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Electrophysiological and Behavioural Markers of Associative Source Memory Decline in Normal Ageing.

Thesis submitted to the Department of Psychology, Faculty of Science and Engineering, in fulfilment of the requirements for the degree of Doctor of Philosophy, National University of Ireland Maynooth.

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Abstract

Memory is the ability to encode and subsequently recall information (Brickman & Stern, 2009) and source memory refers to the ability to recall the source of the information, including all contextual aspects related to an event (Glisky & Kong, 2008; M. Johnson, Hashtroudi, & Lindsay, 1993). The ageing process shows a progressive decline in memory (Cabeza, Anderson, Locantore, & Mcintosh, 2002) which is thought to be related to atrophy in regions of the brain which are essential for memory (Pasquier, 1999). Source memory is particularly sensitive to cognitive ageing and is one of the first types of memory to show impairment (Jennings & Jacoby, 1997; Siedlecki, Salthouse, & Berish, 2005). In the current thesis different aspects of memory were measured to determine the extent of memory decline in ageing using associative, episodic and particularly source memory tasks. Both behavioural and electrophysiological methods were used to investigate cognitive changes in performance due to the ageing process between young and older adults along with an intervention at the time of acquisition to determine if source memory recall can be enhanced in older adults.

In Chapter 3 memory retrieval was examined between young (18-30 years, n=27) and older (55-70 years, n=25) adults at three computer-based tasks, indexing source memory (an Opposition task), associative memory (a Visual Paired-Associates task) and episodic memory (a False Memory paradigm). Young and older adults were matched on estimated scores of IQ, short-term memory and self-ratings of their own memory. The results indicated that older adults have poorer accuracy and slower response times on memory tasks of associative and source memory, with the latter showing particularly large decrements due to ageing. Source deficits were clear on the Opposition task but context had little effect on accuracy on the VPAc task, while few differences were

evident on the False Memory paradigm; therefore appears that memory for temporal context (i.e. the timing of an event) suffers more impairment in ageing. These results suggest that aspects of memory binding may be among the first memory processes to suffer a decline in healthy ageing.

Chapter 4 examined young (18-30 years, n = 14) and older (50-75 years, n = 14) adults' differences in recorded EEG for three computer-based memory tasks which assess source, episodic/associative and false memory. Reduced scalp electrical activity was observed in older adults on the source memory task coupled with a poorer behavioural performance. Reduced activity in older adults was also evident for mistaken lures and the correct identification of lures in the false memory task, but no behavioural differences were evident. For successful trials in associative memory tasks, increased activity was present in older adults while behavioural performance was either equal to or poorer than that of young adults. These data are mostly consistent with the idea that young adults show larger mean ERP amplitudes than older adults, suggesting a reduction in cognitive functioning in older adults which may have resulted in reduced memory accuracy capacity.

In Chapter 5 data is reported from young (18-30, n = 15) and older (55+, n = 15) adults during behavioural measures of source memory and the associated electrophysiology. Participants completed the Opposition task and a Where-Who-What task. Results generally indicated that older adults displayed poorer behavioural performance and reduced amplitude P1 and P3 components on both tasks in comparison to young adults, which may reflect enhanced perceptual ability (linked to the P1) and recognition of the source of information (linked to the P3) in young adults compared to older. However, the electrophysiology predominantly showed enlarged waveform components in older participants at approximately 200ms for source memory tasks, and

revealed more anterior positive scalp activity in the older compared to posterior topographies in the young which may indicate an automatic compensatory function in older adults. These patterns may reflect the recruitment of additional cortical areas acting in a compensatory manner to alleviate the age-related impairment in source memory tasks.

An intervention with two source memory tasks was employed in Chapter 6. Three groups of adults, young control (18-30 years, n = 20), older control (55+ years, n = 20) and older intervention (55+ years, n = 20), took part in the experiment. Both control groups completed two computer-based source memory tasks without the use of an intervention, while the older intervention group used a strategy at the time of acquisition for both source memory tasks under two methods: firstly, sentence generation to enhance semantic binding; and secondly, story generation to increase contextual binding. Results indicate that the use of an intervention allowed for enhanced source memory recall in older adults compared to both control groups. In addition, the interventions led to faster response times compared to the older control group but not the young control group. It is concluded that while an intervention can alleviate the age-related deterioration of source memory accuracy, it does not entirely counteract the impairment in speed of processing typically seen in older adults.

The behavioural results of this series of experiments indicate that source memory is negatively affected by the ageing process and that accuracy on source memory tasks is more affected than tasks involving associative and episodic memory. This supports previous findings indicating that memory for source is one of the first to decline with ageing. However, despite this discrepancy in source memory, an intervention strategy at the time of acquisition can lead to enhanced source memory recall in older adults compared to older and younger control adults. The

electrophysiology may suggest that older adults have a decline in the perceptual processing of the source of information compared to young adults which may be reflected by the poorer behavioural performance on memory tasks. Furthermore older adults may attempt to compensate for these reductions in perceptual processing, as reflected by enlarged components at approximately 200ms. However, this compensation does not appear to be fully effective as the older adults retain poorer accuracies on source memory tasks. Additionally, the electrophysiology indicates further compensation as positive-going activity appears to occur more anteriorly in older adults which may reflect compensation for dysfunction in regions of the brain responsible for perceptual processing. These results provide additional support for two models of cognitive ageing, the Compensatory Related Utilisation of Neural Circuits Hypothesis (CRUNCH; Reuter-Lorenz & Cappell, 2008) and Posterior Anterior Shift in Ageing (PASA) models (S. W. Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008).

Chapter I

General Introduction

1.1 Introduction

Memory is defined as one's ability to recall information which was previously encoded, whether that information consists of facts or events (Brickman & Stern, 2009), and is considered to be a complex aspect of cognition (Westerberg et al., 2006). Memory is considered to consist of encoding, involving the acquisition of information; storage when information is retained; and retrieval whereby information is brought into consciousness via recall or recognition (Campos, Barroso, & de Lara Menezes, 2010). Retrieval can occur in different forms: free recall, where recall occurs in the absence of related information; cued recall, where probes are given to aid recall; and recognition, when provided information is identified as previously encountered (Coluccia, Gamboz, & Brandimonte, 2011).

Memory is important in every aspect of our lives, from remembering to pay bills, to recalling conversations with others, to enhancing knowledge and education. Without memory, humans would not be able to function in their daily lives or to appreciate new experiences. This is evident in the case of Clive Wearing, considered as the man without memory, whose memory span is a few seconds leaving him with a very debilitating life (Sacks, 2007). When memory fails, it can result in forgetting appointments, names, events, knowledge, to pass on information etc. and this can have a detrimental effect on our lives. Theories on forgetting are discussed later.

There are many types of memory within the human memory systems which need to be considered for discussion. The first type of memory to be discussed is Short-term memory (STM) which involves memories that are in our conscious thoughts whether they are retrieved from Long-term memory (LTM) or from paying attention to our current surroundings (Atkinson & Shiffrin, 1968). Studies of STM mainly focused on the span of human memory and it was generally accepted that STM had a capacity of seven items plus or minus two, with performance relying on "chunking" pieces of information (Miller, 1956). More recent studies have indicated that STM can contain three to five "chunks" of information (Cowan, 2001). This indicates that STM may have a smaller capacity that initially theorised. However, Miller (1959) stated that by "chunking" pieces of information, STM performance can be improved. These small chunks of information are typically available for brief periods of time (Cowan, 2008).

STM cannot be considered without the inclusion of Working Memory and although the terms are sometimes used synonymously, they are separate, but interacting processes (Cowan, 2008). Working memory refers to a person's ability to not only retain information temporarily in consciousness (i.e. in STM) but also to simultaneously manipulate and process this information at will (Cowan, 2008); for example, the ability to recall digits in a backward order. Becker and Morris (1999) stated that working memory involves retaining information in STM with the purpose of processing the information concurrently.

Previously, the systems of STM and LTM were regarded as being separate processes (R. Wood, Baxter, & Belpaeme, 2011). However, evidence suggests that the two memory systems must interact as information in LTM must have once existed in STM (Brickman & Stern, 2009) before being transferred, or copied, into LTM (Atkinson & Shiffrin, 1968). In addition, the retrieval process involves recalling long-term memories into the STM system (Atkinson & Shiffrin, 1968).

LTM is considered as the human capacity to store vast amounts of information over long periods of time, for example years (Cowan, 2008). LTM relies on the three processes of encoding, when information is converted into a mental representation; storage, when information is retained; and retrieval, the ability to recall (recollection) or recognise (familiarity) previously stored information (Campos et al., 2010).

Recollection is considered as the ability to remember specific details without external cues, while familiarity is defined as the ability to indicate if an item was previously encountered or not (Yonelinas, 2002); these are considered as two separate processes within LTM. While theories differ over the existence of other types of memory, each theoretical view accepts the existence of the LTM (Cowan, 2008). Despite the extensive duration of LTM, items are subject to the procedure of forgetting, which may be due to decay, where information is lost over time, or interference, where information is disrupted (Wixted, 2004).

Prospective memory is distinct from retrospective memory (which is one's memory for people, events, etc. from the *past*); prospective memory is regarded as the ability to remember to carry out actions at the correct time and place in the absence of an explicit reminder or cue (Graf, 2012). It is generally this type of memory that is utilised in remembering appointments or knowing when to make payments. The emphasis of prospective memory is on recalling *when* something must be carried out or completed, and attention is a necessary component of prospective memory (G. Smith, Della Sala, Logie, & Maylor, 2000). Failures in prospective memory can lead to absent-mindedness for when a required action must be performed, while failures in retrospective memory led to the loss of information (Graf, 2012).

The final type of memory to be considered and discussed is source memory. The original definition for source memory was considered as quite narrow (Glisky & Kong, 2008). Many authors defined source memory as recollecting *how* an event happened (Schmitter-Edgecombe, Woo, & Greeley, 2009), *how* an item was acquired (Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994), or *when* and *where* we learned facts (Jacoby, Shimizu, Daniels, & Rhodes, 2005). However, the term source memory has since been extended to include any and all aspects of context which may be associated with an event (Glisky & Kong, 2008; Johnson, Hashtroudi, & Lindsay, 1993). Source memory is not considered entirely separate from episodic memory, as episodic memory is the entirety of information being recalled including the context, whereas source refers to the context alone (Brickman & Stern, 2009). Although not entirely separate, different neural mechanism have been implicated in the recollection of an episode and the recollection of the source of an event (Wilding, Doyle, & Rugg, 1995; Wilding & Rugg, 1996). The different aspects of context that combine to create a source allow individuals to identify the source of the information and allows for better recall of an event (Mammarella & Fairfield, 2008). As such, when one needs to recall specific features or details of an event, source memory is involved (Dennis, Hayes, et al., 2008). Examining source memory allows for the investigation of which features are responsible for making contextual-based knowledge available in memory (Johnson, 2005). As source memory allows us to determine if the source of information is "fact", it is therefore responsible for our ability to exert control over our own opinions and beliefs (Johnson et al., 1993).

1.2 Historical Overview

The investigation of memory and memory processes has spun centuries and can be dated back to the ancient Roman and Greek periods where they introduced the Method of Loci, which is an imaging technique used to aid memory by associating items with a physical feature of that locus (O'Keefe & Nadel, 1978). Early researchers in Psychology also examined memory, with William James (the father of Psychology) proposing primary (i.e. short-term memory) and secondary memory (i.e. long-term memory), offering one of the earliest insights into different types of memory (Braver, 2007); while Ebbinghaus (1913) is revered for the Forgetting Curve, where information is lost over a period of time when one is not attempting to retain it. As such memory has been of interest throughout our history and is still one of the most studied topics of Psychology today.

1.2.1 The Case of Patient H.M.

The original theory of memory is that memory consisted of a unitary store (i.e. a single store for all memories) and no distinction was made between different types of memory. However, evidence for a multi-store model of memory came from studies of patients with brain lesions (Milner, 1959). One of the most notable studies is patient H.M. who underwent brain surgery as an experimental procedure in the hopes of curing his debilitating epilepsy (Corkin, 1984; Scoville & Milner, 1957). His medial temporal lobe (MTL) was removed bilaterally and the surgery left him with anterograde amnesia (Milner, Corkin, & Teuber, 1968; Scoville & Milner, 1957; see discussion below on anatomy for further information on the role of the MTL in memory). This type of amnesia meant that he was no longer able to create any new long-term memories (Riccio, Richardson, & Guanowsky, 1983); however, his previous long-term memories remained, for the most part, intact, as did his STM (Corkin, 1984; Milner et al., 1968; Scoville & Milner, 1957). The case of H.M. has provided researchers with invaluable knowledge on the workings and the anatomy of the human memory system. As H.M.'s STM remained intact while his LTM did not, his case provided evidence for human memory being composed of multiple systems.

1.2.2 Atkinson-Shiffrin Modal Model

The Atkinson-Shiffrin Modal model or multi-store model of memory was one of the first to introduce a multi-store system (Atkinson & Shiffrin, 1968) which categorised memory into different types (the sensory store, STM and LTM) wherein information is transferred from one store to the next (see Figure 1.1 below). The sensory store received information from the individual sensory modalities (Atkinson & Shiffrin, 1968) such as vision (iconic) and audition (echoic). Iconic memory is responsible for the ability to perceive briefly presented visual items (Sperling, 1963) and echoic memory is the ability to store brief amounts of auditory information (Darwin, Turvey, & Crowder, 1972). The original theory stated that attending to information in the sensory store allowed for memories to be transferred into the STM system and therefore be within conscious awareness (Atkinson & Shiffrin, 1968). One could rehearse the information in STM in order to recall it and if items were rehearsed in STM, the information could then be transferred or "copied" to the LTM system (Atkinson & Shiffrin, 1968). When items in LTM need to be accessed, it was considered that this was performed through retrieval, and the information was transferred back to the STM store (Shiffrin & Atkinson, 1969).

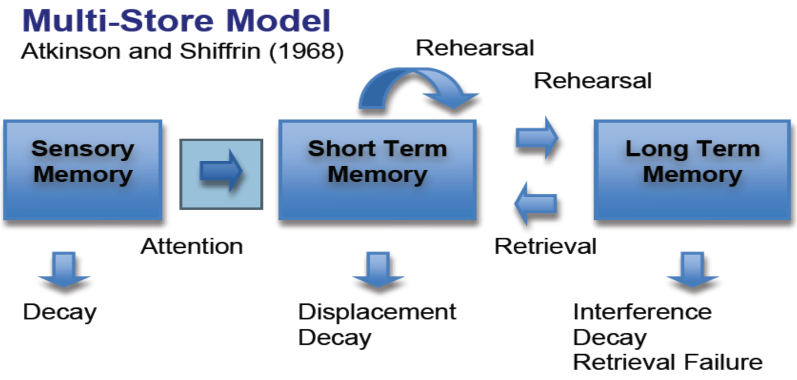

Figure 1.1: Example of the Atkinson-Shiffrin Multi-Modal Store of Memory. Obtained from http://www.smartpsych.co.uk/wp-content/uploads/2010/04/msmmodel2.png. Accessed 8th September 2013.

1.2.3 Baddeley and Hitch Working Memory Model

In an attempt to improve upon the theory of short term memory, Baddeley and Hitch (1974) proposed a new model of working memory. The model consisted of three components; the Central Executive, the Phonological Loop and the Visuo-Spatial Sketchpad, and Baddeley (2000) later extended the model to include the Episodic Buffer (see Figure 1.2 below). The latter model of working memory divided the systems into crystallised or fluid systems. Crystallised systems are those that have the capacity to gain knowledge and are changed by additional resources (shaded areas in Figure 1.2) and Fluid systems are those that do not gain knowledge and remain stable (unshaded areas in Figure 1.2) (Baddeley & Hitch, 1974; Baddeley, 2000). The Central Executive controls the different cognitive processes of the “slave” systems (i.e. the other three systems) by directing attention to relevant information and switching between tasks and retrieval of information (Baddeley, 2001). The Phonological Loop is responsible for processing verbal and auditory information; such information is prevented from decay by refreshing it in an articulatory loop, i.e. by repeating it (Baddeley & Hitch, 1974, 1994). The Visuo-Spatial Sketchpad can be divided into the “visual cache” which stores information, and the “inner scribe” which rehearses information (Pickering, 2001) and is responsible for processing visual and spatial information. The Visuo-Spatial Sketchpad is involved in the manipulation and construction of visual images and mental representations (Baddeley & Hitch, 1974, 1994; Becker & Morris, 1999). The Episodic Buffer is responsible for integrating information from the other two “slave” systems and to link this information to LTM (Baddeley, 2000).

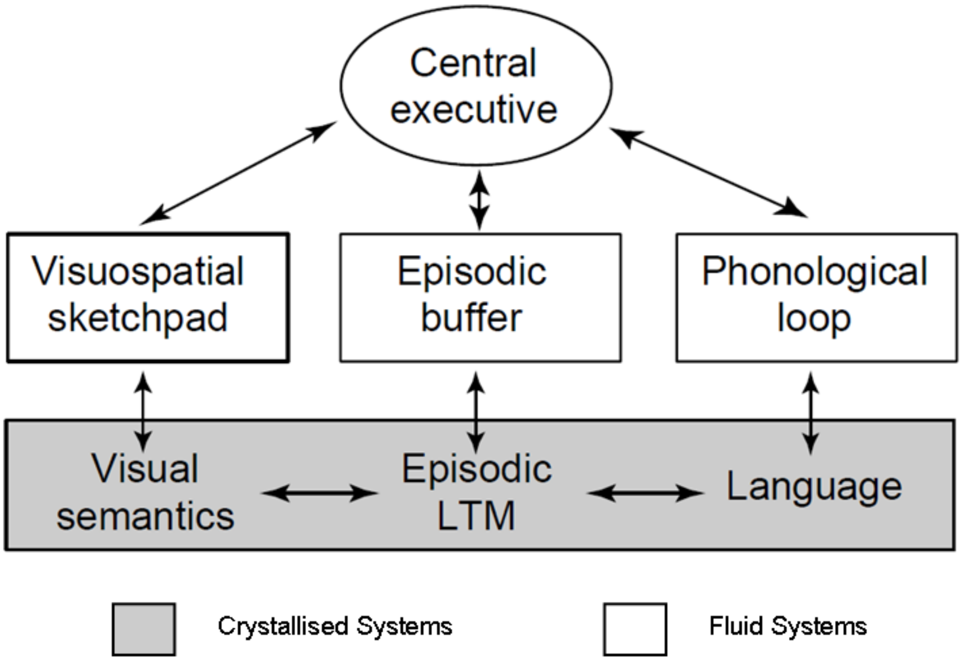

Figure 1.2: The multi-component working memory model.
From "The episodic buffer: A new component of working memory?" by A. Baddeley, 2000, *Trends in Cognitive Sciences, 4,* p. 421. Copyright [2000] by Elsevier. Reprinted with permission.

1.2.4 Squire's Taxonomy

According to Squire's (1986) model, LTM is composed of two separate systems: Declarative (in our conscious control) and Non-Declarative Memory (outside our conscious control) (Milner, Squire, & Kandel, 1998; Squire, 1986) (see Figure 1.3 below). Declarative memory can be further broken down into Episodic and Semantic memory. Episodic memory refers to our ability to recall specific events within our lives and includes all aspects of personal experience that occurs in a particular event in one's life (Squire, 1992, 2004). These memories are often visual, have a short time frame and are easily forgotten (Conway, 2009). Semantic memory is considered as one's memory for facts, concepts and knowledge-based information (Squire, 2004) and is responsible for comprehension (Kutas & Federmeier, 2000; Martin & Fedio, 1983) and symbolic information independent of context (R. Wood et al., 2011). While episodic and semantic memories are two separate and distinct memory systems, they do interact. Items in semantic memory are bound together by episodic memory to form time-based personal events (Brickman & Stern, 2009), and semantic memories may have once had context, but have since lost this context and have become semantic (Battaglia & Pennartz, 2011).

Non-declarative memories consist of our procedural memory, and include priming, classical conditioning and non-associative learning. Procedural memory relates to our ability to perform acts outside of our conscious control; they generally require motor responses, and become relatively automatic (Brickman & Stern, 2009; L R Squire, 1992a). Priming is when exposure to an implicit stimulus impacts on one's subsequent response to that stimulus (Squire, Knowlton, & Musen, 1993). Simple classical conditioning is considered as a type of implicit learning where a neutral stimulus evokes a response as it was previously paired with a response-evoking stimulus (Squire et al., 1993). Non-associative learning occurs when a response to a stimulus changes due to exposure to said stimulus through habituation or sensitization (Squire & Zola-Morgan, 1991).

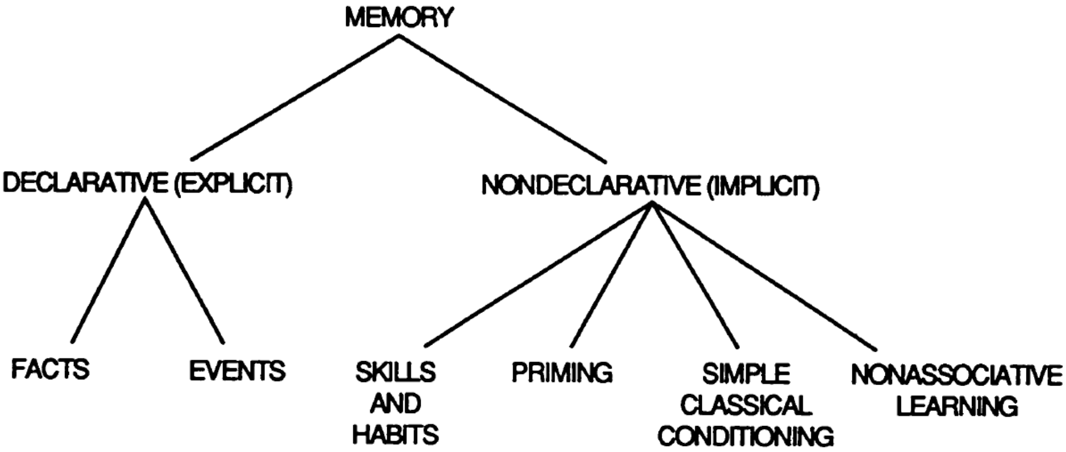

Figure 1.3: The division of the Long term memory system.
From "The medial temporal lobe memory system," by L. R. Squire and S. Zola-Morgan, 1991, *Science, 253,* p. 1381. Copyright [1991] by the American Association for the Advancement of Science. Reprinted with permission.

1.2.5 Forgetting

Atkinson and Shiffrin proposed that information could be lost from LTM via decay (where it is slowly lost), interference (where information is disrupted) or inaccessibility (information cannot be identified; Shiffrin & Atkinson, 1969). According to the Trace Decay theory, forgetting depends on the passage of time from learning the information until retrieval (Ebbinghaus, 1913), meaning that the longer the retention is, the more likely one is to forget the information. Ebbinghaus (1913) outlined in his Trace Decay theory that forgetting occurs because there is natural decay of memory traces over time. However, this does not account for the ability to retain information from childhood, indicating that memories can be retained despite the passage of time.

Possibly the most influential theory of forgetting is the Interference theory (M. C. Anderson & Neeley, 1996) which proposes that recollection is disrupted by what was learned before, or it *will be* disrupted by what is learned later. While this theory is very popular and may be quite plausible, it is lacking information of the processes involved in this disruption (Postman, 1971; Underwood & Postman, 1960). Interference occurs when there is competition between memory traces when two or more contain overlapping or similar information. There are two types of interference, proactive and retroactive. Proactive interference occurs when old knowledge results in increased forgetting of subsequent new knowledge (Underwood, 1957), and retroactive interference is when new knowledge makes it difficult to remember old knowledge (Melton & Irwin, 1987).

With inaccessibility there is a failure in the mechanism which accesses memories (Tulving & Psotka, 1971). The information which was previously stored remains intact but becomes inaccessible at the time of retrieval. This occurs as the storage location cannot be accessed due to insufficient cues resulting in a failure in recall (Reynolds, 1977). According to Tulving (1974), over time the relevant information for retrieval becomes absent as changes in one's cognitive environment occur and as a result the cues for accessing the memory become inaccessible. Each of these theories offers an explanation for how forgetting occurs and considerable empirical evidence has been presented in support of each.

1.3 Current Models of Memory

1.3.1 Classical Consolidation Theory

Classical Consolidation Theory, proposed by Squire (1992), hypothesizes that the hippocampus stores memories through encoding. With the initial registration of new information, the memory becomes retained in the hippocampus and cortical regions (Frankland & Bontempi, 2005), and after the initial acquisition of information, the memory is delicate and prone to disruption (Squire & Alvarez, 1995). However, if the memory remains uninterrupted it will subsequently consolidate over time to other cortical areas. The hippocampus continues to activate different areas of the neocortex allowing for the memory to be continually refreshed (Squire & Alvarez, 1995). However, as the memory consolidates over time, the hippocampus becomes less involved until the memory eventually becomes independent of the hippocampus, with the cortex becoming entirely responsible for the information in memory (Frankland & Bontempi, 2005). The hippocampus is connected to other areas of the neocortex and thus binds the information to such regions allowing for memories to become stable in the neocortex and independent of the hippocampus (Moore & Roche, 2007). When this occurs the memory is more stable and less sensitive to interruption (Squire & Alvarez, 1995).

Evidence has suggested that this consolidation occurs over a period of a few days to a week, and that once this time period has elapsed the information can no longer be disrupted (Dudai, 2004; Frankland & Bontempi, 2005; McGaugh, 2000). Therefore, the hippocampus stores the memory temporally and it is slowly transferred to other cortical regions of the brain. The synapses in the hippocampus change quickly allowing for temporary storage, while the synapses of the neocortex change more slowly and the hippocampus repeatedly activates the representations in the neocortex to strengthen the memory (L R Squire & Alvarez, 1995).

Protein synthesis is necessary for consolidation to occur (McGaugh, 2000; Meeter & Murre, 2004). Therefore, evidence supporting consolidation has emerged suggesting that inhibiting protein synthesis in animals results in severe amnesia following learning new tasks (Frankland & Bontempi, 2005; McGaugh, 2000; Meeter & Murre, 2004). Further evidence for consolidation comes from the amnesia gradient in patients with retrograde amnesia (i.e. memories prior to the trauma; Squire & Alvarez, 1995). Generally, older memories are more likely to be retained with retrograde amnesia compared to newer memories, suggesting that these are the strongest in the neocortex, indicating that consolidation of memories is important for the long-term retention of information.

1.3.2 Multiple Trace Theory

Contrary to the Classical Consolidation theory, Nadel and Moscovitch (1997) proposed the Multiple Trace Theory and argued that the assumption that memories are transferred from the hippocampus to the cortex over time is mistaken. Multiple Trace Theory states that the hippocampus is involved in episodic and spatial memories for the duration of their existence with the other forms of memory (such as semantic) having a contribution from the hippocampus for a limited time (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006; Nadel & Moscovitch, 1997, 1998). The hippocampus functions especially when the memory is rich in contextual details, i.e. episodic memory, and can function for semantic if the memory contains contextual features (Frankland & Bontempi, 2005). However, if semantic memories do not contain any contextual information, they can become stable in regions of the neocortex independent of the function of the hippocampus through the consolidation process (Nadel & Moscovitch, 1997).

When memories are reactivated this results in the hippocampus creating traces which are linked to the neocortex, thereby providing spatial and temporal context (Frankland & Bontempi, 2005) and for as long as a trace exists in episodic and spatial memory, the hippocampus is involved (Nadel & Moscovitch, 1997). If traces exist in the cortex they are considered to be absent of context, and therefore semantic in nature; and MTT further proposes that remote semantic memories can be retrieved without the function of the hippocampus (Frankland & Bontempi, 2005; Nadel & Moscovitch, 1997).

A review of studies of lesions and neuroimaging have provided evidence in favour of the Multiple Trace Theory (see Moscovitch et al., 2005 for review). The theory was implicated as results suggested that the hippocampus functioned in the retrieval of episodic and spatial memories irrespective of the period of time between acquisition and retrieval. In addition, this was observed for semantic memories also, which according to the theory can become independent of the hippocampus; however if episodic elements remain to be associated with the semantic memory, the hippocampus may still function in the retrieval of semantic memories (Moscovitch et al., 2005). In addition, Nadel and Moscovitch (1997) have suggested that autobiographical memories relied on the hippocampus irrespective of the duration these memories had been established for, suggesting that the hippocampus retains a role in memory for the entire duration of its existence.

1.3.3 Variations

A hippocampal model of memory has been proposed by O'Reilly and colleagues (McClelland, McNaughton, & O'Reilly, 1995; O'Reilly & McClelland, 1994; O'Reilly, Norman, & McClelland, 1998). The model posits that the hippocampus initially stores memories via synaptic changes which allows for learning to be fast without disrupting neocortical structures, thus reducing interference (McClelland et al., 1995; O'Reilly et al., 1998). This reduction in interference occurs when the hippocampus and neocortical regions work in union to segregate different cortical patterns to represent different aspects of the environment (O'Reilly & McClelland, 1994; O'Reilly et al., 1998). Changes in the synapses of the hippocampus permit the reinstatement of memories in the neocortex which can be incorporated into structured systems at these cortical sites (McClelland et al., 1995), and reinstatement of memories causes modifications in the synapses of the neocortex which allows for representations in memory to be accumulated (McClelland et al., 1995; O'Reilly & McClelland, 1994).

Sutherland and Rudy (1989) proposed a Configural Association theory of learning which made a clear distinction between simple association and configural association, with only the latter relying on the hippocampal formation. "Configural associations" are when multiple stimulus events are combined to form a novel representation in memory (Sutherland & Rudy, 1989). The theory further stated that this process was hippocampus-dependent and that problem solving based on configural processes in rats relied on intact hippocampi (T. L. Davidson, McKernan, & Jarrard, 1993). However, later evidence suggested that acquisition of "configural associations" could occur in rats without intact hippocampi (T. L. Davidson et al., 1993; Rudy & Sutherland, 1995). Therefore the theory was altered suggesting that cortical circuitry outside the hippocampus is responsible for constructing "configural associations" and that the hippocampus contributes to this process by enhancing the responsible cortical units, thus decreasing similarity, and increasing strength in the "configural associations" (Rudy & Sutherland, 1995). Each of the current models of memory stipulates that the hippocampus plays a role in memory formation and the next section on anatomy details the importance of the hippocampus and other regions of the brain associated with memory.

1.3.4 Anatomy

The anatomy associated with the different types of memory is an essential part of the study of memory. Many regions of the brain have been associated with different types of memory (see Figure 1.4). For example, the pre-frontal cortex (PFC) has been implicated in short-term (Broersen, Heinsbroek, de Bruin, Uylings, & Olivier, 1995; Fuster & Alexander, 1971; Levy & Goldman-Rakic, 2000) and working memory (Goldman-Rakic, 1999; Rypma & D'Esposito, 1999; Rypma, Prabhakaran, Desmond, & Gabrieli, 2001; Rypma, Prabhakaran, Desmond, Glover, & Gabrieli, 1999). The hippocampal formation (HF) and medial temporal lobes (MTL) play a major role in declarative memory (Bayley & Squire, 2003; Squire & Zola-Morgan, 1991; Squire, Stark, & Clark, 2004), in particular episodic memory (Nadel, Ryan, Hayes, Gilboa, & Moscovitch, 2003). Many different regions of the brain are responsible for the different types of non-declarative memory such as the striatum for procedural memory (Barnes, Kubota, Hu, Jin, & Graybiel, 2005), the neocortical regions for priming (Schacter &

Buckner, 1998), the amygdala for emotional responses for conditioning (Sah, Westbrook, & Lüthi, 2008), the cerebellum for motor responses to conditioning (Thompson & Steinmetz, 2009) and the reflex pathways for non-associative learning (Poon & Young, 2006). As this thesis is predominantly interested in declarative memory, the remainder of this section will focus on the roles of the hippocampal formation (HF) and medial temporal lobes (MTL) in declarative memory.

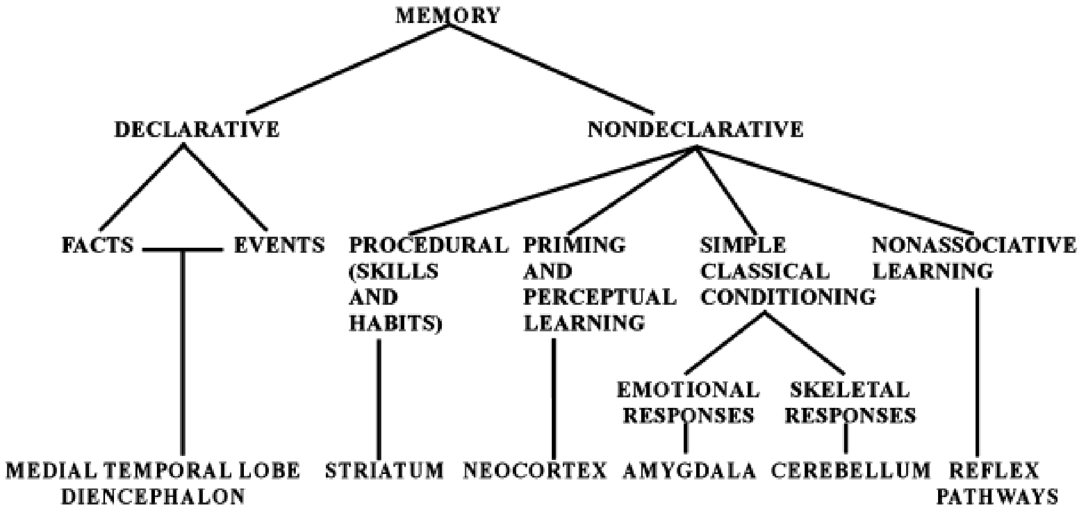

Figure 1.4: A taxonomy of the LTM system depicting the structure and associated cortical regions of declarative and non-declarative memory.
From “Memory systems of the brain: A brief history and current perspective,” by L. R. Squire, 2004, *Neurobiology of learning and memory, 82,* 173. Copyright [2004] by Elsevier. Reprinted with permission.

The hippocampus is a C-shaped structure of the medial temporal lobes (MTL) and its name is derived from Greek meaning “seahorse” as the shape of the hippocampus resembles that of a seahorse. It is located within the MTL(L R Squire et al., 2004), and plays a vital role in the encoding, retention and retrieval of long-term memories (for review see Moscovitch et al., 2005). This is apparent by studying the case of H. M. who, after the bilateral removal of his hippocampi, was no longer able to store new long-term memories (Scoville & Milner, 1957). Similar cases of lesion studies have also shown how the hippocampus is a critical component for memory (see Milner, 1959). The hippocampus is composed of the Cornu Ammonis fields (CA1, CA2, CA3 and CA4), the dentate gyrus (DG) and the subiculum (see Figure 1.5 below; Squire et al., 2004). The parahippocampal region surrounds the hippocampus and is composed of the entorhinal, the perirhinal and the parahippocampal cortices, and together these are considered the medial temporal lobes (Squire et al., 2004).

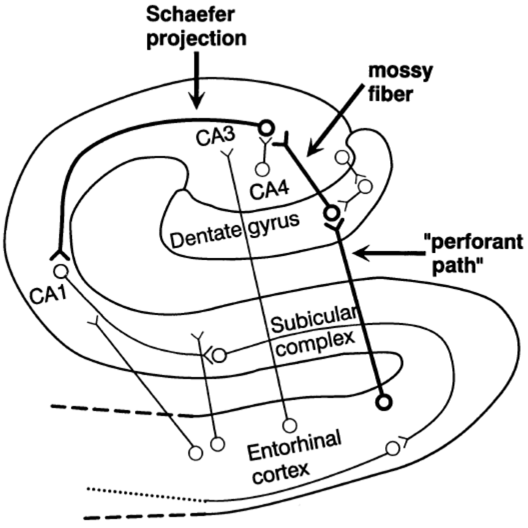

Figure 1.5: The anatomy of the hippocampus.
From "Cell biology of the hippocampal formation in schizophrenia," by D. R. Weinberger, 1999, *Biological Psychiatry, 45,* p. 396. Copyright [1999] by Elsevier. Reprinted with permission.

The medial temporal lobe is vital for memory as it is densely connected to other regions of the cerebral cortex, and many different regions of the brain transfer information to the parahippocampal cortices (Burwell & Amaral, 1998; Suzuki & Amaral, 1994). Information converges on the MTL from many cortical regions including the parietal lobe, the superior temporal sulcus, and the ventral temporal cortex among others (Lavenex & Amaral, 2000; Suzuki & Amaral, 1994). Once information reaches the parahippocampal and perirhinal cortices, stimulation projects to the entorhinal cortex, which is responsible for the transfer of information between the HF and other parts of the cerebral cortex. Activation passes from the EC to CA3 via the dentate gyrus in what is termed the mossy fibre pathway (Amaral & Lavenex, 2007). This pathway projects onto CA1, which then transfers the information to the subiculum (Amaral & Lavenex, 2007). Information is then transferred back to EC via three means[1] to be further transferred to other regions of the cerebral cortex. Information is then transferred out of the EC to parahippocampal and perirhinal cortices to be further transferred to other neocortical regions of the brain (see Figure 1.7 for the schematic view of the MTL). The connections between the parahippocampal region and the HF allows for information to be assimilated in memory (Suzuki & Amaral, 1994; Witter et al., 2000).

Long-term potentiation (LTP) was discovered in the hippocampi of rabbits whereby cells in the hippocampus responded more strongly and for a longer duration to electrical stimulation than they had previously due to stimulation of two neurons occurring concurrently (Bliss & Gardner-Medwin, 1973; Bliss & Lømo, 1973; Cooke & Bliss, 2006). LTP has been implicated as a mechanism in learning as the increase in strength in the hippocampal cells could last for a very long time compared to other processes that affect synaptic strength (Bliss & Collingridge, 1993; Lømo, 2003). Morris and colleagues implicated LTP in the formation of memories (Morris, Anderson, Lynch, & Baudry, 1986). They indicated that rats which had NMDA receptors blocked with APV[2] were impaired on learning the Morris Water Maze where a hidden platform must be located in a pool of water (Morris, 1981). Furthermore, control rats demonstrated LTP in the hippocampus while LTP was absent in APV-treated rats

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[1] From the CA3 through the Shaffer collateral pathways to EC; through the CA1 axons connected to the EC; or directly from the subiculum to the EC (Amaral & Lavenex, 2007).

[2] NMDA receptors are responsible for memory formation (Li & Tsien, 2009) and are inhibited with APV or AP5 (Morris, 1989).

(Morris et al., 1986). As such, long-term potentiation has been implicated in the formation of long-term memories.

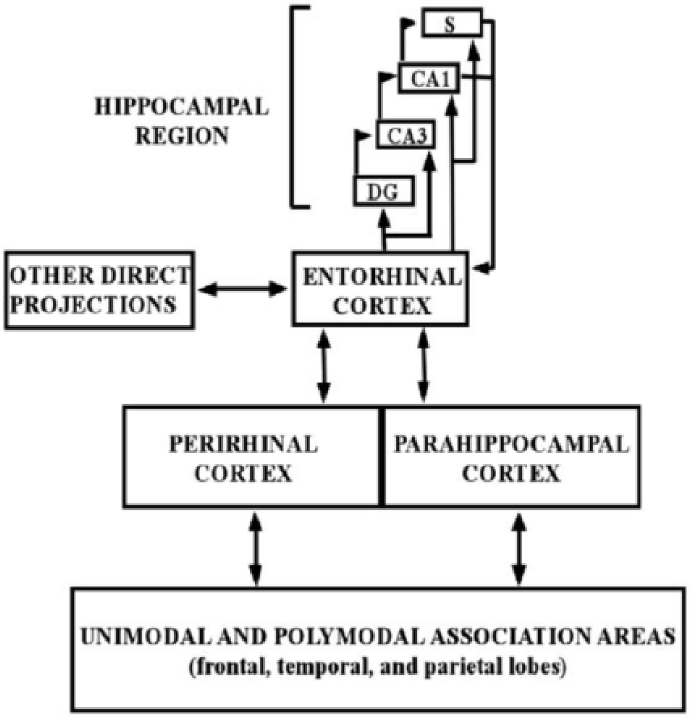


Figure 1.6: Schematic view of the MTL (DG: dentate gyrus; S: subiculum).
From "The medial temporal lobe and declarative memory," by P. J. Bayley and L. R. Squire, 2003, *International Congress Series, 1250,* p. 246. Copyright [2003] by Elsevier. Reprinted with permission.

Cipolotti et al. (2001) has indicated from studying amnesiac patients that the hippocampus is critical for encoding new information, and in addition that it plays a crucial role in the recall of episodic memories which were acquired before the trauma occurred. This has been supported by other studies implicating the hippocampus in episodic memory (Nadel et al., 2003; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994; Tulving & Markowitsch, 1998; Tulving, Kapur, Markowitsch, et al., 1994). However, it remains unclear whether the hippocampus' importance lies in episodic memory while the surrounding regions are important in semantic memory, or if the entire MTL is important in both (Brown & Aggleton, 2001; L R Squire & Zola, 1998;

Tulving & Markowitsch, 1998). However, lesion studies have indicated that large lesions to the MTL impair declarative memory, while lesions restricted to the hippocampus result in less severe memory impairment (Bayley & Squire, 2003). Squire et al. (2004) have also shown how the medial temporal lobes are essential in declarative memory and these results indicate that all components of the MTL play a very large and vital role in declarative memory. Both human and animal studies show the same pattern, specifically that declarative memory is impaired due to damage to the hippocampus but is more severely impaired when damage occurs in the MTL. However, damage to the hippocampus alone spares remote memory for semantic information, while damage to the medial temporal lobes spares remote memory for episodic events (i.e. memories that have been developed for longer; Bayley & Squire, 2003). This indicates that while the hippocampus and the MTL are important in both episodic and semantic memory, the two structures have different roles for the two types of memory.

1.4 Source Memory and Context

1.4.1 Context-Dependent Memory

As stated above, source memory is responsible for recalling all aspects of the context in which an event occurred (Glisky & Kong, 2008; Johnson et al., 1993). Context includes all aspects of the environment in which an event occurs, and can be intrinsic or extrinsic (Hewitt 1977, cited in Godden & Baddeley, 1980). Intrinsic context refers to that which is processed automatically and relevant to the event, such as the voice of a person, while extrinsic or environmental context are features which are irrelevant to the event, such as the type of doors in a room (Mckenzie & Tiberghien, 2004). However context, whether intrinsic or extrinsic (incidental), can have both a positive and negative effect on memory performance. For example, if the original context remains similar to the time of acquisition, recall of the information can be assisted, while if there are alterations to the context memory performance can be impeded (J. C. Davis, Lockhart, & Thomson, 1972; Godden & Baddeley, 1980).

Intrinsic contexts have been shown to aid memory for recognition and recall by manipulating the semantic relations between word pairings (Light & Carter-Sobell, 1970; Tulving & Thomson, 1973), manipulating the colours in which words were presented (Ecker, Zimmer, & Groh-Border, 2007), and the colour and position of words (Boywitt & Meiser, 2012). In each of these studies, intrinsic context improved memory performance when the context matched that of the encoding stage. However, there is less consistency regarding the effects of extrinsic or incidental context on memory (see S. M. Smith & Vela, 2001 for review). Variations in the type of context used in experimental conditions may explain this disparity in the effect of environmental contexts on memory (Mckenzie & Tiberghien, 2004). However, many studies have also indicated that incidental context does have an effect on memory, whereby memory performance is enhanced when the context from encoding is reinstated (S. M. Smith & Vela, 2001). This has been seen in studies which manipulated the room (S. M. Smith, 1979), the natural environment (Godden & Baddeley, 1980), and the position of local cues (Jiang & Wagner, 2004). In addition, manipulating the environmental context affects the extent of interference on memory (Dallett & Wilcox, 1968). If interference is initiated in a different context to that of the target, there is a reduction in the negative effect of interference on memory performance (Dallett & Wilcox, 1968).

Cohen's computational model of context suggests that contextual information is represented in such a manner to reduce the amount of potentially conflicting information to relevant information (Cohen, Barch, Carter, & Servan-Schreiber, 1999; Cohen, Braver, & O'Reilly, 1996; Cohen & Servan-Schreiber, 1992). This occurs as contextual information functions in an attentional manner and processes relevant information over irrelevant interfering information (Cohen et al., 1999, 1996; Cohen & Servan-Schreiber, 1992) and as such may be an important component in source memory.

The Encoding Specificity Principle asserts that if context remains stable between the encoding phase and the time of recognition, then aspects of an event that were attended to will be recalled more easily (Tulving & Thomson, 1973; Tulving, 1974). Therefore, this suggests that if binding of items and context occurs at encoding, memory performance can be facilitated at a later stage (S. M. Smith, 1979). This principle implies that memory for episodes can be enhanced if all contextual information is provided during recognition (S. M. Smith, 1979; Tulving & Thomson, 1973; Tulving, 1974). This occurs because the contextual information is bound to the content, acting as cues and thus allowing for easier access to the information. According to this principle, access to all items in memory will be increased if the circumstances at encoding are re-created.

If the context in which an event was encountered remains the same at retrieval, memory is facilitated (Mckenzie & Tiberghien, 2004) and memory performance is better if testing occurs in the learning environment than compared to a new environment (S. M. Smith & Vela, 2001). This is referred to as the reinstatement effect (S. M. Smith & Vela, 2001). Reinstatement has been shown to assist memory performance in the recognition of faces (Hannula, Federmeier, & Cohen, 2006), time lags of events (Mckenzie & Tiberghien, 2004) and spatial backgrounds (Aggleton & Brown, 1999). In addition, the memory of the original episode can be induced via mental reinstatement of the environmental cues (S. M. Smith, 1979; 1984) and the reinstatement effect can also be extended to retrieval where contextual cues can aid in judgements between new and old items (J. R. Anderson & Bower, 1972).

1.4.2 Anatomy

Studies have connected the pre-frontal cortex (PFC) and the hippocampus, and by extension, the medial temporal lobes, to source memory (Eichenbaum, Yonelinas, & Ranganath, 2007; Leshikar & Duarte, 2012). The PFC has been implicated in the use of source memory (Lundstrom, Ingvar, & Petersson, 2005; Ragland, Valdez, Loughead, Gur, & Gur, 2006; Slotnick, Moo, Segal, & Hart, 2003). These studies used fMRI and the BOLD (Blood-Oxygen-Level-Dependent) response, and indicated activation of the PFC in associating contextual information with memories. Cohen's computational model implies that the PFC may be responsible for the processing of contextual information in memory (Cohen et al., 1999, 1996; Cohen & Servan-Schreiber, 1992). In addition, studies have shown that impairment in source memory exists when lesions occur in the pre-frontal cortex (Swick, Senkfor, & Van Petten, 2006; M. Wheeler & Stuss, 2003) further implicating the PFC in source memory.

The medial temporal lobes also have implications in source memory (Gold et al., 2006; Thaiss & Petrides, 2003), especially as the hippocampus is essential in the storage of memory (Moscovitch et al., 2005). This indicates that the hippocampus may make a contribution to the contextual features of memory and subsequently influence behaviour (Anagnostaras, Gale, & Fanselow, 2001; Maren, 2001; D. M. Smith & Mizumori, 2006). Horner et al. (2012) stated that the hippocampus is of particular importance for recalling contextual details and as such it is especially important in source memory. When considering source memory, studies have shown that the PFC and the hippocampus are particularly responsible for source memory accuracy (Eichenbaum et al., 2007; Leshikar & Duarte, 2012). In particular, the right PFC and the left hippocampus have been indentified as the regions responsible for the binding of item and source within memory

(Mitchell, Johnson, Raye, & D'Esposito, 2000; Mitchell, Johnson, Raye, & Greene, 2004; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000).

As indicated above, the PFC and the hippocampus, which are linked through the uncinate fascicle (Browning & Gaffan, 2008; Ungerleider, Gaffan, & Pelak, 1989), are involved in source memory (Mitchell & Johnson, 2009). However, as source memory also involves the neocortex, other regions of the brain are responsible for the specific context associated with that particular source of the memory. For example, the fusiform face area is responsible for identifying a person (Kanwisher, McDermott, & Chun, 1997), the perirhinal cortex is accountable for processing spatial information (Winters, Forwood, Cowell, Saksida, & Bussey, 2004), the right dorsolateral PFC is utilised when making estimations of the timing of events (Jones, Rosenkranz, Rothwell, & Jahanshahi, 2004), the lateral occipital cortex is responsible for the recognition of objects (Grill-Spector & Sayres, 2008) and Heschl's gyrus and the superior temporal gyrus (STG) processes auditory words (K. C. Harris, Dubno, Keren, Ahlstrom, & Eckert, 2009).

Evidence has indicated that the hippocampus may play a significant role in processing context (see Myers & Gluck, 1994 for review), and has been implicated in spatial context (Wood, Dudchenko, & Eichenbaum, 1999) and sequences of events (Fortin, Agster, & Eichenbaum, 2002). Lesions of the hippocampus can lead to impaired contextual representations which are based on environmental features (Eichenbaum, 2004; Nadel, 2008). Lesions to the hippocampi of rabbits led to contextual deficits following classical conditioning. However, rabbits with intact hippocampi showed a contextual effect when classically conditioned (Penick & Solomon, 1991). In addition, atrophy of the hippocampus in patients with amnesic mild cognitive impairment (aMCI) showed that the aMCI patients had poorer performance on memory recall that was dependent on context compared to both healthy young and older controls (N. D. Anderson et al., 2008). Using fMRI, the hippocampus has been implicated in memory for spatial context (Ross & Slotnick, 2008) and Horner and colleagues (2012) used MEG to show that contextual retrieval was dependent on the hippocampus also.

These studies indicate that the hippocampus does have a significant role in the contextual features of memory. However, the precise nature of such contributions appears to be varied throughout the literature. Nadel and Willner (1980) have suggested that this may be due to the variety within the type of context that is being reported. The authors argue that this may be the case as the hippocampus is primarily concerned with contextual features of the environment. As such any atrophy or lesions of the hippocampus would lead to impairments in specific contexts of the environment (Nadel & Willner, 1980). Despite this discrepancy, the hippocampus has been shown to play a role in context in episodic memory (D. M. Smith & Mizumori, 2006), while studies have shown that memory performance is aided when contextual effects remain stable between acquisition and retrieval (Tulving & Thomson, 1973; Tulving, 1974). Therefore, the evidence suggests that the hippocampus and medial temporal lobes have a function in context and source memory, and that context plays a substantial role in memory performance, even though these roles have not been definitively elucidated.

1.5 Ageing and Memory

1.5.1 Normal Ageing

It is generally accepted that age and memory decline go hand in hand, and much research has indicated this pattern (Cabeza, Anderson, Locantore, & Mcintosh, 2002). It has been found in memory tasks that as one becomes older, fewer areas are activated within the brain and that older adults perform at a lower level than younger adults

(Cabeza et al., 2004) indicating that with age comes memory decline. When investigating human memory and ageing, research has indicated that procedural, perceptual and semantic memory remain relatively intact, while working memory and episodic memory are particularly affected in a negative way by the ageing process (Craik, 2008; Friedman, 2000). As this thesis is primarily concerned with episodic memory, this section will focus on the effects of ageing on episodic memory alone.

Tasks of episodic memory involve presenting participants with stimuli and testing their ability to remember these items at a later stage (Luo & Craik, 2008). Episodic memory tasks which involve free recall, associative learning, prospective memory and source memory (see section 1.1.5 for further discussion) are particularly impaired in older adults which suggests that episodic memory undergoes the greatest change due to ageing (Luo & Craik, 2008).

Tasks involving free recall (i.e. recall in the absence of cues or probes) present participants with list of items to be memorised and at a later stage require participants to recall as many items as possible (Luo & Craik, 2008). Ageing can have a negative effect on free recall performance, where older adults recall fewer items than young adults. This has been shown across a number of tasks involving free recall, including recall of lists of read words (Bryan & Luszcz, 1996), auditory words (Witte, Freund, & Sebby, 1990), recall of pictures (Coluccia et al., 2011) and delayed free recall (Rakitin, Stern, & Malapani, 2005).

When testing associative learning, participants are required to create associative links between items that they have not previously associated. They are then required at a later stage to retrieve these links and identify the correct pairings (Luo & Craik, 2008). Older adults have been shown to be more impaired than young on this type of episodic memory, and this has been seen for associations between stimuli such as pictures

(Gutchess & Park, 2009; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), verbal words (Bender, Naveh-Benjamin, & Raz, 2010), names and faces (Naveh-Benjamin, 2000) and non-descriptive words and faces (Overman & Becker, 2009). As older adults are more impaired on associative learning, this suggests that older adults may be deficient in the binding of information (Craik, 2008).

