address)

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study :

' The Development of a Tablet Visual Learning and Memory Test Battery : A Pilot Study.'

being conducted at Victoria University by : Kate Kelly, Dr. Michelle Ball and Dr. Emra Suleyman, School of Psychology

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by : Miss Kate Kelly and that I freely consent to participation involving the use on me of these procedures

- Demographic Questionnaire
- A tablet based visual learning and memory series of tests.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will now jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed ____

Witness ____

Date __________/_______________/______________

Any queries about your participation in this project may be directed to the researcher Dr. Michelle Ball, (03) 9919 2536 or Dr. Emra Suleyman, (03) 9919 2397. If you have any queries or complaints about the way you have been treated, you may contact the Secretary, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 phone (03) 9919 4781

[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.]

Information to Participants Involved in Research

You are invited to participate

You are invited to participate in a research project entitled ' The Development of a Tablet Visual Learning and Memory Test Battery : A Pilot Study.'

This project is being conducted by student researcher, Miss Kate Kelly, as part of her PhD in psychology at Victoria University, under the supervision of Dr. Michelle Ball and Dr. Emra Suleyman from the School of Psychology in the College of the Arts.

Project Explanation

The ability to learn and remember information is an integral aspect of every day life (Anderson, Lajoie & Bell, 1997). Learning and memory skills underpin all cognitive functioning during development and remain of critical importance during adulthood. Within current learning and memory assessment visual memory is often neglected in comparison to its verbal counterpart. Visual memory is intertwined with visual processing skills in a number of ways. Based on the 'two streams hypothesis' visual processing is divided into two key components : Where (consisting of path and pattern skills) and what (consisting of object recognition skills). While this theory is widely accepted in visual processing tests and forms the basis for most current assessments, this is not replicated in visual memory tasks.

Memory is a vast cognitive domain and to reduce testing times and burden on the participant visual processes are often combined into one or two 'visual memory tests' which can increase the difficulty and reduce the accuracy of interpretation. The present study aims to combine visual processing theories with well established memory theories to develop a series of visual memory tests that can be analysed in a domain specific manner. This index approach to psychological testing is considered best practice as it provides detailed information that can be analysed not only as a whole, but also on sub levels to see how functions differ across the domain. Current test batteries for learning and memory have attempted to provide a full index approach, however, these batteries are often limited in their visual memory assessments. Thus, the present study aims to not only develop an electronic visual learning and memory series of tests, but it also aims to incorporate an index style approach to allow exploration into immediate, working and long term memory in the visual domain. This will provide context to the developed tests that will assist in providing recommendations to individuals and carers.

What will I be asked to do?

You will complete a series of tablet based visual learning and memory tasks which will involve responding to certain stimuli in different ways as it presents on the screen. These tasks will take between 60 - 90 minutes to complete. In addition, you will complete a brief demographic form.

What will I gain from participating?

This research will further add to the extensive international literature on memory test batteries. The present study's unique contribution to the learning and memory knowledge base is the development of a comprehensive, electronic visual memory series of tests that derives it theory from notions of visual processing theory and visual memory theory. By developing visual memory tests in this specific manner that acknowledges memory theory and processing theory it is suspected that this will aid in researchers and clinicians ability to explore strengths and weaknesses in visual memory.

How will the information I give be used?

Your information will be collated with that of other participants to provide data on their performance in each visual learning and memory task. This data will then be computed and compared statistically, to provide insight into what domains of visual processing and memory are being measured. All identifying information about you as the individual will be removed. This information will then be used to complete a PhD thesis. In addition, the anonymous information may be included in research articles to be published in scientific journals.

What are the potential risks of participating in this project?

There is the risk that you will be physically uncomfortable while completing the tablet tasks, as they require you to sit quite still for a single period of up to 90 minutes. You may also experience eye-strain related to focussing intently on the tablet screen. These risks will be managed by keeping the tablet based task as brief as possible, and by conducting the test at a time when you are not feeling tired or fatigued.

There is the risk that you will feel anxious about completing the tablet cognitive tasks. This risk will be managed by providing you with the opportunity to ask questions about the tasks. In addition, you are entitled to withdraw from the project at any stage. If needed, the principal investigator ****** will discuss your concerns with you and if necessary refer you to services outside the university. If you are a student at VU, you will have access to student counselling services if required.

How will this project be conducted?

You will complete a series of visual learning and memory tests that is presented on a tablet. This task will take a maximum of ninety minutes to complete. The test will be completed in a quiet setting under test conditions to ensure minimal distraction occurs. The instructions for the each task will differ, and the researcher will inform you of all requirements prior to beginning the test.

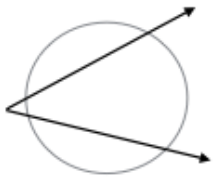
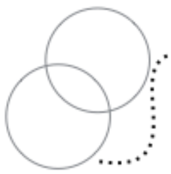
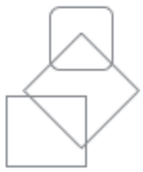
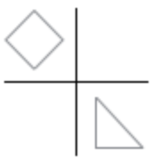
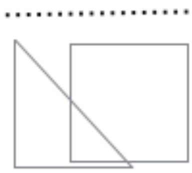
In addition, you will also complete a brief demographic form. This form aims to collect general information about the participant which may aid in explaining the results of the mental rotation task. Your entire participation will take no more than 40 minutes.

Who can participate in the study?

Participant inclusion criteria will include healthy adults aged between 18 - 30. Individual's who have any psychological illness, or physical illness that may affect cognition will be ineligible for the study.

Any queries about your participation in this project may be directed to the Principal Researcher listed above.
If you have any queries or complaints about the way you have been treated, you may contact the Secretary, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 phone (03) 9919 4781.

Appendix M

Object Span Stimuli	**Revised Object Working Memory Stimuli**
	
	
	
	
	
	
	
	

Appendix N

From: Kate Kelly [mailto:Kate.Kelly@vu.edu.au]
Sent: Thursday, May 18, 2017 8:34 PM
To: support@mypad3d.com
Subject: Maze Walk VR - Research Potential

Hello,

My name is Kate Kelly and I am currently completing a PhD in cognitive neuroscience in Melbourne Australia. My project is about furthering our knowledge of how visual memory works within the brain, as surprisingly little is understood. One of the reasons why there is little knowledge about how it works is because until recently it was difficult to measure all aspects of Visual Memory. One of these aspects is called 'Egocentric Processing' and is about how we understand our spatial environment through a first person view.

With the advent of VR this is now possible, however, it is not yet being utilised for this purpose. I have downloaded your Maze Walk - VR app and I think it is fantastic. I was wondering if I would be able to get permission to use it as a test with my participants. It would involve no changes to the test. Simply I would like participants to complete the same maze repeatedly to determine if their reaction times improve. I will be making no profits off this endeavour, just simply trying to gain an understanding of how we process and learn information through a first person perspective.

If you would like further information I can send you through a whole proposal. I look forward to hearing your thoughts. If you have any queries or concerns please do not hesitate to contact me.

Kind regards
Kate

JR Jeff Rayner <jrayner@mypad3d.com>
Fri 19/05/2017, 10:47 AM

Hi Kate

We love this idea.

If it's helpful:

1. It's worth knowing that we have multiple levels with different aspects of movement and puzzle complexity, i.e. speed, jumping, turning, misdirection, etc.
2. We would be happy to supply you with the cheat maps to understand shapes, complexity, obstacles, hidden Easter eggs, etc.
3. We would also be happy to supply you with 'codes' to open up all levels for free
4. We have a good friend with brain cancer who is undergoing trial treatment. Consequently, we are very interested in your testing and results from both a philanthropic perspective as well as personal. Further, owing to this situation, we have very good links to the UW (university of Washington) … so if there are additional assistance and contacts we can provide, don't hesitate to reach out.
5. We would love to hear your proposal and perhaps over time incorporate some special levels especially for your purpose

We look forward to working together, and don't hesitate to reach out at any time.

Cheers!

Jeff Rayner I Co-Founder & CEO I MyPad3D Inc
Cell: (503) 720-6816 I Office: 1-844-697-2333
4132 California Ave SW, Seattle, WA 98116

VR for Everyone

Appendix O

Egocentric Script

'Alright, now we are going to do something a little bit different. What I have here is a virtual reality headset. You may remember that last time I asked you to remember some mazes that were presented to you on the iPad? Now I want to see how you remember a maze when you are inside of one. What I am going to do it show you someone completing the maze, from a first person viewpoint on my computer. As soon as they have completed the maze I am going to ask you to slide the headset down from your forehead over your eyes and you will find that you will be looking at the maze you just saw. Now I will be able to see everything that you are looking at on my computer screen. To move you will have to walk in place and nod your head. If you want to have a look at your surroundings you can do so by looking around like you normally would. I have for you a practice trial so you can see what I mean and get used to moving around in the visual environment. Now I want to let you know that sometimes being in a virtual environment can cause motion sickness if at any point you feel unwell, please let me know and we can discontinue the task. Shall we get started?