Prospective memory tasks involve carrying out an intention at a future time without external cues and can be time- or event-based (Balota, Dolan, & Duchek, 2000; Einstein & McDaniel, 1990). Time-based tasks involve participants conducting an action at a predetermined time without external reminders, while event-based tasks involve a participant carrying out an action in response to an environmental cue, i.e. when something occurs (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). It is presumed that time-based tasks involve high levels of self-initiation as no cues are present, while event-based require lower levels of self-initiated retrieval as an environmental cue is present (Einstein et al., 1995; Luo & Craik, 2008). Research has revealed that older adults are more impaired than young on time-based (Einstein et al., 1995) and event-based prospective memory (Henry, MacLeod, Phillips, & Crawford, 2004) but the decrements appear to be more pronounced in time-based tasks (Einstein et al., 1995; Henry et al., 2004). Prospective memory deficits are often common complaints of older adults as this decline can have a large negative impact on daily life; for example, knowing when to take medication (Luo & Craik, 2008).

As older adults display difficulties with various memory tasks, a number of theories of cognitive ageing have emerged to account for the memory decline associated with ageing. These include reduced processing resources, general slowing, loss of inhibitory functions and lack of cognitive control (Luo & Craik, 2008).

The theory regarding reduced processing resources proposes that there is a decline in resources responsible for attention due to ageing (Craik & Byrd, 1982). The theory further states that these resources are limited, and ageing further exhausts such processes, leading to cognitive decline (Craik, 1986). As attention is a necessary component for processing memory, it follows that if a deficit in attentional resources exists, this would give rise to impairments in memory, with increasing impairments evident in more demanding tasks (Craik & Byrd, 1982; Craik, Routh, & Broadbent, 1983).

The theory regarding slowing was proposed by Salthouse (1996a). The theory argues that there is a reduction in speed of processing due to ageing and that this reduction leads to the decline in cognitive performance (Salthouse, 1996b). The theory further proposes that this slowing is the main factor in age-related impairment and that the ageing process plays an indirect role in memory performance (Salthouse, 1996a, 1996b).

The inhibition theory posits that older adults display defects in controlling inhibitory resources (Hasher & Zacks, 1988). Inhibitory processes are responsible for allowing the entrance of only relevant information into memory, and for erasing information that is no longer relevant (Zacks, Hasher, & Li, 2000). As such, if inhibitory responses are no longer functioning adequately, interference and distractions (i.e. mental clutter) can begin to impair memory (Cabeza, 2002; Luo & Craik, 2008).

The theory regarding changes in control processes states that there is a difference between automatic (i.e. familiarity) and controlled (i.e. recollection) memory processes (Hasher & Zacks, 1979; Jacoby, 1991). The theory suggests that ageing leads to a decline in controlled processes, while automatic processes remain more stable against the ageing process, suggesting that ageing has a larger impact on recollection than on familiarity (Jennings & Jacoby, 1993).

The normal decline in memory performance that accompanies old age is thought to be related to cell loss in regions of the brain which are critical for memory encoding and recall (Pasquier, 1999). Such areas include the frontal and medial temporal lobes (Cabeza & Nyberg, 2000). The Frontal Lobe hypothesis posits that a deterioration to the cells of the frontal lobes due to ageing leads to reduced cognitive function (West, 1996, 2000). This hypothesis is one of the most significant in the cognitive neuroscience domain (Cabeza & Dennis, 2012). Evidence in favour of the theory comes from a number of different sources. Firstly, older adults are more impaired in tasks of executive function which rely on the PFC (Baltes & Lindenberger, 1997; Kramer, Humphrey, Larish, Logan, & Strayer, 1994). The second piece of evidence comes from neuroimaging studies which indicate that the frontal lobes undergo more age-related atrophy than other regions of the brain (Raz et al., 2004). Studies have provided evidence supporting this hypothesis and have shown age-related changes in activation of the frontal lobes accompanied by a corresponding impairment in memory performance (Duarte, Graham, & Henson, 2010; Grady et al., 1995; Lavoie, Willoughby, & Faulkner, 2006).

Age-related changes in the medial temporal lobes have also been indicative of a decline in memory in normal ageing. Grady et al. (1995) found reduced activation of the MTL for encoding which was accompanied by poorer memory performance on testing. Gutchess et al. (2005) also showed reduced activity within the medial temporal lobes of older adults when testing for recognition of scenes. Age-related reductions of activity within the medial temporal lobes, particularly the hippocampus, have been identified in older adults for recollection-based memory (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006). However, an age-related increase in activity was seen in the rhinal cortex for familiarity-based memory (Daselaar et al., 2006) indicating that ageing can have a diverse effect on activity within the medial temporal lobes.

The above literature indicates that the normal ageing process is accompanied by a decline in memory performance across many domains, but with episodic memory having the greatest impairment in older adults. Evidence has been provided suggesting that these impairments may be underpinned by changes in activity levels or integrity of structure in regions within the brain which are crucial for episodic memory, such as the MTL and the PFC. This section has dealt primarily with the normal ageing process, but to have a better comprehension of the changes in memory due to old age; pathological ageing should also be discussed.

1.5.2 Pathological Ageing

Dementia involves impairments in functions of cognition that have a negative impact on daily life, and can involve memory impairments that exceed those which are prevalent in normal ageing (Kelley & Petersen, 2009). Other aspects of cognition should also be affected in dementia (for example attention, language, visuospatial skills and problem solving) and these impairments should exist in the absence of any conditions affecting perception (Kelley & Petersen, 2009). Different conditions can result in dementia, including Mild Cognitive Impairment, Alzheimer's Disease, Frontotemporal Dementia and Vascular Dementia; each of these conditions can have implications on memory performance.

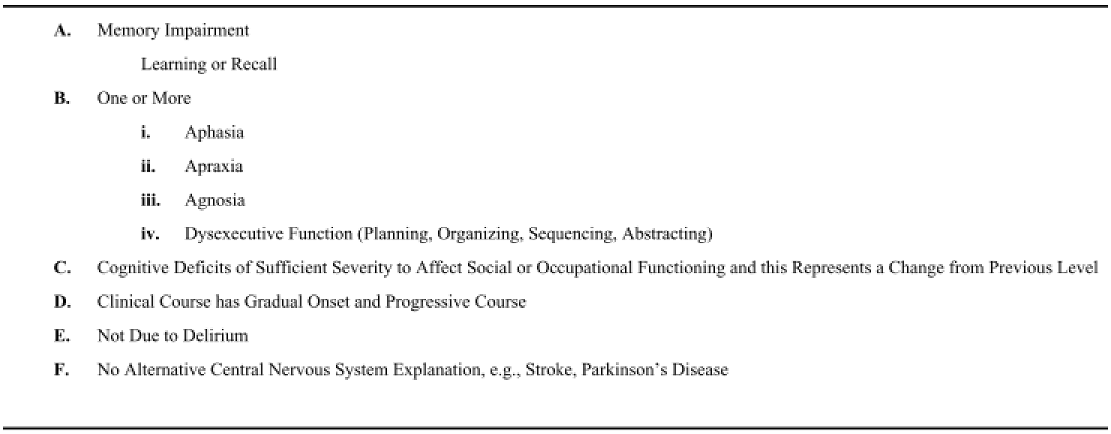
According to Heun et al. (2007), Mild Cognitive Impairment (MCI) can be recognised in people who have unaffected daily lives but a significant impairment in memory. MCI can also be identified as a decline in cognitive processes which is greater than expected for normal ageing (Hämäläinen et al., 2007; Petersen et al., 2001). There is considerable debate over whether or not MCI is pre-requisite of Alzheimer's Disease (AD). It has previously been stated that MCI is associated with the development of AD, that it is an early stage of the disease (Bennett et al., 2002; Heun et al., 2007), and that MCI ranks between normal elderly cognitive decline at one end of a scale and dementia at the other (Bröder, Herwig, Teipel, & Fast, 2008). MCI can be viewed as a high risk group for developing dementia but not all MCI patients progress to this stage (Chertkow et al., 2007; Pike, Rowe, Moss, & Savage, 2008).

Certain criteria must be present in experiments with MCI as participants. These include a presence of memory complaint, impaired performance in memory tasks which have been adjusted for age and education, general cognitive function remaining intact, absence of dementia, and daily living activities remaining normal (Belleville, Bherer, Lepage, Chertkow, & Gauthier, 2008; Meyer, Xu, Thornby, Chowdhury, & Quach, 2002). Wang and Zhou (2002) indicated that encoding in patients with MCI was very susceptible to impairment (Wang & Zhou, 2002), while other previous studies have indicated that retrieval and recollection of memories in MCI can be very impaired (Anderson et al., 2008; Bröder et al., 2008). If one considers the view that MCI is a pre-requisite to AD, then this is a good place to start when investigating pathological ageing.

Alzheimer's Disease (AD) is one of the most common degenerative disorders affecting older adults which results in dementia (Ewers et al., 2012; Kelley & Petersen, 2009; Kidd, 2008), and impairments in memory are usually the first and earliest reported symptoms of AD (Bokde et al., 2010; Kidd, 2008). The disease was first observed by Aloysius Alzheimer in a patient with declining memory, confusion, disorientation, problems with expression and groundless suspicions (Kidd, 2008). After the patient's death, an autopsy revealed atrophy of the brain (Kidd, 2008). The criteria for diagnosing AD include the gradual progression of memory impairment along with cognitive impairments in one or more of the following: aphasia, apraxia, agnosia, dysexecutive function (see Table 1.1 below), and these impairments cannot be explained by other neurological or psychiatric disorders (Kelley & Petersen, 2009).

Memory impairments in AD have been reported in the domains of short- and long-term memory (MacDuffie, Atkins, Flegal, Clark, & Reuter-Lorenz, 2012), episodic memory (Salmon & Bondi, 2009), associative recognition memory (Hanaki et al., 2011) and spatial memory (Kessels, Feijen, & Postma, 2005). As the hippocampus and MTL have been implicated in the formation and storage of memory (Bayley & Squire, 2003; L R Squire et al., 2004), it follows that atrophy of the MTL and hippocampus has been associated with AD (Jack et al., 1997). Jack and colleagues showed how the volume of the MTL and hippocampus was smaller in AD patients compared to healthy controls and that age was a factor in the decline of the volume of these structures (Jack et al., 1997). However, since this atrophy is apparent in the MTL and the hippocampus, these structures may then be used to predict the development of AD in MCI patients (Jack et al., 1999). Therefore atrophy to the hippocampus, which can be viewed with MRI, can be an indicator of subsequent AD.

Table 1.1: Diagnostic Criteria of the Alzheimer’s Type.
From “Alzheimer's disease and mild cognitive impairment,” by B. J. Kelley and R. C. Petersen, 2009, *Neurologic Clinics, 25,* p. 29. Copyright [2009] by Elsevier. Reprinted with permission.



A. Memory Impairment
  Learning or Recall
B. One or More
  i. Aphasia
  ii. Apraxia
  iii. Agnosia
  iv. Dysexecutive Function (Planning, Organizing, Sequencing, Abstracting)
C. Cognitive Deficits of Sufficient Severity to Affect Social or Occupational Functioning and this Represents a Change from Previous Level
D. Clinical Course has Gradual Onset and Progressive Course
E. Not Due to Delirium
F. No Alternative Central Nervous System Explanation, e.g., Stroke, Parkinson’s Disease

Frontotemporal Dementia (FTD) is a degenerative disorder which leads to deficits in behaviour, language and movement and can cause changes in personality, impulsiveness, overactivity or apathy (X. Wang, Shen, & Chen, 2013). After AD, it is the second most common cause of dementia (X. Wang et al., 2013). Pick (1892) first observed this type of dementia in a 71 year old man who was experiencing aphasia, dementia and behavioural problems. The autopsy revealed wasting of the temporal lobes (Goedert, Ghetti, & Spillantini, 2012). As such, degeneration of the frontal and temporal lobes along with other subcortical regions of the brain are associated with FTD (Goedert et al., 2012; Mackenzie et al., 2009).

Different pathologies have been associated with this disorder. These include a behavioural variant (semantic dementia) and progressive non-fluent aphasia (Hodges & Miller, 2001; Mackenzie et al., 2009; Neary et al., 1998). With the behavioural variant, patients can become apathetic or they can exhibit socially improper behaviours (Baborie et al., 2012). Semantic dementia causes decrements in understanding meanings of words and identifying objects (Neary et al., 1998). Progressive non-fluent aphasia can cause problems with articulation, where speech is distorted but understanding words remains intact (Hodges & Miller, 2001). Until recently, it has been accepted that memory remains relatively intact in FTD. However, new evidence suggests that deficits in episodic memory (Hornberger & Piguet, 2012) and short-term and anterograde memory loss may be a factor in FTD (Baborie et al., 2012) with these types of memory declining in sufferers.

Vascular Dementia (VaD) is caused by hypoxia (loss of oxygen) or a haemorrhage (rupture of a blood vessel) in the brain, i.e. stroke (Battistin & Cagnin, 2010), with the consequence of dementia. VaD is used to refer to dementia under three different conditions: (1) multi-infarct dementia, where damage is caused by a series of mini-strokes (Battistin & Cagnin, 2010); (2) a single ischemic lesion, resulting in atrophy due to a lack of oxygen (Sachdev et al., 2004); or (3) sub-cortical VaD, due to infarcts in small blood vessels within the cortex (Moretti et al., 2007; Price, Jefferson, Merino, Heilman, & Libon, 2005). VaD has been shown to cause disruptions and impairments across a range of cognitive domains, including attention, global memory, verbal memory, visual memory, execution function, abstract reasoning, working memory, language and speed of processing (Sachdev et al., 2004).

Leblanc, Meschia, Stuss and Hachinski (2006) have presented evidence for two types of genes involved in Vascular Dementia; one which increases susceptibility to VaD and another which influences the recovery of tissue following cerebrovascular disease. These genetic markers can allow for those at risk to be identified and a possible prophylactic treatment to be put in place (Leblanc et al., 2006). A set of diagnostic criteria have been developed for VaD: a cognitive decline must be present and this must include impairments in memory and deficits in at least two other cognitive domains; cerebrovascular disease must be identified (which can be carried out with neuroimaging); and finally, a clear relationship between the two above disorders must exist (Román et al., 1993), i.e. the impairments did not exist before the presence of cerebrovascular disease.

Four types of pathological ageing have been discussed here; MCI, AD, FTD and VaD, and these have shown to cause a large decrement in memory performance in adults with these conditions. While these decrements are considered to be attributed to disease, models of ageing can offer insight into the underlying processes regarding changes in cognitive performance in normal and pathological ageing.

1.5.3 Models of Memory in Ageing

One of the main aims of ageing research is to be able to account for the effects of ageing on cognitive abilities by offering an explanation for age-related changes in brain anatomy and performance (S. W. Davis et al., 2008). Different researchers in cognitive neuroscience have proposed models of ageing in an attempt to explain the age-related deficits in cognitive performance. The most prominent of these models are outlined below.

Jacoby's Capture Model (Jacoby, Bishara, Hessels, & Toth, 2005) posits that an interference or inhibitory control defect causes improper engagement in the recollection of information. According to Jacoby (1999), capture is composed of two stages: an early-selection stage and a later evaluation stage. The early-selection stage consists of identifying the characteristics of an episode in order to allow for retrieval of that episode (Schacter, Norman, & Koutstaal, 1998). The later evaluation stage involves accepting a recollection as "remembered" once it passes a particular accessibility threshold (Dockree et al., 2006). The model offers an explanation for the decline in cognition by suggesting that an increase in interference can lead to a decrease in the ability to recall characteristics, or the interference can cause a decrease in the accessibility threshold and items are accepted as remembered. The model further suggests that both of these occur without a corresponding change in the other stage of capture (Jacoby, Bishara, et al., 2005). This leads to one identifying a recollection as "remembered" with a high accessibility level when the recollection is incorrect.

Naveh-Benjamin's Associative Deficit Hypothesis (Naveh-Benjamin, 2000) works under the postulation that episodes are composed of individual units of information which have connections with one another. According to the model, the ageing process causes a breakdown in creating and retrieving these links. Furthermore, this breakdown leads to poorer memory recall in older adults (Naveh-Benjamin et al., 2003). The Associative Deficit Hypothesis suggests that the discrepancy in ageing is caused by older adults having more difficulty than young with binding the elements of an episodic memory together, and this is particularly problematic when these elements appear to be unrelated (Naveh-Benjamin, Guez, & Shulman, 2004). However, if the elements of an episode are previously linked, the age-related decrement in memory is less severe (Naveh-Benjamin et al., 2003).

The most prominent and influential neuroanatomical models of ageing suggest a compensatory function in the brains of older adults. These include the HAROLD model, the CRUNCH model and the PASA model. Research has indicated that the left PFC is more involved during the process of encoding an item into memory while the right PFC has more responsibility in the recall of our memories (Tulving et al., 1994). This led to the development of the Hemispheric Encoding/Retrieval Asymmetry (HERA) model (Nyberg, Cabeza, & Tulving, 1996; Tulving et al., 1994) postulating that the right and left hemispheres of the brain play different roles in human memory, i.e. left for encoding, right for recall. However, with the emergence of further studies, it appears as though the HERA model is specific to healthy young adults, and studies have indicated that our brain anatomy and physiology changes with ageing (Cabeza, 2002). The Hemispheric Asymmetry Reduction in Older Adults (HAROLD) model offers a rationalization for why the HERA model may only be seen in younger adults by explaining how brain activity is affected by the ageing process (Cabeza, 2002). As people age the activity in the PFC becomes more bilateral rather than lateralised as is seen in young adults (Bäckman et al., 1997; Cabeza et al., 1997; Grady et al., 1994; Reuter-Lorenz et al., 2000), and this has laid the foundation for the HAROLD model. This bilateral activation is most likely to be caused by compensation, whereby new brain regions become active, rather than by the ineffective recruitment of the required areas (dedifferentiation) (Berlingeri, Danelli, Bottini, Sberna, & Paulesu, 2013). The HAROLD model also postulates that the deviation to bilateral activity may stem from a change in cognitive strategies, or that it may reflect changes in neural mechanisms globally or locally, and that this pattern may be task dependent (Cabeza, 2002).

However, more recent research has indicated that the HAROLD model may not reflect a compensatory function within the ageing brain (Duverne, Motamedinia, & Rugg, 2009; Manenti, Cotelli, & Miniussi, 2011). These findings led to the development of the Compensatory-Related Utilisation of Neural Circuits Hypothesis (CRUNCH) model. The CRUNCH model posits that more activation occurs in the brain in order to allow older adults to have similar recollections to those of young adults (Reuter-Lorenz & Cappell, 2008). The main idea behind this model is that older adults recruit more neural resources than younger adults for simpler tasks (Grady, 2012; Rypma, Eldreth, & Rebbechi, 2007). This additional recruitment causes an increase in activity in the brain of older adults compared to young, and occurs irrespective of hemisphere (Berlingeri et al., 2013). This pattern of overactivation has been observed by many researchers during different aspects of cognition, such as working memory (Cappell, Gmeindl, & Reuter-Lorenz, 2010; V S Mattay et al., 2006; Schneider-Garces et al., 2010) and source memory (Spaniol & Grady, 2012). The model further postulates that as the demands of a task increase, these overactivations plateau, leading to activity that is equivalent to or less than that of young adults (Grady, 2012; Reuter-Lorenz & Cappell, 2008).

Another widely cited model is Cabeza's PASA model, which describes an age-related reduction in occipitotemporal activity which is accompanied by a corresponding increase in frontal activity (S. W. Davis et al., 2008). Thus, there is a shift in activity from the posterior to the anterior regions of the brain (Posterior-Anterior Shift in Ageing, PASA). The model proposes that this occurs as a compensatory function in the brain due to the ageing process (Grady, 2012). Grady et al. (1994) first reported a shift from posterior to anterior activity in older adults. Since then, this pattern has been observed in many cognitive tasks involving older adults (Anderson et al., 2000; Cabeza et al., 2004; Gutchess et al., 2005; Rypma & D'Esposito, 2000). Since these initial studies, Davis and colleagues (2008) have indicated that this shift is independent of task difficulty and, when performance levels are matched between young and older adults, this pattern remains stable irrespective of the confidence levels of groups. This research has indicated that the PASA model may be indicative of a compensatory effect whereby the anterior region of the brain is recruited in order to balance the decline in the posterior regions which may have been caused by ageing (Davis et al., 2008).

Each of these models offers an explanation for the age-related decline seen in memory. However, as the HAROLD, CRUNCH and PASA models discuss changes in neural activation due to the ageing process, these offer the most beneficial explanation for cognitive decline in ageing, and each of the models posits a compensatory effect in ageing, suggesting that the ageing brain can benefit from compensation. As the primary focal point of this thesis is source memory, a more comprehensive account of source memory and ageing is necessary to further understand the processes of change in source memory in the ageing brain.

1.6 Source Memory and Ageing

1.6.1 Effects of Ageing

As stated above, source memory involves encoding the entire context of an event in memory (Glisky & Kong, 2008; Johnson et al., 1993). Source memory is one of the first types of memory to be identified as problematic in cognitive ageing (Jennings & Jacoby, 1997). The brain regions involved in source memory are the PFC, the MTL and context-specific regions of the cortex (Mitchell & Johnson, 2009), and age-related cognitive deficits have been indicated in the PFC and the MTL (Friedman, 2000; Morcom, Good, Frackowiak, & Rugg, 2003; Rajah & D'Esposito, 2005; Reuter-Lorenz et al., 2000). Literature on ageing has indicated that a larger decrement lies in source rather than content memory, and that with increased age comes an increased sensitivity to source memory errors (Siedlecki et al., 2005; Spencer & Raz, 1994; Zacks et al., 2000).

Evidence suggests that older adults have problems with recalling the source of the information they have obtained, and this can occur even if they accomplish accurate item recollection (Brickman & Stern, 2009). A decline in source memory due to ageing has been identified in many studies and across cultures (Chua, Chen, & Park, 2006). Schacter, Kaszniak, Kihlstrom and Valdiserri (1991) showed an age-related error at identifying *who* provided the source of information as different speakers read statements aloud, and older adults were more impaired at identifying the *specific* source, i.e. matching the speaker to the statement. Subsequent studies revealed a similar effect of ageing but showed how this was also extended to *partial* source memory, where older adults had more difficulty with identifying, for example, the gender of the speaker who provided the source (Simons, Dodson, Bell, & Schacter, 2004). In addition, Schacter and colleagues (1994) have indicated that this decline is not merely due to an overload of information or due to attentional resources being focussed on content, but that this impairment in source memory exists when accounting for these external attributes. The authors used one-to-one mapping of facts and sources, and manipulated attentional resources in two separate experiments, and their results indicated that the source deficit is related to ageing and not any external conditions (Schacter et al., 1994).

Evidence suggests that this age-related decrement in source memory may result from a problem in binding the contextual information to the content of the information (Glisky & Kong, 2008; Henkel, Johnson, & De Leonardis, 1998; Kessels, Hobbel, & Postma, 2007). In a study involving target memory, contextual memory and a combination of the two, older adults were more impaired on each condition (Kessels et al., 2007). However, the results revealed a larger discrepancy in conditions which involved binding the target and the context. Kessels et al. (2007) concluded that episodic memory recall may suffer in older adults due to a problem in binding contextual and item memory. Glisky and Kong (2008) have stated that greater demands are set on older adults when items and context must be bound which results in a decline in source memory. Henkel et al. (1998) further state that if items are similar, then the binding process must be more adequate, and older adults can be more impaired on source memory as the binding process has been inadequate.

Dennis et al. (2008) have shown an age-related deficit in source memory when older adults were requested to encode faces and scenes separately (item memory) compared to face-scene pairs (source memory). A larger decrement was seen for encoding source information and an age-related decrement was seen in activity in the PFC and the hippocampus, which have both been implicated in source memory. However, this age-related deficit was not seen in the specific areas of the brain related to items, suggesting that the age-related reduction in source memory is due to a change in activity in the hippocampus and PFC (Dennis et al., 2008). Swick et al. (2006) have also implicated changes in the PFC due to ageing to the deficit in source memory in older adults. As suggested above, normal ageing can have detrimental effects on the

PFC and this may explain these deficits (Spencer & Raz, 1994; West, 1996, 2000). Glisky, Rubin and Davidson (2001) suggest that older adults who have reduced functioning of the frontal lobes are unable to bind the context of information to the content, but that if older adults are instructed to link the item to the context at encoding, this age-related deficit is reduced.

1.6.2 Models of Source Memory and Ageing

Johnson's Source Monitoring Framework (Johnson et al., 1993) suggests that monitoring cues are used to recall the entire context of an event; therefore, impairments in source memory are apparent when there is a deficit in monitoring the cues of the context. In the Source Monitoring Framework, complex event memories are made up of features which are bound together to create the entire context of an event (Johnson et al., 1993; Johnson, 2006; Mitchell & Johnson, 2009). These features can include perceptual, spatial, temporal, semantic and emotional aspects of an event (Johnson & Raye, 1981; Johnson, 2006; Mitchell & Johnson, 2009). Memories are then accessed directly by these features or cues (Dodson & Johnson, 1996). The source of a memory is provided by monitoring these features (Mitchell & Johnson, 2009); therefore the binding of such features is very important for source recall (Mammarella & Fairfield, 2008). How specific the information is distinguishes between familiarity and recollection (Dodson & Johnson, 1996) and if information is incomplete or unclear, the features of an event cannot be evaluated, thus leading to errors in source monitoring (Johnson, 1997).

The Misrecollection Hypothesis of source memory suggests that older people misrecollect rather than remember less and having to guess information (Dodson, Bawa, & Krueger, 2007). The hypothesis states that older adults have false recollections of events as they bind incorrect contexts of episodes within their memory which accounts for the source memory deficit seen in ageing (Dodson, Bawa, & Slotnick, 2007). An important aspect of the hypothesis is that when features are miscombined they produce a *convincing* misrecollection, which leads to high confidence in the incorrect source of the memory (Dodson, Bawa, & Krueger, 2007; Dodson & Krueger, 2006). Older adults have been shown to have higher confidence in judging the source of acquired information compared to young adults, but this high level of confidence has been accompanied by worse performance in older adults (Bryce & Dodson, 2013; Dodson, Bawa, & Krueger, 2007; Dodson & Krueger, 2006; Gopie, Craik, & Hasher, 2010). However, if illusory recollections are accounted for the age-related impairment disappears (Dodson, Bawa, & Krueger, 2007; Dodson, Bawa, & Slotnick, 2007).

Both models indicate that source memory declines with ageing which may be due to a deficiency in monitoring or binding. As a result older adults are left with erroneous recollections of events which they believe to be correct, leading to poorer source memory performances.

1.7 Thesis Objectives

The studies outlined above have indicated that ageing causes a larger decrement in source compared to item memory (Henkel et al., 1998; Simons et al., 2004; Swick et al., 2006). Therefore, when studying the cognitive neuroscience of ageing, the decline in contextual information is a necessary component to investigate. The objectives of this thesis involve studying the effects of ageing on source memory using behavioural and electrophysiological measures. Firstly, the effects of the ageing process on different types of memory will be investigated behaviourally to determine if ageing causes a comparable decline across different memory domains (source, associative, episodic) and if these are related to one another (Chapter 3). Next, the electrophysiological correlates of these memory domains will be analysed to determine if changes in ERP waveforms reflect age-related behavioural differences in memory (Chapter 4). Subsequently, electrophysiological and behavioural measures of source memory alone will be examined using a well-established source memory task (the Opposition task; Jennings & Jacoby, 1993, 1997) and a novel task designed to provide an additional means of measuring source memory decline (Chapter 5). The thesis concludes with the investigation of a depth of processing intervention to enhance source memory recall in older adults (Chapter 6). It is predicted that there will be an age-related decline in a variety of memory tasks coupled with age-related changes in ERP amplitudes reflecting behavioural differences. It is also expected that enhanced memory performance in older adults due to a depth of processing strategy used at the time of acquisition will be seen.

2

Chapter II

Behavioural and Electrophysiological Methods

2.1 Introduction

The purpose of the current chapter is to provide a comprehensive account of the testing methods used within the current thesis. The chapter asserts why particular measures were chosen, how they were carried out and analysed and how they underpin the investigation of age-related memory processes. The testing methods used in the current research included pen and paper tasks, computer-based memory tasks and electrophysiology. Each of the pen and paper tasks comprised control measures, and index capacities such as short-term memory, IQ, Working Memory and Cognitive Failures. The computer-based memory tasks are the main interest in the current research and it is hoped that these will shed light on the process of age-related memory decline. These tap into different capacities of memory such as associative memory, episodic memory and source memory (which is of particular interest within the remits of the current thesis). Electrophysiology is used to further investigate any age-related differences in scalp-recorded activity and to further enhance knowledge on such processes. Therefore, an account of the historical background to electrophysiology, an overview of Event-Related Potentials (ERPs), details of such procedures and the analysis process is necessary for inclusion.

2.2 Participants

Participants consisted of two age groups: a young group (18-30 years) and older adults (55+ years). The young participants were undergraduate students at the National University of Ireland Maynooth and were recruited from the participant pool. Participation was voluntary and no monetary or course credit incentive was given. Recruitment was carried out by a group of postgraduate Psychology students who attended first year lectures and informed undergraduate students about the need for participants for research. Students could then sign up to participate in research. Participants were then contacted by individual postgraduate students and were informed of the particular research study, and told that they could choose to opt in or out of the particular research. Older adults were recruited from the surrounding Maynooth area and participation was entirely voluntary. Recruitment occurred via the use of local newsletters (Maynooth Newsletter, Lucan newsletter), contacting active retirement groups (e.g. Maynooth senior citizens, U3A group, Men's Shed Club) and the Mature Students society in NUI Maynooth.

The exclusion criteria for all participants in the research included: severe visual impairments; history of psychological/neurological impairment; severe head trauma resulting in unconsciousness; history of epilepsy; currently taking psychoactive medication; other relevant medical conditions; high blood pressure/heart condition; history of drug or alcohol problems; claustrophobia; dyslexia; and anyone outside of the age ranges. Participants were asked when they were contacted if they had suffered from any of the above. If they had, they were thanked for their interest in the research but informed that they did not fall in the correct remits for the current research. If they did not suffer from any of the above, and still wanted to volunteer, a day and time was organised for the experiment and participants signed a consent form (each study consisted of an individual consent form which is referred to in each chapter) indicating that they were free from the above exclusion criteria.

2.2.1 Ethical Considerations

The general nature of the study was outlined to interested participants and those who participated were requested to sign a consent form prior to commencing the experiment (see relevant Appendices for consent forms). Participants were informed that they could withdraw from the experiment at any stage and that their results would remain confidential with each participant's data anonymised and kept separate from any identifying material. Older adults participating in the research were informed that the experimental procedure was not used as a diagnostic tool; and if they voiced concerns about their memory performance, they were encouraged to make an appointment with their GP.

2.3 Control Measures

2.3.1 Introduction

The control measures are a very important and necessary part of the current research. They are used to ensure that the two groups tested are as evenly matched as possible so that any differences on the computer-based memory tasks are more likely due to age-related differences rather than differences on, for example, IQ. The control measures which are used throughout the current thesis include the Rey Auditory Verbal Learning Test (RAVLT; Rey, 1964), the National Adult Reading Test (NART; Nelson, 1982), the Digit Span which was based on a subset of the Weschler Memory Scale (WMS; Wechsler, 2009), the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982) and a Source Memory Questionnaire and a description of each of these can be seen below. The RAVLT is used mainly as a measure of short-term memory, although it incorporates other aspects also; group differences would be expected on this task. The NART is used to ensure that the groups are evenly matched on predicted estimates of IQ while Working Memory is investigated by the use of a Digit Span task. The CFQ is administered to ensure that the groups share similar rates of cognitive failures. The Source Memory Questionnaire (SMQ) was newly developed for this thesis; therefore it has not been peer-reviewed, and is being used to determine if deficits in source memory can be identified via the use of a self-report questionnaire.

2.3.2 The Rey Auditory Verbal Learning Test (RAVLT)

2.3.2.1 Description.

Rey (1964) designed the RAVLT to determine different aspects of memory such as immediate memory span, and retroactive and proactive interference. The recall version of the RAVLT (Appendix A) consists of a list (A) of 15 nouns which are read out to the participant one at a time at a rate of approximately one per second. The participant is then requested to recall the words in any order. This process is repeated for a total of 5 trials (Trials A1-A5) and the participants are informed to repeat each of the words whether they have said them for previous trials or not. Following the five trials an interference list (B) of 15 different words is administered and participants are asked to repeat those words also (Trial B1). After they have completed the interference list they are requested to perform free recall of the original list (A) *without the experimenter reading out the words* (Trial A6). They are again asked to perform free recall of the first list once a 20 minute delay has been imposed (Trial A7). The task is scored by marking off the number of correct recalls in each trial. Trials A1-A5 gives a measure of immediate memory span and will typically show an increase in memory span as the trials progress from A1-A5. Proactive interference is measured by comparing Trials A1 and B1 to determine if the learning of list A interfered with the learning of list B. Retroactive interference is measured by comparing Trial A5 and A6 to determine if learning list B interfered with the ability to recall list A. Delay is measured by comparing trials A6 and A7 to determine if a time interval has any effect on recall ability.

2.3.2.2 Scoring and Analysis.

For each word recalled on each trial a score of one was given; therefore, scores were out of 15 for each trial and total number of recalled items was the dependent variable. The RAVLT consisted of four different independent variables: total recall across Trials A1-A5, Proactive Interference (scores on Trials A1 and B), Retroactive Interference (scores on Trials A5 and A6) and Delay (scores on Trials A6 and A7). Scores were input into SPSS where analyses consisted of mixed factorial ANOVAs on the four independent variables, and independent and Bonferroni-corrected dependent t-tests on the individual trials.

2.3.3 The National Adults Reading Test (NART)

2.3.3.1 Description.

The NART (Appendix B), developed by Nelson (1982) is a pre-morbid estimate of IQ. The NART consists of 50 words which participants are asked to pronounce aloud. It involves words which are irregular in terms of normal grapheme-phoneme correspondence whereby, assuming the participants were familiar with the word, accuracy of pronunciation is used to predict IQ as phonetic translation or intelligent guesswork will not provide the correct pronunciation (Bright, Jaldow, & Kopelman, 2002). The value of the test resides in the high correlation between reading ability and intelligence in the normal population (Bright et al., 2002). The responses are recorded in terms of correctly or incorrectly pronounced words. Each incorrectly pronounced word is considered an error; however allowances for accent and pronunciations are made. The estimates are based on the amount of errors made using the conversion table provided (see Appendix B) to determine the estimates of Full Scale IQ, Verbal IQ and Performance IQ.

2.3.3.2 Scoring and Analysis.

A correct mark was given for each word a participant pronounced correctly while an incorrect mark was given for each time a word was mispronounced. The total number of mispronunciations (i.e. errors) was calculated. The error score allowed for identification of the predicted IQs. The NART consisted of three dependent variables: Predicted Full Scale IQ, Verbal IQ and Performance IQ, which were analysed using a one way between groups MANOVA.

2.3.4 Digit Span

2.3.4.1 Description.

The Digit Span Task (Appendix C), based on a subset of the Weschler Memory Scale (WMS), measures participants' memory span for digits, indexing short-term and working memory (Wechsler, 2009). It consists of the experimenter calling out numbers to a participant and the participant recalling the numbers in the same order in the forward direction. The digit span begins with two trials of two numbers and then the trials increase in increments of one digit up to a total nine digits. The task is terminated when the participant completes it or when they have two incorrect recalls in succession (i.e. within an item). The Backward digit span continues in the same manner except the participants are asked to repeat the digits that the experimenter calls out in a reverse direction. The backwards recall also starts with two trials of two numbers but increases to eight digits and again terminates after two errors within an item.

2.3.4.2 Scoring and Analysis.

A score of one was given each time the participant correctly recalled a forward or backward list of numbers. A zero was given if participants incorrectly recalled the list of numbers. Total scores are calculated and participants are given a score out of 16 for forward digit span, out of 14 for backwards digit span and out of 30 for total digit span. Therefore, there are three separate dependent variables: Forward, Backward and Total digit span. These are analysed using a one-way between groups MANOVA.

2.3.5 Cognitive Failures Questionnaire (CFQ)

2.3.5.1 Description.

The CFQ (Appendix D), developed by Broadbent, Cooper, FitzGerald, and Parkes (1982), and measures how probable it is for a person to make an error in everyday tasks (Broadbent et al., 1982). Cognitive failures are described as errors made in simple everyday tasks. The questionnaire consists of 25 short questions on a 5 point Likert scale (0 = never, 1 = very rarely, 2 = occasionally, 3 = quite often, 4 = very often) which participants are asked to answer with regard to how frequently they have experienced the error described in the question in the last 6 months. The questions incorporate problems in attention, memory and motor function (e.g. Do you have trouble making up your mind?).

2.3.5.2 Scoring and Analysis.

Scores are calculated by adding the number of times participants indicated a score of zero to four. The total score ranges from 0 to 100 with 0 indicating no minor lapses in cognitive function and 100 indicating highly frequent lapses in cognitive function. The CFQ is analysed using a one-way between groups ANOVA.

2.3.6 Source Memory Questionnaire (SMQ)

2.3.6.1 Description.

The Source Memory Questionnaire (SMQ) was designed using a subset of questions from the CFQ (Broadbent et al., 1982) and the revised version of the Everyday Memory Questionnaire (EMQ) (Royle & Lincoln, 2008) which were believed to tap into source memory capacity (Appendix E). The questionnaire consisted of 21 short questions on a 5 point Likert scale (0 = never, 1 = rarely, 2 = occasionally, 3 = often, 4 = very often) upon which participants rate how often these events occur to them, incorporating questions involving source memory (e.g. Do you forget when something happened; for example whether it was yesterday or last week?).

2.3.6.2 Scoring and Analysis.

The scores of zero to four on each question are added to give a total score for the SMQ. The total score ranges from 0 to 84, with a score of 0 indicating no lapses in source memory and a score of 84 indicating highly frequent lapses in source memory. A one-way between groups ANOVA was used to analyse the SMQ.

2.4 Computer-based Tasks

2.4.1 Introduction

The computer-based memory tasks used within the current research included the Opposition task (Jennings & Jacoby, 1997), the Visual Paired-Associates task, context version (VPAc; Hogan et al., 2011, 2012), the False Memory task (Roediger & McDermott, 1995) and the Where-Who-What task. The Opposition, VPAc and False Memory tasks were employed in the first two experimental chapters of the thesis (Chapters 3 and 4) and were used to investigate general age-related decline in memory retrieval as they incorporated source, associative and episodic memory. The final two experimental chapters focused purely on source memory; therefore a new task, the Where-Who-What task was designed to provide an additional measure of source memory and was coupled with the Opposition task to further investigate source memory both behaviourally and using electrophysiology.

All computer-based tasks were presented using the E-prime version 1.0 program developed by Psychology Software Tools Inc. on a Dell Latitude E6400 PC using Windows 2003. E-prime allows for experiments to be computerised. This is completed by the development of experimental design and allows for written, verbal, pictorial and auditory stimuli to be presented. Computerised experiments permit more accurate data collection and analysis, and response time recording occurs in the range of milliseconds. The E-prime program allows merging of data sets, along with filtering, editing, analysing and exporting data. In addition, E-prime allows for Transistor-Transistor-Logic (TTL) voltage triggers to be sent to an EEG amplifier in order to time stamp triggers for electrophysiological studies.

2.4.2 Opposition Task

2.4.2.1 Description.

The Opposition task manipulates time estimation of acquisition and thus measures source memory, our memory of where, when and under what circumstances we learned something (Jennings & Jacoby, 1993, 1997). Words were obtained from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982) and were matched for frequency and complexity. This computer task was presented in the E-Prime experimental presentation program and was developed using both E-Prime and Visual Basic (VB). Combining E-Prime with a VB lag algorithm allowed for randomisation of the lagged stimuli, a version of the Opposition task was created that could be altered to allow for different conditions, i.e. different timings of word presentations.

During the study phase, white words in font Arial size 26 were presented to participants on a black background at 2000ms per stimulus with a 500ms inter-stimulus interval (ISI). There were a total of 40 trials where the participants must try to learn the words for a subsequent memory test. The first and last 5 words of the study phase were removed from the test phase in order to control for primacy and recency effects. For the test block, 128 words were presented on screen until a response was recorded, with a 500ms inter-stimulus interval (ISI). The test block consisted of Distractor words (i.e. new) and Target words (i.e. study). In order to test for source memory, Distractor and Target words were presented a second time in the test phase at different stages or lag lengths after the first presentation. The second presentation of either word type occurred at a lag of 0 (no words between presentations), 4 (four words between presentations) or 16 (16 words between presentations). Figure 2.1 shows a graphical representation of the Opposition Task.

The instructions given to the participants were kept simple in order to avoid confusion. They were informed that the words would be presented one at a time and that they were to read each word in the list aloud, try to remember it and that a test would follow. When they were ready to begin, they were instructed to press the "Spacebar". Once the study phase was completed participants were presented with instructions for the test phase. These instructions informed the participants that they would be presented with words and that some words were words that they had just seen on the study list, while some words would be new. They were informed that if they saw a word that they thought was on the study list to press the "S" key (for studied) and if they saw a word they thought was new, they should press the "N" key (for new).

Participants were further informed that both study and new words may appear more than once during the test but it remained that if they saw a word they previously studied that they should press "S" and if they saw a word that was *not* on the study list they should press "N". Participants were instructed to take as much time as they wanted to respond. Once they were ready to begin the task they were instructed to press the "Spacebar".

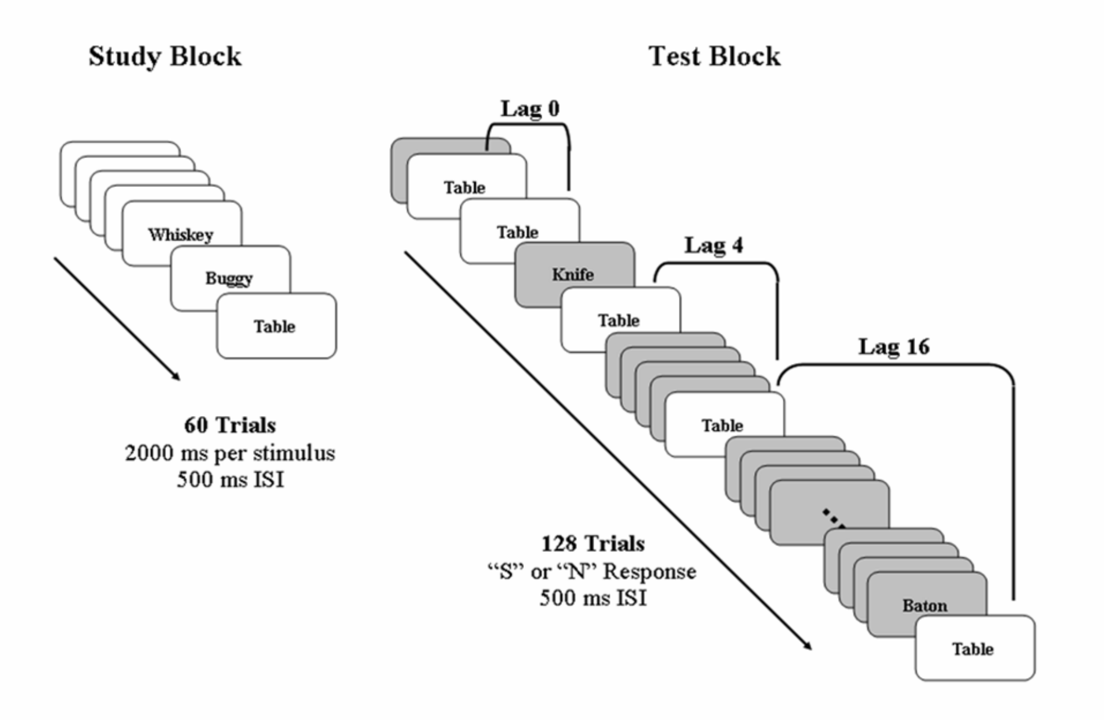


Figure 2.1: Graphical demonstration of the procedure of the Opposition Task

2.4.2.2 Scoring and Analysis

A correct response occurred when a participant pressed "S" when a word from the study list was presented and pressed "N" when a new word was presented. An incorrect response occurred when "S" was pressed for a new words or "N" was pressed for an old word. The Opposition tasks consisted of two different types of stimuli (words), distractors (words *not* in the study list) and targets (words in the study list). Both of these stimuli are further divided into three different lag lengths: lag 0 (no words between the first and second presentation), lag 4 (four words between the first and second presentation) and lag 16 (16 words between the first and second presentation). This yields six different conditions within the Opposition task: Distractor words at Lags 0, 4 and 16, and Targets at Lags 0, 4 and 16. Word type and Lag were the two independent variables in the Opposition task. Accuracy or response times on the first presentation are not reported on as the interest lies exclusively in source memory capacity.

Mean accuracy and mean response times for correct responses were the dependent variables measured for the Opposition task. These were recorded during the test phase of the experiment. Accuracy was recorded as the number of correct responses made. Response times were measured as the interval between the presentation of the stimulus and the response made. Accuracy and response times were recorded for correct trials and were calculated in the E-prime program and exported to SPSS. Mixed Factorial ANOVAs were used to analyse accuracy and response times, and independent and Bonferroni-corrected dependent t-tests were then conducted in SPSS. Graphs were formulated in Microsoft Office Excel.

2.4.3 Visual Paired-Associates Task, context version (VPAc)

2.4.3.1 Description.

Calkins (1894) developed the first Paired-Associates Learning task, whereby a stimulus and a response (usually words) were paired as the participant learned them. When a participant was then prompted with a simple stimulus they were asked to give the correct response. The VPAc was developed based on the original Paired-Associates task, but instead of using words, the stimuli were achromatic, abstract, non-verbalised designs which were obtained from a graphical design website. The VPAc measures contextual memory, whereby if the context changes from learning to retrieval it is harder to have an accurate recall (J. C. Davis et al., 1972).

Stimuli were paired on different backgrounds and the participants were instructed to remember what images make a pair and to ignore the backgrounds. There were 8 pairs of stimuli and each pair was presented 6 times during the study phase in a pseudorandom order. The stimuli were presented at a rate of 3500ms with an ISI of -750ms where a fixation cross was presented. For the test block, pairs were presented on screen until a response was recorded, with a 750ms inter-stimulus interval (ISI). A total of 128 stimuli were presented in the test phase. The task required that if a pair was on the study list (i.e. a true pair) the left mouse button should be pressed. If a pair was not on the study list (i.e. a recombined pair) the right mouse button should be pressed. These buttons were marked on the mouse with coloured stickers and the words “correct” and “incorrect” to allow for easy identification. Figure 2.2 displays a graphical demonstration of the VPAc task. The backgrounds for the test phase could change from those presented in the study phase, yielding four conditional combinations of pair (true/false) and context (congruent/incongruent); these were true-congruent (TC), true-incongruent (TI), false-congruent (FC) and false-incongruent (FI). As context changes, it becomes more difficult for a participant to correctly recognise an item (Davis et al., 1972).

Participants were instructed that they would be shown eight different pairs of stimuli and that each pair would be presented on a different background. They were asked to try to remember which stimuli formed a pair and to ignore the background. Participants pressed the “Spacebar” to begin the task. Upon completion of the study phase, participants were informed that they would be shown different pairs of stimuli. They were instructed that if they saw a correct pair (i.e. from the study phase) that they should press the "left" mouse button and if they saw an incorrect pair (i.e. not from the study) that they should press the "right" mouse button. They were once again told to ignore the backgrounds on which the pairs were presented. Once participants were ready to begin they pressed the "Spacebar".

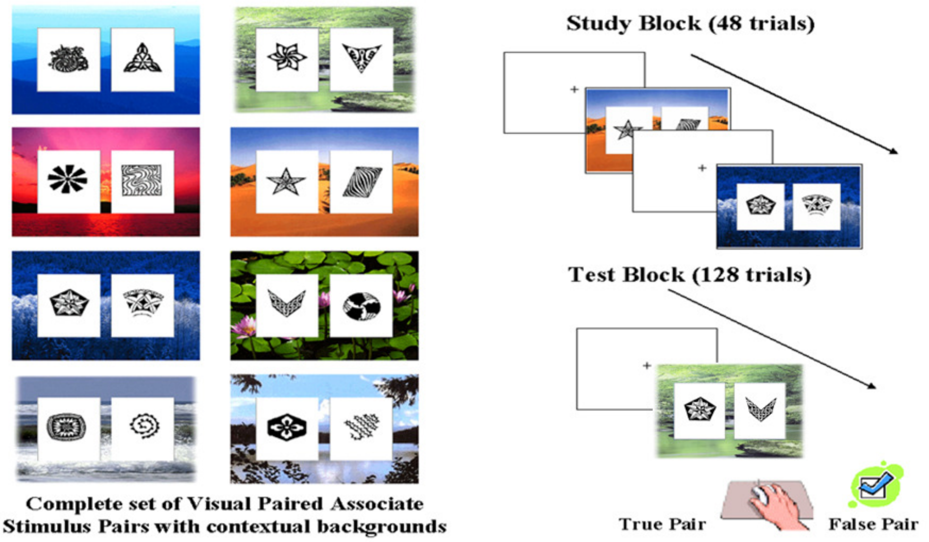


Figure 2.2: Graphical depiction of the procedure of the VPAc.

2.4.3.2 Scoring and Analysis.

A correct response occurred when a participant pressed the left mouse button in response to a true pair and pressed the right mouse button when a false pair was presented. Incorrect responses occurred when the left mouse button was pressed when false pair was presented, or the right mouse button was pressed when a true pair was presented. The VPAc was analysed using two independent variables of Stimulus Type (true/false) and Context (congruent/incongruent), which resulted in four types of stimuli: True Congruent (TC; pair and background matches the study), True Incongruent (TI; pair, but not background matches the study), False Congruent (FC; background, but not the pair, matches the study) and False Incongruent (FI; neither pair nor background matches the study).

Mean accuracy and response times for correct responses were the dependent variables. These were recorded during the test phase of the task. Accuracy was measured as the number of correct responses given. The time interval between the presentation of the stimulus and the response made was recorded as the response time. E-prime computed these data which were then exported to SPSS. SPSS was then used to compute mixed factorial ANOVAs and independent and Bonferroni-corrected dependent t-tests for accuracy and response times. Microsoft Office Excel was then used to create graphs for accuracy and response times.

2.4.4 False Memory Task

2.4.4.1 Description.

False recognition occurs when one either falsely remembers or remembers something that did not happen (Roediger & McDermott, 1995); this can occur frequently when information is semantically related. Here a False Memory task based on the Deese-Roediger-McDermott (DRM) paradigm was used. Words were taken from the revised version of the Toronto Word Pool (Friendly et al., 1982) and semantically related words were generated from this list.

The study list was made up of six categories of semantically related words. These categories included sailing, familial relations, fruit, sleep, seaside and art. In each category there were six words. Black words in font Courier New, size 26, were presented on a white background at 2000ms per stimulus with a fixation cross ISI of 500ms. The words were presented in a sequential order where the semantically related words were presented together. For the test block, 72 words were presented on screen in a random order until a response was recorded, with a 500ms inter-stimulus interval (ISI). For the test phase, if a word had been studied the “S” key should be pressed and if a word had not been studied, the “N” key should be pressed. These keys were marked on the keyboard with coloured stickers to allow for easy identification. The test phase was manipulated with two different types of stimuli. These were: Study Words which were presented in the study list and False Test words which were words that were not in the study list but were related to words in the study list (e.g. brother – sister). Figure 2.3 shows a graphical demonstration of the False Memory task.

Participants were instructed that they would be presented with words which would appear one at a time and that they were required to read the words and try to remember them. Once participants were ready to begin the task they pressed the “Spacebar”. For the test phase of the task, participants were instructed that they would be presented with words on the screen and that some would be words they had studied while others would be new. They were informed that if they saw a word from the study list to press the “S” key and if they saw a new word to press the “N” key. They were told that if they were ready to begin the task they could press the “Spacebar”.

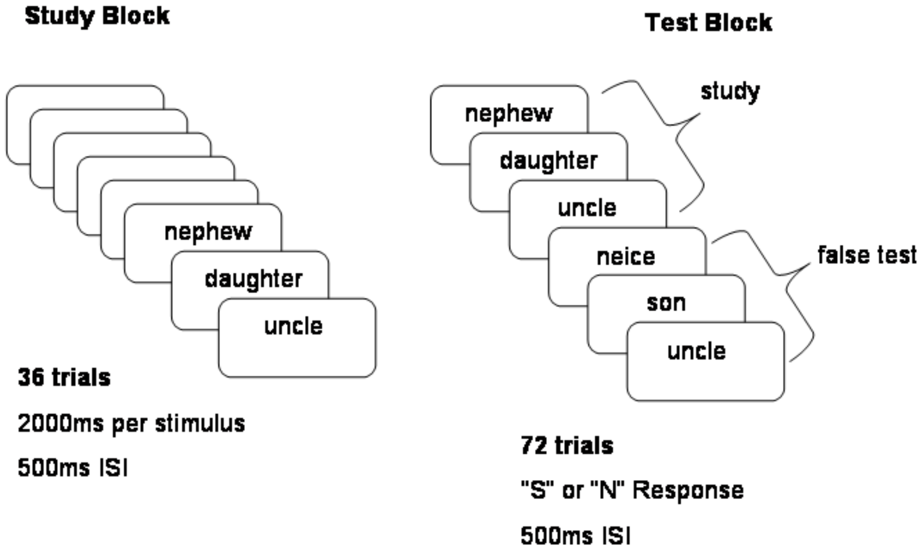


Figure 2.3: Graphical Representation of the False Memory Task

2.4.4.2 Scoring and Analysis.

Two word types were presented in the False Memory task: Study words (i.e. words which were in the study phase) and False Test words (i.e. words that were semantically related to the study words); thus word type was the independent variable. A correct response occurred when a participant pressed “S” when a word from the study list was presented and pressed “N” when a new word was presented, while an incorrect response was recorded when “S” was pressed for a new word or “N” was pressed for a study word.