Show the practice trial and allow the participant to become acquainted with the controls.

Great work! Do you have any questions?

This task that we are about to do it a learning task, so what this will involve is me showing and you completing the maze three times. I just want you to do your best each time, and try to complete the maze as quickly but as accurately as possible.

Administer the task three times

Egocentric Backwards

'Great work ! How are you feeling? We are now going to do one more task. This time I am going to show you a video of a new maze and this time when you watch the video of the maze being completed the person is going to complete the maze from the end, to the centre. When you place the headset on you will find yourself in the centre of the maze. This time you will need to reverse the directions of the video to find your way out of the maze. Any questions? Let's go!

Appendix P

Feature Span Scripts

Contextual Feature Span

‘ We are now going to begin a new task. This task is similar to a task you did with me last time. On the screen you will see a geometric face made up of many different lines and curves.

Show the participant the image of the face from the static practice trial

*‘After a second you will see one of the lines on this face start flashing red, I want you to try very hard to remember the shape and orientation of this line as this is what you will be asked to remember. I know this is tricky but I just want you to do your best. After you have seen a couple of features light up you will see a screen with lots of different features on it. I want you to point with this pen to the ones you saw in the order that you saw them. So for example if I showed you an upside down curved line and a straight vertical line, I would want you to point to * Gesture at them to encourage them to answer* Exactly. As the task goes on the number of designs for you to remember will get bigger, I just want you to do your best. Do you have any questions?’*

*∗ Answer any questions**

‘Alright well let’s begin with a practice trial’

Administer the two practice trials providing feedback if necessary.

‘Great work let’s begin with the first trial’

Contextual Feature Working Memory

‘ We are now going to do a similar task. Like before in this task on the screen you will see the same geometric face made up of lots of different shapes and lines. I want you to remember the individual features that flash as best as you can. After you have seen a couple you will see a screen with lots of features. This time instead of pointing to them in the order you saw them I want you to point them in reverse order. So if I was to show you an upside down curved line and a straight vertical line,, I would want you to point to the straight vertical line first and then the upside down curved line. As with the last task as the task goes on the number of designs for you to remember will get bigger. It is important that you just do your best. Do you have any questions?’

‘Alright well let’s begin with a practice trial’

Administer the two practice trials providing feedback if necessary.

‘Great work let’s begin with the first trial’

Non-Contextual Feature Span

‘ We are now going to begin a new task. On the screen you will see a lot of abstract shapes all close to one another, taking up the entire screen.

Show the participant the image of the abstract background from the static practice trial

*'After a second you will see one of the lines on this screen start flashing red. This line could appear anywhere on the screen so make sure you are scanning and paying attention to the whole screen, not just a single section. I want you to try very hard to remember the shape and orientation of this line that is flashin as this is what you will be asked to remember. I know this is tricky but I just want you to do your best. After you have seen a couple of features light up you will see a screen with lots of different features on it. I want you to point with this pen to the ones you saw in the order that you saw them. So for example if I showed you an upside down curved line and a straight vertical line, I would want you to point to * Gesture at them to encourage them to answer* Exactly. As the task goes on the number of designs for you to remember will get bigger, I just want you to do your best. Do you have any questions?'*

*∗ Answer any questions**

'Alright well let's begin with a practice trial'

Administer the two practice trials providing feedback if necessary.

'Great work let's begin with the first trial'

Non-Contextual Feature Working Memory

' We are now going to do a similar task, to the last. Like before in this task on the screen a lot of abstract shapes all close to one another. Like before I want you to remember the individual features that flash as best as you can. After you have seen a couple you will see a screen with lots of features. This time instead of pointing to them in the order you saw them I want you to point them in reverse order. So if I was to show you an upside down curved line and a straight vertical line,, I would want you to point

to the straight vertical line first and then the upside down curved line. As with the last task as the task goes on the number of designs for you to remember will get bigger. It is important that you just do your best. Do you have any questions?'