The dependent variables of interest were accuracy and response times for correct responses recorded during the test phase. Accuracy was considered as the total number of correct responses made. Response times were measured as the difference between time of presentation of a stimulus and the time a response was made. E-prime was used to compute these data which were then exported to SPSS for further analyses using mixed factorial ANOVAs and independent and Bonferroni-corrected dependent t-tests. All graphs for the False Memory tasks were generated in Microsoft Office Excel.

2.4.5 Where-Who-What Task

2.4.5.1 Description.

The Where-Who-What task was developed as a new measure of source memory, drawing on the real life scenario of *where*, with *whom* and *what* was acquired. It measures a person's ability to recall where they were, who they met and what was said to them. The location stimuli where obtained by the researcher from photographs, the face stimuli were obtained with consent from the Penn ER-40 task (acquired according to Gur et al., 2002; referenced in Kohler et al., 2003), and the words were taken from the Toronto Word Pool (Friendly et al., 1982) and were matched for imagery, frequency and concreteness. The auditory version of the word was either recorded in the Department of Psychology or taken from a previous departmental study.

Three stimuli (a location, a person and a word) were presented together and the participants were instructed to try to remember that the three elements make a triplet. There were eight triplets of stimuli and the stimuli were presented once during the study trial in a pseudorandom order. The location was presented for 1000ms, followed by the face superimposed on the location for 2000ms, followed by the auditory word for a duration of 1000ms. This was then followed by an ISI of 500ms wherein a fixation cross was presented.

For the test phase, stimuli were presented on screen for a duration of 3000ms, during which participants were prompted to make a response, followed by a 500ms ISI. A total of 48 stimuli were presented in the test phase. Two of the three elements were presented together, i.e. location and face, face and word, or location and word. The task required that if the two elements had been presented together during the study phase (i.e. were true) the left mouse button should be pressed, and if the two elements had not been presented together during the study phase (i.e. false) they should press the right mouse button. The participants were prompted on screen for when and how to make a response and the task did not progress onto a new pair of elements until a response was made. These buttons were marked on the mouse with stickers and the words “yes” and “no” to allow for easy identification.

The stimuli for the test phase could deviate from what was presented in the study phase, yielding six combinations of the elements. These were true background-face (BF), face-word (FW), and background-word (BW), and false background-face (BF), face-word (FW), and background-word (BW). These conditions draw on one’s source memory ability to distinguish between where something was acquired and from whom, and what the content was. The participants were informed that they would be presented with a location, a person’s face which would then be followed by an auditory word. They were instructed to try to remember that the three elements went together and when they were ready to begin the task to press the any key. For the test phase of the experiment, the participants were instructed that they would be presented with two out of the three elements from the study phase; a location and a face, a face and a word or a location and a word. They were informed that they would be prompted on screen asking if the elements had been paired together in the study phase and that if they had been previously paired to press the “Left” mouse button and if they had not been paired to press the “Right” mouse button. Participants were instructed to press any key to begin the test phase of the experiment.

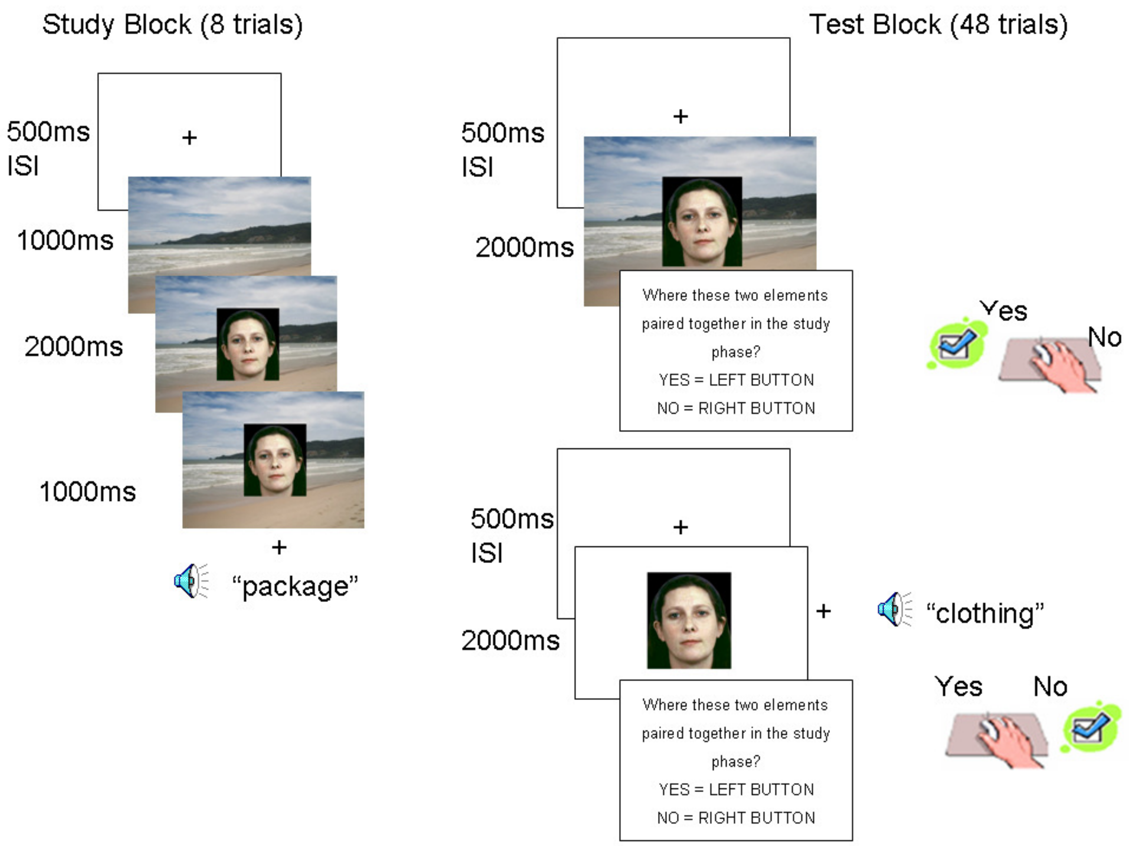


Figure 2.4: Graphical depiction of the WWW Task

2.4.5.2 Scoring and Analysis.

A correct response occurred when the participants pressed the left mouse button when true elements were presented and pressed right mouse button when false (i.e. false/unpaired) elements were presented. Incorrect responses occurred when the left mouse button was pressed for a false pair and the right mouse button for a true pair. The task consisted of two types of stimuli (true/false), and three pair types (BF/FW/BW). Thus, these were the independent variables.

During the test phase of the experiment, the dependent variables of accuracy and response times were recorded. Response times were recorded for correct responses. Accuracy was considered as the total number of correct responses made, while response time was the period between presentation of stimuli and the response logged. These data were computed in E-prime and exported to SPSS where mixed factorial ANOVAs and independent and Bonferroni-corrected dependent t-tests where used for analyses.

2.5 Human Electrophysiology

2.5.1 Historical Background

The study of electrophysiology began with the invention of the galvanometer which measured electrical currents and showed that electrical currents are continuous (Niedermeyer, 2005). Caton (1875) used a galvanometer to measure the first electrical responses from the exposed cerebral hemispheres of rabbits and monkeys. Caton observed currents of varying directions when placing electrodes on the surface of the brain of the animal. This observation is considered as the first indication of electrical potentials in the brain, as it is considered that the needle of the galvanometer moved due to the fluctuations of the electrical currents of the brain (Niedermeyer, 2005). While Caton's findings were limited by the use of a galvanometer and the likelihood of artifacts, his work is still considered a landmark in the study of electrophysiology.

Beck (1890) further built on Caton's work. Using sensory stimuli such as light stimulating the eyes, he discovered that the rhythmical oscillations present in the neural electrical brain responses of rabbits and dogs disappeared due to the stimulus (Niedermeyer, 2005; Scanlon, Commins, & Roche, 2006). While Beck's work furthered that of Caton's, it merely served as a precursor to the work of Berger. Hans Berger recorded human EEG and is considered the father of human electrophysiology. His studies of human EEG started in the 1920s and he was the first person to successfully record electrical activity using an electrode from the scalp of human participants in 1925, and published in 1929 (Nunez & Srinivasan, 2006). Berger recorded between one and three minutes of activity which he then amplified and plotted the change in voltage over time (Luck, 2005). Since Berger's original study, advancements have been made in the study of electrophysiology which has allowed for more accurate and reliable methods of measuring the electrical activity in humans. The most notable of these is the Evoked Potential (EP). Davis (1939) extracted the changes in EEG waves which were recorded in response to a stimulus and named this the Evoked Potential. Until the 1950s, there were no set guidelines for the placement of electrodes for EEG recording. This was rectified when a committee led by Jasper developed the international 10-20 placement system (Reilly, 2005).

Dawson (1954) furthered the work of Davis by averaging larger numbers of EPs and thus increasing the signal-to-noise ratio and eliminating irrelevant data, e.g. muscle movements. This gave rise to the study of Event-Related Potentials (ERPs) which is still in widespread use today and will be used for a predominant portion of this thesis. ERPs reflect ongoing changes in electrical activity within the brain due to a stimulus (Scanlon et al., 2006). They are calculated by averaging a large number of epochs (timeframes) in a recorded EEG which are time-locked to a specific event (Handy, 2005), typically the presentation of a stimulus or a response trigger within an experimental design. When more epochs are used this allows for a higher ratio of useful signals, which in turn allows for clearer components to be seen (Handy, 2005). For the purpose of these experiments, ERPs are time-locked to the presentation of the stimulus and the waveforms are plotted as voltage (microvolts - μV) on the Y-axis, and over time (milliseconds – ms) on the X-axis.

2.5.2 Physiological Basis of EEG

In the Central Nervous System (CNS) including the brain, communication takes place via transmission of electrochemical signals between nerve cells or neurons. A neuron consists of a cell body, an axon and dendrites, and the axon is surrounded by a myelin sheath to speed up the transmission of signals between neurons (see Figure 2.5). The Resting Potential of a neuron is -70mV compared to the surrounding tissue and when the neuron is not sending or receiving a signal, no positively or negatively charged ions are crossing the membrane and it is polarized (Speckmann & Elger, 2005).

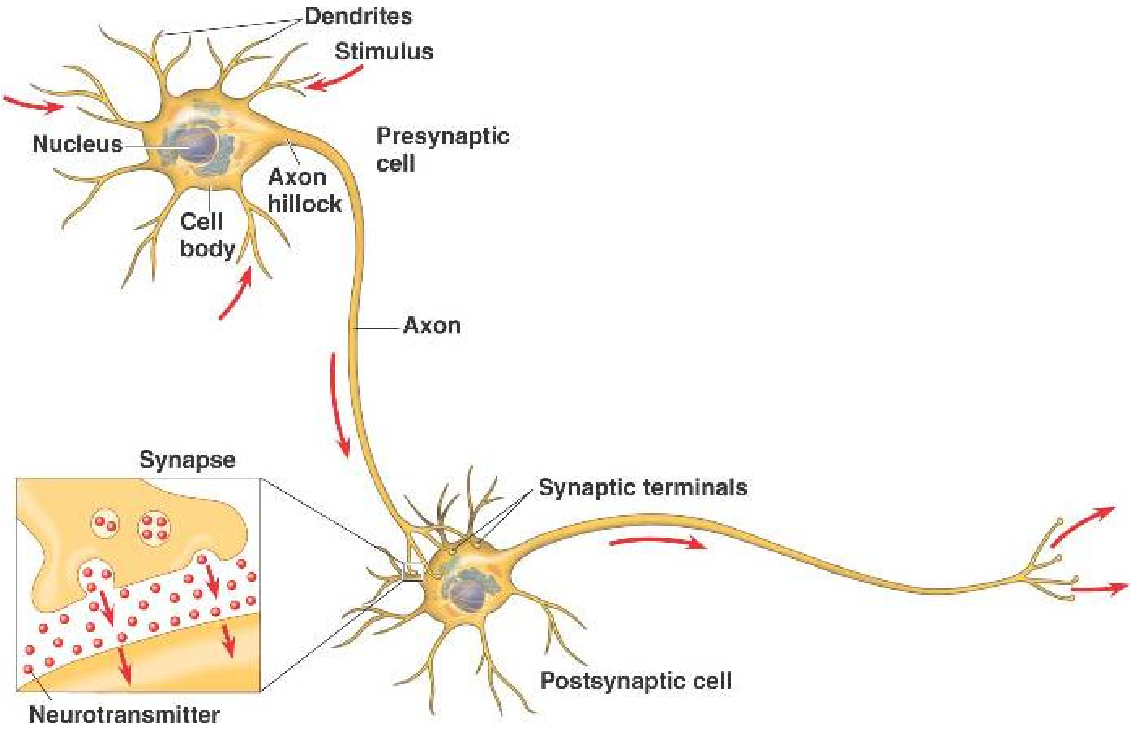


Figure 2.5: The structure of a typical neuron, showing connections between neurons in the brain. Obtained from http://bio1152.nicerweb.com/Locked/media/ch48/neuron.html: Accessed 5th June 2013.

The Resting Potential is due to the presence of charged particles across the cell membrane which includes sodium ions (Na+), chloride ions (Cl-), potassium ions (K+) and protein anions (A-). Whether or not a neuron fires depends on the balance between the excitatory and inhibitory signals at the axon hillock. It is the occurrence of deviations in the charge within a neuron due to the summation of the ions that gives rise to the possibility of the cell generating an Excitatory Post-Synaptic Potential (EPSP) or

Inhibitory Post-Synaptic Potential (IPSP). Deviations from -70mV make it more or less likely for the neuron to fire an action potential (Speckmann & Elger, 2005). Every signal will either inhibit or excite signals that are transmitted due to a signal travelling the length of the axon of the pre-synaptic neuron causing neurotransmitters to be released into the synaptic cleft that diffuse across to the dendritic tree or cell body of the post-synaptic neuron. The action potential originates at the axon hillock and travels down the axon ending at the synaptic boutons, where a neurotransmitter is released (Nunez & Srinivasan, 2006). A synapse occurs between the synaptic boutons of one neuron and the dendrites of another neuron. When the action potential reaches the synaptic boutons, neurotransmitters are released into the synaptic cleft and bind with receptors of the post-synaptic neuron to be further transmitted (Nunez & Srinivasan, 2006). The neurotransmitters influence the activity of the neuron by binding to the receptors which alter the electrical potential across the membrane of the postsynaptic cell (Scanlon et al., 2006).

When neurotransmitters bind to post-synaptic receptors they either depolarize or hyperpolarize the receptive membrane. Depolarisations are called Excitatory Post-Synaptic Potentials (EPSPs) and make it more likely that the neuron will fire. This results in the membrane potential rising from -70mV to 0mV or higher. If the membrane potential rises to -50mV then an action potential is generated in the neuron and a neurotransmitter is released onto another cell (Scanlon et al., 2006). Hyperpolarizations are called Inhibitory Post-Synaptic Potentials (IPSPs) and make it less likely that the neuron will fire causing it to be pushed further from the threshold of action potential generation. EPSPs and IPSPs are graded responses where their amplitude is proportional to the signal elicited by them. Rather than the action potentials themselves, it is the generation of these depolarizations and hyperpolarizations that are recorded by EEG.

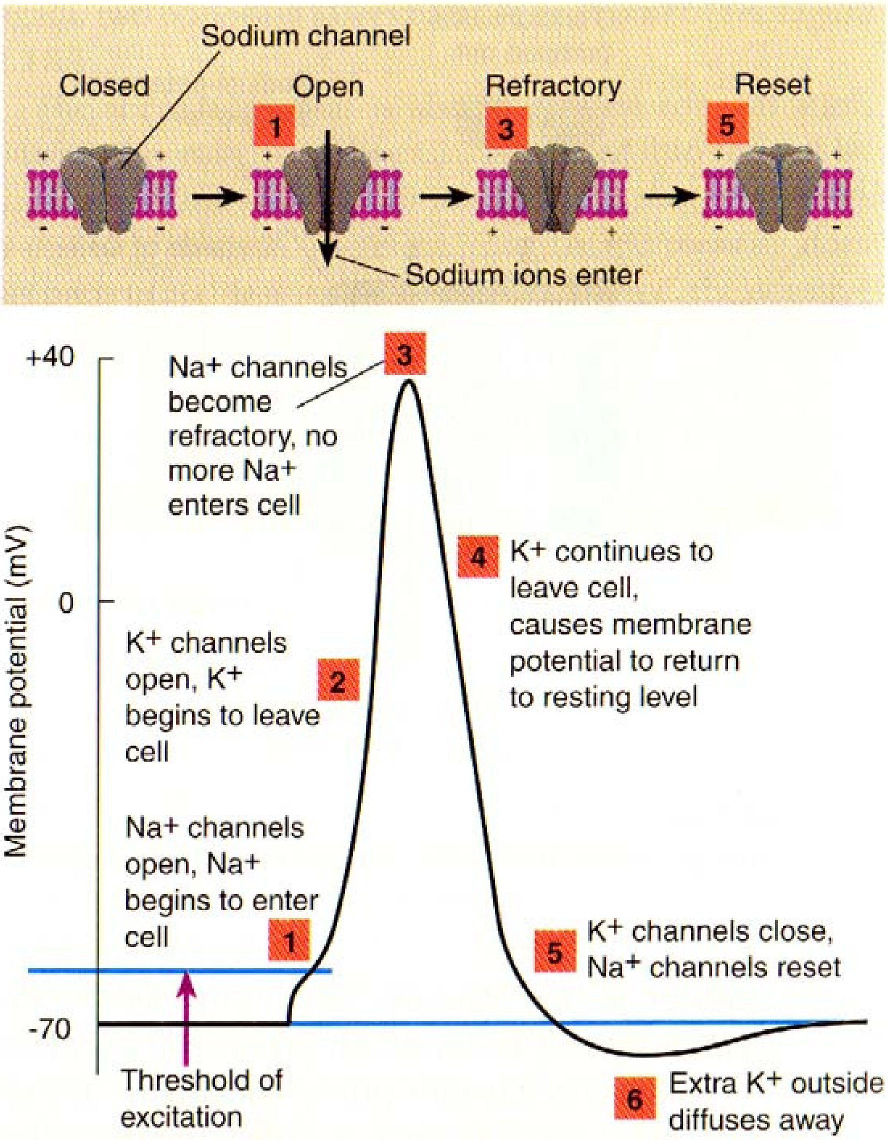


Figure 2.6: Diagram of the processes involved in the generation of an action potential in a neuron. Obtained from: http://2.bp.blogspot.com/mGTtnGanaP0/Txy_ShfDfgI/AAAAAAAAASg/kUegSPnKJ_k/s1600/action_potential.jpg Accessed 5th June 2013.

Due to an EPSP, positively charged ion channels open and sodium and potassium ions pass through the cell membrane (Speckmann & Elger, 2005) creating a “sink” where positive ions get sucked into the cell, causing the potential to move closer to 0mV depolarizing the membrane (Scanlon et al., 2006). As ions move through the neuron, they are ejected at a different location known as a “source” and so the local sink remains balanced. With an IPSP, the opposite occurs whereby a source is produced which releases positive ions, lowering the membrane potential and in return a distant sink will balance the “source” by taking ions in. The occurrence of positivity and negativity in the cells allows for the neuron to be viewed as a dipole. It is the summation of thousands of these EPSPs and IPSPs occurring in neurons that is recorded by EEG.

2.5.3 Event-Related Potentials (ERPs)

Studies of event-related potentials have the advantage of being non-invasive and as such can be used with normal healthy participants completing both simple and complicated tasks. Electrodes are attached to the scalp in order to record the electrical activity in the underlying part of the brain using electroencephalography (EEG). EEG waves are used to measure event-related potentials (ERPs). An ERP is a change in the ongoing electrical activity of the brain measured from the cortex at a given location that are related to specific events (Luck, in press). Any changes due to the demands of tasks are amplified, averaged and extracted as ERP waveforms averaging out most of the noise, leaving a clearer signal. These waveforms are measured as the difference between the electrical activities of a baseline reference electrode (attached to an inactive electrical site, such as the nasion on the nose) and the electrical activity of the areas of the brain recorded by scalp electrodes. A participant completes tasks in which stimuli are presented at predetermined times (time stamped) and the EEG waves that were recorded during the stimuli presentations are averaged (Handy, 2005). As more trials are added the ERP waveform becomes more pronounced and is plotted as voltage (in microvolts;

μV) over time (milliseconds; ms). The waveform gives a detailed temporal account of the neural activity induced by the repeated presentation of a stimulus or a response (Handy, 2005). The signal is often a large positive or negative electrical charge occurring at a particular time point after the presentation of the original stimulus and can be used to assess the performance processes associated with a response (Luck, in press) and the ERP can then be related to mental processes.

An ERP waveform consists of different components, i.e. peaks within the waveform, which correspond to the electrical activity for polarity (i.e. positive or negative) and time latency (Luck, 2005). The polarity of the peak is a result of whether the EEG recorded reflects EPSPs or IPSPs, with EPSPs giving rise to negative peaks, while IPSPs result in positive peaks (Scanlon et al., 2006). The latency of a peak is judged on the time after a trigger at which the peak occurs (Altenmüller, Münte, & Gerloff, 2005). For example, if a positive peak occurred at 300ms this would be considered a P300 or P3 component. ERPs can consist of the early P1 and N1 components, followed by the later P2, N2 and P3 components (Luck, in press). See Figure 2.7 below for an example.

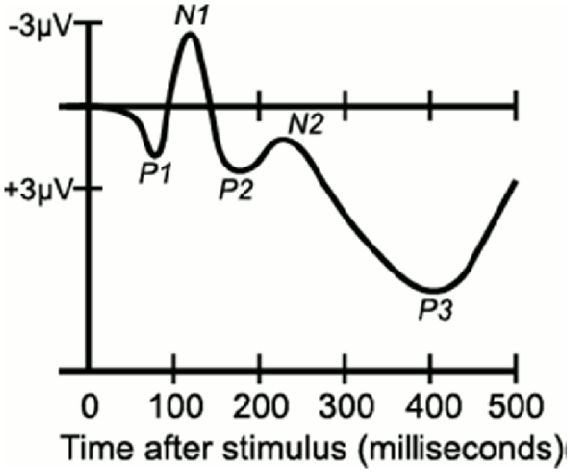


Figure 2.7: Example ERP component showing P1, N1, P2, N2 and P3 components. Negative is plotted upward in this figure.
Obtained from http://neurofeedback.visaduma.info/emotivresearch.htm
Accessed 1st September, 2013.

As the ERP technique has become increasingly accessible, it has become a central means of investigating brain activity during cognitive processes. ERP topography can be used to calculate the missing intermediary values for spatial electrode points, based on values of nearby recorded electrode sites. This is completed through the techniques of interpolation. ERP topography allows for visual inspection of the scalp data and identification of sites of interest for further comparative analyses. ERPs have been used to study a vast array of cognitive processes, from tasks of visual attention (Karayanidis et al., 2000), to language (Jackson, Swainson, Mullin, Cunnington, & Jackson, 2004), learning (Rose, Verleger, & Wascher, 2001), memory (Rugg & Curran, 2007) and the ageing process (Friedman, 2000).

2.5.4 Temporal and Spatial Resolution

Each technique used in neuroimaging can be assessed on its value by looking at its temporal and spatial resolution. Temporal resolution refers to the accurate recording of the timing of activity while spatial resolution refers to the ability to identify the area in which activity occurs (Luck, 2005). Various techniques are used within neuroimaging and these all vary on their spatial and temporal abilities.

Imaging techniques, such as functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) provide excellent spatial resolution as they measure the increase in blood flow to regions of the brain. However, while they have excellent spatial resolution they do not have equivalent temporal resolution (Luck, 2005). This is due to the speed of blood flow being slow in comparison to electrical impulses. Also, many studies involving fMRI and PET cannot use an event-related design and so real time recording is lost.

ERPs consist of scalp recorded electrical activity where voltage changes in the cortex travel through the skull and scalp, within milliseconds, leading to almost instant recording of the electrical activity of the brain. As such, ERPs provide very high temporal resolution (Luck, in press). However, ERPs also provide poor spatial resolution (Nunez & Srinivasan, 2006). This poor spatial resolution is due to the interference of the layers of tissue between the source of the activity and the electrode. The electrical signals can be deflected through layers of meninges, bone and scalp and as such the signal resulting in ERPs may have originated from any point within the brain (Scanlon et al., 2006). However, recent studies are combining EEG with other neuroimaging techniques, such as fMRI, which allows for further understanding of the spatial and temporal aspects of cognition.

2.5.5 EEG Recording, Procedures and Analysis

2.5.5.1 Preparation.

Participants were fitted with a specially produced 32-channel electrode placement cap (Easy-Cap) conforming to the standard 10-20 system. The cap was placed ensuring that the midline electrodes (Fz, Cz, Pz, and Oz) were positioned straight along the sagittal axis of the head (See Figure 2.8). This cap was fastened with a chest strap. Electro-conductive gel (Abraylt 2000) was placed into the 32 electrode sites with a 10ml flat tipped syringe (see Figure 2.8 for map of electrode sites). The gel creates conduction between the scalp and the electrode. The plugs of the electrodes were inserted into the amplifier while the tin electrodes (BrainVision; BrainProducts GmbH, Germany) were connected to the corresponding electrode site on the Easy-Cap. Once the scalp electrodes were in place the reference and EOG electrodes were attached, the reference electrode was placed on the nasion on the tip of the nose and the four EOG electrodes were placed around the eyes to record blinking and eye movements. Two of the electrodes were placed at the external canthi of the eyes to record horizontal movements (HEOG), and the other two on the superior and inferior ridges of the orbit of the left eye to record vertical eye movements (VEOG) (see Figure 2.9). These electrodes were attached using a non-abrasive electro-conduction gel (Signa-Gel) and were held in place with surgical tape.

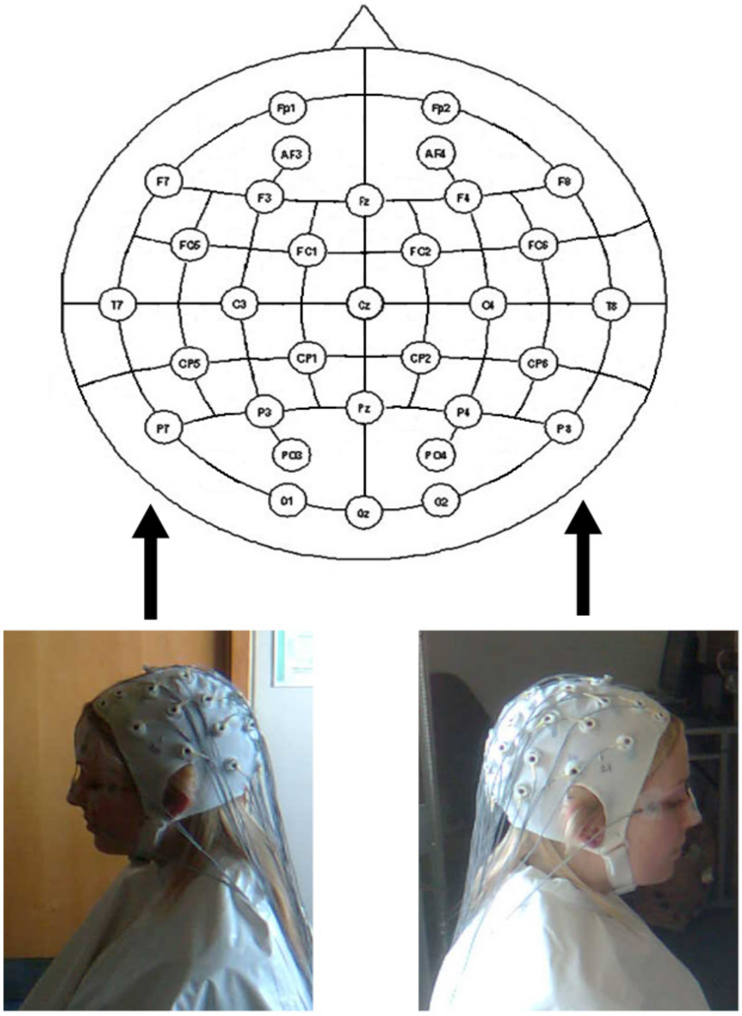


Figure 2.8: 32 ERP channel montage (top) together with actual representation of electrode placement used in this study (bottom). Permission for use obtained from participant in the NUIM Psychology Department 2011.

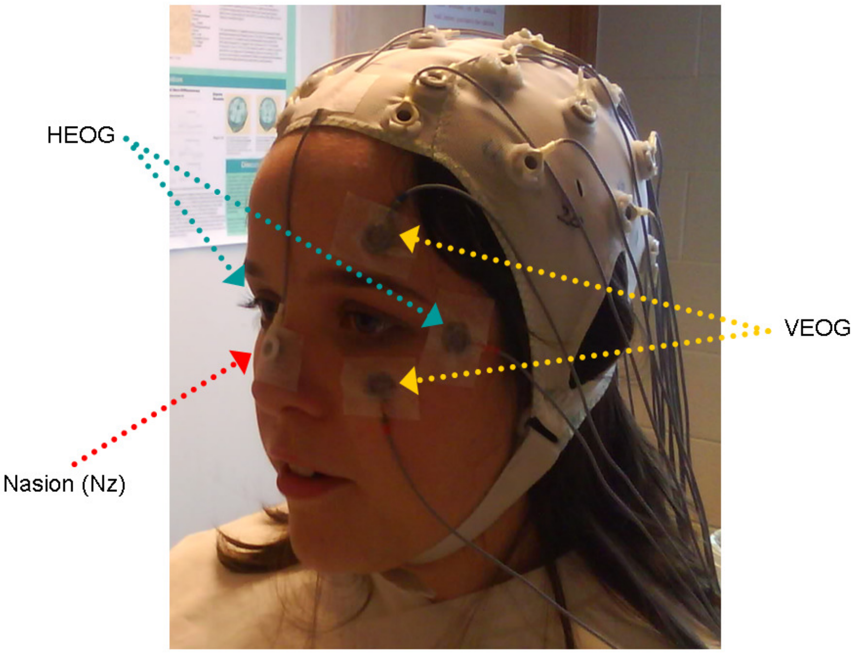


Figure 2.9: An example of ERP array including reference and EOG electrode placements. Permission for use obtained from participant in the NUIM Psychology Department 2011.

2.5.5.2 Reducing impedance and testing.

Impedance testing allows researchers to determine how well the electrodes are conducting activity from the scalp and involves resistance and inductance capacities (Reilly, 2005). Once the electrodes were attached and the BrainVision program started, the program showed a colour-coded measure of impedance quality for each electrode. At one end of the scale was a red colour, signifying poor impedance, while a green colour signified good impedance (5kOhms). If the impedance showed red or not fully green sites, a Q-tip was used to gently improve contact between each electrode site and scalp, and more gel was added in order to obtain a stronger connection. The impedance levels were reduced to below 20kOhms before testing would begin. The process of reducing impedance took approximately 15-25 minutes depending upon individual impedance.

After preparation, participants were seated approximately 50cm from an LCD computer screen on their own in a darkened, electrically shielded and sound attenuated testing cubicle, measuring 150cm x 180cm with access to a mouse and keyboard for making responses. Participants were asked to minimise their movements to reduce the occurrence of artifacts in the data. All experiments were conducted using E-Prime (Psychology Software Tools Inc.). Upon completion of the experimental tasks, the electrodes were removed from both the cap and face, and the gel was cleaned off using paper towels. Participants were then taken to a cubicle with a basin and tap where they could wash the gel off. The participants were thanked and debriefed while any questions or concerns were fully answered. When the participants had left, the cap and electrodes were washed carefully in a sink of warm water and the gel was fully removed.

2.5.5.3 ERP Analysis.

The raw electrophysiological data which were recorded, along with the triggers sent from the stimulus-presentation computer, were transferred to the Brain Electrical Source Analysis program (BESA GmbH, Germany). The EEG data were converted to BESA binary format. After this, a predesigned head coordinate file was loaded to each participant file in order to determine where each electrode was placed, where Cz had the coordinate 0, 0 and each other electrodes coordination was determined based on Cz. Each individual data set was then filtered with a high cut-off filter of 30Hz. Then an automatic blink reduction algorithm was run to minimise the effects of blink artifacts on the data. This algorithm employed a variation of the Berg and Scherg (1994) and Ille, Berg and Scherg (2002) spatial components method for correcting eye artifacts. Artifact and brain signal subspaces are described in terms of spatial topographies. The correction process consisted of four steps. Step one defines the topography for each type of artifact. Step two determines the brain signal topographies underlying the displayed EEG segment. Step three involves the reconstruction of the artifact signal at each scalp electrode with a spatial filter taking into account artifact as well as brain signal subspace. Finally, step four is to subtract the reconstructed artifact signal from the original EEG segment. This allows blink artifacts to be removed with minimal distortion to the data; thresholds for the VEOG and HEOG were set to 150µV to remove maximal blink and eye movement distortions. These data were then visually examined for bad channels and artifacts. Bad channels were those with above average amounts of distortion; these were rectified where possible by interpolating the channel (i.e. taking the average of the other channels surrounding it). Bad channels could also be caused by bridging between electrodes and such channels were instead removed. Any remaining artifacts (due to head movements etc.) were removed from the data by selecting a segment and setting it as an artifact via the use of BESA (Figure 2.10 shows an example of an artifact). After completing these steps, the data for individual participants were considered clean and processing paradigms could then be used on the datasets.

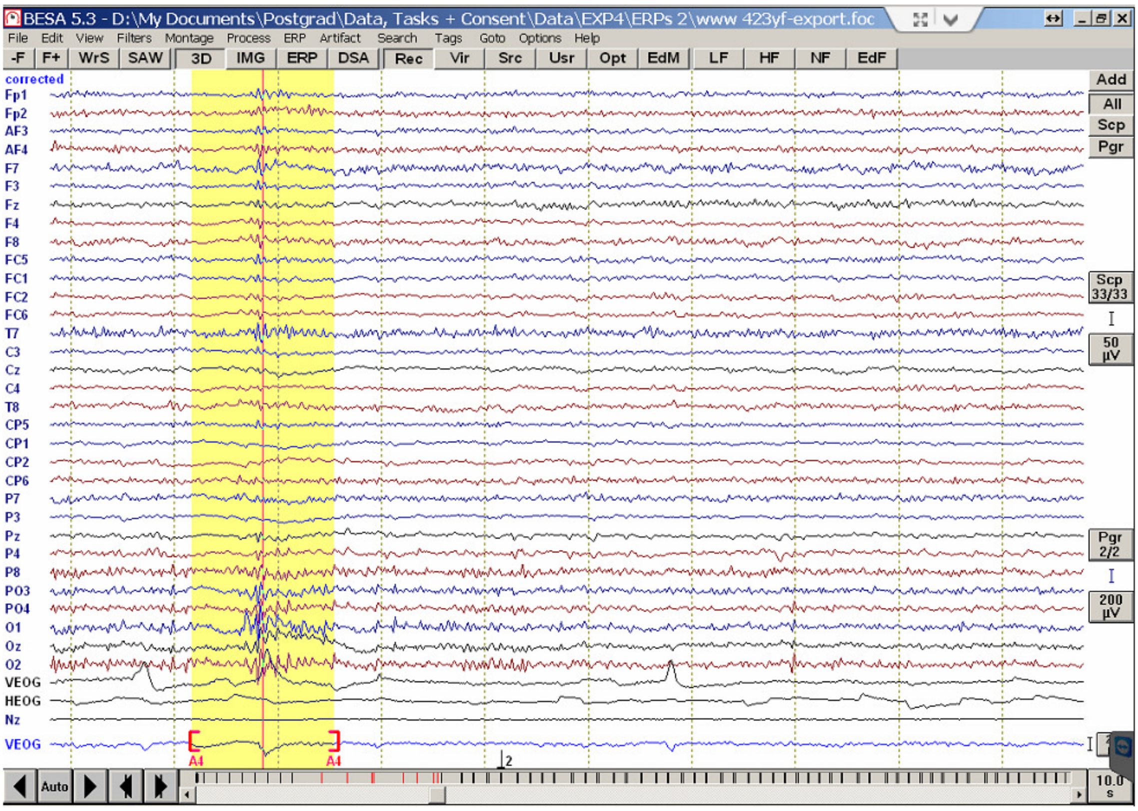


Figure 2.10: Example of an artifact in EEG data (highlighted section)

Paradigms for each task were written in the BESA program whereby epochs based on response times were created for each task (for example an epoch of 1200ms which was preceded by a baseline of 200ms was set for the Opposition task (see Table 2.1 below for all epochs)). The epoch was determined based on the response times of participants. The low cut off filter was set at .30Hz frequency with a slope of 12db/oct and was the type zero phase. The high cut off filter in the paradigm was set at a frequency of 30Hz and also had a slope of 12db/oct and was the zero phase type.

Once the epochs and filters had been set, the conditions using stimuli and response triggers were written which allowed for different conditional ERPs. For example, in the Opposition task a trigger of three was given for Target Lag 0 words and a trigger of ten was given for a correct response. Therefore, the condition of Target Lag 0 with a correct response had a trigger of three followed by a trigger of ten (See Table

2.2 below for triggers). Once the paradigm had been run for each conditional ERP, the artifact tool was used and any datasets that had fewer than 90% of usable data were not included. Each individual participant dataset was averaged according to the conditions creating ERPs for each participant at each electrode site.

Table 2.1: List of epochs for the Opposition, VPAc, False Memory and WWW tasks.

	Baseline	**Epoch**
Opposition Task	-200ms	1200ms
VPAc Task	-200ms	2100ms
False Memory Task	-200ms	1400ms
WWW Task	-200ms	1000ms

Table 2.2: List of stimulus and response trigger values for the Opposition, VPAc, False Memory and WWW tasks.

Task	**Stimuli**	**Triggers**	**Response**	**Triggers**
Opposition	Target Lag 0	3	Correct	10
	Target Lag 4	4	Incorrect	12
	Target Lag 16	5		
	Distractor Lag 0	6		
	Distractor Lag 4	7		
	Distractor Lag 16	8		
VPAc	TC	6	Correct	14
	TI	8	Incorrect	18
	FC	10		
	FI	12		
False Memory	Study word	4	Correct	8
	False Test word	6	Incorrect	10
WWW	True BF	2	Correct	8
	True BW	3	Incorrect	9
	True FW	4		
	False BF	5		
	False BW	6		
	False FW	7		

After the averaged files had been created for each individual participant, the different groups were then averaged to give an overall averaged file for the young and older adults separately. Grand means of the conditions were also created in order to easily identify the latency of peaks within the groups. Visual inspection of the ERP topography allowed for the selection of components at specific channels for further analytical investigation. See Figure 2.11 below for an example ERP topographical map. The topographical map allows for identification of scalp sites at which peak amplitudes are maximal at particular latencies.

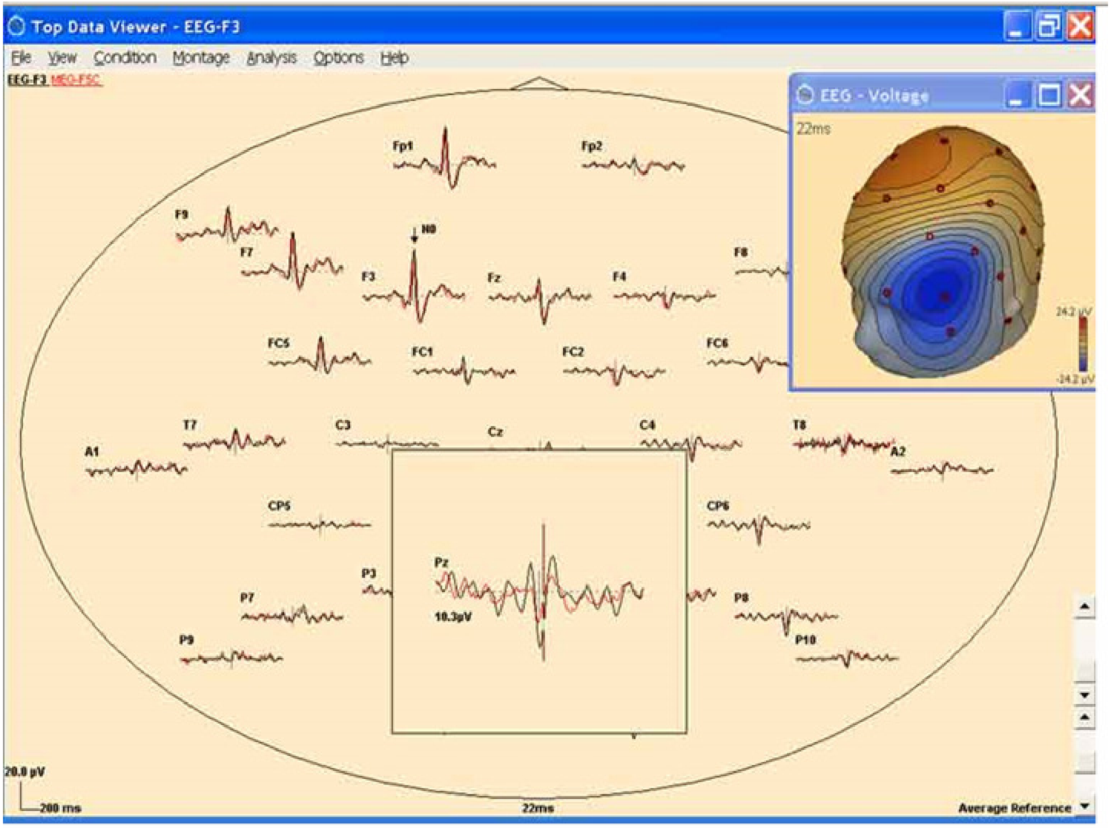


Figure 2.11: ERP Top Viewer and Peak Analysis. Obtained from BESA: Brain Electrical Source Analysis: http://www.besa.de/products/besa/erp-analysis-and-averaging.php
Accessed on 21st March 2011

Mean amplitudes and peak latencies for each individual participant for each component of interest were extracted using the Run Script tool in BESA and were then input to SPSS. Mixed Factorial ANOVAs were then carried out on these data, using the design of the particular task of interest. Any further analyses of the mean amplitudes and peak latencies were conducted using independent and Bonferroni-corrected dependent t-tests.

3

Chapter III

Behavioural performance reveals age-related decline in memory retrieval

3.1 Introduction

Memory complaints are a common problem of the elderly (Levy-Cushman & Abeles, 1998) which leads to the assumption that ageing and memory decline go hand in hand. According to Harris and colleagues (2007), ageing is a complicated process signifying ones biological and social background. Numerous pathological conditions can be linked to the ageing process (Harris et al., 2007) and thus the possibility of disease, impairment in cognitive and physical function, and a reduced quality of life increases (Harris et al., 2007). Two prominent cognitive theories of ageing include the Resource View and the Speed View. The Resource View proposes that the ageing process causes a reduction in the attentional resources that cognition relies on (Craik, Routh, & Broadbent, 1983; Craik & Byrd, 1982; Craik, 1986). The Speed Theory suggests that the decline in cognitive performance in ageing is due to a reduction in the speed at which older adults can process information, both in encoding and retrieval (Salthouse, 1996).

There is evidence that if the mind is kept active then there will not be as great a decline in memory in later life. This evidence comes from studies assessing a group of nuns on their memory performance. Greiner, Snowdon and Schmitt (1996) suggest that, because this sample of nuns constantly partake in mind-exercising games such Scrabble, crosswords and bridge, this led to a lower rate of dementia and Alzheimer's Disease. It was also discovered that they possessed better memory retention and a longer life expectancy. They concluded that this was due to the constant cognitive exercise and associated plastic benefits thereof (Greiner et al., 1996). In addition, Reuter-Lorenz (2002) shows that there is evidence from functional neuroimaging which suggests that ageing does not have to be a progressive mental loss. Older adults recruit different brain regions than younger adults when performing the same memory tasks drawing on both working and episodic memory. For example, recruitment of the prefrontal cortex, essential for memory recall, changes with ageing (Reuter-Lorenz, 2002), whereby the activation becomes more bilateral. This change in recruitment may occur to counteract the decrements seen in memory performance via a compensatory function. However, the ageing process has an impact on all elements of human life and is unavoidable (Cabeza et al., 2004; Venkata S Mattay, Goldberg, Sambataro, & Weinberger, 2008). Ageing can be related to various alterations in physiology and psychology, such as a decline in memory performance, which can unfortunately lead to reduced independence and quality of life (Cabeza et al., 2004; Venkata S Mattay et al., 2008).

Carlesimo et al. (1998) showed that younger adults had better performances than older adults on a variety of memory tests. They found that young groups (20-40 years) performed better than elderly (55-70 years) who, in turn, performed better than very old (80-93 years) on short-term, implicit, episodic and semantic memory. This indicates that the decrement in memory becomes progressively worse as one ages (Carlesimo et al., 1998). It has been found in memory tasks that as one becomes older, fewer brain areas are activated (Cabeza et al., 2002; Cabeza et al., 2004), indicating that normal ageing is associated with the gradual deterioration of the structural integrity of the brain, which occurs earlier and more severely in the frontal cortex than other brain areas (Levy-Cushman & Abeles 1998; MacPherson, Phillips, & Della Sala, 2002; Pasquier, 1999). The frontal lobes appear to undergo the greatest structural change resulting in reduced functioning and therefore impacting dramatically on retrieval processes (Rypma et al., 2001; Stebbins et al., 2002). Three types of memory associated with the frontal cortex are source memory (Craik, Morris, Morris & Loewen, 1990; Janowsky, Shimamura, & Squire, 1989), episodic memory (Wheeler, Stuss & Tulving, 1995; 1997) and false memory (Curran, Schacter, Norman & Galluccio, 1997; Lavoie, Willoughby

& Faulkner, 2005; Schacter, Curran, Galluccio, Milberg & Bates, 1996), and age-related deficits have been shown in each of these capacities.

Source memory is the recollection of the context of an event; *how* an item was acquired, *when* and *where* we learned facts, and any other salient aspects associated with an event (Glisky & Kong, 2008; Jacoby, Shimizu, Daniels, & Rhodes, 2005; Johnson, Hashtroudi, & Lindsay, 1993; Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994; Schmitter-edgecombe, Woo, & Greeley, 2009). According to Jennings and Jacoby (1997), older adults display more difficulty than younger adults when it comes to remembering events in their context of place and time. One of the most commonly used tasks for measuring source memory is the Opposition Task developed by Jennings and Jacoby (1993; 1997). Participants learn a list of words, and during the test phase the participant must declare if a presented word is a new or a study word. However, drawing on the common failure of repeating oneself, the test phase repeats both word types at different intervals; therefore participants must rely on conscious memory to avoid repetition errors with older adults displaying more errors than younger adults when remembering events in their correct place and time (Jennings & Jacoby, 1997). Chua, Chen and Park (2006) found a substantial age-related deficit in source memory in different cultures and concluded that decreased source memory may be a trait of cognitive ageing and it may represent a fundamental marker of cognitive ageing related to the degeneration of neural tissue.

The standard Visual Paired-Associates Task (VPA) task measures a person's associative memory. The VPA context version (VPAc) used in this experiment taps into episodic and associative memory while measuring recognition performance with a changing context (Hogan et al., 2011, 2012). Craik, Luo and Sakuta (2010) found that an older group of adults showed a disproportionate loss of contextual information compared to two younger groups; one group giving their full attention to the task and the other giving divided attention to the task. Their results indicate that there is a specific age-related associative deficit, added to the deficit caused by the loss of resources in the brain (Craik et al., 2010). During the VPAc task abstract images are paired on different backgrounds and participants must remember the pairs and ignore the backgrounds. During the test phase, pairs are presented and the participants must indicate whether it a true (study) or false (recombined) pair, irrespective of the background. When a context differs between a study and a test phase, it is more difficult for a participant to correctly recognise an item (J. C. Davis et al., 1972).

According to Roediger and McDermott (1995), false memory occurs when one remembers events which did not happen or remembers them differently from what actually occurred. According to Schacter, Koustaal and Norman (1997) older adults display more false recognition errors than younger adults and were more disposed to false recognition of items compared to young adults. In a study by Norman and Schacter (1997), participants were asked to give explanations of their answers and these suggested that false memories were composed of associated or semantic information. Based on the Deese-Roediger-McDermott (DRM) paradigm, the False Memory task measures occurrences of when one wrongly identifies a semantically-related item which has not been encountered before as one that has (Roediger & McDermott, 1995). This may be due to participants encoding the gist rather than the specific information (Hudon et al., 2006). The False Memory task has a study and test phase; the study phase consists of a participant learning a list of words from a set of categories (e.g. relatives). For the test phase, words are presented and participants must indicate if the word was a "study" or "new" word. Participants tend to make errors when "new" words are semantically related to "study" words (e.g. brother – sister).

The current study employs three computer-based memory tasks to determine whether younger adults perform better than older adults on tasks of Source Memory, Episodic Memory and False Memory. It uses an Opposition task to measure source memory, a Visual Paired-Associates task to examine associative memory and a False Memory task, to investigate failures of episodic memory. In order to determine if any of these types of memory are related to each other or if they work independently of each other, correlations between behavioural performance measures on each task was carried out. It is hypothesised that the older adults will be more impaired on accuracy on the three computer-based memory tasks and that they will have slower response times than the younger adults. It is also hypothesised that by using a RAVLT the older adults will show a lower immediate recall than younger adults and will be more affected by interference. However, it is not expected that older adults will be more impaired than younger on estimates of IQ, working memory or self-reports of daily cognitive lapses. In addition, as deterioration in memory occurs across many different types of memory, see a relationship between these three memory tasks would be expected.

3.2 Method

3.2.1 Participants

This experiment consisted of 52 participants with two age groups, young and older adults. The young group had 27 participants with 14 females and 13 males (age = 18-30 years, mean = 23.41) and the older group had 25 participants with 13 females and 12 males (age = 55-70 years, mean = 59.99). Each participant had normal or corrected-to-normal vision and reported themselves free of any memory or mental problems. Participants gave informed written consent of their participation in the study (Appendix F). This study was carried out in accordance with the Ethical Standards of the American Psychological Association (APA), the Declaration of Helsinki (World Medical Association, Inc) and was approved by the NUIM Ethics Committee.

3.2.2 Apparatus

3.2.2.1 Control Measures.

The control measures used in this experiment are as set out in Chapter 2 and included the RAVLT (section 2.3.1), the NART (section 2.3.2), the CFQ (section 2.3.3) and the Digit Span (section 2.3.4).

3.2.2.2 Opposition Task.

A version of the Opposition task by Jennings and Jacoby (1997) was employed as set out in Chapter 2 (section 2.2.1).

3.2.2.3 Visual-Paired Associates Task, context version (VPAc).

The VPAc task measuring associative memory was carried out as described in Chapter 2 (section 2.2.2).

3.2.2.4 False Memory Task.

This computer-based task measures false recognition in participants and is similar to the description set out in Chapter 2 (section 2.2.3) with the following methodical changes. In the study phase participants learned a list of 45 trials of semantically related words which were presented in a random order at 2000ms per stimulus with a fixation cross ISI of 750ms. For the test phase the first 5 words of the study phase were removed to control for primacy effects. For the test phase words were presented in a random order and participants must indicate if the word was a study word (by pressing the "S" key) or a new word (by pressing the "N" key). Participants had an unlimited amount of time to make their response and the word did not change until they had made their response. The test phase consisted of four different types of stimuli. These were: Study Words (40) which were presented in the study list, Distractor words (40) which were not in the study list and were not related to any study words, False Test words (25) which were words that were not in the study list but were related to words in the study list (e.g. brother – sister), and False Category words (5) which were the category title of the semantically-related words presented in the study list (e.g. Relations).

3.2.3 Design

3.2.3.1 Control Measures.

Chapter 2 discusses the designs of the RAVLT (2.3.2.1), the NART (2.3.3.2), the Digit Span (2.3.4.2) and the CFQ the CFQ (2.3.5.2).

3.2.3.2 Opposition Task.

The design of the Opposition task is as set out in Chapter 2 (section 2.4.2.2).

3.2.3.3 VPAc.

Chapter 2 (section 2.4.3.2) describes the design of the VPAc task.

3.2.3.4 False Memory Task.

The False Memory task was divided into four separate categories of Distractor words, False Category words, False Test words and Study words.

3.2.4 Procedure

Before the participants commenced the experiment they were briefed and told that they would be taking part in some memory-based tasks which would take approximately one hour. The participants were asked to read and sign a consent form (Appendix F) before beginning the experiment. They were informed that they could take breaks if they needed them and that they could withdraw from the experiment at any stage. The participants then completed each of the three computer-based tasks, the pen-and-paper tasks and the questionnaire. The order of the tasks was counterbalanced. Following the experiment participants were fully debriefed and had any questions answered. All data from the experiment were anonymised, confidential and kept separate from the consent forms which contained no identifiable information.

3.2.5 Data Analysis

All outliers were removed from these data by calculating the IQR and subtracting it from the first quarter and adding it to the third quarter. All data points within these two limits were included in the data set, while data points outside of these were removed. These data for accuracy scores and response times when correct on the Opposition task (section 2.4.2.2 for scoring), the VPAc task (section 2.4.3.2 for scoring), the False

Memory task were analysed with mixed factorial ANOVAs. Scoring for the False memory task consisted of four types of words which were presented: Distractors (new and unrelated words to the study list), false category words (the category title of words in the study list), false test words (words related to the words in the study) and study words (words from the study). As there were a different number of words in each of these categories (distractors – 40 words, false category words – 5 words, false test words – 25 words and study words – 40 words), percentages were computed in order to report accuracy. Bonferroni-corrected dependent t-tests were further used to examine within group differences for accuracy on the tasks, while independent t-tests were used to examine between groups differences for accuracy and response times on the tasks. Mixed factorial ANOVAs were also used to analyse the recall scores on the RAVLT and independent and Bonferroni-corrected dependent t-tests analysed any between and within group differences. MANOVAs were used for the NART and Digit Span, to determine if both groups were matched on estimates of IQ and working memory, while a one-way between groups ANOVA was used on the CFQ to examine for differences between groups on absentmindedness. Bivariate Pearson correlations were conducted on the accuracy for the tasks to determine if there were any relationships between the different types of memory that these tasks purport to index.

3.3 Results

Each participant completed all aspects of the experiment. The results were analysed in terms of control tasks, accuracy and response times for correct responses.

3.3.1 Control Tasks

Mean and standard deviations for each of the control tasks can be seen in Table 3.1.

3.3.1.1 National Adult Reading Test

A one-way between groups MANOVA showed no statistically significant differences between the groups for any of the variables: Predicted Full Scale IQ [F (1, 50) = 1.714, $p > 0.05$; partial eta squared = 0.033]; Predicted Verbal IQ [F (1, 50) = 1.558, $p > 0.05$; partial eta squared = 0.03]; and Predicted Performance IQ [F (1, 50) = 1.944, $p > 0.05$; partial eta squared = 0.037]. Therefore, both groups displayed approximately similar estimates of IQ (see Figure 3.1a and Table 3.1 for means and SDs).

3.3.1.2 Digit Span

A one-way between groups MANOVA revealed no statistically significant differences between the groups on the separate dependent variables of Forward Digit Span [F (1, 50) = 0.103, $p > 0.05$; partial eta squared = 0.002], Backward Digit Span [F (1, 50) = 0.424, $p > 0.05$; partial eta squared = 0.008] and Total Digit Span [F (1, 50) = 0.360, $p > 0.05$; partial eta squared = 0.007]. These results indicate that the young and older adults performed with comparable recall scores for working memory (see Table 3.1 for means and SDs and Figure 3.1b).

3.3.1.3 CFQ

No statistically significant difference using a one-way ANOVA between the young [mean = 41.78, SD = 10.79] and older [mean = 38.67, SD = 14.02] groups was found for scores on the CFQ [F (1, 49) = 0.798, $p > 0.05$]. Both groups were approximately evenly matched on reports of everyday cognitive failures (see Figure 3.1c and Table 3.1 for means and SDs).

3.3.1.4 RAVLT

A 2×5 Mixed Factorial ANOVA showed a significant main effect of Trial [F (4, 192) = 137.93, $p < 0.01$], Group [F (1, 48) = 13.91, $p < 0.01$], and an interaction between Trial and Group [F (4, 192) = 5.66, $p < 0.01$] indicating that both groups' recall increased across Trials 1-5, but the older group had poorer recall accuracy from Trials 2-5 (Figure 3.1d). A series of independent t-tests were carried out to determine where the differences lay between the two groups across trials 1-5. Independent t-tests revealed no significant difference between the two groups for Trial A1, [t (50) = 1.188, $p > 0.05$]; however, they indicated significantly better accuracy for the young group on each of the other trials: A2 [t (50) = 3.176, $p < 0.01$]; A3 [t (49) = 4.474, $p < 0.01$]; A4 [t (49) = 3.728, $p < 0.01$]; A5 [t (50) = 3.971, $p < 0.01$] indicating that both groups began with similar recall scores but as the trials progressed, the younger group were better equipped to learning and recalling the words.

Significant effects were found for retroactive interference [F (1, 49) = 58.19, $p < 0.01$], group [F (1, 49) = 34.5, $p < 0.01$] and the interaction between retroactive interference and group [F (1, 49) = 12.32, $p < 0.01$]. Bonferroni corrected dependent t-tests showed that both groups' accuracy decreased from Trial 5 to Trial 6 [Young: t (25) = 3.302, $p < 0.01$; Older: t (24) = 7.076, $p < 0.01$] and independent t-tests revealed that the young group had higher accuracies on Trials A5 [t (50) = 3.971, $p < 0.01$] and A6 [t (49) = 5.876, $p < 0.01$], therefore the older group showed more interference, i.e. a greater decrease from Trials 5 to 6.

No significant main effect was found for proactive interference, i.e. between Trials A1 and B [F (1, 50) = 0.330, $p > 0.05$]; a group effect was found [F (1, 50) = 4.913, $p < 0.05$] and this difference was seen at Trial B, where the young had a higher recall [t (50) = 2.627, $p < 0.05$]; and no interaction was found between proactive interference and group [F (1, 50) = 1.305, $p > 0.05$].

A statistically significant effect was found for the delay trials [F (1, 49) = 8.405, $p < 0.01$] and group [F (1, 49) = 31.974, $p < 0.01$], while no significant effect was found for the interaction between delay trials and group [F (1, 49) = 0.244, $p > 0.05$]. Bonferroni corrected dependent t-tests showed that the younger group had a statistically significantly better performance on Trial 6 than Trial 7 [t (25) = 2.953, $p < 0.05$] while the older group did not show the same [t (24) = 1.455, $p > 0.05$]. Independent t-tests revealed that the young group had higher recall scores on Trials A6 [t (49) = 5.876, $p < 0.01$] and A7 [t (50) = 4.516, $p < 0.01$].

Table 3.1: Means and standard deviations for NART based IQ estimates, Digit Span, Cognitive Failures Questionnaire and the RAVLT.

	Young (N = 27)		Older (N = 25)	
	Mean	SD	Mean	SD
Predicted Full Scale IQ	106.56	5.01	109	8.19
Predicted Verbal IQ	105.22	4.39	107.36	7.64
Predicted Performance IQ	106.26	4.31	108.56	7.32
Digit Span Forward	11.37	2.31	11.16	2.43
Digit Span Backwards	8.22	2.41	7.76	2.7
Digit Span Total	19.67	4.27	18.92	4.7
CFQ	41.78	10.79	38.67	14.02
RAVLT A1	6.56	2.31	5.8	2.27
RAVLT A2	9.93	3.04	7.64	2.1
RAVLT A3	12.23	2.5	9.04	2.59
RAVLT A4	12.52	2.55	9.96	2.33
RAVLT A5	13.19	2.27	10.52	2.3
RAVLT B1	6.74	1.81	5.24	2.3
RAVLT A6	12.35	2.59	7.4	3.39
RAVLT A7	11.19	3.44	6.8	3.56

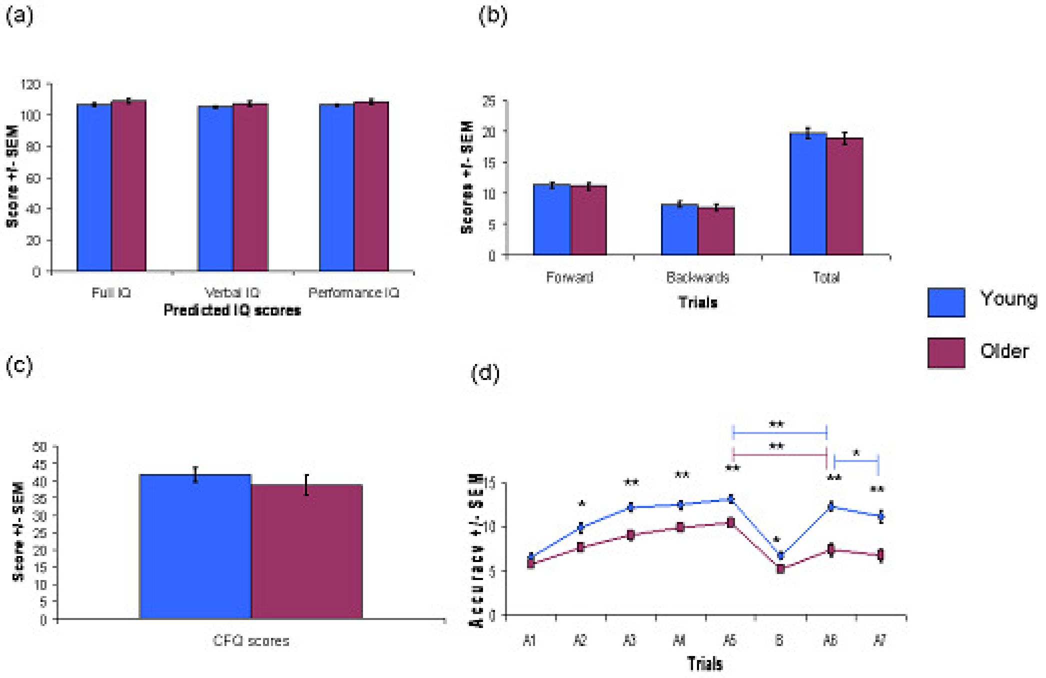


Figure 3.1: (a) Predicted Full Scale, Verbal Scale and Performance Scale IQs based on NART performance for young and older adults +/- SEM, (b) Forward, backward and total digit span scores for young and older adults +/- SEM, (c) CFQ scores for young and older adults +/- SEM, (d) RAVLT accuracy scores for Trials A1-A7 for young and older adults +/- SEM
($p < 0.05$, ** $p < 0.01$)*

3.3.2 Opposition Task

3.3.2.1 Accuracy

A 2×3×2 Mixed Factorial ANOVA was conducted to determine whether there was a difference between the two groups on accuracy at the lag lengths for the different word types. No main effect was found for Word Type. However, a significant main effect was found for Lag [F (2, 94) = 5.555, $p < 0.01$] where accuracy decreased across the lag lengths for Distractor words and increased for Target words. The main effect for Group was also significant [F (1, 47) = 4.971, $p < 0.05$] with the young group showing better accuracy. Significant interactions were observed between Word Type and Group [F (1, 47) = 7.02, $p < 0.05$], Word Type and Lag [F (2, 94) = 70.67, $p < 0.01$], and Word Type, Lag and Group [F (2, 94) = 4.101, $p < 0.01$]. No significant interaction was found between Lag and Group.

Subsequent independent t-tests were carried out to determine if the groups differed on the individual lag lengths. The groups differed significantly at lag 0 [young: mean = 9.68, SD = 0.56; older: mean = 9.04, SD = 1.16; t (47) = 2.439, $p < 0.05$], lag 4 [young: mean = 8.48, SD = 1.7; older: mean = 6.36, SD = 2.23; t (50) = 3.875, $p < 0.01$] and lag 16 [young: mean = 7.29, SD = 2.05; older: mean = 5.84, SD = 2.5; t (50) = 2.305, $p < 0.05$] for distractor words, with the young group showing greater accuracies in both cases (Figure 3.2). No other between group differences were significant [all $t < 1.874$, all $p > 0.05$].

Furthermore, Bonferroni-corrected dependent t-tests were carried out to determine where the differences lay for the word types and lags for each group. For the young group a significant difference was seen between Distractors at lag 0 [mean = 9.68, SD = 0.56] and lag 4 [mean = 8.48, SD = 1.7; t (24) = 3.464, $p < 0.01$], lag 0 [mean = 9.68, SD = 0.56] and lag 16 [mean = 7.30, SD = 2.05; t (24) = 3.6, $p < 0.01$], and lag 4 [mean = 8.48, SD = 1.7] and lag 16 [mean = 7.30, SD = 2.05; t (26) = 3.6, $p < 0.01$] with lag 0 having the highest accuracy followed by lag 4 (see Figure 3.2). In addition, the young group had a higher accuracy for targets at lag 16 [mean = 7.96, SD = 1.5] compared to lag 0 [mean = 6.96, SD = 1.81; t (26) = -2.762, $p < 0.05$]. For the older group, significant differences were found between distractors at lag 0 [mean = 9.04, SD = 1.16] and lag 4 [mean = 6.36, SD = 2.23; t (23) = 7.092, $p < 0.01$], and at lag 0 [mean = 9.04, SD = 1.16] and lag 16 [mean = 5.84, SD = 2.5; t (23) = 6.608, $p < 0.01$] with a higher accuracy at lag 0 for both comparisons. Significant differences were also seen for the older group for targets at lag 0 and lag 4 [lag 0: mean = 6.44, SD = 1.85; lag 4: mean = 7.8, SD = 1.8; t (23) = -3.369, $p < 0.01$], and at lag 0 [mean = 6.44, SD = 1.85] and lag 16 [mean = 8.64, SD = 1.08; t (23) = -5.336, $p < 0.01$] with lag 0 having a lower accuracy for both comparisons. All other comparisons within groups were not statistically significant [all $t < 2.068$, all $p > 0.05$].

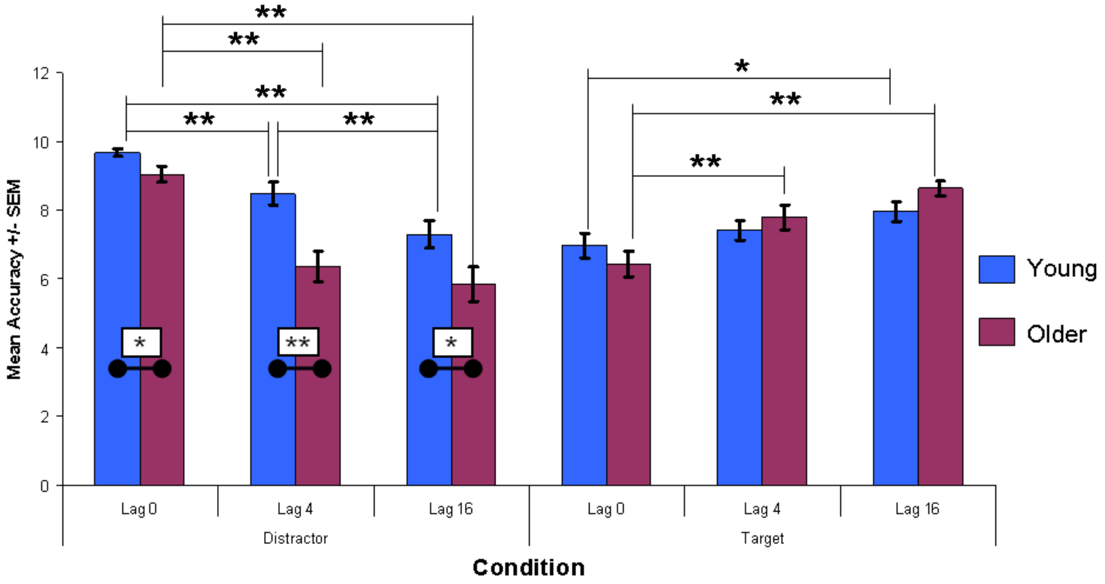


Figure 3.2: Mean total accuracy +/- SEM for Distractors and Targets words at Lags 0, 4 and 16 for young and older adults on the Opposition task
($p < 0.05$, ** $p < 0.01$)*

3.3.2.1 Response Times for Correct Responses

A 2×3×2 Mixed Factorial ANOVA found statistically significant main effects for Word Type [$F (1, 43) = 29.982$, $p < 0.01$], Lag [$F (2, 86) = 87.467$, $p < 0.01$] and Group [$F (1, 43) = 23.946$, $p < 0.01$] where response times increased across the lag lengths and were faster for the young group (see Figure 3.3). The interactions of Word Type and Group [$F (1, 43) = 1.588$, $p > 0.05$], Lag and Group [$F (2, 86) = .418$, $p > 0.05$], and Word Type, Lag and Group [$F (2, 86) = 2.277$, $p > 0.05$] were not statistically significant. However, a significant interaction was found between Word Type and Lag [$F (2, 86) = 2.277$, $p < 0.01$].

Independent t-tests showed that the young group responded significantly faster for correct responses on each of the Lags for Distractor words: Distractor Lag 0 [young: mean = 520.42, SD = 55.29; older: mean = 826.82, SD = 199.38; $t (49) = -7.415$, $p < 0.01$], Distractor Lag 4 [young: mean = 1038.07, SD = 286.10; older: mean = 1420.45, SD = 458.73; $t (50) = -3.574$, $p < 0.01$] and Distractor Lag 16 [young: mean = 1091.78, SD = 392.89; older: mean = 1433.17, SD = 439.37; $t (47) = -2.869$, $p < 0.01$]. The older adults had significantly slower response times compared to the young group for the Target words at each lag: Targets Lag 0 [young = 537.40, SD = 95.75; older: mean = 897.51, SD = 275.02; $t (49) = -6.196$, $p < 0.01$], Targets Lag 4 [young: mean = 837.14, SD = 206.08; older: mean = 1066.11, SD = 275.02; $t (48) = -3.636$, $p < 0.01$] and Targets Lag 16 [young: mean = 840.97, SD = 250.36; older: mean = 1058.41, SD = 293.16; $t (50) = -2.883$, $p < 0.01$].

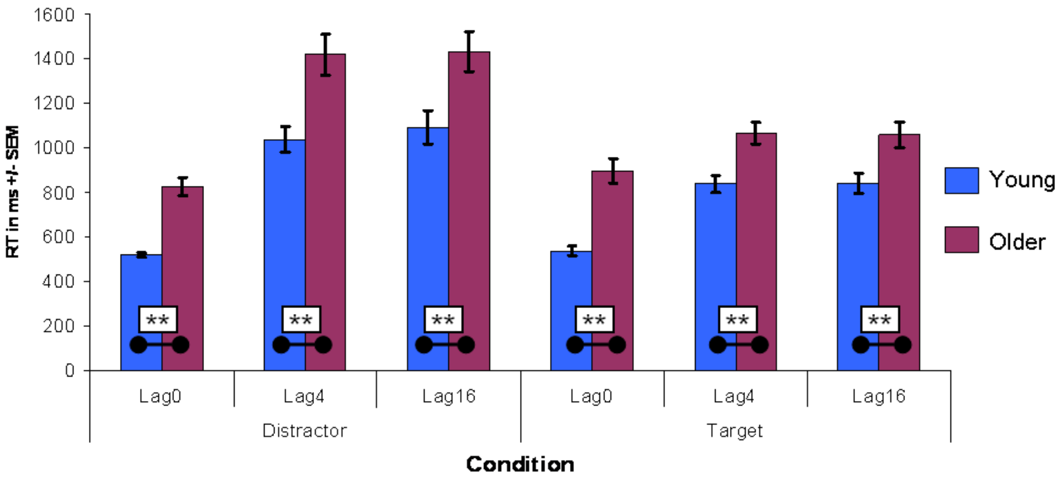


Figure 3.3: Mean response times in ms +/- SEM for both Distractors and Targets words at lags 0, 4 and 16 on the Opposition Task for young and older adults for correct responses
($p < 0.05$, ** $p < 0.01$)*

3.3.2 VPAc Task

3.3.2.1 Accuracy

For accuracy, a 2×2×2 Mixed Factorial ANOVA was conducted investigating whether there were differences between Congruence (congruent and incongruent), Pair Type (true or false pairs) and Group (young and older). The main effects of Congruence [F (1, 46) = 4.278, p < 0.05] and Group [F (1, 46) = 66.614, p < 0.01] were statistically significant with the young group showing higher accuracies than the older and accuracy on false pairs being higher for incongruent pairs, i.e. where the background did not match what was displayed in the study phase. No significant main effect was found for Pair Type [F (1, 46) = .043, p > 0.05]. The interaction of Pair Type and Group [F (1, 46) = 13.887, p < 0.01] and Congruence and Pair Type [F (1, 46) = 13.339, p < 0.01] were statistically significant while the interactions of Congruence and Group [F (1, 46) = 1.119, p > 0.05] and Congruence, Pair Type and Group [F (1, 46) = 0.437, p > 0.05] were non-significant.

Subsequent independent t-tests found significant differences between the two groups for TC [young: mean = 26.67, SD = 3.9; older: mean = 22.74, SD = 3.28; t (48) = 3.807, p < 0.01]; TI [young: mean = 26, SD = 4.3; older: mean = 22.13, SD = 4.424; t (48) = 3.128, p < 0.01]; FC [young: mean = 28.58, SD = 3.19; older = 18.12, SD = 6.64; t (49) = 7.128, p < 0.01]; and FI pairs [young = 30.16, SD = 2.46; older: mean = 20.48, SD = 5.36; t (48) = 8.212, p < 0.01] with the young group having higher memory performance than the older for each pair type (Figure 3.4).

Bonferroni-corrected t-tests were carried out to determine if there were any within group differences. For both groups significant differences were found between FC and FI pairs; young [FC: mean = 28.58, SD = 3.19; FI: mean = 30.16, SD = 2.461; t (24) = -2.915, p < 0.05]; older [FC: mean = 18.12, SD = 6.64; FI: mean = 20.48, SD = 5.36; t (24) = -3.573, p < 0.01] with a higher accuracy seen for FI pairs in both comparisons.

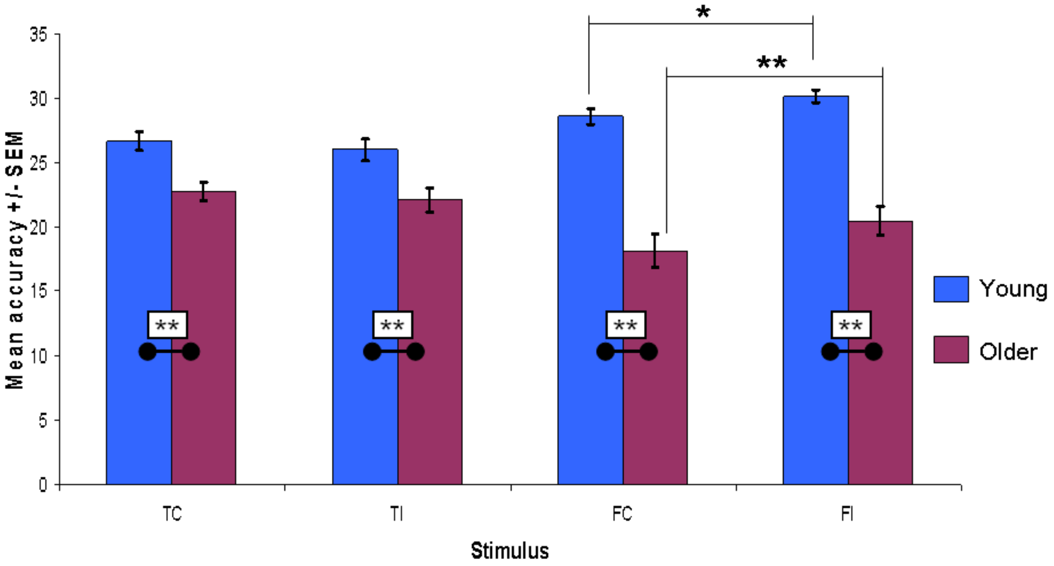


Figure 3.4: Mean total accuracy +/- SEM on the VPAc Task on True Congruent (TC), True Incongruent (TI), False Congruent (FC) and False Incongruent (FI) pairs for young and older adults
(p < 0.05, ** p < 0.01)*

3.3.2.2 Response Times for Correct Responses

A 2×2×2 Mixed Factorial ANOVA that was carried out on response times found no main effect for Congruence, i.e. how the backgrounds related to the study phase [F (1, 46) = 0.05, $p > 0.05$] or Pair Type [F (1, 46) = 2.480, $p > 0.05$]. A Group effect was found for response time when correct [F (1, 46) = 84.834, $p < 0.01$] with the young group responding faster than the older. No significant interactions were found between Congruence and Group [F (1, 46) = 1.370, $p > 0.05$], Congruence and Pair Type [F (1, 46) = 3.486, $p > 0.05$], or Congruence, Pair Type and Group [F (1, 46) = 0.005, $p > 0.05$]. However, the interaction of Pair type and Group [F (1, 46) = 10.399, $p < 0.01$] was statistically significant.

Subsequent independent t-tests were carried out to determine where the groups' response times differed for each stimulus. Response time differences were found between each pair type with the young showing faster response times than the older for each stimulus (see figure 3.5a); TC [young: mean = 1346.92, SD = 223.23; older: mean = 1766.45, SD = 275.78; t (50) = -6.050, $p < 0.01$], TI [young: mean = 1387.14, SD = 264.33; older: mean = 1766.94, SD = 303.60; t (50) = -4.821, $p < 0.01$], FC [young: mean = 1304.61, SD = 174.58; older: mean = 1917.59, SD = 232.58; t (47) = -10.508, $p < 0.01$] and FI [young: mean = 1302.404, SD = 232.45; older: mean = 1896.86, SD = 266.60; t (48) = -8.421, $p < 0.01$].

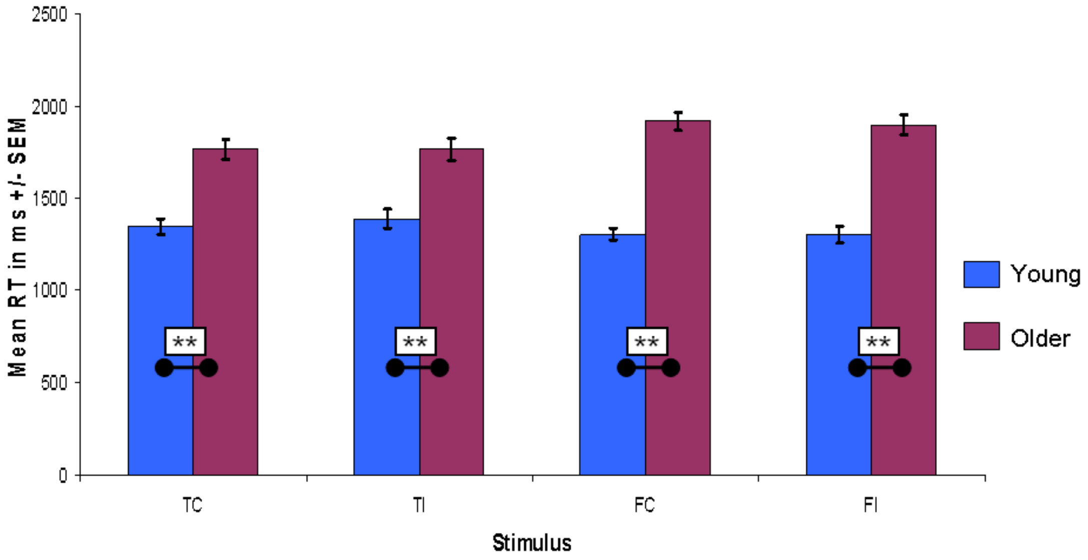


Figure 3.5: Mean response times in ms +/- SEM for True Congruent (TC), True Incongruent (TI), False Congruent (FC) and False Incongruent (FI) pairs on the VPAc task for correct responses
(P <0.05, ** p < 0.01)*

3.3.3 False Memory Task

3.2.3.1 Accuracy

A 4×2 Mixed Factorial ANOVA revealed significant main effects for Word Type [F (3, 147) = 5.988, p < 0.01], and Group [F (1, 49) = 6.942, p < 0.05] but no significant interaction was found between Word Type and Group [F (3, 147) = 0.373, p > 0.05]. Accuracy was higher on a selection of word types (see Figure 3.6 below) and was higher for the young adults on a selection of types of words (see Figure 3.6 below).

Independent t-tests were performed to examine differences between the groups. Significant differences were found for study words [young: mean = 87.04, SD = 7.846; older: mean = 77.1, SD = 15.89; t (50) = 2.825, p < 0.01] where the older group had a lower accuracy than the young group (see Figure 3.6). The other word types did not have a significant difference between the groups [all t < 2.004, all p > 0.05].

Bonferroni-corrected dependent t-tests were used to examine differences within word types for both groups separately. The young group showed significantly higher accuracies for distractor words compared to false test words [mean = 84.3, SD = 8.66; t (25) = 5.371, p < 0.01] and compared to study words [mean = 87.04, SD = 7.846; t (25) = 3.528, p < 0.01]. The older group showed a significant difference between distractor words [mean = 88.5, SD = 18.65] and false test words [mean = 76.32, SD = 18.07; t (24) = 4.278, p < 0.01] with false test words having a lower accuracy. No other within group comparisons were significant [all t < 2.016, all p > 0.05].

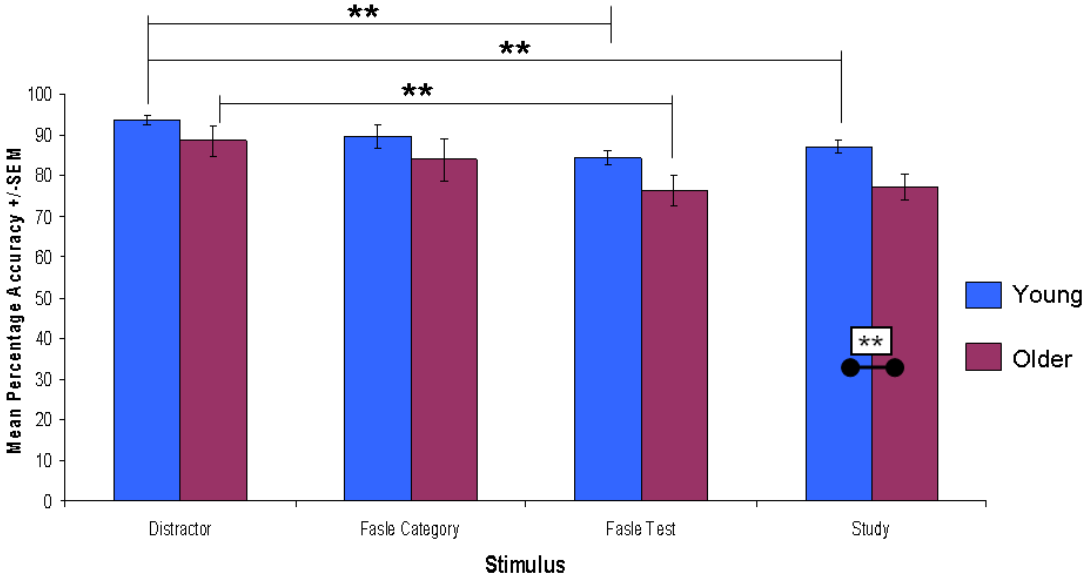


Figure 3.6: Mean percentage accuracy +/- SEM for Distractor, False Category, False Test and Study words on the False Memory task
(p < 0.05, ** p < 0.01)*

3.2.3.2 Response Times for Correct Responses

A 4×2 Mixed Factorial ANOVA revealed a significant main effect for Word Type [F (3, 138) = 4.342, p < 0.01]. However, no significant effect was found for Group [F (1, 46) = 3.966, p > 0.05], or the interaction between Word Type and Group [F (3,138) = 2.323, p > 0.05].

Subsequent independent t-tests found a significant difference for Distractor words where the young group had faster response times [mean = 1022.76, SD = 244.18] than the older group [mean = 1325.74, SD = 422.64; t (47) = -3.117, $p < 0.01$]. Statistical significance was not found for any other between group comparisons [all t < 1.685, all $p > 0.05$].

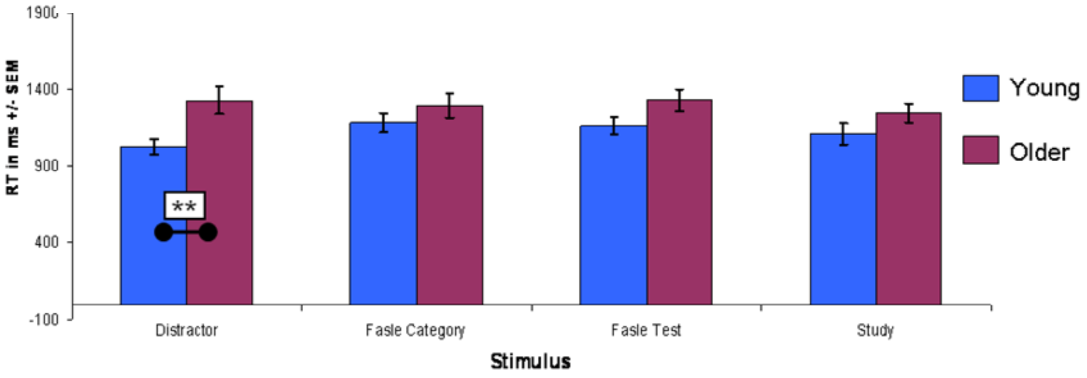


Figure 3.7: Response times in ms +/- SEM for Distractor, False Category, False Test and Study words on the False Memory task for correct responses
($p < 0.05$, ** $p < 0.01$)*

3.2.4 Correlations

A Pearson's correlation was conducted to determine if accuracy for the Opposition task (abbreviated as Opp, D = Distractor words, T = Target words), VPAc task and False Memory task (abbreviated as FM) displayed any relationships. All of the correlations can be seen in Table 3.2 below and significant correlations at $p < 0.05$ are highlighted blue, while significant correlations at the $p < 0.01$ are highlighted yellow. Each correlation that was found was positive which indicates that as scores on one variable increased the scores on the other variable increased also.

For young False Test words had a positive correlation with Distractor Lag 4 words on the Opposition task [r = .472, n = 27, $p < 0.05$] indicating that as accuracies increased on Distractor Lag 4 words they also increased on False Test words. Study words of the False Memory task had a positive correlation with Target Lag 0 words on the Opposition task [$r = .485$, $n = 27$, $p < 0.05$]. The Study words of the False Memory task were also significantly correlated with the TC pairs of the VPAc task [$r = .452$, $n = 27$, $p < 0.01$]. Between the Opposition and VPAc tasks two significant positive correlations were found between Distractor Lag 4 words and FC pairs [$r = .446$, $n = 26$, $p < 0.05$] and separately between Distractor Lag 16 and FC pairs [$r = .412$, $n = 26$, $p < 0.05$].

For older Distractor words at Lag 4 on the Opposition task had significant positive correlations with Distractor words [$r = .485$, $n = 25$, $p < 0.05$]; False Category words [$r = .417$, $n = 25$, $p < 0.05$]; and False Test words on the False Memory task [$r = .455$, $n = 25$, $p < 0.05$]. FC pairs on the VPAc task also had a positive correlation with Target Lag 4 words on the Opposition task [$r = .450$, $n = 25$, $p < 0.01$]; while FI pairs on the VPAc tasks were positively correlated with Target Lag 4 words [$r = .534$, $n = 25$, $p < 0.01$] and Target Lag 16 words on the Opposition task [$r = .509$, $n = 25$, $p < 0.01$].

Table 3.2: Correlations between the Opposition, VPAc and False Memory tasks.

Young		FM Dist	FM Category	FM Test	FM Study	VPAc TC	VPAc TI	VPAc FC	VPAc FI
Opp D0	Pearson Correlation	0.11	-0.18	-0.11	0.08	0.32	0.09	-0.13	-0.20
	Sig. (2-tailed)	0.63	0.39	0.62	0.71	0.13	0.69	0.56	0.38
	N	23.00	24.00	24.00	24.00	24.00	24.00	23.00	22.00
Opp D4	Pearson Correlation	0.07	0.02	.472*	0.11	0.30	0.20	.446*	0.29
	Sig. (2-tailed)	0.74	0.93	0.01	0.58	0.14	0.32	0.02	0.17
	N	26.00	27.00	27.00	27.00	27.00	27.00	26.00	25.00
Opp D16	Pearson Correlation	0.19	0.12	0.34	0.00	0.28	0.33	.412*	0.21
	Sig. (2-tailed)	0.36	0.54	0.09	0.99	0.16	0.10	0.04	0.32
	N	26.00	27.00	27.00	27.00	27.00	27.00	26.00	25.00
Opp T0	Pearson Correlation	-0.19	-0.15	-0.15	.485*	0.19	0.24	-0.03	0.05
	Sig. (2-tailed)	0.36	0.47	0.47	0.01	0.35	0.22	0.90	0.81
	N	26.00	27.00	27.00	27.00	27.00	27.00	26.00	25.00
Opp T4	Pearson Correlation	-0.22	0.10	0.01	0.14	0.16	0.01	0.19	0.22
	Sig. (2-tailed)	0.29	0.63	0.96	0.50	0.42	0.98	0.35	0.29
	N	26.00	27.00	27.00	27.00	27.00	27.00	26.00	25.00
Opp T16	Pearson Correlation	0.08	-0.07	-0.16	0.02	0.29	0.11	0.21	0.28
	Sig. (2-tailed)	0.68	0.74	0.43	0.92	0.14	0.59	0.31	0.18
	N	26.00	27.00	27.00	27.00	27.00	27.00	26.00	25.00
FM Dist	Pearson Correlation					0.08	-0.03	0.21	0.02
	Sig. (2-tailed)					0.69	0.87	0.32	0.94
	N					26.00	26.00	25.00	24.00
FM Category	Pearson Correlation					-0.07	0.01	0.00	0.12
	Sig. (2-tailed)					0.71	0.95	1.00	0.58
	N					27.00	27.00	26.00	25.00
FM Test	Pearson Correlation					0.15	-0.05	0.22	0.35
	Sig. (2-tailed)					0.46	0.82	0.28	0.09
	N					27.00	27.00	26.00	25.00
FM Study	Pearson Correlation					.452*	0.26	0.05	-0.05
	Sig. (2-tailed)					0.02	0.19	0.82	0.83
	N					27.00	27.00	26.00	25.00
Older		FM Dist	FM Category	FM Test	FM Study	VPAc TC	VPAc TI	VPAc FC	VPAc FI
Opp D0	Pearson Correlation	0.35	0.29	0.29	-0.34	0.21	0.14	-0.02	-0.05
	Sig. (2-tailed)	0.08	0.16	0.16	0.10	0.33	0.52	0.91	0.81
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
Opp D4	Pearson Correlation	.485*	.417*	.455*	-0.06	-0.02	-0.13	-0.05	-0.03
	Sig. (2-tailed)	0.01	0.04	0.02	0.77	0.94	0.55	0.81	0.89
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
Opp D16	Pearson Correlation	0.37	0.37	0.22	-0.06	0.06	0.04	-0.11	-0.06
	Sig. (2-tailed)	0.07	0.07	0.30	0.77	0.79	0.85	0.61	0.79
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
Opp T0	Pearson Correlation	0.09	0.12	0.06	-0.21	-0.11	-0.08	0.09	0.17
	Sig. (2-tailed)	0.68	0.57	0.79	0.33	0.63	0.71	0.68	0.40
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
Opp T4	Pearson Correlation	0.02	0.24	0.22	-0.11	0.01	-0.11	.450*	.534**
	Sig. (2-tailed)	0.94	0.24	0.29	0.60	0.96	0.63	0.02	0.01
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
Opp T16	Pearson Correlation	-0.01	-0.05	-0.01	-0.05	-0.01	0.13	0.36	.509**
	Sig. (2-tailed)	0.98	0.83	0.97	0.83	0.98	0.55	0.08	0.01
	N	25.00	25.00	25.00	25.00	23.00	23.00	25.00	25.00
FM Dist	Pearson Correlation					0.11	-0.09	0.15	0.13
	Sig. (2-tailed)					0.63	0.70	0.48	0.55
	N					23.00	23.00	25.00	25.00
FM Category	Pearson Correlation					-0.09	-0.31	0.07	0.11
	Sig. (2-tailed)					0.70	0.15	0.76	0.59
	N					23.00	23.00	25.00	25.00
FM Test	Pearson Correlation					0.17	-0.08	0.13	0.13
	Sig. (2-tailed)					0.45	0.71	0.53	0.55
	N					23.00	23.00	25.00	25.00
FM Study	Pearson Correlation					-0.37	-0.29	0.01	0.08
	Sig. (2-tailed)					0.08	0.18	0.95	0.69
	N					23.00	23.00	25.00	25.00

* $p < 0.05$ (highlighted blue), ** $p < 0.01$ (highlighted yellow)

3.4 Discussion

The young and older groups showed similar estimated IQ scores, digit span and absentmindedness/cognitive failures. As the scores on these conditions were similar between the groups, this indicates that IQ, working memory and absentmindedness should not have any effect on behavioural memory performance despite these older adults being high functioning. However, behavioural task performance indicated that the young group performed with superior accuracy on all RAVLT trials except the first, and showed reduced retroactive interference effects. However, the older group showed a general decrement in memory that was not seen in the younger group on the computer-based memory tasks. For Distractor words in the Opposition task both groups' accuracy declined as the lag lengths increased with the older group having a lower accuracy than the young group. In addition, the young group responded faster for each condition with regard to giving a correct response. The VPAc showed that the older group showed a general overall lower accuracy than the younger group for each stimulus type and they took longer than the young group when giving a correct response. In the False Memory test the young group showed higher accuracies for study words in particular. However, they were only faster at responding correctly on Distractor words. The correlations between the different variables of the tasks show that, generally associative memory (i.e. the VPAc task) and source memory (i.e. the Opposition task) are related, and that some aspects of source and episodic memory may be also related; further associative and episodic memory also appear to have a positive relationship. However, the young and older adults show these relationships in different variables within the tasks different aspects of memory are being used between the young and older adults.

The Opposition Task revealed that both groups' accuracy decreased across the lag lengths for Distractor words; however, the older adults displayed more difficulty with increasing lag length, which manifested in higher accuracy for the shorter lag lengths and the poorest performance for the longest lag length, i.e. lag 16. This condition consists of the longest time difference between repetitions of the word and as a result requires a more intact source memory capacity than the shorter lag lengths. As older adults showed the largest discrepancy for distractor lag 16 words compared to young adults, this suggests that older adults may have a reduced source memory capacity. This may have led to older adults having more difficulty in placing items into the correct context of place and time (Jennings & Jacoby, 1997). The Target words showed a different pattern to the Distractor words where accuracy increased across the lag lengths, with longer lag lengths leading to higher accuracy rates in both age groups and subsequently showing no difference on accuracy between the groups. An explanation for this may be due to increased familiarity. If participants initially responded incorrectly on a Target word (i.e. indicate that an old word is new), any subsequent presentations of these words may have elicited increased familiarity to the Target words, thus rectifying the initial incorrect response to a correct one and, as seen in the Distractor words, the longer the time delay between presentations the more pronounced this effect may have been. Additionally, this effect may have been more pronounced due to a poorer source memory capacity in older adults which afforded them similar accuracy scores to the young group rather than poorer.

Research has indicated that source memory may be selectively disrupted by ageing (Dywan & Jacoby, 1990; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991; Schacter et al., 1994) and previous studies (Jennings & Jacoby, 1993, 1997) have found that older adults display more difficulty than younger adults on an Opposition task.

Jennings and Jaboby's (1997) task differed to the current one as there was one presentation of target words, i.e. old words, compared to two presentations in the current study and it can therefore not determine if the same pattern is seen for target words between the two studies. However, in Jennings and Jacoby's study (1997) older adults showed lower accuracies than the young at correctly identifying the repetition of distractor (i.e. new words) and showed a poorer performance on longer lag lengths than the younger group, corresponding with the results in the current study. Distractor words rely more on recollection to obtain a correct result as one must consciously recollect that a word remains new despite having been previously seen on an earlier presentation. However, on the contrary Target words rely more on familiarity processes as one can obtain a correct response by recognising the word as previously seen at any stage. As older adults were more impaired than young on Distractor than Target words, the results offer additional support to previous studies indicating that recollection processes in memory are more impaired in older adults while memory-based familiarity remains relatively intact (N. D. Anderson et al., 2008; Hay & Jacoby, 1999; Jacoby, 1999b; Jennings & Jacoby, 1997; Tse, Balota, Moynan, Duchek, & Jacoby, 2010). In the current study, the young group also responded faster than the older group when responding correctly. This indicates that not only are young adults better at identifying the context of place and time in which they acquired an item but they also have a faster speed of processing when doing so, supporting the Speed Theory (Salthouse, 1996).

The VPAc showed that both groups were equally affected by manipulating congruence or the changing context; however the young participants were more accurate at correctly identifying the association between the pairs, i.e. if the pair was true or false, and this resulted in the young adults displaying higher accuracy for each of the four pair types. These findings have been supported by other research. Hogan and colleagues (Hogan et al., 2012, 2011) found a similar pattern with a young group outperforming older groups on accuracy with this version of the VPAc also. In addition, the authors found a further decrease with ageing when compared with older declined participants, indicating that this task may be sensitive to the decline in memory seen with ageing. Previous researchers have found that older adults show a disproportionate loss of contextual information compared to younger, which may indicate a specific age-related associative deficit (Craik et al., 2010; Kessels, Hobbel, & Postma, 2007). However, the results from the current study indicate that older adults have poorer performance than younger in correctly identifying true and false pairs (i.e. association rather than context) and thus do not correspond entirely with the results of Craik et al. (2010) and Kessels et al. (2007). Both studies reported a contextual deficit in memory; however they differed from the current one as these studies manipulated of item, context and the combination of item-context which may have led to the differences between the studies. However, both studies also found a large impairment in older adults in associated items (Craik et al., 2010; Kessels et al., 2007) which was also evident in the current study. As there were no differences between the two groups due to the manipulation of the congruity of the context, this dysfunction in older adults may lie in insufficient encoding of associated items rather than context alone, corresponding with the results of Gutchess and Park (2009) who found that older adults had poorer performances than young on associative memory. This may be due to inefficient processing resources, i.e. binding of the associations between elements (Craik et al., 2010; Gutchess & Park, 2009; Spencer & Raz, 1994). The older group were slower at correctly identifying the item, indicating that age may cause one to become less likely to be able to quickly process the correct contextual and associative information. These results support the Speed theory as age-related impairment in processing speed has been previously seen in paired-associate tasks (Salthouse, 1993, 1994).

In the False Memory task significant differences were seen for the study words where the young group showed higher accuracy than older indicating that for this task these older adults had poorer performance on familiar words compared to young adults. This finding does not support that of the Opposition task which found no difference for familiarity between the groups. However, the False Memory task is a simpler task which may have afforded the young adults higher accuracy scores rather than resulting in a discrepancy in older adults' memory-based familiarity. Other studies (Dennis, Kim, & Cabeza, 2007, 2008; Hudon et al., 2006; Norman & Schacter, 1997; Schacter et al., 1997; Watson, Dermott, & Balota, 2004) have found that older adults were more likely than younger to fall victim to falsely recognising items and both studies found an age-related decline in correct identification of words which was not seen in the current study. It has been found that, even upon warning of the procedure and difficulty of the DRM paradigm, older adults still fall victim to false recognition (Watson et al., 2004). In the study by Norman and Schacter (1997) significant between group differences were found with respect to false category words (their task differed from the current one in that there were no false test words). Similar differences on False Category words may have not been seen in the current study due to a reduced number of categories leading to fewer possible errors. However, a study by Dennis et al. (2007) was more similar to the current study as it included semantically-related lures. However, the study by Dennis et al. (2007) included a higher number of lures compared to the current study which may have contributed to a greater inability in older adults to correctly identify words. The False Memory task showed fewer differences between the groups on response times compared to the other memory tasks discussed above which may be explained by this version of the task being less complex.

Due to older adults having memory complaints (Levy-Cushman & Abeles, 1998), it is generally accepted that memory performance declines as people age. An additional purpose of this research was to determine if there was any relationship between these different types of memory. The memory tasks used in the current study relied on source memory, associative memory and episodic memory. The correlations indicated that accuracy for the different trial types between the tasks shared a relationship for the young and older adults. For the young adults a positive correlation was evident between distractor words of the Opposition task and recombined items of the VPAc task which be explained by the fact that both conditions are new items within the test phases and would not have been familiar. The correlations between the Opposition and False Memory tasks revealed that new stimuli and stimuli which were presented at the study were both positively correlated across tasks. This may have resulted as the items are similar within the tasks, i.e. study items will be familiar while new will not. The correlational results between the VPAc and the False Memory task indicated a similar pattern where True pairs from the VPAc (i.e. from the study) were positively correlated with Study words from the False Memory task, which again may be due to similar items within the tasks being processed as familiar. For older adults the distractor words of the Opposition task (i.e. new words) were positively correlated with each type of new word of the False Memory task, which may again be explained by the words not being familiar and so being treated in a similar manner within the tasks. Finally, for the older adults the Target words of the Opposition task were positively correlated with the recombined items of the VPAc task, which may have a relationship in older adults as both items are being used as lures within the test phase. The correlational results between the tasks may suggest that the three types of memory may be related, in particular source and associative memory, which may suggest that both types of memory rely on similar processing resources, such as binding. However, as a large set of linear correlations was carried out, these correlations may have been observed by chance, as with each test conducted there is a five percent chance of error; therefore with a larger number of tests conducted, there is a greater possibility that the test is showing a false positive or Type I error (Haslam & McGarty, 2003). If one is to accept these results were not obtained by chance it may be concluded that the relationship between these types of memory may change due to the ageing process, as different conditions between young and older adults were positively correlated.

The current results indicate a behavioural decline in a variety of types of memory namely (source and associative memory), while few differences were evident in episodic memory. With Jacoby's Capture Model, memory impairments in ageing are caused by an increase in interference which leads to items in memory being distorted or accepted as recollected due to a reduction in the accessibility threshold (Dockree et al., 2006; Jacoby, Bishara, et al., 2005; Jacoby, 1999a). When reviewing the results in light of this model, it may be suggested that contextual and associative details may have interfered with older adults' ability to identify the correct items, and thus, resulted in increased errors in tasks of source and associative memory. In light of Craik's Resources theory of ageing (Craik et al., 1983; Craik & Byrd, 1982; Craik, 1986) there may have been a reduction in the processing resources due to the ageing process resulting in impairments in source and associative memory. The results generally support Salthouse's (1996) Speed theory which states that speed of processing declines due to ageing, as slower response times were evident in the older adults. A reduction in speed of processing may have had a negative effect on accuracy as older adults may have needed more time during the encoding phase in order to produce comparable accuracies to the young group. However, the most influential theories on memory generally posit the process of binding items and context. Naveh-Benjamin's Associative Deficit Hypothesis posits that ageing results in a breakdown in binding the units of information within an episode of memory (Naveh-Benjamin et al., 2004, 2003; Naveh-Benjamin, 2000). The Misrecollection Hypothesis suggests that older adults bind information incorrectly (Dodson, Bawa, & Krueger, 2007; Dodson, Bawa, & Slotnick, 2007; Dodson & Krueger, 2006). As such the current results can offer support for the importance of the process of binding within memory as deficits were apparent in the memory tasks which rely on the binding process, i.e. the Opposition and VPAc task.

The results generally show that these older adults display more difficulties with correctly and quickly identifying items compared to younger adults despite appearing to be high functioning. This was seen in particular with respect to tasks measuring source and associative memory. The current study provides further evidence that memory does display a downward trajectory with ageing (Cabeza et al., 2002; Craik, 2008; Friedman, 2000). Furthermore, the binding process in memory may be the among the first to decline with ageing as older adults were more impaired on tasks of source and associative memory, which rely on binding, while this was not evident for the episodic memory task, which relied on accessing the gist of the information. This may indicate that age-related impairments are more pronounced in source/associative memory as both types rely on the binding process in memory and as such these types of memory may decline faster than other types. If the correlations are not by chance this also suggest that the three types of memory may share a relationship, particularly source and associative memory, and thus the reasons for these various decrements may lie in the dysfunction associated with the different regions of the brain driving the processes involved in these tasks, such as binding and recollection versus familiarity.

The next chapter will utilise Event-Related Potentials (ERPs) to determine whether there is a difference between older and younger adults' scalp-recorded electrical activity while completing the Opposition task, the context version of the Visual Paired-Associates task and False Memory task which may help to shed light on why behavioural differences are seen in memory as the population ages.

4

Chapter IV

ERP waveform differences may reflect age-related decline in memory performance.

4.1 Introduction

As discussed in Chapter 3, ageing affects all aspects of one's life and it can have a detrimental effect on one's cognitive abilities, including memory performance (Cabeza et al., 2004; Cabeza, Anderson, Locantore, & Mcintosh, 2002; Carlesimo et al., 1998; Harris et al., 2007; Mattay, Goldberg, Sambataro, & Weinberger, 2008). Since the ageing process appears to cause such a decrement in behavioural performance in memory, this leads to the prediction that a corresponding change should also be seen in electrical brain activity due to ageing.