∗ *Answer any questions**

'Alright well let's begin with a practice trial'

Administer the two practice trials providing feedback if necessary.

'Great work let's begin with the first trial'

Appendix Q

Table. Analysis of Sex Differences for Each of the Developed Tasks

	Males M*(SD)* N = 28	Females M*(SD)* N = 34	T*(df)*	P Value
Span and Working Memory Tasks				
Spatial Span	4.61 *(1.26)*	4.38 *(1.02)*	.779 *(60)*	0.44
Spatial Working Memory Span	1.68 *(1.36)*	1.79 *(1.41)*	-3.26 *(60)*	0.75
Object Span	2.50 *(1.11)*	2.91 *(1.23)*	-1.33 *(60)*	0.18
Object Working Memory Span	2.11 *(1.34)*	2.15 *(1.27)*	-0.13 *(60)*	0.89
Contextual Feature Span	2.75 *(1.37)*	2.76 *(1.18)*	-0.30 *(39)*	0.97
Contextual Feature Span Backwards	0.95 *(1.40)*	1.48 *(1.17)*	-1.31 *(39)*	0.20
Non-Contextual Feature Span	1.35 *(1.46)*	1.67 *(1.20)*	-0.76 *(39)*	0.45
Non-Contextual Feature Span Backwards	0.60 *(1.09)*	0.81 *(1.08)*	-0.62 *(39)*	0.54
Learning and Delayed Tasks				
Spatial Learning Immediate Recall	18.70 *(5.08)*	18.71 *(4.38)*	-0.00 *(60)*	0.99
Spatial Learning Delayed Recall	22.65 *(3.82)*	24.15 *(2.39)*	-1.86 *(60)*	0.07
Egocentric Learning Trial 1	95.50 *(18.65)*	87.62 *(19.16)*	1.33 *(39)*	0.19
Egocentric Backwards	114.90 *(21.58)*	109.24 *(26.50)*	0.75 *(39)*	0.46
Designs Learning Immediate Recall	22.67 *(6.64)*	26.88 *(5.47)*	-2.69 *(60)*	<0.001
Designs Learning Delayed Recall	32.32 *(3.15)*	34.29 *(2.38)*	-2.81 *(60)*	<0.001
Visual Pairs Immediate Recall	3.22 *(1.55)*	4.25 *(1.70)*	-2.40 *(60)*	<0.001
Visual Pairs Delayed Recall	7.04 *(1.13)*	7.47 *(1.05)*	-1.54 *(60)*	0.13

Appendix R

Dear DR MICHELLE BALL,

Your ethics application has been formally reviewed and finalised.

» Application ID: HRE17-121
» Chief Investigator: DR MICHELLE BALL
» Other Investigators: MS Kate Kelly, MRS EMRA SULEYMAN
» Application Title: The Development of a Model For Visual Memory Capacity : Bridging the Gap Between Perception and Memory
» Form Version: 13-07

The application has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)' by the Victoria University Human Research Ethics Committee. Approval has been granted for two (2) years from the approval date; 10/07/2017.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date or upon the completion of the project (if earlier). A report proforma may be downloaded from the Office for Research website at: http://research.vu.edu.au/hrec.php.

Please note that the Human Research Ethics Committee must be informed of the following: any changes to the approved research protocol, project timelines, any serious events or adverse and/or unforeseen events that may affect continued ethical acceptability of the project. In these unlikely events, researchers must immediately cease all data collection until the Committee has approved the changes. Researchers are also reminded of the need to notify the approving HREC of changes to personnel in research projects via a request for a minor amendment. It should also be noted that it is the Chief Investigators' responsibility to ensure the research project is conducted in line with the recommendations outlined in the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007).'

On behalf of the Committee, I wish you all the best for the conduct of the project.

Secretary, Human Research Ethics Committee
Phone: 9919 4781 or 9919 4461
Email: researchethics@vu.edu.au

Appendix S

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you to return to be a part of a study extending the findings of the Visual Memory project that you participated in 2015/2016.

Since your initial participation new research along with the findings of the first study suggests that the two streams of visual memory also vary in how much visual information they are able to hold, and this may be influenced by the nature of the spatial or object information that is being processed. The information gathered in the previous study has assisted in understanding and uncovering the importance of these divisions and thus, the present study aims to measure the two components that have been unearthed (one spatial and one object) that were not measured in the first study. The present study aims to develop a comprehensive understanding of how much information each component of our visual memory can hold, manipulate and remember. It is expected that this will vary on the type of visual task you are asked to complete. This knowledge will be used to develop a preliminary model for visual memory that highlights each of the four areas.

For this phase of the study you will be asked to complete 4 more iPad based visual memory tasks that are similar to the ones you completed in the first study. These tasks will involve asking you to remember parts of objects in pictures that appear on the screen. You will also be asked to complete a maze task that uses virtual reality. Finally, you will be asked to complete one pen to paper and two oral memory tests.

The risks in participating in this research are minimal and the appropriate precautions will be taken to ensure your safety as a participant. However, it is noted that a small minority of people may experience motion sickness when undertaking the virtual reality task. There is also the slight risk that you may trip while participating in the same task. Finally, some people experience mild anxiety when completing memory tasks.

CERTIFICATION BY PARTICIPANT

I, ____

of

____

____

certify that I am at least 18 years old and that I am voluntarily giving my consent to participate in the study on Visual Memory being conducted at Victoria University by Miss Kate Kelly, Dr. Michelle Ball and Dr. Emra Suleyman

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Miss Kate Kelly and that I freely consent to participation involving the below mentioned procedures:

• 4 iPad based memory tasks • 2 virtual reality maze tasks • 1 pen to paper memory test • 2 oral memory tests.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

____

____

Date:

____

____

Any queries about your participation in this project may be directed to the researchers

Dr Michelle Ball Dr Emra Suleyman Miss Kate Kelly
9919 2536 9919 2397 kate.kelly@vu.edu.au

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

We are grateful that in 2015/2016 you participated in a study on Visual Memory for our research team. Based on the findings of that study and new research in the area we are hoping to extend our study to explore the way visual memory works in greater detail, and we would like to invite you to continue your involvement with this project.

As before. this project is being conducted by student researcher, Miss Kate Kelly, as part of her PhD in psychology at Victoria University, under the supervision of Dr. Michelle Ball and Dr. Emra Suleyman from the College of Health and Biomedicine.

Project explanation

Memory is considered a foundational skill for our ability to think. It is one of the first thinking skills to develop and allows us to process and understand our environment and items within the environment from a very early age. Memory is a modality specific function which means that verbal and visual memory function independently from one another and it is well established that both consist of short term memory, long term memory and working memory (manipulation) components. Knowledge of these components has allowed researchers to understand verbal memory exceptionally well, however, the findings related to visual memory are not as clear. What is known is that visual information is processed using two streams; one for object information (the 'what' stream) and one for spatial information (the 'where' stream), and both follow separate pathways in the brain. However, models and measures of visual memory do not accurately portray or assess the influence these two streams have on visual memory. There is also a lack of sufficient exploration into how these two streams are processing information within each component of memory (short term, long term and working memory).

The present study aims to further explore the findings of the first study that you previously participated in for us. Since your initial participation new research along with the findings of the first study suggests that the two streams of visual memory also vary in how much visual information they are able to hold, and this may be influenced by the nature of the spatial or object information that is being processed. The information gathered in the previous study has assisted in understanding and uncovering the importance of these divisions and thus, the present study aims to measure the two components that have been unearthed (one spatial and one object) that were not measured in the first study.

The present study aims to develop a comprehensive understanding of how much information each component of our visual memory can hold, manipulate and remember. It is expected that this will vary on the type of visual task you are asked to complete. This knowledge will be used to develop a preliminary model for visual memory that highlights each of the four areas.

What will I be asked to do?

You will be asked to complete 4 more iPad based visual memory tasks that are similar to the ones you completed in the first study. These tasks will involve asking you to remember parts of objects in pictures that appear on the screen. You will also be asked to complete a maze task that uses virtual reality. Finally, you will be asked to complete one pen to paper and two oral memory tests. These tasks will take between 30 - 45 minutes total to complete.

What will I gain from participating?

Although you will not gain any specific personal advantage, you will be contributing to research that hopes to make a unique contribution to the memory knowledge base through the development of a comprehensive, and specific visual memory model. The new visual memory tests developed for this study are designed to measure a wider array of skills than current tests, and it is suspected that this will aid in the ability to explore strengths and weaknesses in visual memory, especially for people who are experiencing memory problems.

How will the information I give be used?