The HAROLD model (as discussed in Chapter 1) offers an explanation for how ageing affects brain activity (Cabeza, 2002) wherein activity in the frontal lobes becomes bilateral (Bäckman et al., 1997; Cabeza et al., 1997; Grady et al., 1994; Reuter-Lorenz et al., 2000). Initially this was believed to be a compensatory function; however, more recent research has indicated that this may not be the case (Duverne, Motamedinia, & Rugg, 2009; Manenti et al., 2011). The CRUNCH model (see Chapter 1) suggests that older adults recruit additional neural resources to produce similar task performance to young adults, which results in overactivations in older adults (Reuter-Lorenz & Cappell, 2008). As the results from the previous chapter indicated that an age-related decline can be seen in source, episodic and false memory, it may follow that these behavioural patterns may be mirrored by electrophysiological differences.

As stated in Chapter 3, source memory is a person's memory for when, where and under what circumstances something happened (Glisky & Kong, 2008; Jacoby, Shimizu, Daniels, & Rhodes, 2005; Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994; Schmitter-edgecombe, Woo, & Greeley, 2009) and source memory has been found to decline due to ageing (see Chapter 3). The Opposition task measures source memory by manipulating the identification of time estimation for when an item was acquired and it was shown in the previous chapter that older adults are more impaired behaviourally on the Opposition task and, by extension, source memory, than younger adults, thereby replicating previous studies (Chua, Chen, & Park, 2006; Dywan & Jacoby, 1990; Jennings & Jacoby, 1993; Jennings & Jacoby, 1997; Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994). Differences in brain activity in source memory tasks have been identified by numerous researchers whereby age-related reductions can be seen not only in diminished activation within the brain but also by different areas of the brain being recruited during source memory recall (Dennis, Hayes, et al., 2008; Swick et al., 2006; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Wegesin, Friedman, Varughese, & Stern, 2002).

Episodic memory is our memory for personally-experienced events at a specific time and place and our ability to relive these events (Tulving, 1985). Researchers (Craik et al., 2010; Kessels et al., 2007) have shown that performance in episodic memory declines as one ages. As discussed previously, the context version of the Visual Paired-Associates task (VPAc) measures recognition memory in the presence of context changes, thereby tapping into episodic, associative and contextual memory, and previous results both here and by other researchers (Hogan et al., 2011, 2012) have shown that performance on this task decreases with ageing. A number of previous studies (Klimesch, Schimke, & Schwaiger, 1994; Mark & Rugg, 1998) have shown that the electrical brain activity associated with episodic memory, changes due to the ageing process. This age-related change causes differences in recruitment for episodic memory. It has also been seen that electrical activity levels decline due to the ageing process. More specifically, this age-related change can be seen in a Visual Paired-Associates task (Hogan et al., 2011, 2012) where older adults showed reduced ERP waveforms compared to the young.

As previously indicated, false memory is recalling events incorrectly or recalling events which never happened, and this may occur due to the gist of the information being recalled (Hudon et al., 2006; Roediger & McDermott, 1995). Using semantic lures, the Deese-Roediger-McDermott (DRM) paradigm measures false memory, a capacity on which older adults' performance is particularly impaired (Dennis, Kim, & Cabeza, 2008; Norman & Schacter, 1997; Schacter, Koustaal, & Norman, 1997; Watson, Dermott, & Balota, 2004). However, as the results from the False Memory task in the previous study here did not render as many similar results to previous studies employing a DRM design, the task was adapted to enhance its susceptibility to false memory errors and thus follows the description set out in the Methods chapter. It has been shown by comparison studies of young and older adults that through the ageing process neural activity within the brain changes (Cabeza, Rao, Wagner, Mayer, & Schacter, 2001; Dennis, Daselaar, & Cabeza, 2007; Dennis, Kim, et al., 2008; Morcom, Good, Frackowiak, & Rugg, 2003). It can be seen that there is less activation in the brains of older adults and that falsely recognising items causes different recruitment for older adults compared to younger adults.

The current study employs the use of control tasks reporting estimates of IQ (NART), lapses in everyday memory (CFQ) and short-term memory as well as interference (RAVLT). However, the aim of this study is to examine the effects of the ageing process on different types of memory with electrophysiology and behavioural computer-based tasks to determine if there are any differences in electrical brain activity, specifically Event-Related Potentials (ERPs) of the electroencephalogram. These tasks include the Opposition task (measuring source memory), the VPAc task (measuring episodic/associative memory with reference to context) and a variant of the DRM paradigm (measuring false memory). It is hypothesised that the groups shall have similar estimates of IQ and lapses in everyday memory but that the young group will perform better on short-term memory. It is also hypothesised that the older group will show poorer memory performance and slower reaction times than the younger group, along with reduced ERP waveforms which will be examined at P1, N2 and P3 for the Opposition task and N2 and P3 for the VPAc and False Memory tasks.

4.2 Method

4.2.1 Participants

Twenty-eight participants divided into two age groups, young (18-30 years, mean age = 24.27) and older adults (50+ years, mean age = 64.5), took part in this experiment. Of the young group 7 were female and 14 were right handed and of the older group 7 were female and 14 were right handed. All participants had normal or corrected-to-normal vision and were self-reported free of any memory or mental problems. Participants gave written informed consent of their participation in the study (Appendix G) and completed three computer-based memory tasks and three control measures. This study was carried out in accordance with the Ethical Standards of the American Psychological Association (APA), the Declaration of Helsinki (World Medical Association Inc.) and was approved by the local ethics committee.

4.2.2 Apparatus

4.2.2.1 Control Measures.

The control measures used in this experiment included the National Adult Reading Test (section 2.3.3), the Cognitive Failures Questionnaire (section 2.3.5) and the Rey Auditory Verbal Learning Test (section 2.3.2). See the relevant sections in the Methods Chapter (Chapter 2) for complete discussions of each of these tasks.

4.2.2.2 Opposition Task.

The Opposition task, developed by Jennings and Jacoby (1997) was conducted as per instructions in Methods chapter (see section 2.4.2).

4.2.2.3 Visual Paired-Associates Task, context version (VPAc).

The VPAc was carried out as described in the Methods chapter (see section 2.4.3).

4.2.2.4 False Memory Task.

The False Memory task, based on the Deese-Roediger-McDermott (1995) paradigm, was performed as set out in the Methods Chapter (see section 2.4.4).

4.2.3 Design

4.2.3.1 Control Measures.

See Chapter 2 for discussion of the design of the RAVLT (2.3.2.1), the NART (2.3.3.2) and the CFQ (2.3.5.2).

4.2.3.2 Opposition Task.

Chapter 2 (section 2.4.2.2) discusses the design of the Opposition task.

4.2.3.3 VPAc.

Section 2.4.3.2 of Chapter 2 covers the design of the VPAc task.

4.2.3.4 False Memory Task.

The design of the False Memory task is as described in Chapter 2 (section 2.4.4.2).

4.2.4 Procedure

Before commencing the experiment, participants were briefed and informed that they would be taking part in some memory tasks while scalp-recorded electrical activity was acquired and that the entire procedure would take approximately two hours. Participants read and signed a consent form before beginning the experiment and were informed that they were free to depart the experiment at any stage. The participants complete the control tasks first and were then prepared for the EEG section of the experiment. The EEG set-up is as described in the Methods Chapter (see section 2.5.5). Once participants were prepared for EEG they completed the three computer-based memory tasks which were counterbalanced. The data from the experiment were anonymised, confidential and kept separate from the signed consent forms which contained no information which could identify individual participants.

4.2.4 Data Analysis

Before analysis, all outliers were removed from these data by subtracting the IQR from the first quarter and adding the IQR to the third quarter, thereby creating a range of data within the variables for each group. Any data points outside of the lower and upper limits were removed. Accuracy and response time data from the Opposition, the VPAc and the False Memory tasks (see Method chapter sections 2.4.2.2, 2.4.3.2 and 2.4.4.2 for scoring of the tasks) for correct responses were analysed using mixed factorial ANOVAs. Independent t-tests were used to examine between group differences for accuracy and response times. Bonferroni-corrected dependent t-tests were used to analyse within group differences for accuracy only. The RAVLT was also analysed using mixed factorial ANOVAs and independent and Bonferroni-corrected dependent t-tests to determine any differences between and within the groups. The NART was analysed using a MANOVA and a one-way between groups ANOVA was used to examine the CFQ (see sections 2.3.2, 2.3.3 and 2.3.5 for scoring).

For the recorded electrophysiology, stimulus-locked ERPs were obtained (see Chapter 2, section 2.5.5.3 for analysis of ERPs). For the Opposition task, 6 separate conditional ERPs based on the possible combinations of stimulus and response made were created (target stimulus at lag 0, 4, or 16 where a correct response was made, and distractor stimulus at lag 0, 4, or 16 where a correct response was made). Due to a low number of errors being made, only correct responses were of interest.

For the VPAc, the participant EEG was used to create 4 separate conditional ERPs based on the possible combinations of stimulus and response (true-congruent when a correct response was given, true-incongruent when a correct response was given, false-congruent when a correct response was given and false-incongruent when a correct response was given). Only correct responses were of interest as few incorrect responses were made.

For the False Memory task, participant EEG was used to produce 4 conditional ERPs based on the stimulus and response made (study word with a correct and incorrect response and false test words with a correct and incorrect response). Both correct and error responses were examined for this task.

An overall grand-mean waveform was obtained by averaging across each condition and group. This allowed for visual inspection of peak amplitudes at each electrode site leading to easy identification of components of interest. Mixed Factorial ANOVAs were used to analyse the different conditional ERPs discussed above for the Opposition task, the VPAc and the False Memory task, using the mean amplitude as the dependent variable. Independent t-tests were conducted to assess differences between the groups for mean amplitude. Chapter 2 (section 2.5.5.3) covers the EEG preprocessing procedure and extraction of mean amplitudes. Visual inspection of the ERP topographies allowed for identification of components of interest. P1 components (80-200ms) at the posterior channels PO3 and PO4, N2 components (185-360ms) at parietal FC1 and FC2 channels and P3 components (360-750ms) at the anterior channels FP1 and FP2 were identified for the Opposition task. The components selected for the VPAc task consisted of an N2 (120-220ms) and a P3 (220-500ms) at the posterior sites PO3 and PO4. The components of interest for the False Memory task were an N2 (150-250ms) at the posterior sites PO3 and PO4, while a P3 (300-600ms) was identified at the anterior sites FP1 and FP2 for both correct and incorrect responses.

4.3 Results

The results are discussed below in terms of control tasks, accuracy and response times on the computer-based memory tasks and electrophysiology on the computer-based memory tasks.

4.3.1 Control Tasks

See Table 4.1 below showing the means and standard deviations for each of the control tasks and Figure 4.1 showing graphs for each of the control measures.

4.3.1.1 National Adult Reading Test.

The NART was examined using a one way between groups MANOVA which revealed that the older group displayed significantly higher predicted IQs than the younger group for each measure of IQ associated with the NART (see Table 4.1 and Figure 4.1a): Predicted Full Scale IQ [F (1, 23) = 5.230, $p < 0.05$, partial eta squared = .185]; Predicted Verbal IQ [F (1, 23) = 8.547, $p < 0.01$, partial eta squared = .271]; Predicted Performance IQ [F (1, 23) = 8.858, $p < 0.01$, partial eta squared = .278].

4.3.1.2 Cognitive Failures Questionnaire.

Statistically significant differences were found between the young and older adults on the CFQ using a one way between groups ANOVA [F (1, 22) = 5.186, $p < 0.05$] which showed that the older adults [mean = 33.83, SD = 8.36] reported fewer cognitive failures than the young [mean = 43.17, SD = 11.47] (see Figure 4.1b).

4.3.1.3 Rey Auditory Verbal Learning Test.

A 2×5 Mixed Factorial ANOVA was conducted on the RAVLT and revealed significant main effects for Trial A1-A5 [F (4, 92) = 104.599, $p < 0.01$] with recall increasing across Trial A1-A5, and Group [F (1, 23) = 10.912, $p < 0.01$] with the young group showing higher recall (see Figure 4.1c); but no significant interaction was seen between Trial and Group [F (4, 92) = .690, $p > 0.05$]. Independent t-tests were conducted to determine where in these data differences lay between the groups (see Table 4.1 for means and SDs). Statistically significant differences were found for Trials A1 [t (23) = 2.097, $p < 0.05$], A2 [t (23) = 2.614, $p < 0.05$], A3 [t (23) = 2.413, p < 0.0 1] A4 [t (23) = 2.413, $p < 0.05$] and A5 [t (23) = 3.023, $p < 0.01$] with the young adults showing higher recall scores for each of these trials.

A statistically significant main effect for Proactive Interference was found using a 2×2 Mixed Factorial ANOVA [F (1, 23) = 4.834, $p < 0.05$] where recall for Trial A1 was higher than Trial B. However, no Group effect was found [F (1, 23) = 10.912, $p > 0.05$] indicating that both groups' recalls were similar, and no interaction was found between Proactive Interference and Group [F (1, 23) = 1.355, $p > 0.05$]. Bonferroni-corrected dependent t-tests were conducted to examine where in these data the differences lay for Proactive Interference. It was found that the young group showed significant decrease in recall from Trials A1 to B [t (11) = 2.569, $p < 0.05$, however this was rendered non-significant due to Bonferroni correcting, $p > 0.05$]. The older group showed no significant difference between Trials A1 to B [t (12) = 3.247, $p < 0.01$]. As stated above there was a significant difference between the groups on A1 [t (23) = 2.097, $p < 0.05$] with the young showing higher recall but no difference was seen between the groups on Trial B [t (23) = 1.358, $p > 0.05$].

A 2×2 Mixed Factorial ANOVA was carried out on Retroactive Interference and showed a statistically significant main effect for Retroactive Interference [$F (1, 23) = 18.413$, $p < 0.01$] where recall was higher on Trial A5 compared to A6. However, no Group effect was found [$F (1, 23) = 5.727$, $p > 0.05$] nor was an interaction found between Retroactive Interference and Group [$F (1, 23) = .125$, $p > 0.05$]. A Bonferroni-corrected dependent t-test revealed that the young group had a higher recall for Trial A5 compared to A6 [$t (11) = 2.833$, $p < 0.05$] and the older group showed the same [$t (12) = 3.247$, $p < 0.05$]. As stated above the young group showed a higher recall than the older on Trial A5 [$t (23) = 3.023$, $p < 0.01$] but no difference was seen on Trial A6 [$t (23) = 1.831$, $p > 0.05$].

A 2×2 Mixed Factorial ANOVA revealed no statistically significant main effect for the Delay Trials [$F (1, 23) = .488$, $p > 0.05$] indicating that the recall scores across the delay period did not differ. In addition, no Group effect was seen [$F (1, 23) = 3.275$, $p > 0.05$] suggesting that both groups had similar recall scores and no interaction was seen between Delay and Group [$F (1, 23) = .028$, $p > 0.05$]. Furthermore, no differences were seen between the groups on Trials A6 [$t (23) = 1.831$, $p > 0.05$] or A7 [$t (23) = 1.656$, $p > 0.05$]

Table 4.1: Means and standard deviations for the NART based predicted IQs, Cognitive Failures Questionnaire and the RAVLT.

	Young (N = 14)		Older (N = 14)	
	Mean	SD	Mean	SD
Predicted Full Scale IQ	112.25	6.78	121.15	5.58
Predicted Verbal IQ	110.50	6.30	118.54	5.22
Predicted Performance IQ	111.42	6.14	119.46	5.17
CFQ	43.17	11.47	33.83	8.36
RAVLT A1	8.00	1.86	6.46	1.81
RAVLT A2	11.25	2.14	8.92	2.10
RAVLT A3	12.58	1.93	10.15	1.82
RAVLT A4	13.50	1.45	11.85	1.86
RAVLT A5	14.00	0.85	12.15	1.95
RAVLT B	6.64	1.43	6.00	1.22
RAVLT A6	12.50	2.20	10.23	3.27
RAVLT A7	12.25	2.30	10.08	3.25

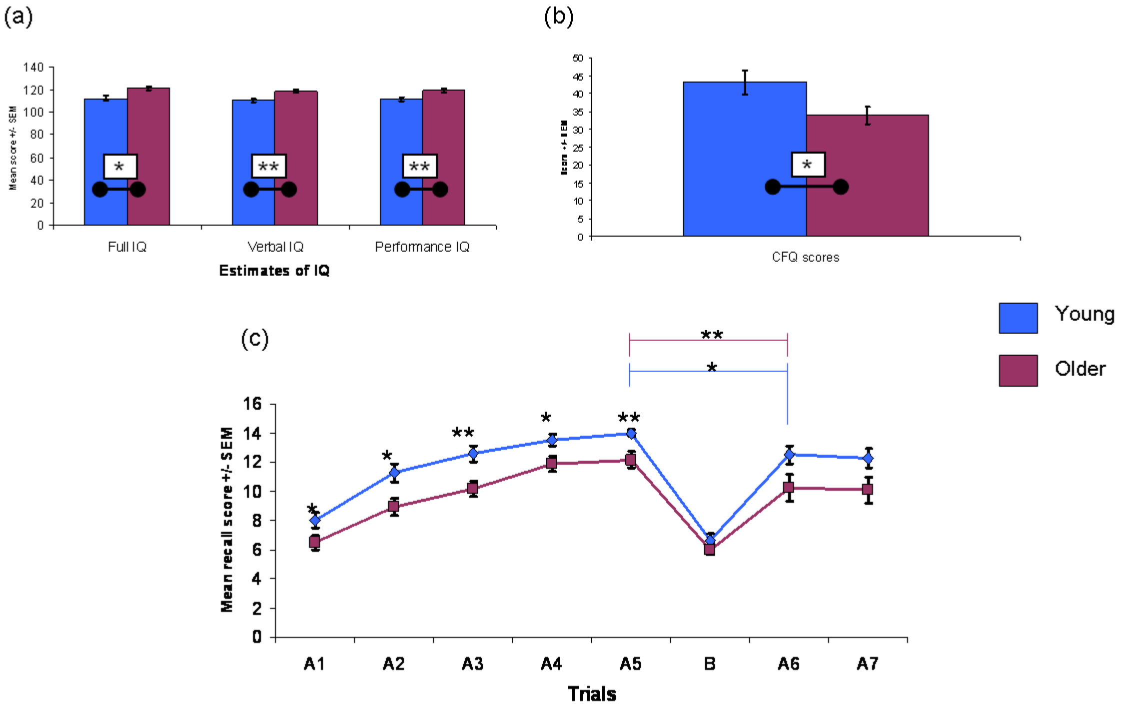


Figure 4.1: (a) Predicted Full scale, Verbal and Performance IQ based on the NART for young and older adults +/- SEM, (b) CFQ scores for young and older adults +/- SEM, (c) RAVLT accuracy scores for Trials A1-A7 for the young and older adults +/- SEM
*(*p < 0.05, **p < 0.01)*

4.3.2 Opposition Task

4.3.2.1 Accuracy.

A 2×3×2 Mixed Factorial ANOVA revealed no significant main effect for Word Type or Lag indicating similar accuracies between Distractor and Target words and across the three lags. However, a significant effect was seen for Group [F (1, 25) = 8.483, $p < 0.01$] with the young group showing higher accuracies on a selection of conditions (see Figure 4.2 below). In addition, significant interactions were seen between Word Type and Group [F (1, 25) = 8.184, $p < 0.01$], Lag and Group [F (2, 50) = 4.064, $p < 0.05$], Word Type and Lag [F (2, 50) = 14.222, $p < 0.01$] and Word Type, Lag and Group [F (2, 50) = 9.053, $p < 0.01$]. Further analyses were carried out to determine where these differences lay in these data.

Independent t-tests showed that the young group had higher accuracies for each Lag on the Distractor Words: Lag 0 [young: mean = 9.64, SD = 0.63; older: mean = 9, SD = 0.96; t (26) = 2.090, $p < 0.05$], Lag 4 [young: mean = 9.29, SD = 1.204; older: mean = 6.79, SD = 1.72; t (26) = 4.459, $p < 0.01$] and Lag 16 [young: mean = 9.54, SD = 0.78; older; mean = 5.86, SD = 2.35; t (25) = 5.547, $p < 0.01$]. No differences were found between the groups on Target words at any of the Lags [all t <.714, all $p > 0.05$].

Bonferroni-corrected dependent t-tests revealed that the young group had no differences within Distractor words [all $t < 1.587$, all $p > 0.05$] or Target words [all $t < .744$, all $p > 0.05$]. However, the older group showed significantly higher accuracies for Distractor words at Lag 0 [mean = 9, SD = 0.96] compared to Lag 4 [mean = mean = 6.79, SD = 1.72; t (13) = 4.590, $p < 0.01$], as well as compared to Lag 16 [mean = 5.86, SD = 2.35; t (13) = 5.896, $p < 0.01$]. In addition, the older group showed a lower accuracy for Targets at Lag 0 [mean = 7.07, SD = 1.86] compared to Lag 16 [mean = 8.21, SD = 1.53; t (13) = -2.447, $p < 0.05$].

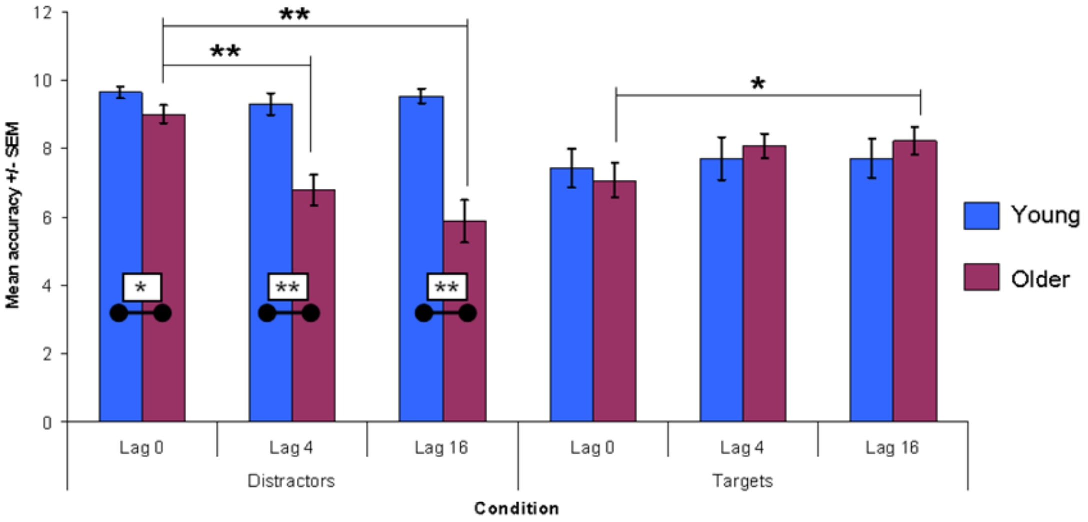


Figure 4.2: Mean total accuracy +/- SEM for young and older adults for Distractor and Target words at Lags 0, 4 and 16 on the Opposition task
*(*p < 0.05, **p < 0.01)*

4.3.2.2 Response Times for Correct Responses.

A 2×3×2 Mixed Factorial ANOVA reveal a significant main effect for Word Type [F (1, 22) = 14.199, p < 0.01], with faster response times on Target Words, and a significant main effect for Lag [F (2, 44) = 59.266, p < 0.01] with faster response times on the shorter lag lengths (see Figure 4.3). However, no Group effect was found indicating that the two groups had similar response times across the different conditions. In addition, a significant interaction was found for Word Type and Group [F (1, 22) = 7.179, p < 0.05], Lag and Group [F (1, 22) = 4.299, p < 0.01], Word Type and Lag [F (2, 44) = 7.596, p < 0.05], while no interaction was seen for Word Type and Lag and Group.

Despite no group effect being seen, independent t-tests found differences between the groups on Distractor words at Lag 4: young [mean = 1152.07, SD = 376.30] and older [mean = 1493.98, SD = 398.71; t (26) = -2.334, p < 0.05]; and Distractor words at Lag 16 young [mean = 1157.51, SD = 267.16] older [mean = 1723.72, SD = 758.49; t (25) = -2.623, p < 0.05] with the young group having faster response times in both instances (see Figure 4.3). No differences were found on Distractors at Lag 0 or any of the Target words [all t < 1.456, all p > 0.05].

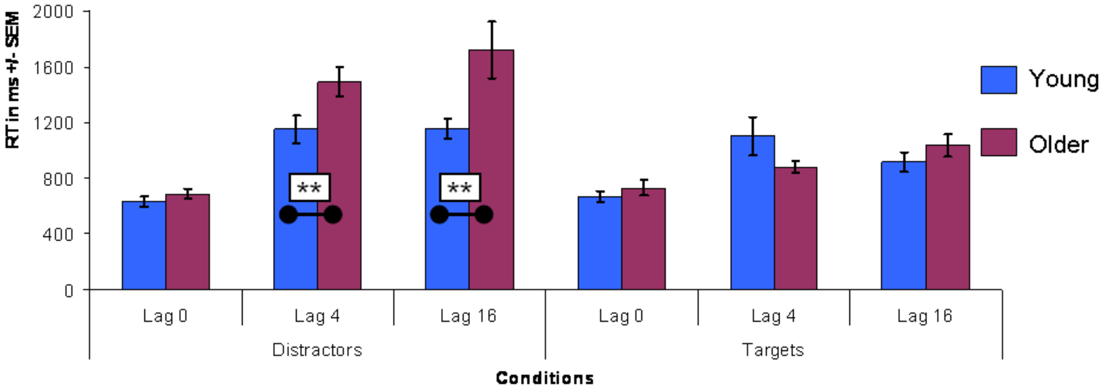


Figure 4.3: Mean response times in ms +/- SEM for a correct response at Lags 0, 4 and 16 on Distractor and Target words for the Opposition task
*(*p < 0.05, **p < 0.01)*

4.3.2.4 Electrophysiological Results.

P1, N2 and P3a components were identified in the Opposition task. P1 components were identified at the posterior channels PO3 and PO4, N2 components were examined at frontal channels FC1 and FC2, while P3a components were identified at the anterior channels FP1 and FP2. Six separate 2×3×2 Mixed Factorial ANOVAs were carried out on the mean amplitudes of these components at each channel to determine if there were any differences for Word Type, Lag and Group.

4.3.2.4.1 P1 component (80-200ms)

For the P1 component (80-200ms) at the left posterior site PO3 there was no statistically significant effect found for Word Type, Lag or Group. In addition, no interaction effects were seen between Word Type and Group, Lag and Group, Word Type and Lag, or Word Type by Lag by Group (see Figure 4.4, highlighted orange).

Independent t-tests revealed a significant difference for Distractor words at Lag 4 on the P1 component at PO3, with the young group showing larger mean amplitudes, suggesting increased positivity (see Figure 4.4): Distractor Lag 4 young [mean = 5.72, SD = 4.18], older [mean = 2.52, SD = 3.34; t (26) = 2.236, p < 0.05]. The other conditions revealed non-significant results [all t < 1.626, all p > 0.05].

Analyses on the P1 component (80-200ms) at the right posterior channel PO4, revealed no significant main effects for Word Type, Lag or Group. The interactions between Word Type by Group, Lag and Group, Word Type×Lag [F (2, 52) = .255, p > 0.05], and Word Type by Lag by Group were also revealed as non-significant and independent t-tests showed that there were no differences between the groups on any of the conditions [all t < 1.540, all p > 0.05].

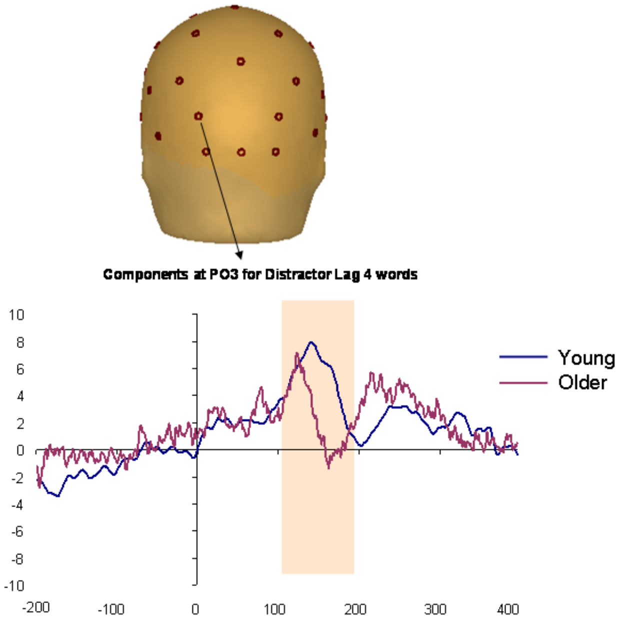


Figure 4.4: P1 component (highlighted orange) at PO3 for young and older adults on Distractor words at Lag 4.

4.3.2.4.2 N2 component (185-360ms)

A 2×3×2 Mixed Factorial ANOVA was carried out on the N2 component (185-360ms) at left frontal FC1 but no significant main effects were found for Word Type, Lag, or Group. The interactions of Word Type and Group, Lag by Group and Word Type by Lag by Group were non-significant. An independent t-test revealed that the older group had more negative electrical activity [mean = -1.67, SD = 1.23] than the young group [mean = .4682, SD = 1.70; t (24) = 3.657, $p < 0.01$] for Distractor Lag 0 words (see Figure 4.5 below, highlighted green). No other between group differences were significant [all $t < 1.004$, all $p > 0.05$].

Analyses on the N2 component (185-360ms) at right frontal FC2 revealed a significant main effect for Word Type [F (1, 23) = 4.836, $p < 0.05$], but no main effects of Lag or Group. The interaction between Lag and Group was statistically significant [F (2, 46) = 4.196, $p < 0.05$], while the interactions of Word Type and Group, and Word Type by Lag by Group were not significant. Independent t-tests revealed no significant differences between the groups for any condition [all $t <1.004$, all $p > 0.05$].

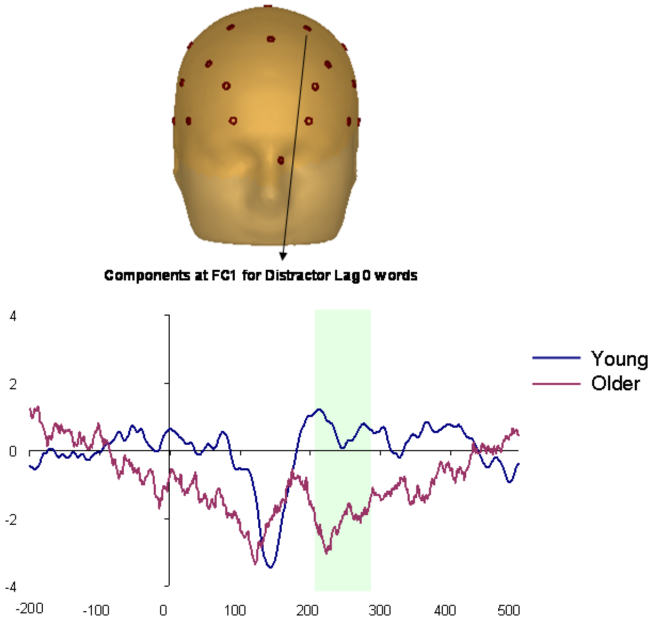


Figure 4.5: N2 component (highlighted green) at left parietal FC1 for young and older adults on Distractor Lag 0 words on the Opposition task.

4.3.2.4.3 P3a component (300-570ms)

The 2×3×2 Mixed Factorial ANOVA carried out on the P3a component (300-570ms) at left frontal FP1 revealed no significant main effects for Word Type, Lag or Group. The interactions between Word Type and Group, Lag and Group, Word Type by Lag, and the three way interaction of Word Type, Lag and Group did not reveal statistical significance either. In addition, no between groups differences were found, using independent t-tests, for the P3a component at FP1 [all $t < 1.487$, $p > 0.05$].

Statistical significance was not reached for the main effects of Word Type, Lag and Group for a P3a component (360-750ms) at FP2. In addition, the interactions between Word Type×Group, Lag and Group, Word Type and Lag, and Word Type by Lag by Group did not reach significance. Independent t-tests revealed no statistically significant differences between the groups for any of the conditions for the P3a component at FP2 [all $t < 1.049$, all $p > 0.05$].

4.3.3 VPAc

4.3.3.1 Accuracy.

A 2×2×2 Mixed Factorial ANOVA was conducted on the accuracy for the VPAc and statistically significant main effects were found for Stimulus Type [F (1, 26) = 6.532, $p < 0.05$], Congruence [F (1, 26) = 7.089, $p < 0.05$] and Group [F (1, 26) = 6.264, $p < 0.05$] where accuracy was higher for False, and Congruent pairs, along with higher accuracy in the young group on a selection of stimuli (see Figure 4.6). No interactions were found between Stimulus Type and Group, Congruence by Group, Stimulus Type × Congruence or Stimulus Type by Congruence by Group (Figure 4.6).

Independent t-tests revealed statistically significant differences between the groups on TC pairs with the young group [mean = 29, SD = 3.06] showing higher accuracies than the older group [mean = 25.36, SD = 4.96; t (26) = 2.340, $p < 0.05$]. This was also seen in FI pairs: young [mean = 30, SD = 2.18386], older [mean = 26.2857, SD = 5.1654; t (26) = 2.478, $p < 0.05$]. No differences were found between the groups for TI and FC pairs [all $t < 2.007$, all $p > 0.05$].

Bonferroni-corrected dependent t-tests showed that the young groups accuracy on TC pairs [mean = 29, SD = 3.06] was significantly higher than on TI pairs [mean = 27.21, SD = 3.04; t (13) = 5.623, $p < 0.01$]. In addition, they showed lower accuracies for TI pairs [mean = 27.21, SD = 3.04] compared to FI pairs [mean = 30.00, SD = 2.18; t (13) = -5.404, $p < 0.01$]. No other within groups differences were seen for young or older adults [all $t < 1.727$, all $p > 0.05$].

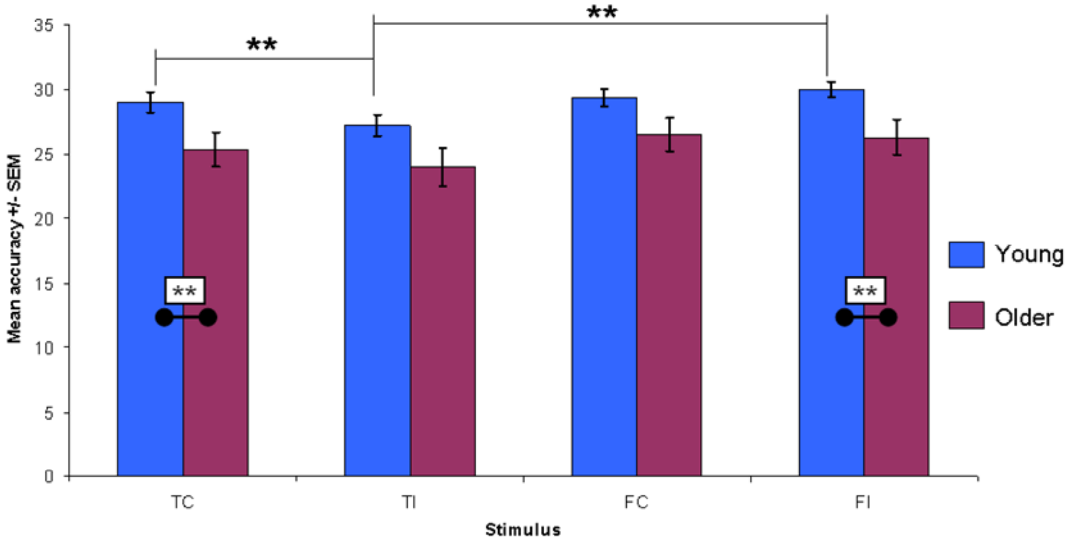


Figure 4.6: Mean total accuracy +/- SEM for True Congruent (TC), True Incongruent (TI), False Congruent (FC) and False Incongruent (FI) pairs for young and older adults on the VPAc task
*(*p < 0.05, **p < 0.01)*

4.3.3.2 Response Times for Correct Responses.

A 2×2×2 Mixed Factorial ANOVA found no significant main effects for Stimulus Type, Congruence, or Group. The ANOVA also revealed no statistically significant interactions for Stimulus Type by Group, Congruence by Group, Stimulus Type × Congruence, or Stimulus Type, Congruence and Group.

The only difference seen between the two groups on response times for correct responses was on FI pairs (see Figure 4.7) with the young group [mean = 1568.25, SD = 572.19] responding faster than the older group [mean = 2120.33, SD = 692.38; t (25) = -2.247, p < 0.05]. No other differences were seen between the two groups [all t < 1.581, all p > 0.05].

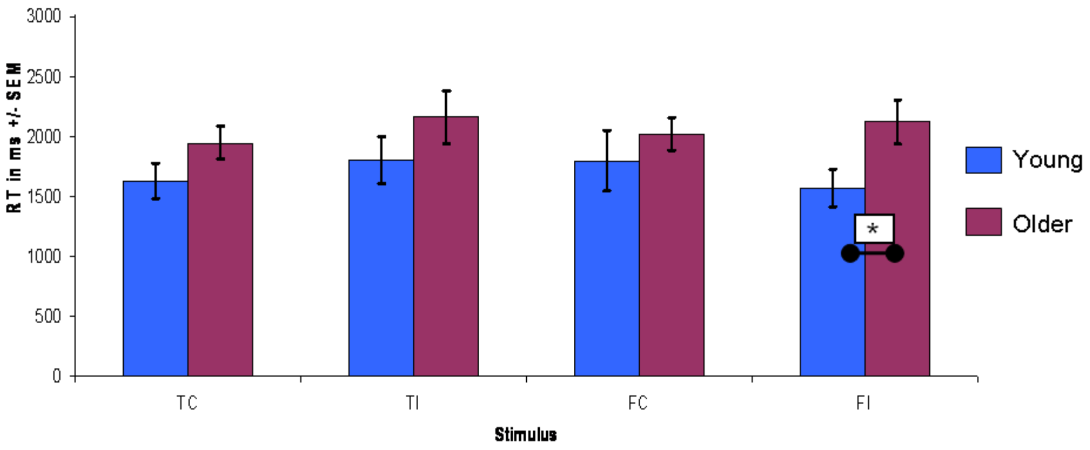


Figure 4.7: Mean response times in ms +/- SEM for correct responses between young and older adults on True Congruent (TC), True Incongruent (TI), False Congruent (FC) and False Incongruent (FI) pairs on the VPAc task
*(*p < 0.05, **p < 0.01)*

4.3.3.4 Electrophysiological Results.

Visual inspection of these data revealed N2 and P3b components at posterior sites PO3 and PO4. Four separate 2×2×2 ANOVAs were conducted to determine whether there were any differences within Stimulus Type, Congruence or Group for either of the components at any of the channels.

4.3.3.4.1 N2 component (120-220ms)

The 2×2×2 Mixed Factorial ANOVA showed that the N2 component (120-220ms) at left posterior PO3 had no statistically significant effect for Stimulus Type; however, significant effects were seen for Congruence [F (1, 25) = 4.850, p < 0.05] and Group [F (1, 25) = 5.198, p < 0.05], where the older group had smaller mean amplitudes on a selection of conditions, indicating more negativity. The interactions between Stimulus Type and Group, Congruence × Group, Stimulus Type by Congruence, and Stimulus Type by Congruence by Group did not reach statistical significance.

Independent t-tests revealed that the young group showed larger negative mean amplitudes [mean = 5.18, SD = 3.31] than the older group for TC pairs [mean = 2.02, SD = 3.56; $t (26) = 2.432$, $p < 0.05$] and TI pairs: young [mean = 5.38, SD = 2.24] older [mean = 2.97, SD = 2.91; $t (25) = 2.418$, $p < 0.05$] indicating that the older group had more negativity on the N2 component for TC and TI pairs at channel PO3 (Figure 4.8, highlighted green). No other between group differences were seen [all $t < 2.028$, $p > 0.05$].

No statistically significant effect was found for Stimulus Type at the right posterior channel PO4 for the N2 component (120-220ms). However, significant main effects were seen for Congruence [$F (1, 26) = 6.987$, $p < 0.05$] and Group [$F (1 26) = 4.914$, $p < 0.05$] where the older group showed a lower mean amplitude on a selection of stimuli, indicating more negativity. The interactions of Stimulus Type and Group [$F (1, 26) = 4.773$, $p < 0.05$] and Congruence and Group [$F (1, 26) = 5.852$, $p < 0.05$] also reached statistical significance, while the interactions between Stimulus Type and Congruence and the three way interaction of Stimulus Type by Congruence by Group was not significant.

Group differences were found on TC pairs where the older group [mean = 1.11, SD = 3.72] showed a larger negative mean amplitude than the young group [mean = 5.12, SD = 4.17; $t (26) = 2.687$, $p < 0.05$] indicating that the older group had more negativity on the N2 component at PO4 (Figure 4.8, highlighted green). All other group comparisons were non-significant [all $t < 2.044$, $p > 0.05$].

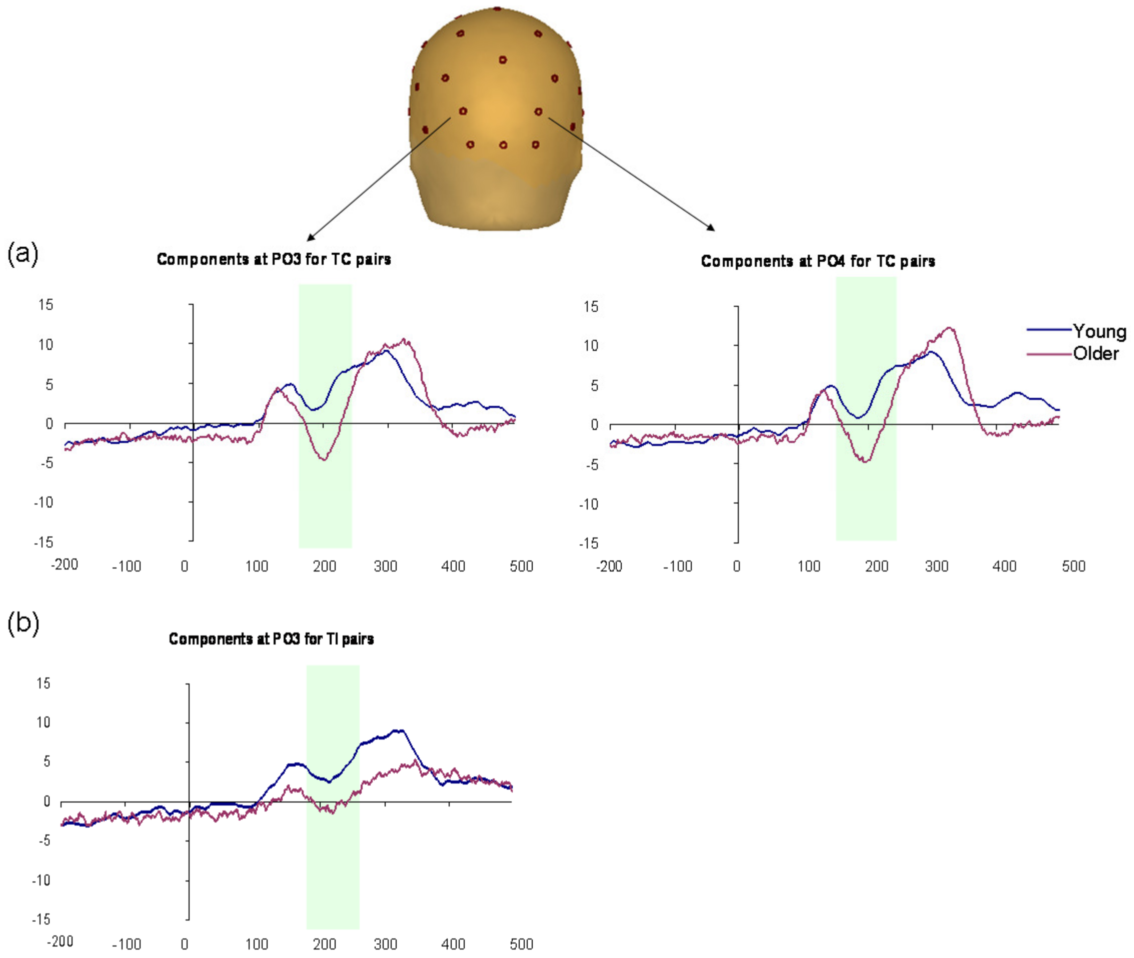


Figure 4.8: N2 components (highlighted green) for young and older adults at posterior channels PO3 and PO4 for (a) TC pairs and (b) TI pairs

4.3.3.4.2 P3b component (220-500ms)

The P3b component (220-500ms) at left posterior PO3 revealed that the main effects of Stimulus Type, Congruence and Group were not significant. In addition, no significant effects were seen for the interactions between Stimulus Type and Group, Congruence by Group, Stimulus Type × Congruence, or Stimulus Type by Congruence by Group. Independent t-tests [all $t < 1.396$, all $p > 0.05$] revealed no differences between the groups.

The P3b component (220-500ms) at right posterior channel PO4 also showed no significant main effects for Stimulus Type, Congruence, or Group. The interactions of Stimulus Type by Group, Congruence and Group, Stimulus Type × Congruence, or Stimulus Type, Congruence and Group did not reach statistical significance either. No between groups [all $t < 1.845$, all $p > 0.05$] differences were found.

4.3.4 False Memory Task

4.3.4.1 Accuracy.

A 2×2 Mixed Factorial ANOVA was carried out on the False Memory task for accuracy (see Figure 4.9) and revealed no statistical significance for the main effects of Word Type, Group, or the interaction between Word Type and Group. Independent t-tests revealed no difference between the groups on False Test or Study words [all $t < 1.370$, all $p > 0.05$]. In addition, Bonferroni-corrected dependent t-tests showed no differences for either group within Word Types [all $t < .812$, all $p > 0.05$] (see Figure 4.9 below).

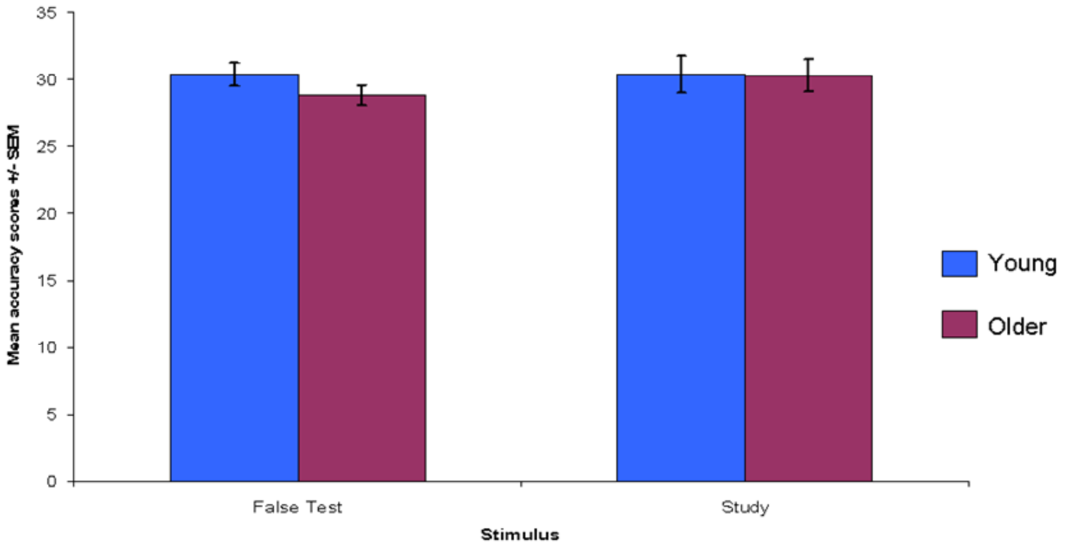


Figure 4.9: Mean total accuracy +/- SEM for young and older adults for False Test and Study words on the False Memory task
($p < 0.05$, ** $p < 0.01$)*

4.3.4.2 Response Times for Correct Responses.

A 2×2 Mixed Factorial ANOVA was carried out to examine differences in response times for correct responses and revealed a significant difference for Word Type [F (1, 26) = 17.346, $p < 0.01$] with faster response times for false test words (see Figure 4.10a). However, no Group effect was found, nor was an interaction found between Word Type and Group. No significant differences were found between the groups using Independent t-tests on either Word Type [all $t < .799$, all $p > 0.05$].

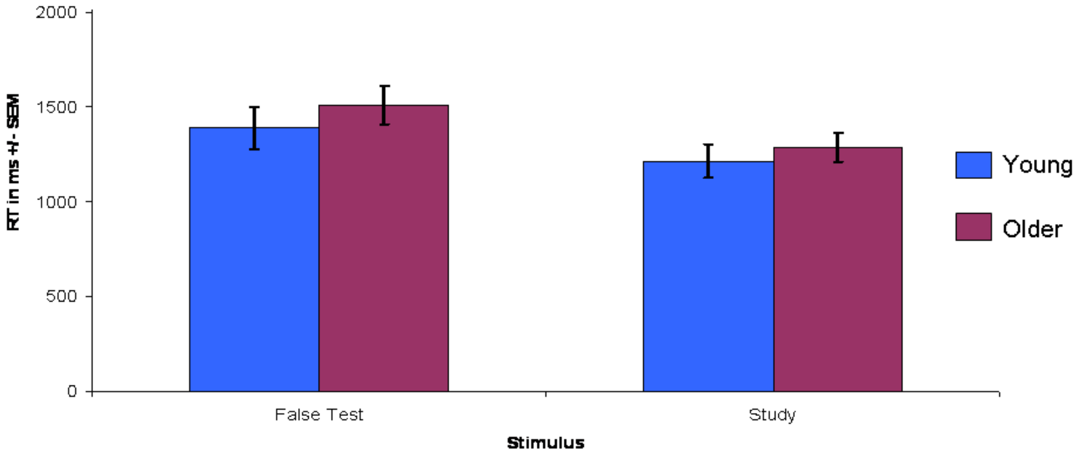


*Figure 4.10: Response times in ms +/- SEM for correct responses on False Test and Study words between young and older adults on the False Memory task (*p < 0.05, **p < 0.01)*

4.3.4.4 Electrophysiological Results.

Examination of these data for the False Memory task revealed N2 components at posterior sites PO3 and PO4 and a P3a components at anterior sites FP1 and FP2 for correct and error responses. Therefore, six separate 2×2 ANOVAs were performed to determine if Word Type or Group showed any differences for mean amplitude.

4.3.4.4.1 N2 component (150-250ms)

The N2 component (150-250ms) when responding correctly at channel PO3 had no main effect of Word Type but there was a main effect of Group [F (1, 24) = 5.268, $p < 0.05$] where the young group had greater negativity for a selection of stimuli (see Figure 4.11). In addition, no interaction was seen between Word Type and Group.

An independent t-test showed that the young group [mean = -2.39, SD = 2.79] showed a larger negative mean amplitude for False Test words than the older group [mean = -0.16, SD = 1.98; t (25) = -2.382, $p < 0.05$] indicating that the young group had more negative activity for the N2 component (150-250ms) at PO3 (Figure 4.11, highlighted green). However, no difference was seen on Study words [t (25) = -.909, p > 0.05].

The 2×2 Mixed Factorial ANOVA carried out on the N2 component at channel PO4 for a correct response found no significant effects for Word Type, Group, or a significant interaction between Word Type and Group. Independent t-tests [all t < .792, p > 0.05] found no difference between the groups on either word type.

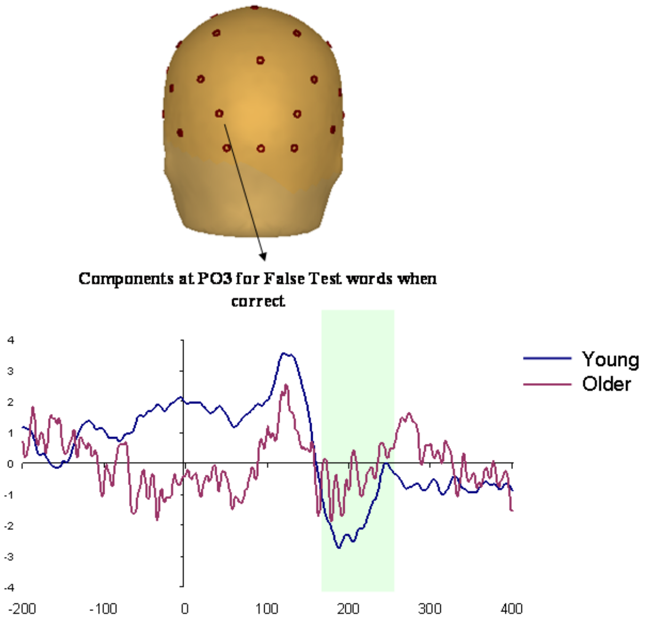


Figure 4.11: N2 component (highlighted green) at left posterior channel PO3 for correct responses to False test words between young and older adults

4.3.4.4.2 P3a component (300-600ms)

No significant main effects were seen for Word Type, Group or the interaction between Word Type and Group for the P3a component (300-600ms) on correct responses at left frontal FP1. The P3a component for correct responses at right frontal FP2 showed a similar pattern where Word Type, Group and the interaction between Word Type and Group did not reach statistical significance.

The 2×2 Mixed Factorial ANOVA at left frontal FP1 for a P3a component (280-730ms) on error responses revealed no significant main effects for Word Type or Group. However, a significant interaction was found between Word Type and Group [$F (1, 23) = 5.275$, $p < 0.05$] and independent t-tests revealed that this difference was seen on False Test words where the young group [mean = 9.05, SD = 11.80] showed a greater mean amplitude than the older [mean = 1.53, SD = 5.93] indicating more positive activity [$t (26) = 2.131$, $p < 0.05$] (see Figure 4.12, highlighted blue). No difference was seen on study words [$t (23) = -1.591$, $p > 0.05$].

Examination of the P3a component (280-730ms) at right frontal FP2 for incorrect responses found that there was no main effect of Word Type or Group. However, as before, a significant interaction was revealed between Word Type and Group [$F (1, 23) = 4.484$, $p < 0.05$]. Independent t-tests showed that this difference again existed for the False Test words [$t (25) = 2.214$, $p < 0.05$] where the young group [mean = 9.38, SD = 13.40] showed larger mean amplitudes than the older group [mean = .60, SD = 5.14] (Figure 4.12, highlighted blue). No difference was seen for Study words [$t (24) = -.742$, $p > 0.05$].

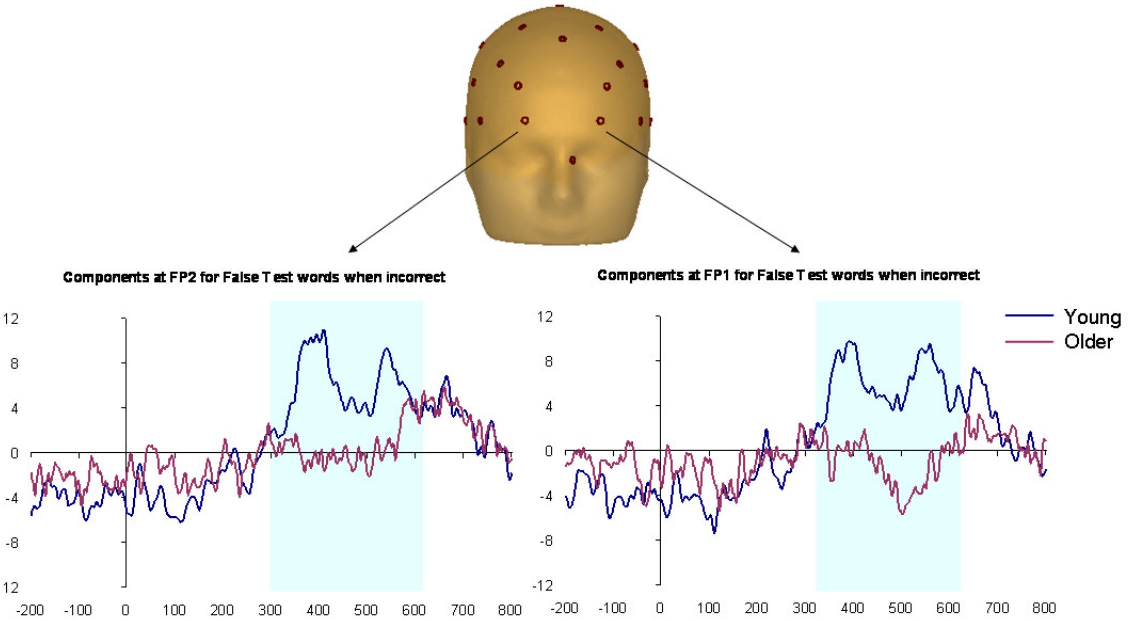


Figure 4.12: P3a components (highlighted blue) at FP2 and FP1 for errors on False Test words for young and older adults

4.4 Discussion

Despite showing higher predicted IQ scores and lower lapses of memory, the older adults generally showed a behavioural impairment in accuracy on Distractor words on the Opposition task and for a selection of stimuli on the VPAc task, but this was not seen for the False Memory task. In addition, the young group responded quicker when answering correctly on Distractor words for the Opposition task and for one stimulus type of the VPAc task but there was no difference between the groups for speed of responding for the False Memory task. The electrophysiology showed some differences between the groups where the young group showed more electrical activity for the P1 component on the Opposition task and correct and error responses for the False Memory task for the P3a components and N2 on the False Memory task. However, the older group showed enlarged N2 components on the Opposition and VPAc tasks.

The Opposition task revealed that both groups' accuracies decreased across the lag lengths for Distractor (new) words, indicating that the longer the time difference between presentations the more difficult it is to place the item into its correct time. The results also suggested that older adults had more difficulty doing this than young. This pattern was also observed in the previous chapter where accuracy decreased across the lag lengths for Distractor words with older adults having poorer performance than young. However, as no differences were seen between the groups for Target words (which was also observed in the previous chapter), this leads to the conclusion that older adults are more prone to mistake a repeated "new" (distractor) word for an "old" (target) word. This may indicate that they have more difficulty in correctly estimating the time of presentation of an item than younger adults. In addition, the younger group were faster when responding correctly to distractor words on the longer lengths but not on the shorter lag lengths. This indicates that older adults are not only more impaired at identifying items in their correct time but they also need more time to correctly identify them. Similar behavioural results were seen and discussed by previous researchers investigating source memory where older adults showed poorer behavioural performances on source memory than young adults (Dywan & Jacoby, 1990; Jennings & Jacoby, 1993; Jennings & Jacoby, 1997; Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994). The results of the previous chapter reported the older adults as slower across each condition, while in this study the older adults performed at a slower rate on only Distractor words at the longer lag lengths of 4 and 16. This may imply that this particular cohort of older adults were not as impaired on speed of processing as the previous sample (Salthouse, 1994). One explanation for this may be due to the high functioning of these older adults as evident from the control tasks. Another explanation for this may be due to the smaller sample size attenuating differences between the two groups.

Event-related potentials recorded during the Opposition task did not show many group differences which may have been due to large standard deviations and, therefore, dispersion of data points within each group. However, a significant difference was seen for the Distractor words at lag 4, where the left parietal P1 component at channel PO3 for the young group showed larger mean amplitudes indicating that they had more positive activity. These results correspond with previous studies comparing ERP components of young and older adults on source memory tasks (Dywan, Segalowitz, & Arsenault, 2002; Dywan, Segalowitz, Webster, Hendry, & Harding, 2001; Mathewson, Dywan, & Segalowitz, 2005). These studies reported fewer source memory errors in young adults coupled with increased ERP amplitude for correct responses to new repeated items. The young group in the current study also showed a better behavioural performance at Distractor lag 4 which may suggest that increased amplitude may lead to a better performance for accuracy on this particular task. As this was seen for the early P1 component, it may be concluded that automatic early sensory processing contributes to better behavioural accuracy performance for young, but not older adults. However, this cannot be conclusively stated as this was the only component and channel which showed this pattern, and as the young group were also better on Lag 0 and Lag 16 with no corresponding ERP differences. Therefore, more investigation of this may be needed. In addition, the older adults showed increased negative mean N2 amplitudes. In light of behavioural performance, this increased N2 component may reflect the recruitment of additional neural resources in older adults as proposed in the CRUNCH model (Reuter-Lorenz & Cappell, 2008; Schneider-Garces et al., 2010). This overactivation may be functioning to attempt to establish comparable behavioural performances to young adults. Older adults may be paying more attention to the stimuli in order to produce a more accurate performance. For the young adults this additional attention may not be necessary, as early sensory processing of the item has already occurred enabling easier identification the item as familiar or novel. However, this early sensory processing may not have occurred for the older adults (as suggested above), resulting in the need for additional attentional resources to be utilised for correct identification of items. However, these results were apparent in only one condition and may need more investigation which will be explored in the next chapter.

For the VPAc, it was apparent that association and context affected the accuracy of the participants but this was only the case for younger adults. They showed more difficulty with identifying incongruent pairs compared to congruent pairs when the pair was true, but were better at identifying false compared to true pairs when they were incongruent. This indicates that for young adults both association and context may affect recognition performance in different ways. Young adults were better at identifying pairs that were true and retained the context from the study phase; this suggests that when context remains the same from acquisition items are easier to identify supporting previous research (J. C. Davis et al., 1972). When the context changed, young adults more readily identified recombined pairs than true, perhaps as the entire presentation was novel. The older adults did not display differences between the conditions suggesting that association and congruence have a similar effect on recognition performance for these older adults.

In addition, the young adults performed more accurately than older for TC and FI pairs and they responded quicker on FI pairs when responding correctly. This indicates that for these particular participants, older adults generally had more difficulty in correctly identifying pairs, and they also took more time in doing so. These results, while not fully consistent, appear similar to those discussed in the previous chapter. The previous chapter reported group differences for each condition while the current study found differences for the True Congruent and False Incongruent pairs only. This may have resulted from a smaller sample size. While differences are evident for the two remaining conditions, these may have not reached significance as the young adults may have had a greater ability for correct identification for the conditions of True Congruent and False Incongruent pairs due to the familiarity and novelty of the stimuli respectively. Additionally previous research has found that older adults were more behaviourally impaired on tasks of paired-associates than young adults (Craik et al., 2010; Hogan et al., 2011, 2012; Kessels et al., 2007; Leech & Witte, 1971; Treat & Reese, 1976) indicating that an age-related decrement may lie in the association of items within memory.

ERP waveforms elicited during the VPAc task revealed that the older adults showed larger amplitudes on the N2 components for both TC and TI pairs at left posterior and TC pairs at right posterior scalp. The findings are not consistent with other studies using paired-associate learning where young and healthy older adults showed similar activities, or the young had increased activity (Hogan et al., 2011, 2012). However, these studies did not report or discuss the N2 component and therefore it cannot be determined if the same pattern was present for the N2 component as seen in the current study. These results indicate that the true pairs may require more attentional effort in older adults for correct identification. Although the older adults may be working harder cognitively, this did not allow for better recognition than the young. This may be clarified by the CRUNCH model whereby older adults exhibit more activity to perform with similar scores as younger adults (Berlingeri et al., 2013; Grady, 2012; Reuter-Lorenz & Cappell, 2008). The older adults displayed larger mean amplitudes and equivalent accuracy performance to the young group for the True Incongruent pairs which may suggest that the increase in ERP activity allowed for similar scores on this condition. However, while increased activity was also apparent for True Congruent pairs, equivalent performance scores were not observed. An explanation for this pattern may lie with the young group. It could be suggested that the young group exceeded performance on True Congruent pairs as this condition may be considered as one that is more readily identified. Additionally a larger N may have led to slightly different findings regarding these results.

The False Memory task revealed no behavioural group differences and therefore may not be sensitive enough to reveal memory decrements in older adults for accuracy or for speed of processing during response. While the task was adjusted from the previous chapter, the current results are similar to those of the previous cohort as both young and older adults displayed similar behavioural performances for accuracy and response times. Although this task was edited since the previous chapter, it does not appear as though behaviourally it is sensitive enough to the false recognition of memories as behavioural differences were seen between young and older groups in other studies (Dennis, Kim, et al., 2008; Kensinger & Schacter, 1999; Norman & Schacter, 1997; Watson et al., 2004) but not here. Alternatively, it may be concluded that this particular version of the DRM paradigm does not reflect age-related difficulties in false memory. This may be stated as the older adults in both this, and the previous chapter, were high functioning (as evident per their estimated IQ scores and low reports of absentmindedness) and as a result may have been less susceptible to errors. However, it was found that both groups of participants were faster at responding correctly on False Test words than on Study words which indicates that this particular group of participants did not show any delay for identifying semantically-related items which may be explained by the new item being novel and therefore more readily identified. This variant of the DRM may be considered as an easier version as both groups performed with comparably high accuracy or due to the older adults being high functioning and therefore less prone to false memory errors.

The electrophysiological results indicated that the young adults showed increased electrical activity compared to the older adults when responding both correctly and incorrectly for False Test words. In view of the behavioural results, this may indicate that this reduced activity does not impede behavioural performances on this particular task. However, despite producing similar accuracies behaviourally for False Test words, the young group showed larger mean amplitudes when they responded incorrectly compared to older group. Therefore, the young group showed greater electrical activity than the older when mistakenly identifying lures, i.e. making errors on False Test words. These results regarding lure words replicate finding of other researchers who also found more reduced activity in older adults for a DRM paradigm

(Butler, McDaniel, Dornburg, Price, & Roediger, 2004; Dennis, Kim, et al., 2007; Duarte et al., 2010). However, these studies reported a neural activity decrease along with a behavioural performance decrease in older adults and concluded that the reduction in activity may contribute to an increase in false memory errors in older adults. However, the results of the current study do not entirely corroborate with these. A reduction in activity was evident; however, a corresponding behavioural decrement was not seen, which may again point to this particular DRM paradigm being considered easier than the versions utilised in the above discussed studies.

It would appear as though the results of this chapter concur predominantly with the predictions of the CRUNCH model (Reuter-Lorenz & Cappell, 2008). The CRUNCH model suggests that, irrespective of hemisphere, more activation occurs in older adults in order to produce comparable behavioural performance to younger adults (Berlingeri et al., 2013; Grady, 2012; Reuter-Lorenz & Cappell, 2008; Schneider-Garces et al., 2010). Both the VPAc task and the Opposition task showed a similar pattern to this model where the older adults showed more activity on the N2 components, and although they may be working harder by utilising more attentional resources that the young adults, they are showing similar or poorer behavioural performances. This would concur with the suggestion that these adults are recruiting additional neural resources in order to compensate for a decline in efficiency in the brain (Reuter-Lorenz & Cappell, 2008). This decline may be related to early sensory processing (P1) as was suggested by the results of the Opposition task; however, more investigation of this is needed across different stimulus domains to determine if this reduction in sensory processing may then lead to an increase in attentional resources in older adults. Although this pattern regarding mean amplitudes was not seen for the False Memory task, no behavioural differences were seen on this task either. This could suggest that this version of the task was simple enough that older adults did not need to recruit additional resources, as behavioural results indicated that the older adults did not find this task any more difficult than the young. Therefore the increase in neural activity was not necessary for this task as the older adults already performed with comparable results to the young adults. This behavioural pattern was also evident in the previous chapter.

The results of this chapter again revealed an age-related deficit in the VPAc and Opposition tasks but not the False Memory task, replicating the behavioural results of the previous chapter and again suggesting that associative/source memory may be among the first to be negatively affected by ageing. Additionally, increased activity in older adults was observed for associative and source memory, which may suggest that additional attentional resources are being recruited in older adults in an attempt to produce comparable results to those of young. When using the CRUNCH model as a guide, based on the observed scalp-recorded activity and behavioural accuracies, the results may suggest that the False Memory task is the simplest, followed by the VPAc task, with the Opposition task as the most difficult for older adults. This may be the case as, firstly; the False Memory task showed no behavioural differences along with no overactivations for older adults. Secondly, the VPAc task again revealed increased electrical activations but poorer behavioural performance in older adults, indicating that this task was more difficult than the False Memory task. Finally, as the Opposition task showed overactivations, along with the greatest behavioural differences, this may imply that this was the most difficult task for older adults to perform. However, the increased activity for associative and source memory was observed for a small number of conditions and thus is in need of more investigation. Therefore, it may be of interest to examine whether other tasks assessing source memory will show a similar pattern, providing additional valuable information on source memory and determining if source memory deficits are present across different stimulus domains. This is carried out in the next chapter.

5

Chapter V

Event-related potentials may reflect age-related performance decrements and compensatory cortical recruitment in source memory tasks.

5.1 Introduction

In the previous chapter, overactivations were found in older adults on an associative/episodic memory task (VPAc) and on a source memory task (Opposition) with most age-related behavioural differences on the source memory task (see Chapters 1, 3 and 4 for discussion on the decline of source memory in ageing). These results may suggest that the source memory task was the most difficult for the older adults, which coincides with findings from previous researchers suggesting that source memory declines with ageing (Siedlecki et al., 2005; Spencer & Raz, 1994). There are many models which attempt to explain the decline seen in memory due to the ageing process which can also account for the source memory decline seen in ageing. These include Jacoby's Capture Model (Jacoby, Bishara, et al., 2005), Naveh-Benjamin's Association Deficit Hypothesis (Naveh-Benjamin et al., 2003), Slotnick's Misrecollection Hypothesis (Dodson, Bawa, & Slotnick, 2007) and Johnson's Source Monitoring Framework (Hashtroudi, Johnson, & Chrosniak, 1989); (see Chapter 1 for full discussion of these). Here, the aim is to investigate if source memory can be assessed more accurately with the use of a new task, if a decline can be identified via a self-report questionnaire and if any compensatory recruitment occurs in older adults to alleviate performance decline in source memory tasks, as suggested by the CRUNCH (Reuter-Lorenz & Cappell, 2008) and PASA models (S. W. Davis et al., 2008).

The Opposition task, as discussed previously, measures a person's ability to judge the timing of when an item was acquired. This function of the task can be measured as new and old items are repeated at different times during the test phase using a lag procedure (Jennings & Jacoby, 1997). Therefore, an incorrect judgement of a repeated new item is likely to have been caused by a discrepancy in one's time estimation, which is a function of the right dorsolateral pre-frontal cortex (Jones et al., 2004). As the pre-frontal cortex is a necessary component in source memory (Craik et al., 1990; Janowsky et al., 1989; Mitchell & Johnson, 2009), this means that various regions of the brain are not being recruited in the use of the Opposition task (e.g. visual, auditory, etc.). This led to the development of a new task engaging additional regions of the brain, with the intention of allowing for a more accurate and realistic measurement, and providing further valuable information on the nature of source memory decline in ageing. This also led to the creation of a Source Memory Questionnaire (SMQ) based on subsets of the Cognitive Failures Questionnaire (Broadbent et al., 1982) and the revised Everyday Memory Questionnaire (Royle & Lincoln, 2008) in order to determine if subtle source memory differences could be identified via measures of self-report.

The Where-Who-What (WWW) task was designed to draw on the real life situation of *where* you were, *who* you met, and *what* they said to you. This task provides participants with three different elements (a location, a face, and a word), thus providing three contextual features. Therefore, this task engages different material specific areas of the brain such as the perirhinal cortex for spatial memory, which allows for recognition of a location (Winters et al., 2004), the fusiform face area for processing faces (Kanwisher et al., 1997), and Heschl's gyrus and superior temporal gyrus in the auditory cortex which specialises in processing auditory words (K. C. Harris et al., 2009). Previous studies have shown an age-related decline in spatial memory, where older adults had more difficulty with the retrieval of spatial information when compared to young adults (Cansino et al., 2013; Uttl & Graf, 1993). The ageing process also appears to affect one’s ability to recognise faces, as older adults are more impaired than younger at identifying faces they have previously studied (Cabeza et al., 1997; Grady et al., 1994; Pfütze, Sommer, & Schweinberger, 2002). In addition, it has been found that older adults who have a reduction in gray matter in the auditory cortex can have more difficulty when asked to distinguish between auditory words (K. C. Harris et al., 2009). Older adults have also been shown to be more impaired on identification of face-scene pairs (Dennis, Hayes, et al., 2008) and were slower at matching the correct face to a location (Grady et al., 1994). However, there has been no task measuring memory for the source of a location, a face and a word together. This task should draw on many material specific regions of the brain, along with the pre-frontal cortex and hippocampal formation responsible for source memory (Craik et al., 1990; Janowsky et al., 1989). As older adults have been found to be impaired on recognising spatial locations, faces and words in separate studies, this task should prove to be a useful measure of source memory decline in ageing.

The current study used a range of control tasks measuring estimates of IQ, self-reports of cognitive failures, working memory, short-term memory and a Source Memory Questionnaire. The main purpose of this study was to examine any age-related differences in source memory and the associated electrophysiology, using the Opposition and WWW tasks. In addition, this study provides insight into whether this novel task is a good measure of source memory which can be used to broaden source memory knowledge. It is also hypothesised that the older adults will be no more impaired than young on estimates of IQ, working memory or self-report of cognitive failures. However, it is expected that the young adults will surpass the older on short-term memory, the Source Memory Questionnaire and each of the source memory tasks behaviourally. It is also anticipated that an age-related difference will be identified in scalp-recorded activity and in the distribution in scalp topographies whereby additional cortical recruitment can be seen in older adults despite poorer behavioural performance. In addition, correlations will be carried out across the behavioural performances on the Opposition and WWW tasks, and it is predicted that these tasks will share a positive relationship as both purport to measure source memory. Furthermore, it is expected that a negative correlation will be found between the source memory tasks and the Source

Memory Questionnaire as it is anticipated that the questionnaire measures subtle changes in self-reports of source memory.

5.2 Method

5.2.1 Participants

This experiment employed 30 participants divided evenly into two age groups, young (18-30 years, mean age = 23.33) and older adults (55+ years, mean age = 68.73). Both groups consisted of 8 female and 13 right handed participants. All participants reported that their vision was normal or corrected-to-normal and that they were free from any memory or mental impairments. Written informed consent was obtained from each participant before commencing the experiment (Appendix H) and each completed a series of control tasks, as well as two computer-based memory tasks while electrophysiology was recorded. This study was carried out in accordance with the Ethical Standards of the American Psychological Association (APA) and the Declaration of Helsinki (World Medical Association Inc.), and was approved by the NUI Maynooth ethics committee.

5.2.2 Apparatus

5.2.2.1 Control Tasks.

The control tasks used in this experiment consisted of a NART, a Digit Span, a CFQ, a Source Memory Questionnaire and a RAVLT as per the descriptions set out in the Methods Chapter 2 (see section 2.3).

5.2.2.2 Opposition Task.

The Opposition task, developed by Jennings and Jacoby (1997) was conducted as per instructions in the Methods Chapter (see section 2.4.2).

5.2.2.3 Where-Who-What Task (WWW).

The WWW (as discussed in Methods chapter, section 2.4.5) measures a person's ability to recall where they were, who they met and what was said to them.

5.2.3 Design

5.2.3.1 Control Tasks.

Discussions of the designs for the RAVLT (2.3.2.1), the NART (2.3.3.2), the Digit Span (2.3.4.2), the CFQ (2.3.5.2) and the Source Memory questionnaire (2.3.6.2) are covered in Chapter 2 (see relevant sections).

5.2.3.2 Opposition Task.

Chapter 2 discusses the design of the Opposition task (see section 2.4.2.2).

5.2.3.3 WWW.

The design of the WWW task is as described in Chapter 2 (section 2.4.5.2).

5.2.4 Procedure

The participants were briefed and informed that they would be participating in a two hour experiment which involved completing two computer-based memory tasks while electrophysiology was recorded. All participants were required to read and sign a consent form and were informed that they could exit the experiment at any stage if they wished. Participants completed the control tasks first and were then prepared for the EEG which followed the procedure as described in the Methods Chapter (section 2.5.5). Upon preparation, the participants completed the counterbalanced computer-based memory tasks. All data from the experiment were made anonymous using participant

ID numbers, and were kept confidential and separate from the consent forms which contained no information which could identify individual participants.

5.2.3 Data Analysis

All outliers were removed from both the behavioural and electrophysiological data; the IQR was subtracted from the first quarter and added to the third quarter and any points of data outside of these limits were then removed. The data from the Opposition task and WWW task were analysed using Mixed Factorial ANOVAs for accuracy and response times (see sections 2.4.2.2 and 2.4.5.2 respectively for scoring). Any further examinations were made using independent t-tests for both accuracy and response times, and Bonferroni-corrected dependent t-tests for accuracy only. The RAVLT was analysed using Mixed Factorial ANOVAs; the NART and Digit Span were examined with MANOVAs; and the CFQ and Source Memory Questionnaire were investigated using one-way between groups ANOVAs. Any further investigation employed independent and Bonferroni-corrected dependent t-tests. Bivariate Pearson correlations were conducted between the behavioural results on the computer-based source memory tasks and the source memory questionnaire.

EEG data were pre-processed, filtered, artifact reduced and segmented as described in section 2.5.5.3. The stimulus presentation acted as a trigger allowing for stimulus-locked ERPs to be obtained. The data for the Opposition task generated six conditional ERPs (target stimuli at lags 0, 4, or 16; distractor stimuli at lags 0, 4, or 16). Due to a low number of errors, only ERPs for correct responses were examined.

Analysis of EEG for the WWW task resulted in six separate conditional ERPs (true/studied stimuli with background-face, background-word, or face-word; and false/recombined stimuli with background-face, background-word, or face-word).

Again, only ERPs where correct responses were made were analysed due to low error rates.

Averaging across the groups and conditions generated an overall grand-mean waveform which allowed for clear inspection of ERP components of interest at each channel, and the process for extraction of mean amplitudes and the latencies of peak amplitudes is covered in Chapter 2 (section 2.5.5.3). Mixed Factorial ANOVAs were used to analyse the mean amplitudes and latencies peak amplitudes of the ERPs for the Opposition task and the WWW task. Further, Bonferroni-corrected dependent t-tests and independent t-tests were conducted to assess differences within and between the groups. P1 (80-160ms), P2 (180-250ms) and P3 (220-320ms) components were identified and examined for the Opposition task, while P1 (100-170ms), N2 (170-340ms), P2 (170-340ms) and P3 (180-570ms) components were investigated for the WWW task. Differences in the distribution of scalp topographies were also examined at between 150ms and 250 ms (i.e. the P2 latency window) for both tasks.

5.3 Results

The results are discussed below in terms of the control tasks, and accuracy, response times and electrophysiology on the computer-based memory tasks.

5.3.1 Control Tasks

See Table 5.1 for the means and standard deviations for each trial on each control task, and see Figure 5.1 depicting graphs of the results for each of the control tasks.

5.3.1.1 National Adults Reading Test (NART).

As can be seen in Figure 5.1a, a one-way between groups MANOVA revealed no differences between the groups for Predicted Full Scale IQ [F (1, 28) = .003, $p > 0.05$, partial eta squared = .0001], Predicted Verbal IQ [F (1, 28) = .004, $p > 0.05$, partial eta squared = .0001] or Predicted Performance IQ [F (1, 28) = .002, $p > 0.05$, partial eta squared = .0001], indicating that both groups had similar estimates of IQ.

5.3.1.2 Digit Span.

A one-way between groups MANOVA revealed no difference between the groups for Forward Digit Span [F (1, 27) = 2.433, $p > 0.05$, partial eta squared = .083], but a difference was seen for Backwards Digit Span [F (1, 27) = 4.498, $p < 0.05$, partial eta squared = .143] and Total Digit Span [F (1, 27) = 4.244, $p < 0.05$, partial eta squared = .136] where the young group performed better on measures of working memory (Figure 5.1b).

5.3.1.3 Cognitive Failures Questionnaire (CFQ).

No difference was found between the groups on CFQ scores using a one way between groups ANOVA [F (1, 27) = .313, $p > 0.05$], which indicated that the young [mean = 34.73, SD = 10.67] and older groups [mean = 36.86, SD = 9.71] did not differ on self reports of everyday cognitive failures (see Figure 5.1c).

5.3.1.4 Source Memory Questionnaire.

A one way between groups ANOVA showed no difference between the young [26.93, SD = 10.76] and older groups [mean = 28.54, SD = 8.43] (Figure 5.1d) on self reports of source memory failures [F (1, 27) = .189, $p > 0.05$].

5.3.1.5 Rey Auditory Verbal Learning Test (RAVLT).

A 2×5 Mixed Factorial ANOVA revealed a significant main effect of Trials A1-A5 [F (4, 104) = 112.592, $p < 0.01$] whereby recall increased from A1 to A5 (see Figure 5.1e), of Group [F (1, 26) = 32.675, $p < 0.01$] where the young had a better recall than the older adults, and an interaction effect of Trials by Group [F (4, 104) = 3.289, $p < 0.01$]. Independent t-tests revealed that the young group had significantly better recall for Trials A1 [t (28) = 4.158, $p < 0.01$], A2 [t (28) = 6.385, $p < 0.01$], A3 [t (28) = 5.364, $p < 0.01$], A4 [t (28) = 4.319, $p < 0.01$] and A5 [t (28) = 5.488, $p < 0.01$] (see Figure 5.1e).

No significant main effect was found for Proactive Interference using a 2×2 Mixed Factorial ANOVA [F (1, 28) = 2.563, $p > 0.05$] but a Group effect was seen [F (1, 28) = 24.052, $p < 0.01$] with the young having a higher recall (Figure, 5.1e). No interaction was seen between Proactive Interference and Group [F (1, 28) = .285, $p > 0.05$]. Independent t-tests showed that the young group performed better on Trials A1 [t

($28) = 4.158$, $p < 0.01$] and B [$t\ (28) = 3.867$, $p < 0.01$]. Bonferroni-corrected dependent t-tests showed no differences between Trials A1 and B for the young or older group [all $t < 1.740$, all $p > 0.05$].

A 2×2 Mixed Factorial ANOVA showed that the main effects of Retroactive Interference [$F\ (1, 27) = 26.511$, $p < 0.01$] and Group [$F\ (1, 27) = 40.572$] = $p < 0.01$] were significant, with higher recall on Trial A5 compared to A6 with the older adults recalling fewer words (see Figure 5.1e). No significant interaction effect was seen for Retroactive Interference by Group [$F\ (1, 27) = .558$, $p > 0.05$]. To further investigate these differences independent t-tests revealed that the young had higher recall for A5 [$t\ (28) = 5.488$, $p < 0.01$] and A6 [$t\ (27) = 5.597$, $p < 0.01$], while Bonferroni-corrected dependent t-tests showed that recall was better on Trial A5 compared to A6 for both the young [$t\ (14) = 4.413$, $p < 0.01$] and older [$t\ (14) = 3.322$, $p < 0.01$] groups.

The 2×2 Mixed Factorial ANOVA carried out on Trials A6 and A7 found main effects for Delay [$F\ (1, 25) = 9.571$, $p < 0.01$], where recall declined from A6 to A7, and Group [$F\ (1, 25) = 27.029$, $p < 0.01$], where the young group had better recall (Figure 5.1e). No significant interaction was found for Delay and Group [$F\ (1, 25) = .044$, $p > 0.05$]. As stated above, independent t-tests showed that the young group showed higher recall for A6 [$t\ (27) = 5.597$, $p < 0.01$] and again for A7 [$t\ (26) = 4.900$, $p < 0.01$]. The difference between Trials A6 and A7 for the young group was rendered non-significant by Bonferroni-correction [$t\ (14) = 2.347$, $p > 0.05$] and no significant difference was seen for the older group [$t\ (11) = 2.030$, $p > 0.05$].

Table 5.1: Means and standard deviations for the NART based predicted IQs, the Digit Span, the Cognitive Failures Questionnaire, the Source Memory Questionnaire and the RAVLT.

	Young (N = 15)		Older (N = 15)	
	Mean	SD	Mean	SD
Predicted Full Scale IQ	113.00	9.65	113.20	10.16
Predicted Verbal IQ	111.13	9.00	111.33	9.12
Predicted Performance IQ	112.07	8.77	112.20	8.95
Forward Digit Span	12.60	1.50	11.73	2.05
Backward Digit Span	7.67	1.88	6.36	1.39
Total Digit Span	20.27	2.94	18.47	3.70
CFQ	34.73	10.67	36.86	9.71
Source Memory Questionnaire	26.93	10.76	28.54	8.43
RAVLT A1	7.13	1.46	4.80	1.61
RAVLT A2	10.46	0.88	7.07	1.83
RAVLT A3	12.47	1.46	8.80	2.21
RAVLT A4	12.80	1.82	9.53	2.29
RAVLT A5	13.67	1.18	9.40	2.77
RAVLT B	6.73	2.37	4.00	1.36
RAVLT A6	12.07	1.87	7.64	2.37
RAVLT A7	11.27	1.91	6.23	3.42

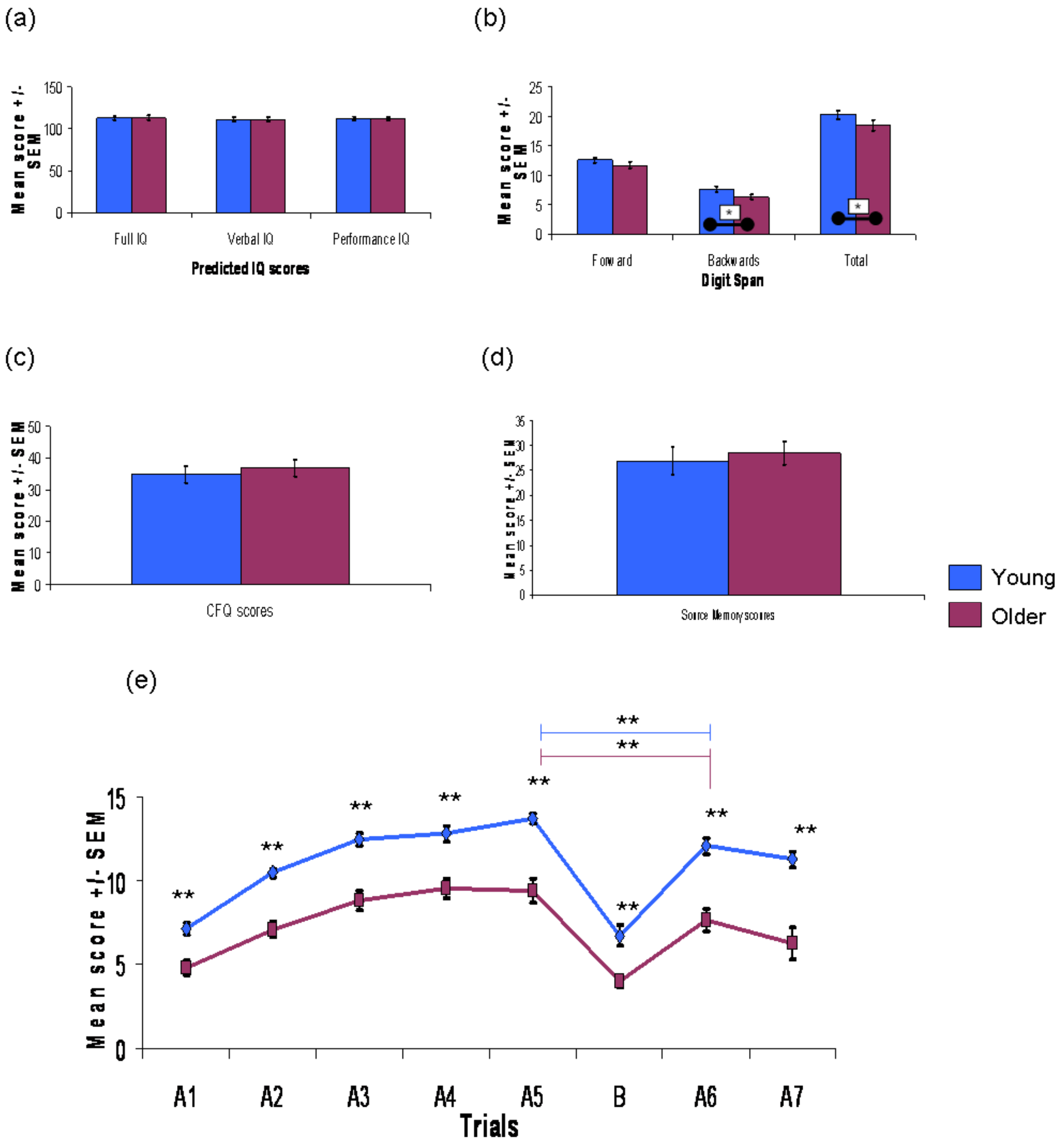


Figure 5.1: (a) Predicted Full scale, Verbal and Performance IQs +/- SEM based on the NART for young and older adults, (b) Forward, Backward and Total Digit Span +/- SEM for young and older adults, (c) CFQ score +/- SEM for young and older adults, (d) Source Memory Questionnaire score +/- SEM for young and older adults, (e) RAVLT accuracy scores on Trials A1-A7 +/- SEM for young and older adults ($p < 0.05$, **$p < 0.01$)*

5.3.2 The Opposition Task

5.3.2.1 Accuracy.

A 2×3×2 Mixed Factorial ANOVA showed that there was no main effect for Word Type. However, main effects were found for Lag [F (2, 52) = 12.151, $p < 0.05$] where accuracy generally decreased across the lags, and Group [F (1, 26) = 13.897, $p < 0.01$], where the older group performed with a lower accuracy (see Figure 5.2). Significant interactions were found for Word Type and Group [F (1, 26) = 4.330, $p < 0.05$], Lag by Group [F (2, 52) = 5.618, $p < 0.01$], Word Type by Lag [F (2, 52) = 23.421, $p < 0.01$] and a three-way interaction was seen for Word Type × Lag × Group [F (2, 52) = 4.512, $p < 0.05$].

To further examine where in these data differences lay, both independent and Bonferroni-corrected dependent t-tests were conducted. It was found that the young group showed higher accuracies for Distractor Lag 4 words [mean = 8.13, SD = 2.00] than older adults [mean = 5.64, SD = 2.56; t (27) = 2.933, $p < 0.01$] and for Distractor Lag 16 words: young [mean = 7.93, SD = 1.75] older [mean = 5.07, SD = 2.34; t (27) = 3.750, $p < 0.01$].

In addition, Bonferroni-corrected dependent t-tests revealed that the young group had statistically higher accuracies for Distractor Lag 0 words [mean = 9.57, SD = 0.65] compared to both Lag 4 words [mean = 8.13, SD = 2.00; t (13) = 3.019, $p < 0.05$], and Lag 16 words [mean = 7.93, SD = 1.75; t (13) = 3.387, $p < 0.05$]. For older adults, significant differences were found within Distractor Lag 0 words [mean = 9.29, SD = 0.83] and Lag 4 words [mean = 5.64, SD = 2.56; t (13) = 5.824, $p < 0.01$], and Distractor Lag 0 words [mean = 9.29, SD = 0.83] and Lag 16 words [mean = 5.07, SD = 2.34; t (13) = 6.593, $p < 0.01$] where accuracies were higher for Lag 0 words in both comparisons (see Figure 5.2).

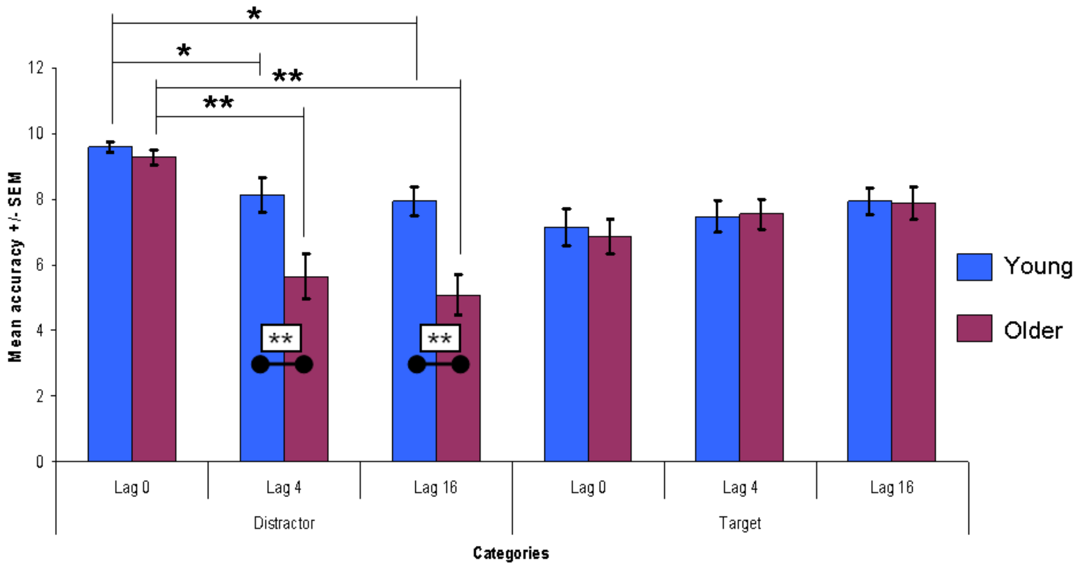


Figure 5.2: Mean total accuracy +/- SEM for at Lags 0, 4 and 16 for Distractor and Target words for young and older adults on the Opposition task
($p < 0.05$, **$p < 0.01$)*

5.3.2.2 Response Times for Correct Responses.

A 2×3×2 Mixed Factorial ANOVA was carried out on response times when a correct response was made, and significant main effects were found for Word Type [F (1, 25) = 40.591, p < 0.01], where responses were faster for Target words, Lag [F (2, 50) = 43.389, p < 0.01], where response times increased across the lags, and Group [F (1, 25) = 33.002, p < 0.01] with the young group responding faster than the older (see Figure 5.3). In addition, significant interactions were found between Word Type and Group [F (1, 25) = 12.640, p < 0.01], Lag and Group [F (2, 50) = 4.406, p < 0.05], Word Type and Lag [F (2, 50) = 7.702, p < 0.01] and Word Type, Lag and Group [F (2, 50) = 3.723, p < 0.05].

Independent t-tests showed that the young group responded faster than the older for each condition: Distractor Lag 0, young [mean = 603.92, SD = 113.21] older [mean = 863.31, SD = 184.06; t (27) = -4.533, p < 0.01], Distractor Lag 4, young [mean = 960.93, SD = 246.01] older [mean = 1740.11, SD = 535.31; t (26) = -4.949, p < 0.01], Distractor Lag 16 young [mean = 978.57, SD = 179.20] older [mean = 1732.58, SD = 642.71; t (26) = -4.228, p < 0.01], Target Lag 0 young [mean = 552.77, SD = 103.28] older [mean = 859.91, SD = 225.74; t (28) = -4.792, p < 0.01] Target Lag 4 young [mean = 872.80, SD = 169.38] older [mean = 1269.28, SD = 299.24; t (28) = -4.466, p < 0.01] and Target Lag 16 young [mean = 832.27, SD = 242.03] older [mean = 1168.38, SD = 387.25] [t (28) = -2.851, p < 0.01].

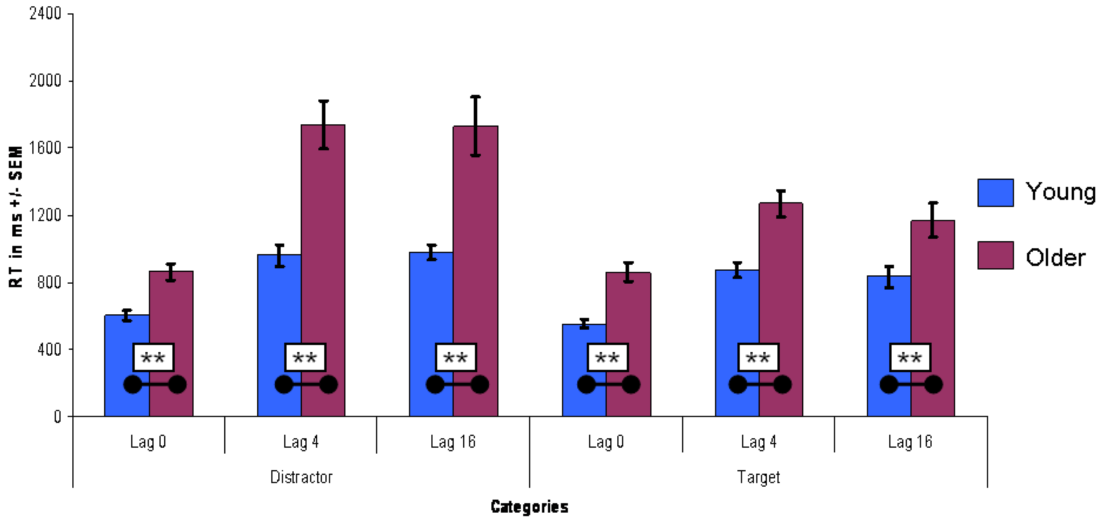


*Figure 5.3: Mean response times in ms +/- SEM for a correct response on Distractor and Target words at Lags 0, 4 and 16 for young and older adults on the Opposition task (*p < 0.05, **p < 0.01)*

5.3.2.4 Electrophysiological Results.

P1, P2 and P3b components were identified in the Opposition task.

5.3.2.4.1 P1 component (80-160ms)

For the P1 component (80-160ms) at left posterior electrode PO3, no main effect was seen for Word Type or Group; however a significant main effect was seen for Lag [F (2, 50) = 13.158, p < 0.05] where mean amplitude increased on a selection of conditions. A statistically significant interaction was seen for Word Type and Group [F (1, 25) = 12.572, $p < 0.01$], but no other significant interactions were seen for Lag and Group, Word Type and Lag, or Word Type, Lag and Group. An independent t-test revealed that the young group had a significantly larger mean amplitude on the P1 component for Target Lag 4 words at channel PO3 [t (27) = 2.572, $p < 0.05$] (see Figure 5.4a highlighted orange). No other between groups differences were seen [all $t < 1.793$, all $p > 0.05$].

The 2×3×2 Mixed Factorial ANOVA on the P1 component at right posterior PO4 revealed no significant main effects for Word Type or Lag, but a Group effect was seen [F (1, 26) = 7.257, $p < 0.05$] with the older group showing lower mean amplitudes on a selection of conditions. The interactions of Word Type by Group, Lag by Group, Word Type and Lag, and Word Type × Lag × Group were non-significant. Between group differences were seen for Distractor Lag 16 [t (26) = 2.855, $p < 0.01$], Target Lag 4 [t (27) = 3.090, $p < 0.01$] and Target Lag 16 words [t (26) = 2.506, $p < 0.05$] where the young group showed larger mean amplitudes (see Figure 5.4c, d and f, highlighted orange). No other between group differences were significant [all $t < 1.798$, all $p > 0.05$].

5.3.2.4.2 P2 component (180-250ms)

For the P2 component (150-250ms) at left frontal electrode FC1 there was no statistically significant effect for Word Type or Lag. However, the 2×3×2 ANOVA revealed a significant effect for Group [F (1, 24) = 5.308, $p < 0.01$], where the older group showed larger mean amplitudes on a selection of the conditions. Each interaction was non-significant: Word Type by Group, Lag and Group, Word Type × Lag, and Word Type by Lag by Group were revealed as non-significant. Independent t-tests found a significant difference between the groups for Distractor Lag 0 [$t(27) = -2.373$, $p < 0.05$], Target Lag 4 [$t(27) = -3.347$, $p < 0.01$] and Target Lag 16 [$t(27) = -2.402$, $p < 0.05$] where the older adults had larger mean amplitudes for each comparison (see Figure 5.5a, b and c, highlighted green). No other between group differences were seen [all $t < 1.544$, all $p < 0.05$].

The main effects of Word Type and Lag for the P2 component at right frontal channel FC2 were revealed as non-significant. However, a main effect of Group was seen [$F(1, 25) = 8.846$, $p < 0.01$] where the older adults had greater positivity for a selection of conditions. No significant effects were seen for the interactions of Word Type by Group, Lag and Group, Word Type by Lag, or Word Type × Lag × Group. Older adults had significantly larger mean amplitudes for the P2 component than the young adults at FC2 for Distractor Lag 0 [$t(27) = -2.080$, $p < 0.05$], Target Lag 4 [$t(27) = -4.745$, $p < 0.01$] and Target Lag 16 words [$t(27) = -3.135$, $p < 0.01$] indicating that more activity was occurring for the older adults (see Figure 5.5d, e and f, highlighted green). Independent t-tests revealed no other between group differences [all $t < 1.937$, all $p > 0.05$].

5.3.2.4.3 P3b component (220-320ms)

A 2×3×2 ANOVA conducted on the P3b (220-320ms) component at left posterior PO3 revealed no significant main effects for Word Type, Lag or Group. In addition, the interactions of Word Type by Group, Lag and Group, Word Type × Lag and Word Type by Lag by Group were non-significant. Independent t-tests found a significant difference between the young and older group on Distractor Lag 0 words [$t(24) = -2.217$, $p < 0.05$] where the older group showed a larger mean amplitude (see

Figure 5.4b, highlighted blue). However, no other between groups differences were seen [all $t < 1.589$, all $p > 0.05$].

Analyses of the P3b component at right frontal PO4 using a 2×3×2 Mixed Factorial ANOVA found that the main effects of Word Type and Lag were non-significant. However, a Group effect was found [$F(1, 27) = 5.505$, $p < 0.05$] where the young group revealed higher mean amplitudes on a selection of conditions. The interaction of Lag by Group was statistically significant but each of the other interactions were non-significant: Word Type and Group; Word Type and Lag; and Word Type, Lag and Group. Independent t-tests revealed significant group differences for Target Lag 16 words [$t(27) = 3.520$, $p < 0.01$], Distractor Lag 4 [$t(24) = 2.232$, $p < 0.05$] and Distractor Lag 16 [$t(27) = 2.567$, $p < 0.05$] where the young group had larger mean amplitudes (see Figure 5.4 d, e and f, highlighted blue). No other significant between group differences were seen [all $t < 1.601$, all $p > 0.05$].

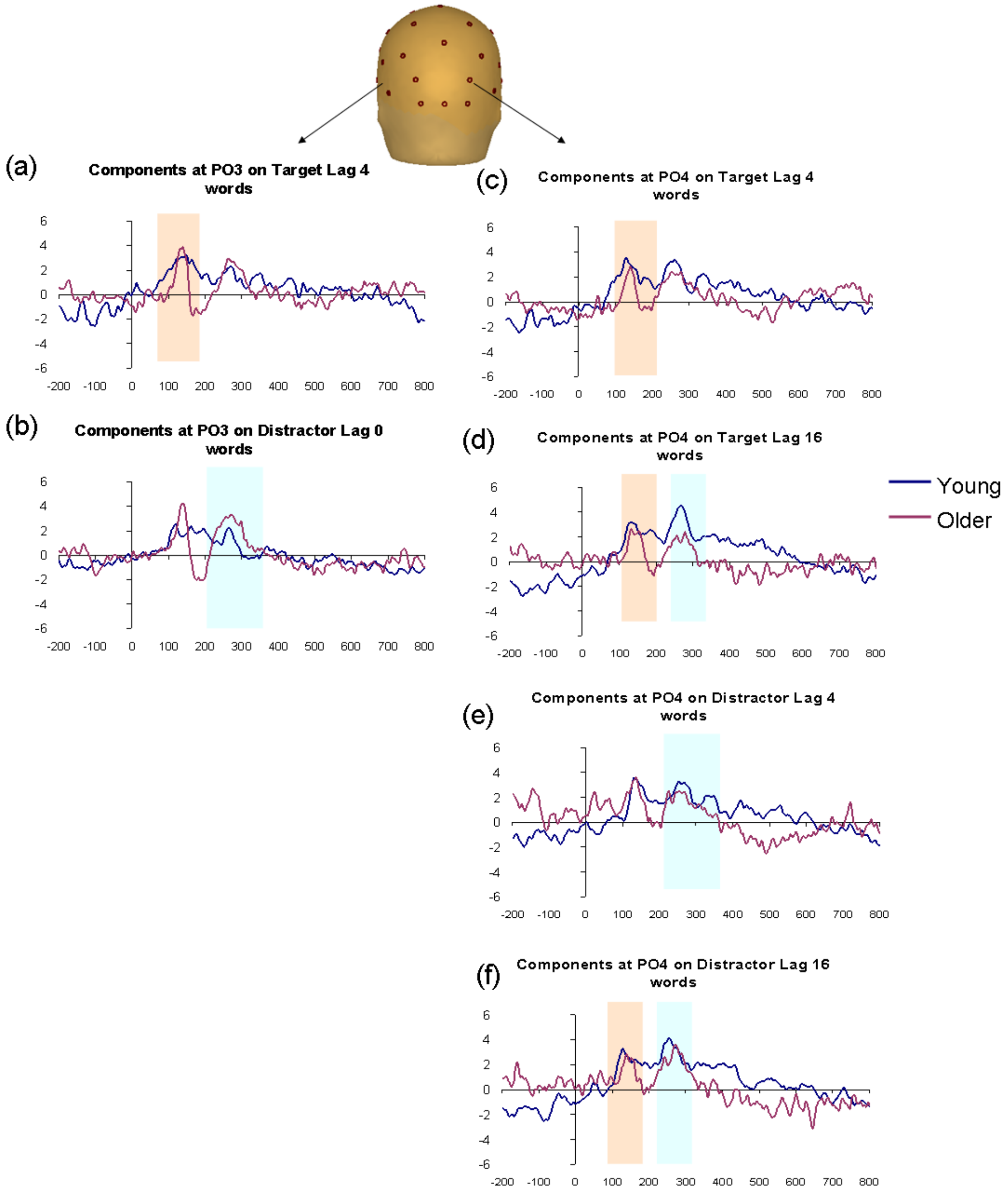


Figure 5.4: P1 (highlighted orange) and P3b (highlighted blue) components for young and older adults on the Opposition task at channel PO3 for (a) Target Lag 0, (b) Distractor Lag 0 and (c) Distractor Lag 4. P1 and P3b components for young and older adults at channel PO4 for (d) Target Lag 4, (e) Target Lag 16, (f) Distractor Lag 4 and (g) Distractor Lag 16.