Your information will be collated with your previous data and the data from other participants to provide information on how people perform on each visual memory task. This data will then be computed and compared statistically, to provide insight into what areas of visual processing and memory are being measured. All identifying information about you as the individual will be removed. This data will then be used to complete a PhD thesis. In addition, the anonymous information may be included in research articles to be published in scientific journals.

What are the potential risks of participating in this project?

A small minority of people experience motion sickness during virtual reality tasks. If at any point you feel unwell please let the researcher know and the task can be paused or ended. Furthermore, although we will only require you to walk on the spot, there is also a small risk that you may trip while competing the virtual reality task. Should this occur we will have an ice pack that can be applied to any sore spots. Should a trip result in more serious injury we will call an ambulance or transport you to your GP for treatment if necessary, Some people also experience mild anxiety when completing memory tasks. Should this apply to you, please feel free to ask questions about any aspect of the tasks that is making you feel anxious.

Please remember that like last time you are entitled to withdraw from the project at any stage with no penalty to yourself. If needed, Dr Romana Morda (who has no involvement in the study) will discuss your concerns with you and if necessary refer you to services outside the university. She can be contacted on 99195223.

How will this project be conducted?

Just the same as last time you will be asked to complete a series of visual learning and memory tests. These task will take a maximum of 45 minutes to complete. The test will be completed in a quiet setting under test conditions to ensure minimal distraction occurs. The instructions for the each task will differ, and the researcher will inform you of all requirements prior to beginning the test.

Who is conducting the study?

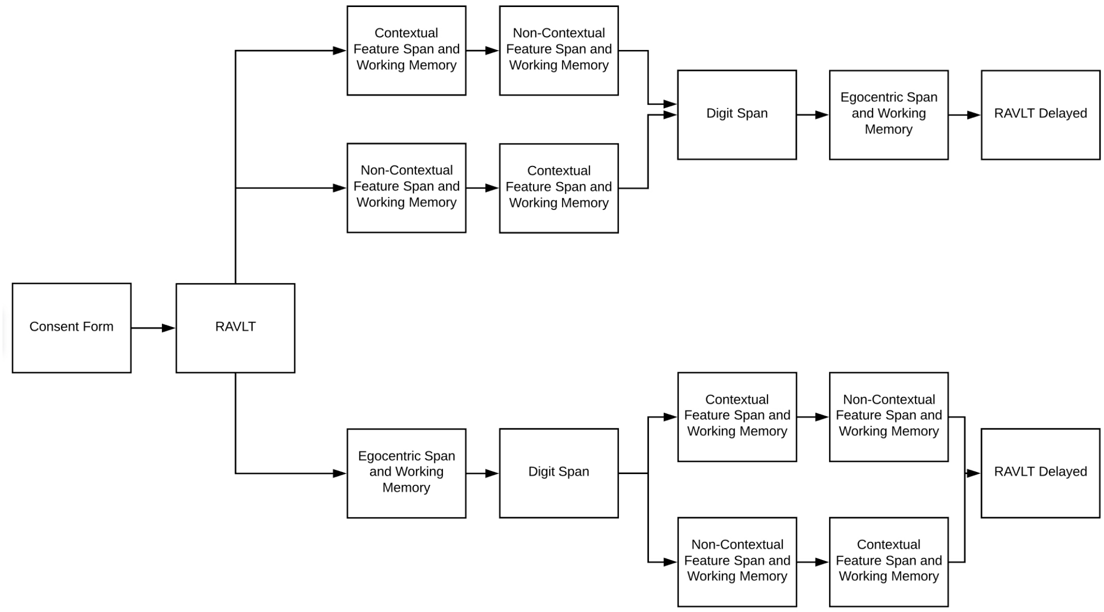
The present study is being conducted by PhD candidate Kate Kelly, under the supervision of Dr. Michelle Ball and Dr. Emra Suleyman as part of her PhD in psychology at Victoria University.

Any queries about your participation in this project may be directed to the researchers Dr Michelle Ball Dr Emra Suleyman Miss Kate Kelly

9919 2536 9919 2397 kate.kelly@vu.edu.au

Any queries about your participation in this project may be directed to the Chief Investigator listed above.
If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix T



Administration Order for Experiment 3.

Note. All participants completed the first two steps and then one of the four branches. Each branch consists of the same assessments however, the order they are conducted in differs.