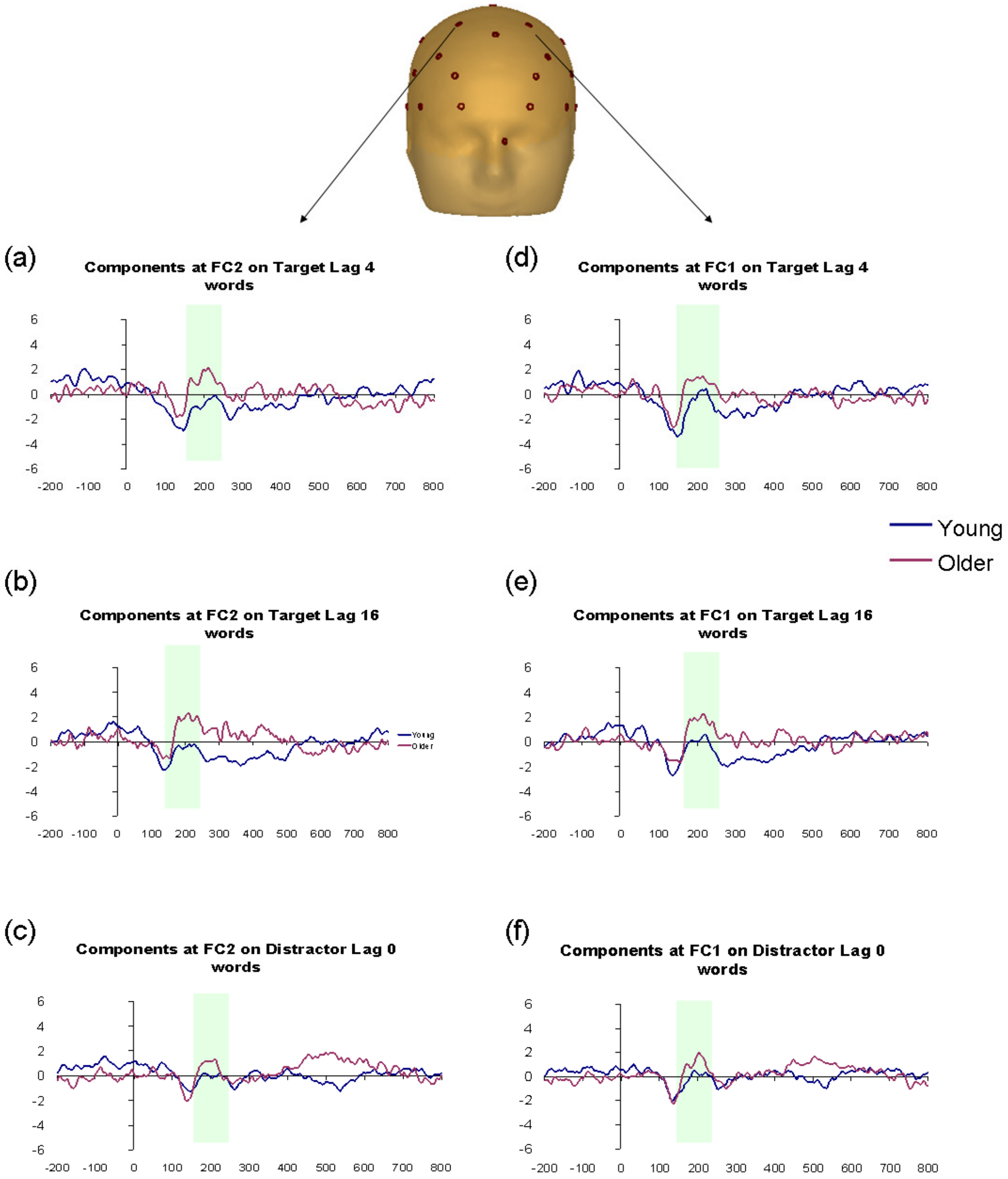


Figure 5.5: P2 components (highlighted green) for young and older adults on the Opposition task at channel FC2 for (a) Target Lag 4, (b) Target Lag 16 and (c) Distractor Lag 0. P2 components for young and older adults on the Opposition task at FC 1 for (d) Target Lag 0, (e) Target Lag 16 and (f) Distractor Lag 0.

The scalp topographies below (Figure 5.6) reveal different scalp activations between the two groups for each condition at approximately 200ms, whereby components are maximal over posterior scalp for the young adults, but peak over more anterior areas in the older adults. This difference in pattern is more obvious for the longer lag lengths of 4 and 16 in both Distractor and Target conditions.

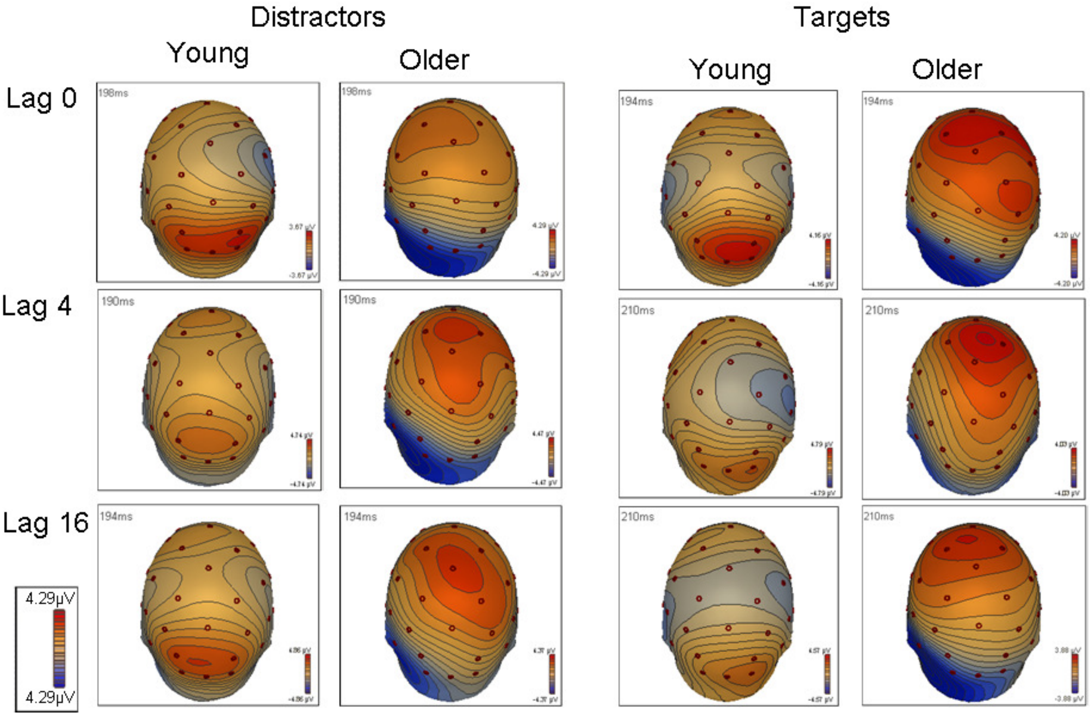


Figure 5.6: Scalp topographies for young and older adults on the Opposition task

5.3.3 The Where-Who-What (WWW) Task

5.3.3.1 Accuracy.

A 2×3×2 Mixed Factorial ANOVA was conducted on accuracy scores on the WWW task. Statistically significant main effects were found for Stimulus Type (i.e. True or False) [F (1, 24) = 9.965, $p < 0.01$], Pair Type (i.e. background-words, BW; background-face, BF; face-word, FW) [F (2, 48) = 5.344, $p < 0.01$] and Group [F (1, 24) = 28.302, $p < 0.01$] where accuracy was higher for True stimuli on a selection of pairs and higher for the young group (see Figure 5.8). The interactions of Stimulus Type by Group, Pair Type by Group, and Stimulus Type by Pair Type by Group were found to be non-significant. However, the interaction of Stimulus Type and Pair Type [F (2, 48)

= 7.485, $p < 0.01$] was statistically significant indicating that accuracy at identifying pair type was affected by whether the pair was true or false.

Independent t-tests were conducted to determine where in these data between group differences lay. The young group had a significantly higher accuracy for each True Pair stimulus compared to the older group; BF: young [mean = 6.2, SD = 1.66], older [mean = 4.57, SD = 1.74; $t (27) = 2.581$, $p < 0.05$]; BW: young [mean = 5.46, SD = 0.97] older [mean = 4.27, SD = 1.16; $t (26) = 2.928$, $p < 0.01$]; and FW: young [mean = 6.69, SD = 0.85] older [mean = 4.93, SD = 1.58; $t (26) = 3.580$, $p < 0.01$]. The older group showed lower accuracy scores than the young group for each False pair: BF: young [mean = 7.27, SD = 0.59] older [mean = 5.73, SD = 1.91; $t (28) = 2.973$, $p < 0.01$]; BW: young [mean = 6.67, SD = 1.05] older [mean = 5.50, SD = 1.22; $t (27) = 2.764$, $p < 0.05$]; and FW: young [mean = 5.67, SD = 1.35] older [mean = 4.67, SD = 1.23; $t (28) = 2.121$, $p < 0.05$].

Bonferroni-corrected dependent t-tests only revealed within group differences for the young group. Statistically significant effects were seen within True BW [mean = 5.46, SD = 0.97] and FW pairs [mean = 6.69, SD = 0.85; $t (11) = -3.463$, $p < 0.05$] where accuracy was higher for FW pairs. Statistically significant differences were also seen within False BF [mean = 7.27, SD = 0.59] and FW pairs [mean = 5.67, SD = 1.35; $t (14) = 4.989$, $p < 0.01$], and False BW [mean = 6.67, SD = 1.05] and FW pairs [mean = 5.67, SD = 1.35; $t (14) = 4.090$, $p < 0.05$] were accuracy was lower on FW pairs in both comparisons. No other significant within group differences were significant [all $t < 2.086$, all $p > 0.05$].

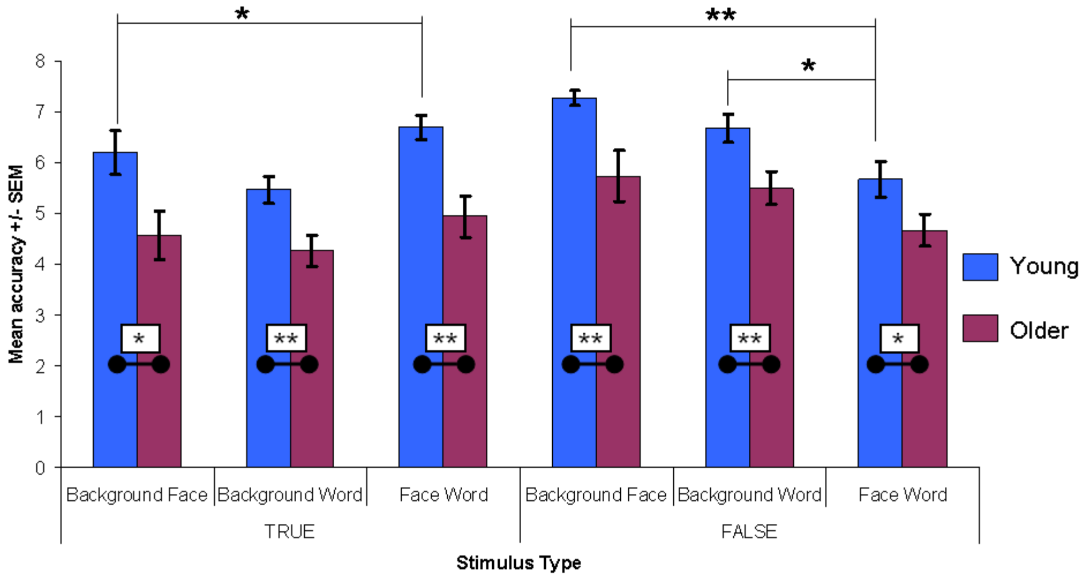


*Figure 5.7: Mean total accuracy +/- SEM for True and False Background-Face, Background-Word and Face-Word Stimuli for young and older adults on the WWW task (*p < 0.05, **p < 0.01)*

5.3.3.2 Response Times for Correct Responses.

A 2×3×2 Mixed Factorial ANOVA was carried out on response times for correct response and revealed no main effects for Stimulus Type or Pair Type. However, a main effect of Group [F (1, 22) = 16.805, p < 0.01] was seen, with the young group showing faster response times on a selection of stimuli (see Figure 5.8 below). The interaction of Pair Type and Group [F (2, 44) = 5.220, p < 0.01] was found to be significant, while the other interactions of Stimulus Type by Group, Stimulus Type and Pair Type, and Stimulus Type × Pair Type × Group were not statistically significant.

Between group differences were found for True BF pairs where the young group [mean = 1437.35, SD = 773.60] had a faster response time than the older [mean = 2520.15, SD = 781.81; t (25) = -3.597, p < 0.01]. The young group [mean = 1152.02, SD = 471.23] also had a quicker response times than the older [mean = 1887.54, SD = 982.91; t (27) = -2.539, p < 0.05] for True BW pairs. Older adults showed slower response times [mean = 2380.06, SD = 1206.41] than the young group [mean = 801.56, SD = 191.10; t (27) = -4.843, p < 0.01] for False BF pairs. No other between group differences were found [all t <1.609, all p > 0.05].

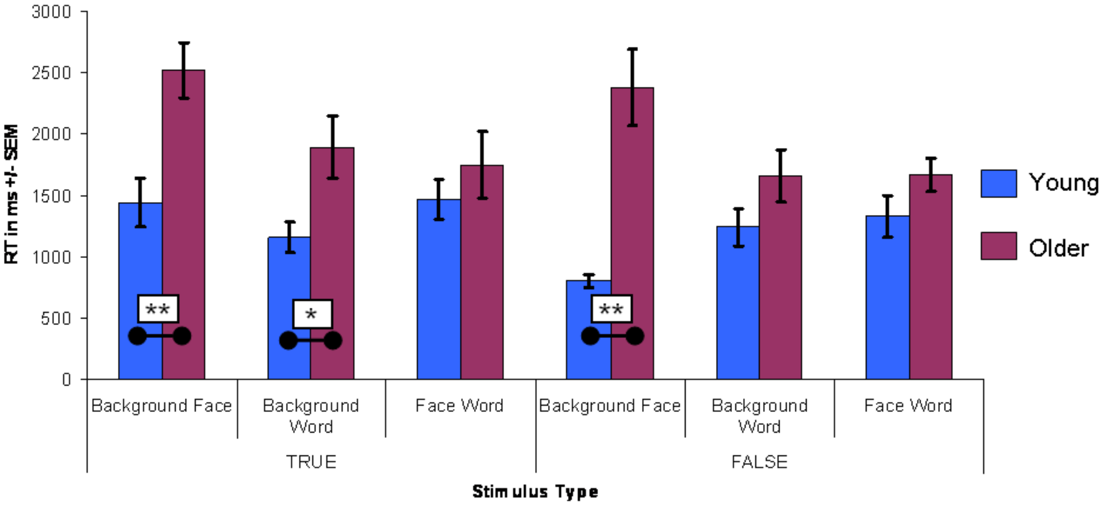


Figure 5.8: Mean response times in ms +/- SEM for correct responses to True and False Background-Face, Background-Word and Face-Word stimuli on the WWW task between young and older adults
*(*p < 0.05, **p < 0.01)*

5.3.3.4 Electrophysiological Results.

A late P1, N2, P2 and P3b components were examined in the WWW task.

5.3.3.4.1 P1 component (100-170ms)

A 2×3×2 Mixed Factorial ANOVA was carried out on the P1 component (100-170ms) at PO3 and revealed significant main effects of Stimulus Type [F (1, 22) = 22.006, p < 0.01], Pair Type [F (2, 44) = 3.774, p < 0.05] and Group [F (1, 22) = 6.706, p < 0.05] where there was larger positivity on a selection of True pairs and for the young group. The interactions of Stimulus Type and Group [F (1, 22) = 4.435, p < 0.01] and Stimulus Type and Pair Type [F (2, 44) = 25.679, p < 0.01] were also significant while the interactions of Pair Type × Group, and Stimulus Type × Pair Type × Group were non-significant. Independent t-tests showed that the young group had higher mean amplitudes than the older group on stimuli True BW [t (24) = 2.129, $p < 0.05$] and True FW [t (27) = 2.182, $p < 0.05$] (see Figure 5.9b and c, highlighted orange). No other between group differences were significant [all $t < 1.655$, all $p > 0.05$].

The P1 component at right posterior PO4 had a significant main effect of Stimulus Type [F (1, 24) = 21.780, $p < 0.01$] and Pair Type [F (2, 48) = 8.624, $p < 0.01$] where mean amplitudes were higher on a selection of True stimuli, but no Group effect was seen. There was a significant interaction of Stimulus Type and Pair Type [F (2, 48) = 21.371, $p < 0.01$]. However, the interactions of Stimulus Type by Group, Pair Type and Group, and Stimulus Type × Pair Type × Group were not statistically significant. Independent t-tests showed that the young group had larger mean amplitudes for True BW stimuli [t (27) = 2.785, $p < 0.01$] (Figure 5.9b, highlighted orange) but no other group differences were seen [all $t < 1.833$, all $p > 0.05$].

5.3.3.4.2 N2 component (170-340ms)

A 2×3×2 Mixed Factorial ANOVA was carried out on the N2 component (170-340ms) at channels left posterior P7 and right posterior N2 component at P7 had a significant main effects of Pair Type [F (2, 48) = 7.963, $p < 0.01$] with smaller mean amplitudes on a selection on pairs, and Group [F (1, 24) = 11.056, $p < 0.01$] where the older adults showed more negative electrical activity. However, no main effect of Stimulus Type was seen. The interactions of Stimulus Type by Group [F (1, 24) = 4.289, $p < 0.05$] and Stimulus Type by Pair Type [F (2, 48) = 5.289, $p < 0.01$] were significant but no significant effects were seen for the interactions of Pair Type by Group or Stimulus Type × Pair Type × Group. Independent t-tests revealed that the older adults had larger mean amplitudes on the N2 component at P7, indicating more negativity for each stimuli: True BF [t (26) = 2.882, $p < 0.01$], True BW [t (26) = 3.859, $p < 0.01$], True FW [t (27) = 2.897, $p < 0.01$], False BF [t (25) = 2.828, $p < 0.01$], False BW [t (26) = 2.562, $p < 0.05$] and False FW [t (27) = 2.398, $p < 0.05$] (Figure 5.10, highlighted green).

The 2×3×2 Mixed Factorial ANOVA carried out on the N2 at P8 found a significant main effect of Pair Type [F (2, 51) = 9.692, $p < 0.01$] and Group [F (1, 26) = 27.241, $p < 0.01$] where there was more negativity on a selection of stimuli and for the older adults. No main effect was seen for Stimulus Type. The interaction of Stimulus Type by Group [F (1, 26) = 10.531, $p < 0.01$] was significant, while the interactions of Pair Type and Group, Stimulus Type by Pair Type and Stimulus Type × Pair Type × Group were non-significant. Independent t-tests showed that the older adults had greater negativity than the young on each of the stimuli types: True BF [t (26) = 5.501, $p < 0.01$], True BW [t (27) = 3.849, $p < 0.01$], True FW [t (27) = 5.013, $p < 0.01$], False BF [t (27) = 3.952, $p < 0.01$], False BW [t (27) = 3.779, $p < 0.01$] and False FW [t (27) = 5.471, $p < 0.01$] (see Figure 5.9, highlighted green).

5.3.3.4.3 P2 component (170-340ms)

A 2×3×2 Mixed Factorial ANOVA was carried out on the P2 component (170-340ms) at right frontal channel FC1 and revealed no significant main effect of Pair Type. However, the main effects of Pair Type [F (2, 50) = 11.805, $p < 0.01$] and Group [F (1, 25) = 45.266, $p < 0.01$] were statistically significant. The only interaction which was significant was Pair Type × Group [F (1, 25) = 4.598, $p < 0.05$]; Stimulus Type × Group, Stimulus Type by Pair Type, and Stimulus Type × Pair Type × Group were revealed as non-significant. Independent t-tests revealed that the differences between the groups on each condition was statistically significant with the older group showing larger mean amplitudes (see Figure 5.11, highlighted green): True BF [$t (26) = -5.025$, $p < 0.01$], True BW [$t (27) = -4.171$, $p < 0.01$], True FW [$t (27) = -6.245$, $p < 0.01$], False BF [$t (27) = -4.283$, $p < 0.01$], False BW [$t (27) = -4.471$, $p < 0.01$] and False FW [$t (27) = -5.454$, $p < 0.01$].

Analyses on the P2 component at left frontal FC2 revealed that the main effect of Pair Type was not significant. However, the main effects of Stimulus Type [$F (2, 50) = 10.761$, $p < 0.01$] and Group [$F (1, 25) = 40.285$, $p < 0.01$] were statistically significant. Each of the interactions of the 2×3×2 ANOVA was revealed as non-significant. Independent t-tests showed that the older group had larger mean amplitudes than the young on the P2 component at FC2 for True BF [$t (26) = -5.286$, $p < 0.01$], True BW [$t (27) = -4.173$, $p < 0.01$], True FW [$t (27) = -6.049$, $p < 0.01$], False BF [$t (27) = -4.211$, $p < 0.01$] and False FW pairs [$t (27) = -5.804$, $p < 0.01$] (see Figure 5.11, highlighted green). However, on False BW pairs [$t (27) = 5.395$, $p < 0.01$] the young group had larger mean amplitudes.

5.3.3.4.4 P3b component (180-570ms)

A 2×3×2 Mixed Factorial ANOVA was performed on the P3b component (180-570ms) at left posterior PO3 and revealed significant main effects of Stimulus Type [$F (1, 26) = 10.424$, $p < 0.01$], Pair Type [$F (2, 52) = 8.108$, $p < 0.01$] and Group [$F (1, 26) = 18.426$, $p < 0.01$] where there was a larger mean amplitude on a selection of stimuli and for the young group. None of the interactions in the ANOVA reached statistical significance. Independent t-tests were conducted to determine where in these data differences existed. It was found that the young group had larger mean amplitudes for each stimulus type (see Figure 5.9, highlighted blue): True BF [$t (27) = 3.311$, $p < 0.01$], True BW [$t (26) = 4.368$, $p < 0.01$], True FW [$t (27) = 3.687$, $p < 0.01$], False BF [$t (27)$

= 3.091, $p < 0.01$], False BW [t (27) = 4.036, $p < 0.01$] and False FW [t (27) = 5.077, $p < 0.01$].

The P3b component at right posterior PO4 revealed a significant main effect of Stimulus Type [F (1, 20) = 4.631, $p < 0.05$] and Group [F (1, 20) = 58.365, $p < 0.01$] where a significant difference was seen within a selection of stimuli and electrical activity was larger for the young group compared to the older. However, no main effect was found for Pair Type. The interaction of Pair Type and Group [F (2, 40) = 10.384, $p < 0.01$] was the only interaction to yield a significant result. Independent t-tests revealed that for the conditions of True BF [t (21) = 9.656, $p < 0.01$], True BW [t (26) = 7.557, $p < 0.01$], True FW [t (27) = 4.154, $p < 0.01$], False BF [t (26) = 5.799, $p < 0.01$], False BW [t (27) = 4.775, $p < 0.01$] and False FW [t (27) = 3.902, $p < 0.01$] older adults had smaller mean amplitudes (Figure 5.9, highlighted blue) than the young.

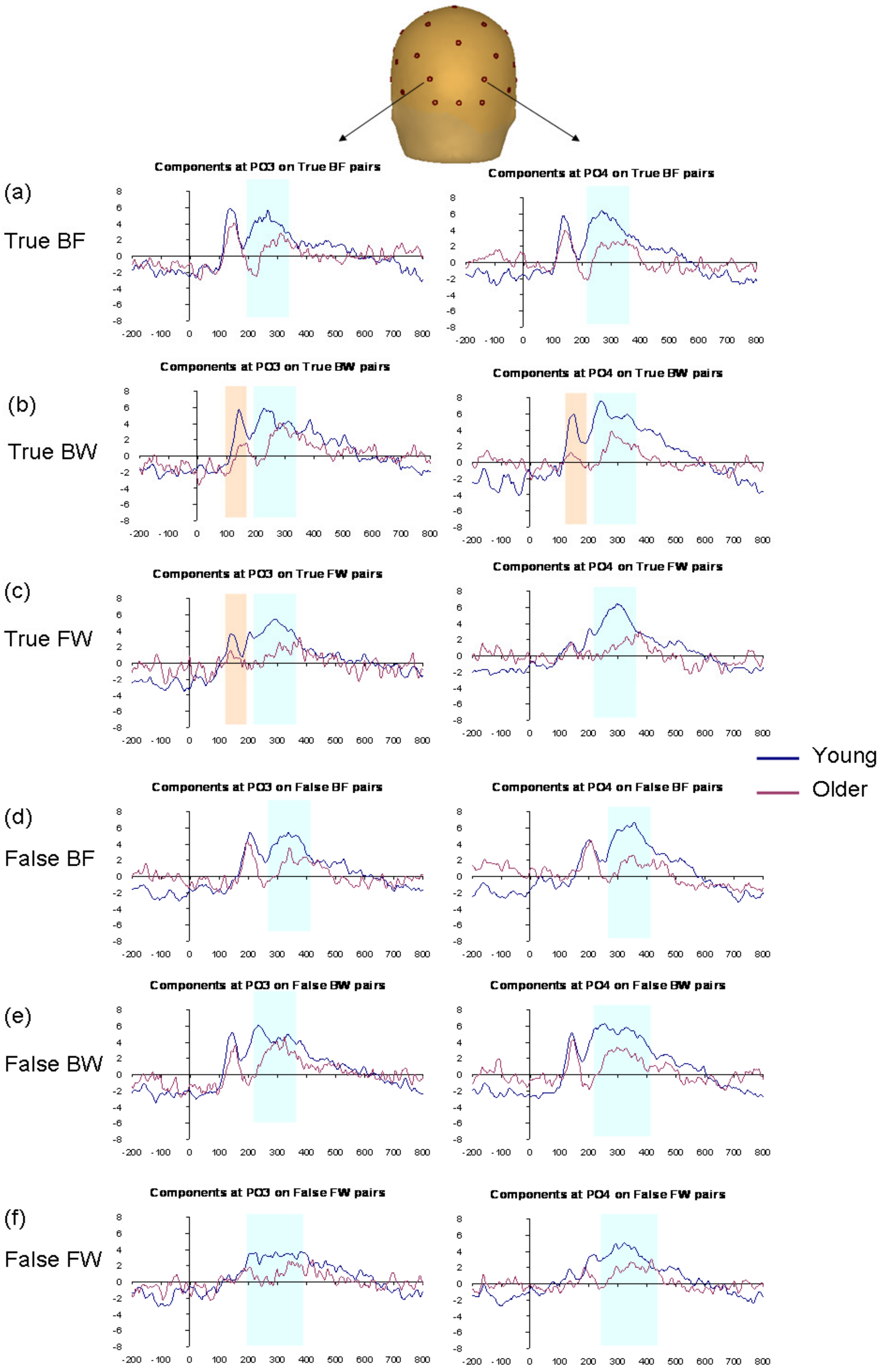


Figure 5.9: (a) P3b components (blue) on True Background Face (BF), (b) P1(orange) and P3b (blue) components on True Background word (BW), (c) P1(orange) and P3b (blue) components on True Face-Word, (d) P3b (blue) components on False Background-Face, (e) P3b (blue) components on False Background-Word and (f) P3b (blue) components on False Face-Word pairs on the WWW task.

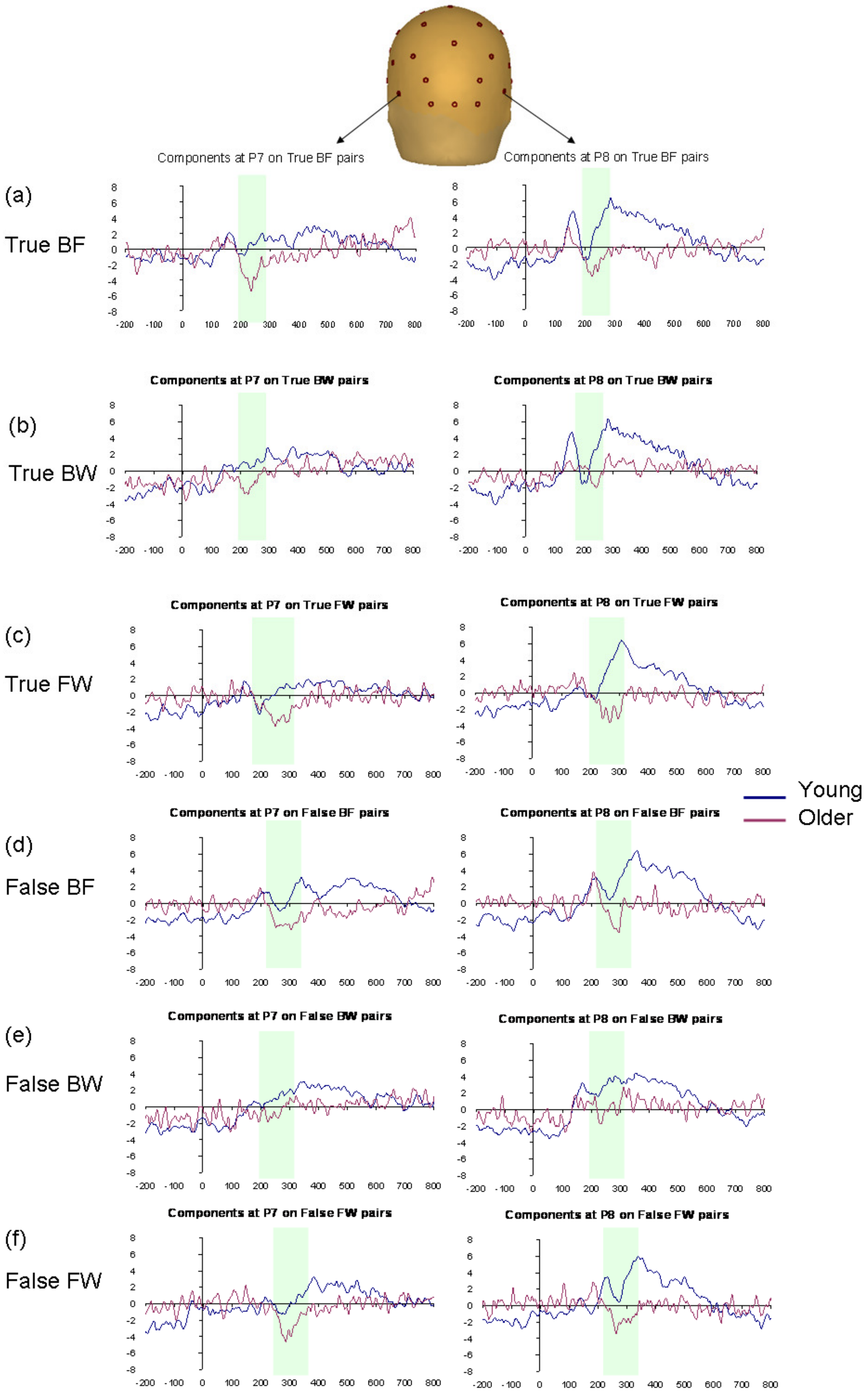


Figure 5.10: N2 components (highlighted green) for young and older adults on the WWW task at P7 and P8 on (a) True Background-Face (BF), (b) True Background-Word (BW), (c) True Face-Word (FW), (d) False Background-Face (BF), (e) False Background-Word (BW) and (f) False Face-Word (FW)

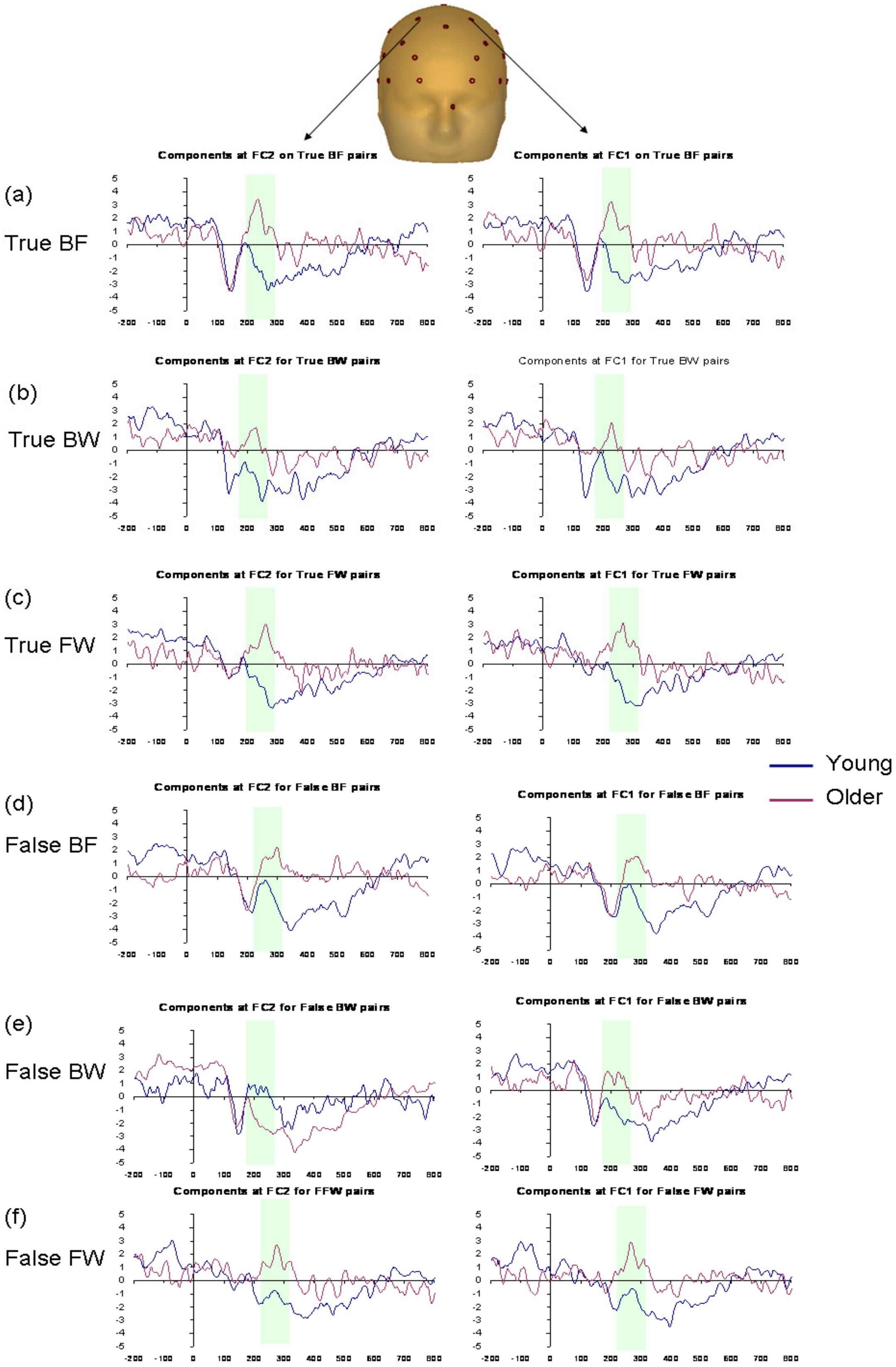


Figure 5.11: P2 components (highlighted green) at FC1 and FC2 for young and older adults on the WWW task for (a) True Background-Face (BF), (b) True Background-Word (BW), (c) True Face-Word (FW), (d) False Background-Face (BF), (e) False Background-Word (BW) and (f) False Face-Word (FW)

5.3.3.4.5 Latency Effects

In addition, a latency difference was apparent between True and False background-face stimuli on P1 and N2 components for both young and older adults which could be seen at all 32 channels. 2×2 Mixed Factorial ANOVAs were carried out on each of these latencies for the P1 and N2 components at each channel and a significant main effect was seen on each analysis where True BW pairs revealed P1 and N2 components before False BW pairs [all $F > 14.210$, all $p < 0.01$]. Figure 5.12 depicts an example of latency differences at posterior channels PO3 and PO4 where the P1 components are highlighted orange and the N2 components are highlighted green. Any group effects showed that for the older group, P1 and N2 components occurred significantly earlier than the young [all $t > 2.168$, all $p < 0.05$], with the exception on the P1 component at channel P7 for False BW stimuli [$t\ (27) = 2.232$, $p < 0.05$] where the young showed a P1 component before the older.

Bonferroni-corrected dependent t-tests were conducted within the young and older groups, and revealed that the P1 and N2 components for True BW peaked significantly earlier than did the False BW components [all $t > 2.365$, all $p < 0.05$]. This was seen at each channel for both groups except for channels AF4, C3 and CP5 for the P1 components for older adults.

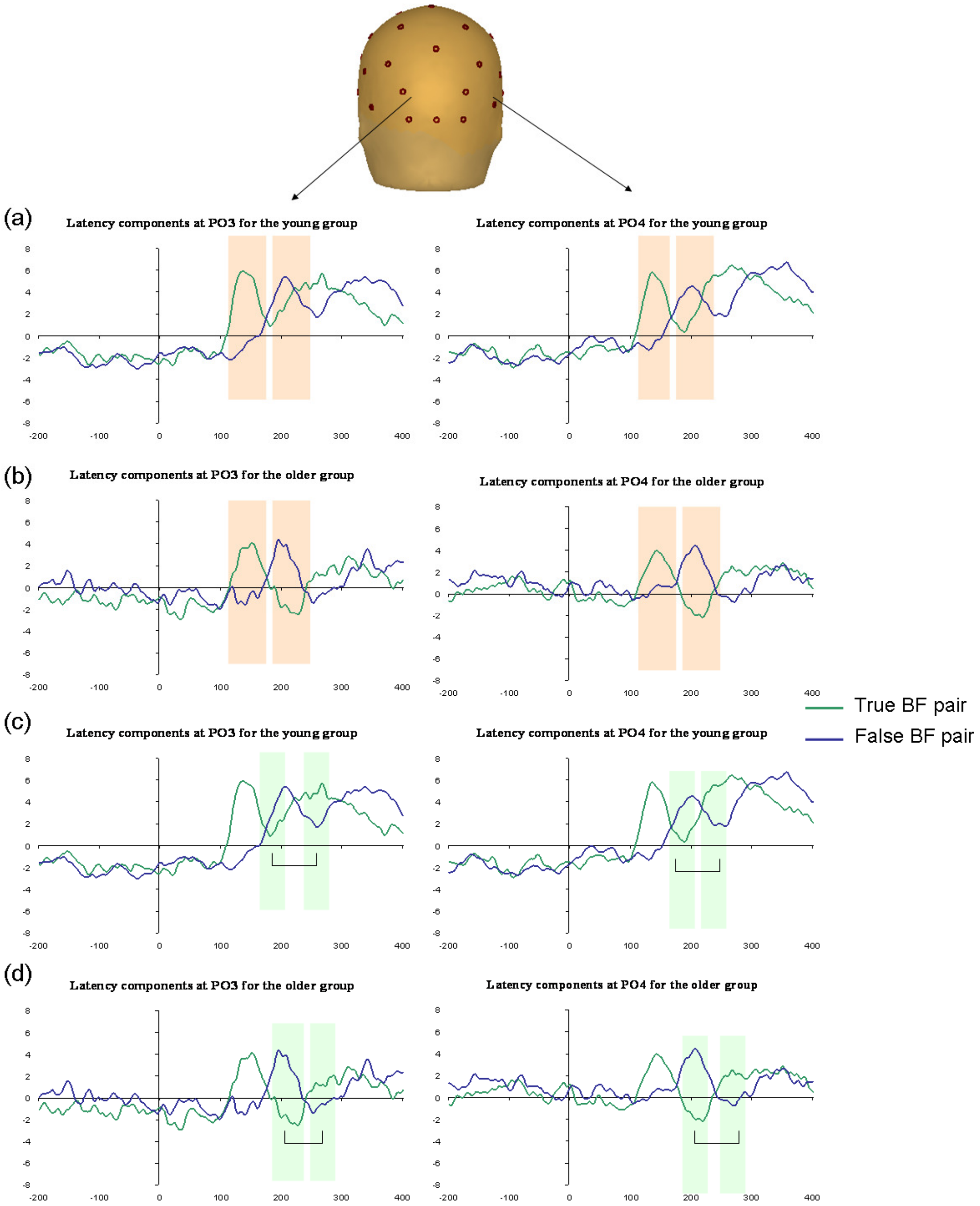


Figure 5.12: Latency differences between True and False BF pairs on the WWW task at PO3 and PO4 for (a) P1 (highlighted orange) for young adults, (b) P1(highlighted orange) for older adults, (c) N2 (highlighted green) for young adults and (d) N2 (highlighted green) for older adults.

Scalp topographies below (Figure 5.13) show that at approximately 200ms, positive activity (i.e. red) was more predominate in the young group over posterior scalp.

In the older group, this activity was distributed more anteriorly during this time window with the exception of both True and False Background-Word pairs.

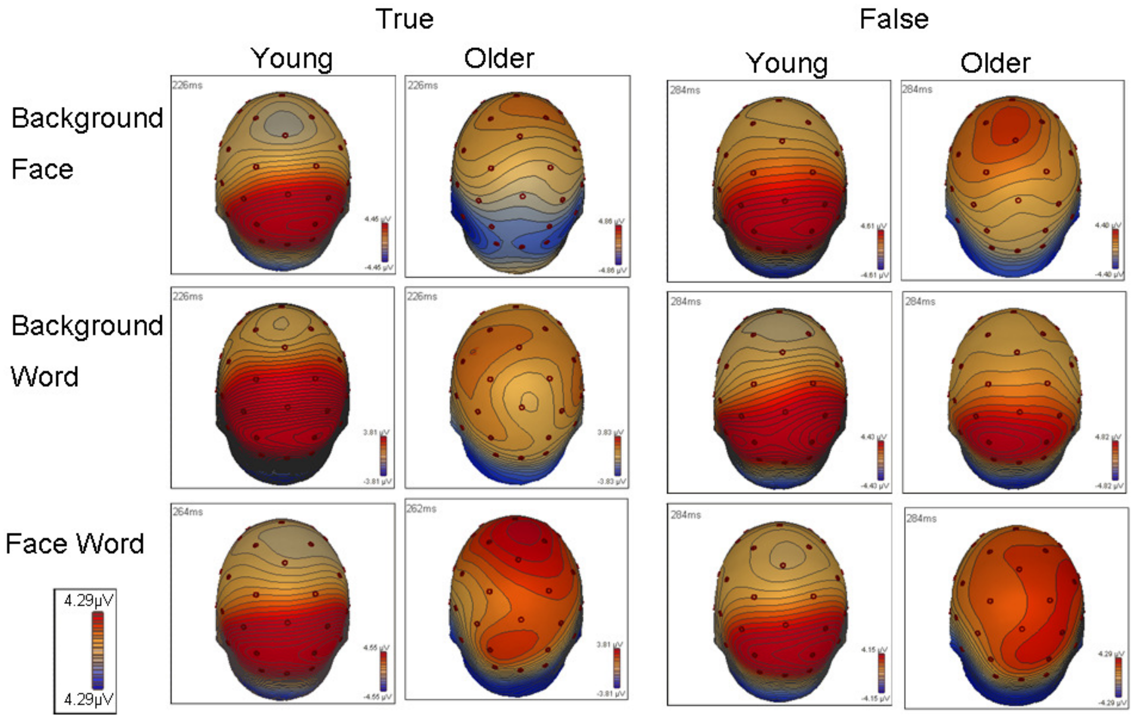


Figure 5.13: Scalp topographies for young and older adults on the WWW task

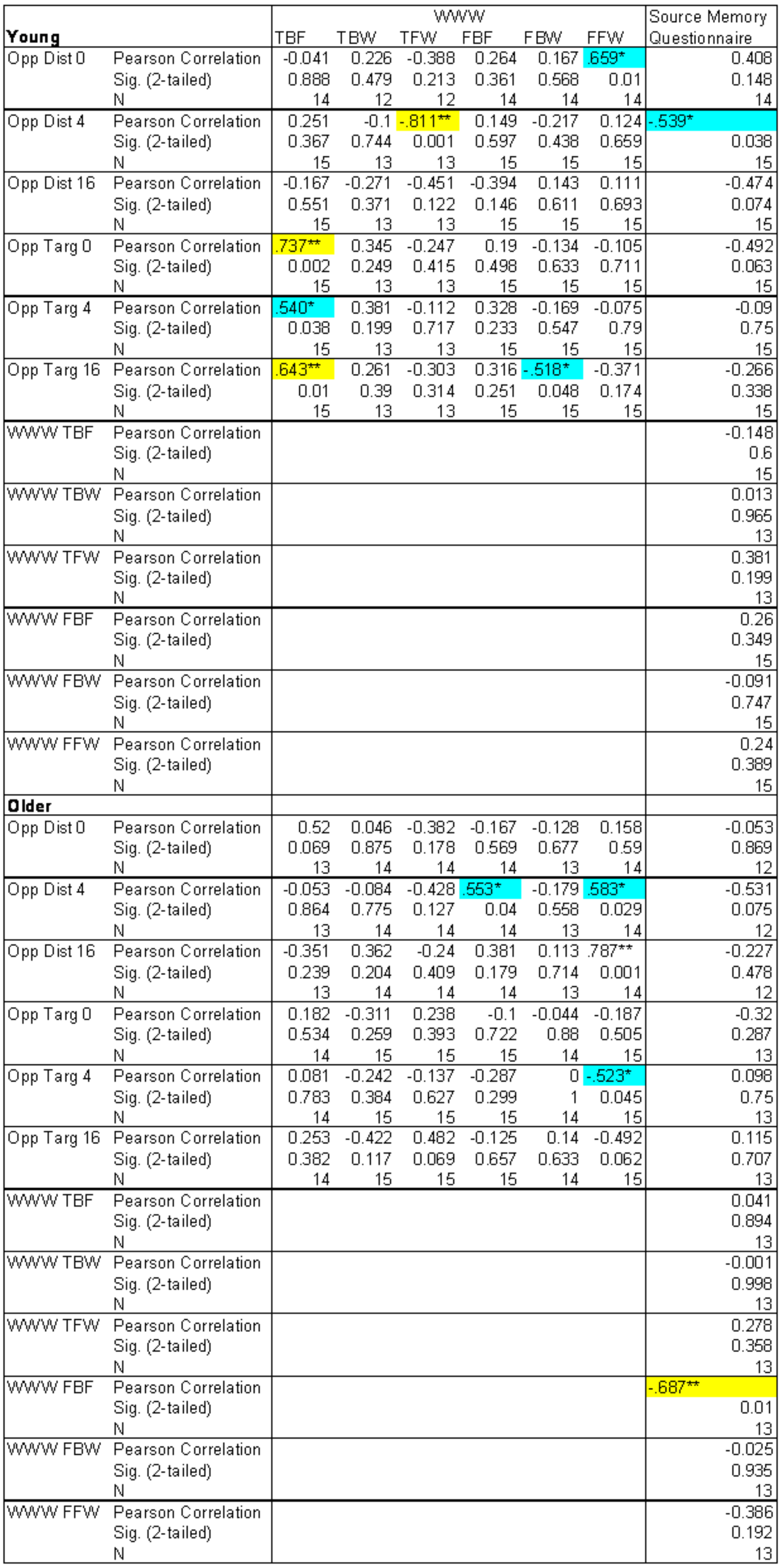
5.3.4 Correlations

A Pearson's correlation was conducted between the Opposition task accuracy (abbreviated as Opp, Dist = distractor words, Targ = Target words), the WWW task accuracy (T = true, F = false) and the Source Memory Questionnaire to investigate any relationships between these tasks. Table 5.2 below shows all the correlations and significant relationships at $p < 0.05$ are highlighted blue, while significant correlations at $p < 0.01$ are highlighted yellow.

For the young group, the condition of True BF of the WWW task was positively correlated with Target Lag 0 [r = .737, n =15, p < 0.01] and Target Lag 16 words [r = .643, n = 15, p < 0.01] of the Opposition task. Target Lag 16 words of the Opposition task were also negatively correlated with False BW pairs of the WWW task for the young group [r = -.518, n = 15, p < 0.05]. The young group also showed a positive correlation between Distractor Lag 0 words and False FW pairs [$r = .669$, $n = 14$, $p < 0.01$], while a negative correlation was revealed between Distractor Lag 4 words and True FW pairs [$r = -.811$, $n = 13$, $p < 0.01$]. The older adults revealed positive correlations between Distractor Lag 4 words of the Opposition task and False BF [$r = .553$, $n = 14$, $p < 0.05$] and False FW pairs of the WWW task [$r = .583$, $n = 14$, $p < 0.05$]. The conditions of Target Lag 4 and False FW pairs were negatively correlated in the older adults [$r = -.523$, $n = 15$, $p < 0.05$].

The Source Memory Questionnaire was negatively correlated with Distractor Lag 4 words of the Opposition task for the young group [$r = -.539$, $n = 15$, $p < 0.05$]. In addition, scores on the Source Memory Questionnaire were also negatively correlated with False BF pairs of the WWW task for the older group [$r = -.687$, $n = 13$, $p < 0.01$].

Table 5.2: Correlations between the Opposition task, the WWW task and the Source Memory Questionnaire.



		WWW						Source Memory Questionnaire
Young		TBF	TBW	TFW	FBF	FBW	FFW	
Opp Dist 0	Pearson Correlation	-0.041	0.226	-0.388	0.264	0.167	.659*	0.408
	Sig. (2-tailed)	0.888	0.479	0.213	0.361	0.568	0.01	0.148
	N	14	12	12	14	14	14	14
Opp Dist 4	Pearson Correlation	0.251	-0.1	-.811**	0.149	-0.217	0.124	-.539*
	Sig. (2-tailed)	0.367	0.744	0.001	0.597	0.438	0.659	0.038
	N	15	13	13	15	15	15	15
Opp Dist 16	Pearson Correlation	-0.167	-0.271	-0.451	-0.394	0.143	0.111	-0.474
	Sig. (2-tailed)	0.551	0.371	0.122	0.146	0.611	0.693	0.074
	N	15	13	13	15	15	15	15
Opp Targ 0	Pearson Correlation	.737**	0.345	-0.247	0.19	-0.134	-0.105	-0.492
	Sig. (2-tailed)	0.002	0.249	0.415	0.498	0.633	0.711	0.063
	N	15	13	13	15	15	15	15
Opp Targ 4	Pearson Correlation	.540*	0.381	-0.112	0.328	-0.169	-0.075	-0.09
	Sig. (2-tailed)	0.038	0.199	0.717	0.233	0.547	0.79	0.75
	N	15	13	13	15	15	15	15
Opp Targ 16	Pearson Correlation	.643**	0.261	-0.303	0.316	-.518*	-0.371	-0.266
	Sig. (2-tailed)	0.01	0.39	0.314	0.251	0.048	0.174	0.338
	N	15	13	13	15	15	15	15
WWW TBF	Pearson Correlation							-0.148
	Sig. (2-tailed)							0.6
	N							15
WWW TBW	Pearson Correlation							0.013
	Sig. (2-tailed)							0.965
	N							13
WWW TFW	Pearson Correlation							0.381
	Sig. (2-tailed)							0.199
	N							13
WWW FBF	Pearson Correlation							0.26
	Sig. (2-tailed)							0.349
	N							15
WWW FBW	Pearson Correlation							-0.091
	Sig. (2-tailed)							0.747
	N							15
WWW FFW	Pearson Correlation							0.24
	Sig. (2-tailed)							0.389
	N							15
Older								
Opp Dist 0	Pearson Correlation	0.52	0.046	-0.382	-0.167	-0.128	0.158	-0.053
	Sig. (2-tailed)	0.069	0.875	0.178	0.569	0.677	0.59	0.869
	N	13	14	14	14	13	14	12
Opp Dist 4	Pearson Correlation	-0.053	-0.084	-0.428	.553*	-0.179	.583*	-0.531
	Sig. (2-tailed)	0.864	0.775	0.127	0.04	0.558	0.029	0.075
	N	13	14	14	14	13	14	12
Opp Dist 16	Pearson Correlation	-0.351	0.362	-0.24	0.381	0.113	.787**	-0.227
	Sig. (2-tailed)	0.239	0.204	0.409	0.179	0.714	0.001	0.478
	N	13	14	14	14	13	14	12
Opp Targ 0	Pearson Correlation	0.182	-0.311	0.238	-0.1	-0.044	-0.187	-0.32
	Sig. (2-tailed)	0.534	0.259	0.393	0.722	0.88	0.505	0.287
	N	14	15	15	15	14	15	13
Opp Targ 4	Pearson Correlation	0.081	-0.242	-0.137	-0.287	0	-.523*	0.098
	Sig. (2-tailed)	0.783	0.384	0.627	0.299	1	0.045	0.75
	N	14	15	15	15	14	15	13
Opp Targ 16	Pearson Correlation	0.253	-0.422	0.482	-0.125	0.14	-0.492	0.115
	Sig. (2-tailed)	0.382	0.117	0.069	0.657	0.633	0.062	0.707
	N	14	15	15	15	14	15	13
WWW TBF	Pearson Correlation							0.041
	Sig. (2-tailed)							0.894
	N							13
WWW TBW	Pearson Correlation							-0.001
	Sig. (2-tailed)							0.998
	N							13
WWW TFW	Pearson Correlation							0.278
	Sig. (2-tailed)							0.358
	N							13
WWW FBF	Pearson Correlation							-.687**
	Sig. (2-tailed)							0.01
	N							13
WWW FBW	Pearson Correlation							-0.025
	Sig. (2-tailed)							0.935
	N							13
WWW FFW	Pearson Correlation							-0.386
	Sig. (2-tailed)							0.192
	N							13

* $p < 0.05$, highlighted blue

** $p < 0.01$, highlighted yellow

5.4 Discussion

The control tasks showed some group differences for scores on working memory and all trials on the RAVLT where the older group had poorer performances in both cases. No difference was seen between the groups on predicted scores of IQ, on self-reports of everyday memory or the Source Memory Questionnaire. However, it is apparent that the young group generally had better accuracies and faster response times than the older on the Opposition and WWW tasks. In addition, the young group showed larger mean amplitudes on the P1 and P3 components; however the older group showed enlarged N2 and P2 components and scalp topographies revealed a change in distribution moving from posterior to anterior activity at approximately 200ms for older adults. The WWW task also revealed a latency effect within True and False background-face stimuli, where the P1 and N2 components occurred earlier for the True pairs. The correlational results indicate that there is a relationship between some conditions on the two tasks suggesting they may be employing similar cognitive resources within source memory. The Source Memory Questionnaire had negative correlations with the tasks. However, as this was only apparent for one condition within each group, it cannot be explicitly stated that the questionnaire is revealing source memory errors.

Behavioural results on the Opposition task showed that the older adults had comparably poorer performance than the young on Distractor (i.e. new) words at the longer lag lengths. This indicates that the longer a time difference between presentations of new words, the more likely it is for older adults to mistakenly identify a word, suggesting that the ageing process has a negative effect on the process of time estimation in source memory. This pattern was not seen for Target (i.e. old) words, which may have been due to a familiarity effect, as discussed in Chapter 3. These results are consistent with those found in previous research where older adults had a poorer performance on similar Opposition tasks measuring source memory (Chapters 3 and 4; Jennings & Jacoby, 1993; Jennings & Jacoby, 1997). In particular, the previous findings reported in this thesis have consistently shown that older adults are impaired on Distractor (i.e. new) words rather than Target (i.e. old) words. Both previous chapters reported this decrease across the Distractor words, with the older adults showing larger deceases than the young adults, and also reported no differences between the two groups on Target words. Therefore, this pattern of results is consistent with both previous cohorts of young and older adults.

Coupled with lower accuracy, the results indicate that older adults were also slower at responding correctly to each condition of the Opposition task, indicating that, not only have they more difficulty with correct identification, but they are also slower at doing so, suggesting that the ageing process causes a downward trajectory in speed of processing (Salthouse, 1996). These results are entirely consistent with those found within the first cohort of participants, where young adults responded faster on each condition. The second sample of participants showed group differences on two conditions only, which was possibly attributed to the high estimated IQ scores of the older adults. However, the older adults in the current cohort were not as a high functioning as those in Chapter 4 and were more similar to those in Chapter 3 (as seen in the estimated IQ scores). Therefore, it may be due to this reduction in estimated IQ that there are more group differences in response times.

The electrophysiology of the Opposition task indicated an age-related decrease in scalp-recorded activity for the P1 component on a selection of conditions. This was also evident for the P3b component over right posterior scalp where group differences showed that the young adults had larger amplitudes. Previous researchers have also found that younger adults elicit larger ERP amplitude and displayed fewer errors than older adults during source memory tasks (Dywan, Segalowitz, & Webster, 1998; Dywan et al., 2001; Mathewson et al., 2005). The authors reported that the ERP components for new repeated words (i.e. the equivalent of Distractor words at any lag length) resulted in larger mean amplitudes for young adults. These findings offer support for the results of the current study. In particular, increased ERP activity was seen for Distractor words on the longer lag lengths, corresponding with the poorer behavioural performance seen in older adults on these conditions and which may indicate that older adults are not recruiting sufficient activity to perform to the same standards as young adults.

The P2 component showed a different pattern, whereby differences between the groups showed that the older adults had larger mean amplitudes. These significantly larger amplitudes were seen for conditions where there were no behavioural differences between the groups, which may indicate that the older adults were using additional resources in order to perform to the same standard as the young adults with respect to the P2 component. This increase in activity may reflect a compensatory function within older adults whereby an increase in activity has allowed for similar recall to that of young adults, consistent with the CRUNCH model (Berlingeri et al., 2013; Grady, 2012; Reuter-Lorenz & Cappell, 2008; Schneider-Garces et al., 2010). This model posits that an increase in activity, irrespective of hemisphere, is recruited in order to compensate for deficits elsewhere in the brain of older adults. The results indicate a low level of activity in early sensory processing, such as perception (i.e. P100), followed by a large increase in the slightly later component (P200), which may indicate an increase in attentional resources. It may follow that this increase in ERP activity at 200ms occurs to compensate for the previous reduction in the P100 component. Additionally, the behavioural results indicate that conditions in which this increased activity occurred older adults showed behavioural performance at the same level as young. Therefore, the increase in attentional processing may have had a benefit for older adults on this particular type of source memory task. The CRUNCH model posits that this increase in activity further continues in accordance with the difficulty of the task, until it eventually plateaus whereby behavioural performance is no longer similar between young and older adults. Therefore, older adults may have not elicited increased ERP activity for the Distractor words at the longest lag lengths as these conditions within the task are considered the most difficult (which has consistently been seen throughout this thesis) and therefore, older adults remain poorer on these conditions as the increase in activity is not substantial enough to facilitate equivalent accuracy performances.

In addition, the scalp topographies of the Opposition task at approximately 200ms showed a pattern where activity for the older adults was becoming more anterior while remaining posterior for the young adults. This anterior shift corresponds with the increased activity for the P2 component in the older adults and may reflect an automatic compensatory function within the older adults. This shift of activity from the posterior to the anterior follows the pattern described by Davis and colleagues (2008) in the PASA model, and this shift in activity has been seen previously in other research involving memory (N. D. Anderson et al., 2000; Dennis, Daselaar, et al., 2007; Gutchess et al., 2005). This model posits that the shift in activity from posterior to anterior is as a result of a reduction in resources for sensory information. The model suggest that in order to counteract the deficit in the posterior brain, additional cognitive processes (such as attention) are recruited in the frontal region of the brain (S. W. Davis et al., 2008). In light of the current results, the theory behind this model persists as the results indicate that there is a reduction in posterior sensory processing (P100 at PO3 and PO4), followed by an increase in activity which is more anterior. Therefore, it may be concluded that the implication of the PASA model within the current results is as a compensatory function for the deficit in perceptual/sensory processing.

The WWW task proved to be a difficult task for the older adults, with the young adults outperforming them on accuracy for each of the trial types. Older adults showed poorer performance for both True and False pairs, which suggests that older adults have difficulty with correctly recollecting the context in order to identify which items go together. This further leads to the conclusion that older adults are more likely to incorrectly reconstruct a memory. As stated previously, older adults show poorer performance on spatial memory (Cansino et al., 2013; Uttl & Graf, 1993), identifying faces (Cabeza et al., 1997; Grady et al., 1994; Pfütze et al., 2002) and auditory words (K. C. Harris et al., 2009). In addition, it has been found that older adults have poorer memory recognition than young on the correct identification of faces, scenes and face-scene pairs (Dennis, Hayes, et al., 2008) despite attempts to limit differences in performance. The results from the current study correspond with these and specifically the older adults showed poorer performance than the young on the location and face pairs regardless of whether the pair was True or False. As no other study has included auditory words with a location or face, the specific results of these conditions cannot be compared to others. However, other studies have reported a decrement in older adults for the source of the information (Dennis, Hayes, et al., 2008; M. Johnson et al., 1993) and the results of the current experiment also indicate such a pattern.

The young adults were faster on a selection of the trials when responding correctly, with group differences being seen when the Background was paired with the Face regardless of whether the pairing was True or False. A previous study using a face-location paradigm showed a similar results where older adults performed more slowly with regard to matching faces to locations (Grady et al., 1994) and the results of the current study indicate that older adults may need longer to correct identify matching stimuli. Additionally, the VPAc results from the previous chapters additionally indicate that older adults need a longer period of time to correctly identify matching pairs, corroborating the current results. While the VPAc relies more on associative memory, the WWW task also includes a certain aspect of associative memory and not source alone as one must match the three elements in order to identify the entire source of the information. This pattern of results may suggest that older adults need more time with respect to placing a person in the correct context.

The event-related potentials for the WWW task revealed an interesting pattern. The young group had enlarged P1 components for a selection of trials. The P3b component for the WWW task showed that the young adults similarly had more activity than the older for each trial, which corresponds with their better accuracy on the WWW task. As this task is particularly difficult for older adults, it may be stated that older adults are not recruiting sufficient neural activity in order to display similar accuracies to young adults. This larger ERP activity in young adults, and subsequent superior behavioural performance, corresponds with those seen in the Opposition task discussed above, and with previous research involving source memory (Dywan et al., 2002, 1998; Mathewson et al., 2005) suggesting that this reduction in activity may be considered detrimental to behavioural performance as it is not seen in young adults who display superior cognition in the form of source memory accuracy.

The N2 and P2 components revealed an interesting pattern whereby the older adults displayed an increase in activity for the majority of trial types but one. This indicates that the older adults may be recruiting more neural resources consistent with the CRUNCH model (Berlingeri et al., 2013; Reuter-Lorenz & Cappell, 2008; Schneider-Garces et al., 2010). However, in this case, this additional recruitment (and presumed compensation) did not yield comparable behavioural performance with the young group, and the older adults remained to show poorer behavioural performances. These results may indicate that there is an attempt at compensation within this task but that it is not always effective. Based on the results, this attempt at compensation via an increase in attentional processing (P200 and N200) is possibly as a result of reduced sensory/perceptual processing (P100) as a reduction in older adults was evident in this component. While the results give a clear indication of compensation within older adults, it is apparent that the compensation is not effective enough to allow for comparable behavioural performances of young adults. This may be explained by the difficulty of the WWW task, and thus, the additional recruitment did not allow for a beneficial effect on behavioural performance.

In addition, the WWW task showed a notable pattern at approximately 200ms where activity in the older group appeared to be shifting to anterior scalp while remaining posterior in the young adults. This pattern is consistent with the PASA model (S. W. Davis et al., 2008) and has been reported in other studies utilising the combination of a face with a location or scene (Dennis, Hayes, et al., 2008; Grady et al., 1994). The timing of this shift to the anterior in older adults reflects the increased activity seen at the N2 and P2 components. Taken together, these patterns may reflect a compensatory function in the older adults despite their behavioural performance not being equated to that of the young group. Again, as with the Opposition task, it is postulated that this shift in activity from the posterior to anterior reflects the deficit in perceptual processing, resulting in an increase in attentional processing that is more anterior (S. W. Davis et al., 2008). With regard to this task, this compensation mechanism does not appear to be behaviourally beneficial. However, the presence of this shift in positive-going ERP activity supports the PASA model, which postulates that this shift in posterior to anterior activity in older adults occurs irrespective of task difficulty.

The WWW task also revealed a latency difference which was irrespective of age when a background was paired with a face. This pattern was revealed for both the young and older groups on nearly all 32 channels whereby the True BF pairs elicited an earlier P1 component compared to the False BF pairs. This was also apparent for the N2 components where again the component occurred earlier for the True BF pairs compared to the False BF pairs. This may indicate that despite age, True pairs are eliciting activity earlier perhaps due to familiarity or pattern recognition. This may be concluded as early sensory processes such as perception are involved. Previous studies have reported earlier elicited components for studied or recognised items at testing compared to new items (R. Johnson, Pfefferbaum, & Kopell, 1985; Tsivilis, Otten, & Rugg, 2001). Additionally, Moore, Cassidy and Roche (in preparation) also showed earlier elicited components for study items in a visual paired-associates task and concluded that this may imply that the association of context and pair may occur at a perceptual level.

For the young adults positive correlations were found between distractor words of the Opposition task and recombined stimuli of the WWW task which can be considered as similar, as both items were new in the study phase. Additionally, Target words of the Opposition task were positively correlated with True items of the WWW task and this correlation may be explained by the fact that both conditions were study items and may have been more familiar. Also, Distractor words were negatively correlated with a True pair, while some Target words were negatively correlated with a False pair. This may have resulted as the items were acting in the opposite manner, i.e. one was presented first in the study while the other was only presented in the test.

For older adults accuracy on the distractor words of the Opposition task (i.e. new words) was positively correlated with False pair accuracy of the WWW task, which may again be explained by the words being treated in a similar manner within the tasks as they were not familiar. Additionally, Target words in the Opposition task showed a negative correlation with False pairs of the WWW task; this may again be explained as both types of stimuli were acting in the opposite manner, i.e. one was considered new while the other was old.

The Source Memory Questionnaire was negatively correlated with accuracy on each task, indicating that as source memory performance decreases, source memory error reports increase. However, this pattern was only seen for one condition on each task for the young and older adults separately, meaning that the source memory questionnaire cannot be generalised as assessing source memory errors. A large number of linear correlations were carried out, meaning that there is a higher chance of error, as described in Chapter 3. However, if one is to accept these results were not obtained by chance, and are attributed to the explanations above, it may be concluded that both tasks are relying on similar cognitive processes such as association, binding and source memory. Additionally, as the young and older group showed differences with regard to the exact correlations seen, it may be further concluded that the ageing process may have an effect on the relationship upon which these tasks draw.

The current research indicates that source memory does decline with ageing, supporting findings of previous research (Schacter et al., 1994; Siedlecki et al., 2005; Spencer & Raz, 1994), and it appears as though the results of the Opposition and WWW task correspond with two models discussed in the literature. Firstly, increased activity was seen on selected conditions in older adults, corresponding with the CRUNCH model (Berlingeri et al., 2013; Grady, 2012; Reuter-Lorenz & Cappell, 2008;

Schneider-Garces et al., 2010). Overactivations in brain activity have been reported in previous research investigating young and older adults (Cabeza et al., 2004; Grady et al., 1994; Reuter-Lorenz et al., 2000) and it has been suggested that this increase in activity functions to produce similar results to those of young adults. This was mainly the case with the Opposition task, where an increase in activity was apparent for those conditions in which the older adult performed with similar accuracies to the young adults. This corresponds entirely with the model suggesting that this increase in attentional resources may have allowed for behavioural results similar to those of the young adults. The conditions in which the older adults had poorer performances than the young did not display increased ERP activity. These particular results indicate that overactivations allowed for equivalent behavioural performances but when absent behavioural performance in older adults decreased, corresponding with the theory set out in the CRUNCH model and suggesting that additional resources, such as attention, may be recruited in order to compensate for a decline in sensory processing or source identification (Reuter-Lorenz & Cappell, 2008). However, while increased activity was seen for the older adults for the WWW task they did not display similar accuracies on the task; however this may be due to the difficulty of this particular task, and the model does account for this by stating that as the difficulty of a task increases this compensatory function becomes less effective, where the increase in activity plateaus and comparable behavioural performances are no longer evident between young and older adults. Therefore, based on this aspect of the model, it may be implied that the WWW task resulted in overactivity in ERP components, but as the task was more difficult this resulted in the activity reaching a maximum and not allowing for comparable results to those of the young adults, and the young group may not have found the task as difficult as the older. In addition, these data also showed a shift from posterior to anterior activity for the older adults, supporting the PASA model (S. W. Davis et al., 2008; Grady et al., 1994; Morcom et al., 2003) which posits a shift in activity due to the ageing process reflecting compensation in older adults.

Overall, the results may indicate that enhanced early sensory processing is occurring in young but not older adults. In order to counteract this the older adults may have subsequently recruited additional attentional resources resulting in enlarged P2 and N2 components. For the Opposition task this increase in attentional resources had a beneficial effect as accuracy is equivalent to that of young adults with the exception of the two most difficult conditions. However, for the WWW task this was not the case and an explanation for this may lie in the difficulty of the task as multiple types of stimuli are presented. Subsequently, the results indicate that compensation in the form of a shift in positive-going activity occurs irrespective of the difficulty of the task, as this shift was identified for both tasks where older adults had behavioural results that were either equivalent or poorer than young adults. This further suggests that the manifestation of PASA is primarily a result of the ageing process. Furthermore, these models both appear to be supported by as these data suggest that both compensatory processes are occurring at approximately the same time point. The two compensatory processes may be occurring simultaneously, as firstly, the increased activity may be occurring in order to counteract for the reduction in early sensory perceptual processes (as described above), and secondly, this increased positive activity may then occur in more frontal regions to further compensate for deficits in sensory processing which occur in more posterior regions (Cabeza et al., 2004; S. W. Davis et al., 2008; Grady et al., 1994). Therefore, not only are the two compensatory processes occurring concurrently, but they may also be occurring to compensate for the same deficit.

Although both models suggest that the ageing process causes additional neural components to be recruited, it appears as though this recruitment is unsatisfactory, as older adults continue to show impairment in behavioural performance on source memory. Therefore, it may be of benefit to employ an intervention to elicit enhanced processing at the time of acquisition in the hopes of increasing behavioural performance in older adults on source memory. As the Opposition and WWW tasks indicated a possible compensatory function within older adults but did not consistently reveal similar behavioural performances, these tasks would appear to be the most beneficial for determining if an intervention may improve accuracy and quicken response times in older adults compared to both young and older adults not using an enhanced processing strategy. This is explored in the next chapter.

Chapter VI

Investigating the use of a depth of processing intervention on source memory recall in older adults

6.1 Introduction

Source memory includes any aspects of the context of a memory which may be associated with a learned event (Glisky & Kong, 2008; M. Johnson et al., 1993). Previous studies have indicated that source memory can be particularly disrupted in older adults (Dywan & Jacoby, 1990; Kausler & Puckett, 1981; Schacter et al., 1994) and data from Chapters 3, 4 and 5 support this observation. Jennings and Jacoby (1997) suggested that ageing severely affects retention in source memory tasks, with older adults showing more repetition errors than young. Schacter et al. (1994) further suggested that older adults can exhibit impaired memory performance for the source of newly learned facts. Furthermore, the experiments reported in this thesis indicate that older adults are impaired on source memory tasks that require identification of the correct time of presentation (study or test block) and the recollection and binding of spatial, auditory facial context.

Neural systems may decline due to a lack of practice of mental skills, and general lifestyle may have serious consequences on mental capability (Hultsch, Hertzog, Small, & Dixon, 1999). Greiner, Snowdon and Schmitt (1996) showed how participants who declined from low normal to impaired cognitive function were more likely to lose independence than those with high normal cognitive function. However, there is compelling evidence of how mental activities can protect against the deterioration of cognitive performance. Studies of those who partake in activities that constantly require cognitive activity (e.g. scrabble, bridge, crosswords) indicates that cognitive training interventions during old age may improve cognitive performance (Snowdon, 1997, 2003; Snowdon et al., 1996, 1997; Snowdon, Tully, Smith, Riley, & Markesbery, 2000). As source memory impairment can lead to vulnerability in the older generation it is important to enhance source memory in order to aid the ageing population. Therefore, the use of an intervention for tasks measuring source memory may ameliorate age-related ailments related to failures of this capacity.

The use of an intervention in source memory can include anything from mnemonics, i.e. a technique to help one retrieve learned information (Saczynski, Whitfield, & Plude, 2007), to a cognitive interview, i.e. giving instructions to the participants before an interview to enhance recall (Dornburg & Mcdaniel, 2006), to Depth of Processing, i.e. when processing is deeper, involving meaning, inference and implications, more information will be retained and thus, lost at a slower rate (Craik, 2002; Craik & Lockhart, 1972). Each of these techniques have had positive implications in the deterioration of memory recall in the aged (Dornburg & Mcdaniel, 2006; Froger, Taconnat, Landré, Beigneux, & Isingrini, 2008; Jacoby, Shimizu, Velanova, & Rhodes, 2005; Saczynski et al., 2007; Verhaeghen, Marcoen, & Goossens, 1992). However, as deeper processing requires a greater degree of semantic or cognitive engagement, it follows that an intervention using such processes would be the most beneficial in the context of a source memory task as deeper processing could increase the binding of context to item in memory by offering more semantic information to the memory.

The framework of Levels of Processing states that the strength of a trace memory is a direct result of how deeply an item was processed; and the deeper the processing the longer a trace is likely to last (Craik & Tulving, 1975; Craik & Lockhart, 1972; Moscovitch & Craik, 1976). The framework further implies that one can retain information for longer periods of time when one processes information deeply, and should information be lost, it will be lost at a slower rate (Craik & Tulving, 1975; Craik & Lockhart, 1972; Moscovitch & Craik, 1976). Moscovitch and Craik (1976) have stated that it is very probable that encoding processes determine what is stored in memory. However, the only way to infer the presence of memory is to test recall and/or recognition (Moscovitch & Craik, 1976). Thus, should recall and/or recognition be greater following deeper processing techniques, it can be concluded that such measures can have a positive effect on encoding.

Studies have indicated that deeper processing can aid memory retention, especially as people do not necessarily learn best when they are told to learn and not given any instruction as to *how* to learn (Craik & Tulving, 1975). Moscovitch and Craik (1976) showed that the use of deep processing enhanced item memory (for word stimuli), and they further indicated that the level of recall depended on the quality of the trace memory, with deeper levels of processing associated with greater recall and shallower levels related to lower levels of retention. Craik and Tulving (1975) tested deep processing by asking many and different questions about the items being presented, and when participants were later tested it was found that deeper encoding took longer to achieve but subsequently led to better retention of the information. The authors suggest that when deep processing is conducted, memory performance is improved as encoding is semantically linked with the word presented leading to easier and better recall of items (Craik & Tulving, 1975).

On recognition tests patients with MCI were also able to benefit from deeper encoding (Froger et al., 2008). Recognition can be increased from 24.7% to 47.2% after the use of a deep encoding strategy, with all participants performing significantly better on memory recognition tests after deep encoding (Puregger, Walla, Deecke, & Dal-Bianco, 2003). As deep encoding can enhance memory performance in both controls and the declined elderly, it follows that deep processing should be a useful tool for enhancing source memory in healthy older adults.

Jacoby, Shimizu, Daniels, et al. (2005) showed how deep processing can lead to an improvement in source memory for foil words compared to item words. Participants either read words while rating their pleasantness (deep), or heard words at two second intervals with no rating required (shallow). Greater memory performance was seen for those words which had been deeply processed via ratings of pleasantness (Jacoby, Shimizu, Daniels, et al., 2005). Furthermore, Jacoby, Shimizu, Velanova, et al. (2005) provided evidence that deep processing can benefit source memory in older adults. This experiment required participants to either rate words on pleasantness (deep) or make vowel judgements (shallow) and found that deep processing of target words allowed for better recognition of foil words in older adults (Jacoby, Shimizu, Velanova, et al., 2005). Techniques using deeper processing can elicit increased brain activity (as shown with MEG) which may be due to additional activation of neural systems during processing, thus allowing for the information to be accessible for longer periods of time (Walla et al., 2001). As stated above, a lack of mental activity can lead to a decline in neural systems which may cause deterioration in memory performance. As deeper processing may involve the activation of more widespread neural systems, it may be used to improve everyday source memory performance in older adults. Therefore, this type of intervention was utilised for the current study as it appeared to be the most beneficial for recollection of general and source memory as indicated through the studies discussed above.

There are different techniques for processing information at deeper levels; for example, when learning a list of words, linking the items together in a story, stating the meanings of the words, or putting the words into a sentence where a clear meaning for the word is evident are all effective strategies. Each of these techniques would elicit deep processing as they involve semantic processes. The intervention which shall be utilised by older adults in the current study will involve, for the Opposition task, putting words into sentences that provide a clear meaning of the word. This method would appear to be most beneficial as it involves the deepest level of processing, i.e. semantic, as one must understand and comprehend the meaning of the word in order to create a sentence around it. Thus, it would follow suit that this type of strategy should lead to an advantage with recollection at a later stage. For the Where-Who-What task, participants were requested to create a short story (2-3 sentences) linking the three elements of location, face and word together. This method was utilised as it was anticipated that this would allow for an increase in binding the different types of context together. According to many theories binding is negatively affected in the ageing processes resulting in a decrement in source memory (Dodson, Bawa, & Slotnick, 2007; M. Johnson et al., 1993; Naveh-Benjamin, 2000). A depth of processing intervention will not be used with the young adults as it is anticipated that young adults will perform at close to ceiling levels of source memory. Thus, the young adults will be employed here purely as controls in order to provide assurance that the older adult control group are performing to the same standard as previously indicated. In addition, performance of the older controls will enable any accuracy or reaction time benefits of the depth of processing strategy to be identified in the current tasks.

It is hypothesised that there will be no difference between the young, older control and older intervention groups on estimates of IQ, working memory or reports of everyday memory. However, it is expected that the young adults will perform with superior accuracies to both older groups on short-term memory, while both older groups will display similar short-term memory scores. In addition, it is anticipated that the young control group will show greater accuracy than the older control group on the computer-based source memory tasks. Furthermore, it is hypothesised that the intervention will enhance older adults’ source memory accuracy and/or response times compared to the older control group while showing similar performances to the young control group.

6.2 Method

6.2.1 Participants

The sample tested in this experiment consisted of 60 participants divided into three groups, Young Control (18-30 years, mean = 24.5), Older Control (55+ years, mean = 64.52) and Older Intervention (55+ years, mean = 63.55). The Young Control group had 20 participants with 13 females and 7 males, the Older Control group had 20 participants with 13 females and 7 males and the Older Intervention group had 20 participants with 13 females and 7 males. The Intervention group were given a strategy to use at the time of acquisition of the items, i.e. during the study phase of both the Opposition task and the WWW task. The two control groups did not use an intervention. Participants reported themselves free from any memory or mental problems and had normal or corrected-to-normal vision. Participants gave informed written consent for their participation in the study (Appendix I). Participant data were anonymised and kept separate from any identifying material. This study was carried out in accordance with the Ethical Standards of the American Psychological Association (APA), the Declaration of Helsinki (World Medical Association, Inc.) and was approved by the local ethics committee in NUI Maynooth.

6.2.2 Apparatus

6.2.2.1 Control Tasks.

The control tasks were carried out as set out in the Methods Chapter 2 and included the RAVLT (section 2.3.2), the NART (section 2.3.3), the Digit Span (section 2.3.4), the CFQ (section 2.3.5) and the Source Memory Questionnaire (section 2.3.6).

6.2.2.2 Opposition Task.

The Opposition task was carried out as described in Chapter 2 (section 2.4.2) for both the Young and Older Control groups. However, for the Older Intervention group, the words appeared on screen for the standard 2000ms, upon which the screen went blank and participants were then requested to put the word into a sentence which they spoke aloud. Once the participant had completed their sentence they could press any key to progress to the next word. The experimenter remained with the participant to ensure that the participant had generated a meaningful sentence.

6.2.2.3 Where-Who-What (WWW) task.

This task was carried out in accordance with the description given in Chapter 2 (section 2.4.5) for both Control groups, Young and Older. The Intervention group were asked to place the three elements into a short story after they had been presented and once the screen had gone blank. They were asked to speak this story aloud and once they had verbalised their story they could press any key to move onto the next set of elements. The experimenter remained with each participant to ensure that they had generated a story for each set of stimuli.

6.2.3 Design

6.2.3.1 Control Tasks.

The tasks are as described in the Methods chapter. See section 2.3.2.1 for the RAVLT, section 2.3.3.2 for the NART, section 2.3.4.2 for the Digit Span, section 2.3.5.2 for the CFQ and section 2.3.6.2 for the Source Memory Questionnaire.

6.2.3.2 Opposition Task.

The design of the Opposition task is as described in the Methods Chapter (section 2.4.2.2).

6.2.3.3 WWW Task.

The WWW task follows the design as set out in the Methods Chapter (section 2.4.5.2).

6.2.4 Procedure

Before commencing the experiment, participants were fully briefed and informed that the experiment would take approximately one hour and would involve some memory based experiments. They were asked to read and sign a consent form before beginning the experiment and were made aware that they could request breaks if necessary and were free to withdraw their participation at any stage. Each participant completed the pen and paper tasks and the two computerised tasks. Both Control groups completed the tasks without the use of a learning strategy, while the Intervention group implemented a strategy of enhanced processing during acquisition. The order of the tasks was counterbalanced. After the experiment the participants were fully debriefed and had any questions answered. All data from the experiment were made anonymous using participant numbers, and were kept confidential and separate from the consent forms which contained no means of identifying individual participants.

6.2.5 Data Analysis

The data for accuracy scores and response times on the Opposition task, the WWW task and the RAVLT were analysed with Mixed Factorial ANOVAs with Group (3) as the between subjects variable and Condition (levels varied for each task) as the within. Independent and Bonferroni-corrected dependent t-test further examined any differences in the tasks. One-way ANOVAs were used to analyse the CFQ and the Source Memory Questionnaire, while MANOVAs were used on the data for the NART and the Digit Span tasks.

6.3 Results

6.3.1 Control Tasks

All means and standard deviations for the three groups are displayed below for the control tasks (Table 6.1) and bar graphs for the tasks can be viewed in Figure 6.1.

6.3.1.1 National Adult Reading Test.

A one-way between groups MANOVA showed that no differences existed between the groups for Predicted Full Scale IQ [F (2, 54) = 1.526, $p > 0.05$, partial eta squared = .003], Predicted Verbal IQ [F (2, 54) = 1.668, $p > 0.05$, partial eta squared = .058] or Predicted Performance IQ [F (2, 54) = 1.566, partial eta squared = .053] (see Figure 6.1a). Furthermore, Tukey HSD Post-hoc tests found that there was no difference in estimates of IQ between the Young and Older groups for Full Scale IQ [$p > 0.05$], Verbal IQ [$p > 0.05$] or Performance IQ [$p > 0.05$]. This was also evident for the Young and Intervention groups: Full IQ [$p > 0.05$], Verbal IQ [$p > 0.05$], Performance IQ [$p > 0.05$] and the Older and Intervention groups: Full IQ [$p > 0.05$], Verbal IQ [$p > 0.05$], Performance IQ [$p > 0.05$].

6.3.1.2 Digit Span.

The Digit Span was analysed using a one-way between group MANOVA and no differences were found across groups for any of the scores on the task: Forward Digit Span [F (2, 57) = 2.040, $p > 0.05$, partial eta squared = .067]; Backward Digit Span [F (2, 57) = .745, $p > 0.05$, partial eta squared = .025]; and Total Digit Span [F (2, 57) = 1.792, $p > 0.05$, partial eta squared = .059] (see Figure 6.1b). In addition, Tukey HSD Post-hoc tests revealed no difference between the Young and Older Groups for any of the measures: Forward Digit Span [$p > 0.05$]; Backward Digit Span [$p > 0.05$]; and

Total Digit Span [$p > 0.05$]. The Young and Intervention Groups showed no significant differences for Forward Digit Span [$p > 0.05$], Backward Digit Span [$p > 0.05$] or Total Digit Span [$p > 0.05$]. No significant differences were seen between the Older and Intervention groups for the Forward Digit Span [$p > 0.05$], Backward Digit Span [$p > 0.05$] or Total Digit Span [$p > 0.05$].

6.3.1.3 CFQ.

A one-way between groups ANOVA revealed a significant main effect of Group for the CFQ [$F(2, 56) = 3.552$, $p < 0.05$]. Post-hoc tests revealed no differences between the Young and Older groups [$p > 0.05$] or the Older and Intervention groups [$p > 0.05$]. However, a significant difference was found between the Young and Intervention groups [$p < 0.05$] where the Intervention group [mean = 32.50, SD = 13.74] reported fewer everyday cognitive failures than the young group [mean = 41.10, SD = 9.08] (see Figure 6.1c).

6.3.1.4 Source Memory Questionnaire.

No main effect of Group was found for the Source Memory Questionnaire [$F(2, 57) = 1.800$, $p > 0.05$] using a one-way between groups ANOVA. Additionally, post-hoc tests found no differences between any of the groups: Young and Older [$p > 0.05$]; Young and Intervention [$p > 0.05$]; and Older and Intervention [$p > 0.05$].

6.3.1.5 RAVLT.

A 5×3 Mixed Factorial ANOVA was conducted on the RAVLT for Trials A1-A5 and found significant main effects for Trial [$F(4, 212) = 179.489$, $p < 0.01$], Group [$F(2, 53) = 20.433$, $p < 0.01$] and the interaction of Trial × Group [$F(8, 212) = 2.838$, p

< 0.01]. All groups' scores increased across the five trials, and post-hoc tests revealed that the Young group had better recall than both the Older [$p < 0.01$] and Intervention groups [$p < 0.01$] while no difference was found between the Older and Intervention groups [$p > 0.05$]. Independent t-tests revealed that the Young group had higher recall scores than the Older on each of the trials A1-A5 [all $t > 4.093$, all $p < 0.01$] and than the Intervention group on four out of the five trials A2-A5 [all $t > 2.811$, all $p < 0.01$]. The Intervention group had a significantly higher recall than the Older group on trial A1 [$t (39) = -3.019$, $p < 0.01$] but no other differences were revealed [all $t < 1.954$, all $p > 0.05$].

A 2×3 Mixed Factorial ANOVA was conducted for Proactive Interference on the RAVLT and revealed a significant main effect for Proactive Interference [$F (1, 53) = 19.598$, $p < 0.01$] and Group [$F (2, 53) = 14.361$, $p < 0.01$] where some groups' scores decreased from Trials A1 to B and post-hoc tests showed that the Young group had higher recall scores than both the Older and Intervention groups [all $p < 0.01$]. However, no difference was found between the Older and Intervention groups [$p > 0.05$]. The ANOVA revealed no interaction between Proactive Interference and Group. Bonferroni-corrected dependent t-tests showed that both the Young and Older groups had no significant difference within trials A1 and B. However, the Intervention group had a higher recall for trial A1 than trial B [$t (16) = 4.136$, $p < 0.01$]. Independent t-tests showed that the Young group had higher recall scores than the Older for trials A1 [$t (37) = 4.093$, $p < 0.01$] and B [$t (38) = 3.284$, $p < 0.01$]. There was no difference between the Young and Intervention groups on Trial A1 but there was a difference for Trial B [$t (38) = 3.866$, $p < 0.01$]. There was a statistically significant difference between the Older and Intervention groups for trial A1 [$t (39) = -3.019$, $p < 0.01$] but not for trial B.

A 2×3 Mixed Factorial ANOVA found a statistically significant main effect for Retroactive Interference [F (1, 57) = 82.626, p < 0.01] were recall was higher on trial A5 compared to A6. A main effect was also found for Group [F (2, 27) = 17.995, p < 0.01] where post-hoc tests revealed that the Young group had better recalls than both the Older [p < 0.01] and Intervention groups [p < 0.01]. However, no statistically significant difference was found between the Older and Intervention groups [p > 0.05]. The interaction effect of Retroactive Interference and Group was non-significant. Bonferroni-corrected dependent t-tests showed that each group had a higher recall for Trial A5 compared to A6 [all t > 5.048, all p < 0.01]. Independent t-tests showed that the Young group had higher recalls than both the Older and Intervention groups on Trials A5 and A6 [all t > 2.782, all p < 0.01]. No significant difference was found between the Older and Intervention groups for Trial A5 but a significant difference was found for A6 [t (38) = -2.748, p < 0.01] where the Intervention group had a higher recall.

A 2×3 Mixed Factorial ANOVA was carried out on trials A6 and A7 and revealed no significant main effect for Delay [F (1, 56) = 3.223, p > 0.05] or the interaction between Delay and Group [F (2, 56) = .327, p > 0.05] but a main effect was revealed for Group [F (2, 56) = 21.086, p < 0.01]. Post-hoc tests revealed that the Older and Intervention groups did not differ [p > 0.05] but the Young group had higher recall than both the Older and Intervention groups [all p < 0.01]. Bonferroni-corrected dependent t-tests found no significant statistical difference within Trials A6 and A7 for any of the groups. Independent t-tests found that the Young group had higher recall scores than both the Older and Intervention groups for Trials A6 and A7 [all t > 2.782, all p < 0.01]. The Intervention group had a higher recall for Trial A6 than the Older group [t (38) = -2.748, p < 0.01] but not for Trial A7.

Table 6.1: Means and Standard Deviations for NART based estimates of IQ, Forward, Backward and Total Digit Span, the CFQ, the Source Memory Questionnaire and the RAVLT.

	Young (N = 20)		Older (N = 20)		Intervention (N = 20)	
	Mean	SD	Mean	SD	Mean	SD
Predicted Full Scale IQ	113.00	6.43	110.94	7.94	115.60	6.82
Predicted Verbal IQ	111.15	5.96	109.11	7.19	113.55	6.30
Predicted Performance IQ	112.05	5.88	110.22	7.09	113.84	5.66
Forward Digit Span	12.50	2.33	10.85	2.58	11.35	3.00
Backward Digit Span	8.10	2.29	7.25	2.51	7.55	1.85
Total Digit Span	20.65	4.02	18.10	4.55	18.90	4.48
CFQ	41.10	9.08	39.63	9.11	32.50	13.74
Source Memory	31.20	12.63	34.05	10.52	27.05	11.95
RAVLT A1	7.25	1.55	5.37	1.30	6.47	0.80
RAVLT A2	10.30	2.05	7.60	2.01	8.30	2.43
RAVLT A3	12.70	1.84	9.65	1.93	9.75	2.34
RAVLT A4	13.05	1.67	9.85	2.18	11.05	2.37
RAVLT A5	13.75	1.16	10.05	2.74	11.55	2.06
RAVLT B	6.50	1.82	4.55	1.93	4.60	1.23
RAVLT A6	11.80	2.07	7.50	2.82	9.80	2.46
RAVLT A7	11.79	1.58	6.85	3.07	8.85	3.51

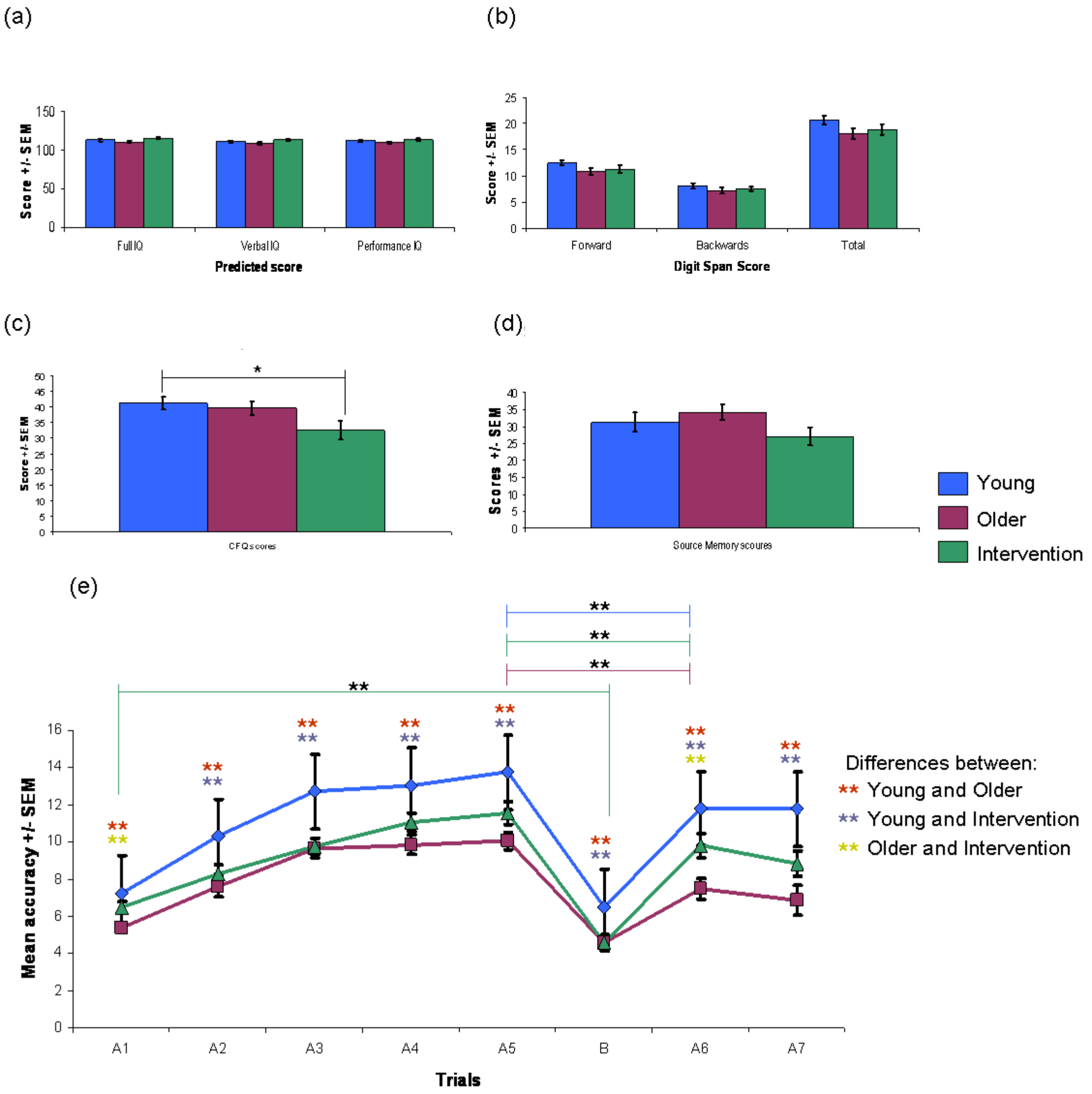


Figure 6.1: Differences between young, older and intervention groups for (a) NART based estimates of Full scale, verbal and performance IQ +/- SEM, (b) Forward, Backward and Total Digit Span recall +/-SEM, (c) CFQ scores +/- SEM, (d) Source Memory Questionnaire Scores +/-SEM and (e) Accuracy RAVLT scores for Trials A1-A7l +/ SEM
($p < 0.05$, **$p < 0.01$)*

6.3.2 Opposition Task

6.3.2.1 Accuracy.

Table 6.2 below shows the mean and SDs for the three groups on accuracy on the Opposition task. A 2×3×3 Mixed Factorial ANOVA was carried out on accuracy of the Opposition task and revealed no statistically significant main effect for Word Type, i.e. Distractor or Target words. However, significant main effects were found for Lag [F (2, 106) = 6.897, $p < 0.01$] where accuracy decreased across the lags (see Figure 6.3), and Group [F (2, 53) = 44.813, $p < 0.01$] (see Figure 6.2) where Tukey HSD post-hoc tests revealed that the intervention group had higher accuracies than both the Young and Older adults [all $p < 0.01$]. In addition, the Young group had higher accuracies than the Older adults [$p < 0.01$]. The interactions of Word Type by Group, and Lag by Group were non-significant. However, significant effects were found for Word Type and Lag [F (2, 106) = 80.206, $p < 0.01$] and Word Type, Lag and Group [F (4, 106) = 23.520, $p < 0.01$].

Independent t-tests found a statistically significant difference between the Young and Older groups on Distractor Lag 4 words [t (38) = 3.145, $p < 0.01$] where the Young adults had higher recalls (see Figure 6.2). In addition, the Young group had a significantly higher accuracy than the Older on Distractor Lag 16 words [t (38) = 3.280, $p < 0.01$]. No other significant differences were found between the Young and Older adults [all $t < 2.010$, all $p > 0.05$].

Independent t-tests found that the Intervention group had a higher recall than the Young group for each condition Distractor Lag 0 [t (36) = -2.964, $p < 0.01$], Distractor Lag 4[t (37) = -2.501, $p < 0.05$], Distractor Lag 16 [t (38) = -3.093, $p < 0.01$], Target Lag 0 [t (37) = -2.926, $p < 0.01$] and Target Lag 4 [t (38) = -3.351, $p < 0.01$]. The only condition this was not seen for was for Target words at Lag 16 [t (37) = -1.860, $p > 0.05$].

The Older adults had a lower mean accuracy than the Intervention group on Distractor Lag 0 words [t (36) = -4.916, $p < 0.01$]. For Distractor Lag 4 words the Intervention group had significantly higher means than the Older group [t (37) = -6.305, $p < 0.01$]. Distractor Lag 16 words revealed lower mean accuracies for the Older group compared to the Intervention group [$t (38) = -6.727$, $p < 0.01$]. The Intervention group had higher mean accuracies than the Older group on Target Lag 0 words [$t (38) = -2.260$, $p < 0.01$]. Mean accuracies on Target Lag 4 words for Older adults were lower than those for the Intervention group [$t (37) = -1.251$, $p > 0.05$]. Mean accuracies on Target Lag 16 words between the Older and Intervention groups were non-significant [$t (37) = -1.251$, $p > 0.05$].

Bonferroni-corrected dependent t-tests on the Young group found significantly higher accuracies for Distractor Lag 0 compared to Distractor Lag 16 words [$t (18) = 4.100$, $p < 0.01$]. In addition, the Young group showed higher mean accuracies for Distractor Lag 4 compared to Distractor Lag 16 words [$t (18) = 4.073$, $p < 0.01$] (see Figure 6.3a). No other within group differences were significant for the Young group [all $t < 2.334$, all $p > 0.05$].

The only comparison within categories for the Older group (see Figure 6.3b) which were non-significant was within Target Lag 4 and Lag 16 words [$t (19) = -1.395$, $p > 0.05$]. For the older adults significant differences were found between Distractor Lag 0 and Distractor Lag 4 words [$t (18) = 6.870$, $p < 0.01$] and Distractor Lag 0 and Distractor Lag 16 words [$t (18) = 8.114$, $p < 0.01$] were accuracy was higher for Lag 0 words in both comparison. Distractor Lag 4 words had significantly higher accuracies compared to Distractor Lag 16 words [$t (19) = 3.367$, $p < 0.05$]. Target Lag 0 words had higher accuracies than Target Lag 4 words [$t (19) = -3.327$, $p < 0.01$] and Target Lag 16 words [$t (19) = -4.414$, $p < 0.01$].

The only significant within group difference found for the Intervention group was seen within Distractor Lag 0 and Distractor Lag 16 words [$t (18) = 3.153$, $p < 0.01$] (see Figure 6.3c). No other significant differences were found within categories for the intervention group [all $t < 2.348$, all $p > 0.05$].

Table 6.2: Means and SDs for the Young, Older and Intervention groups on accuracy on Distractor and Target words of the Opposition task.

	Young		Older		Intervention	
	Mean	SD	Mean	SD	Mean	SD
Distractor Lag 0	9.53	0.70	9.26	0.65	10.00	0.00
Distractor Lag 4	8.40	2.09	6.20	2.33	9.63	0.68
Distractor Lag 16	7.55	2.14	5.15	2.48	9.20	1.06
Target Lag 0	7.42	1.30	6.30	2.11	8.75	1.52
Target Lag 4	7.70	0.98	7.65	2.06	8.85	1.18
Target Lag 16	8.25	1.21	8.30	2.00	8.95	1.13

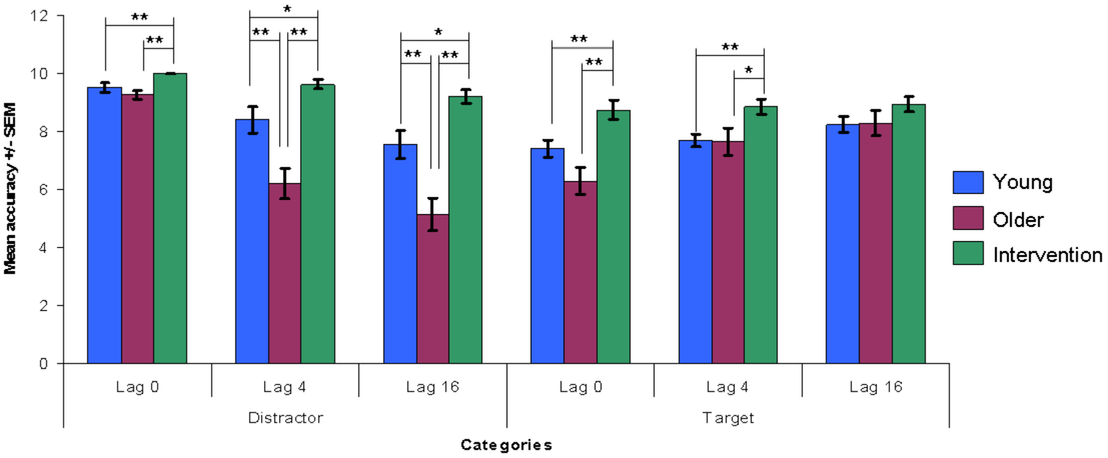


Figure 6.2: Mean total accuracy scores +/- SEM between the young, older and intervention groups on at Lags 0, 4 and 16 for Distractor and Target words on the Opposition task
*(*p < 0.05, **p < 0.01)*

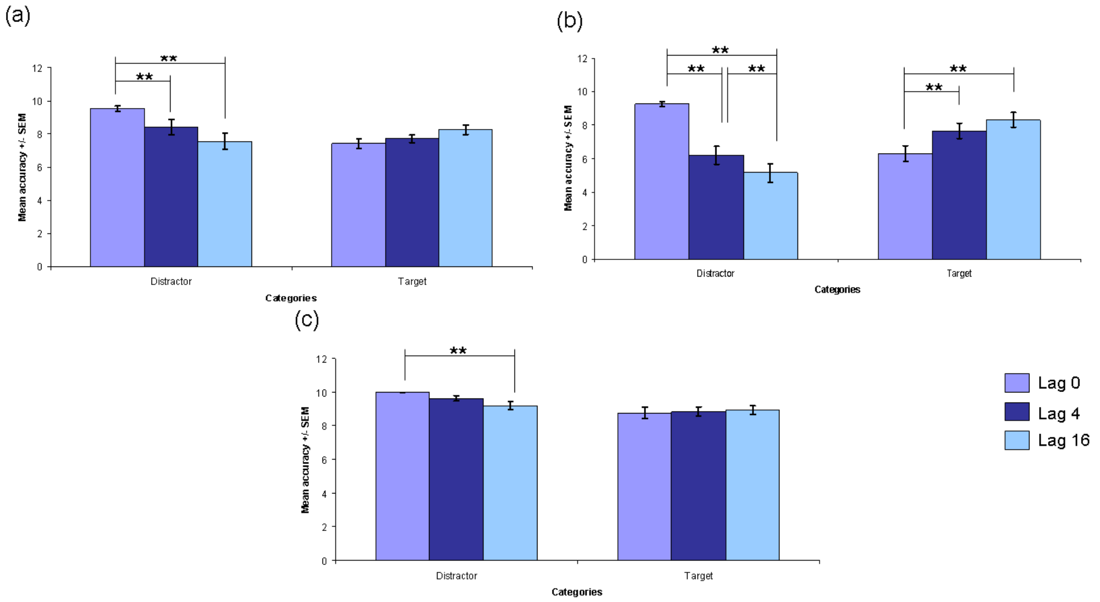


Figure 6.3: Mean total accuracy score +/- SEM on Distractor and Target words at Lags 0, 4 and 16 within categories for (a) the young, (b) the older and (c) the intervention groups
*(*p < 0.05, **p < 0.01)*

6.3.2.1 Response Times for Correct Responses.

See Table 6.3 below for the means and standard deviations for response times when giving a correct response. A 2×3×3 Mixed Factorial ANOVA was conducted on these data for response times for correct responses and revealed statistically significant main effects for Word Type [F (1, 46) = 52.543, $p < 0.01$], Lag [F (2, 92) = 9.426, $p < 0.01$] and Group [F (2, 46) = 18.281, $p < 0.01$] where response times increased across the lag lengths. Post-hoc test revealed that both the Young and Intervention groups responded faster than the Older group [all $p < 0.01$] but the Young and Intervention groups had few differences on responses times when correct [$p > 0.05$] (see Figure 6.4). The interactions of Word Type × Group [F (2, 46) = 9.426, $p < 0.01$], Lag and Group [F (4, 92) = 2.492, $p < 0.05$], and Word Type by Lag [F (2, 92) = 19.522, $p < 0.01$] were revealed as statistically significant. However, the three way interaction of Word Type, Lag and Group was non-significant.

Independent t-tests were conducted on response times for correct responses between Young and Older adults and revealed that the Young adults responded faster than the Older control adults on each of the lag lengths for both Distractor and Target words [all $t > 3.603$, all $p < 0.01$].

Independent t-tests were conducted on the response times between the Young and Intervention groups and the only non-significant result between the Young and Intervention groups was for Distractor Lag 4 words. Each of the differences on the conditions was revealed as significant with the Young group responding faster than the Intervention group [all $t > 2.099$, all $p < 0.05$]

The older adults had significantly slower response times than the Intervention group on Distractor Lag 0 words [$t (36) = 3.224$, $p < 0.01$], Distractor Lag 4 words [$t (36) = 3.308$, $p < 0.01$] and Distractor Lag 16 words older [$t (35) = 2.675$, $p < 0.05$]. No other between group differences were found [all $t < 1.706$, all $p > 0.05$].

Table 6.3: Means and SDs of Response Times when correct for Distractor and Target words for the Young, Older and Intervention groups on the Opposition task.

	Young		Older		Intervention	
	Mean	SD	Mean	SD	Mean	SD
Distractor Lag 0	603.03	164.16	931.80	249.27	733.31	110.92
Distractor Lag 4	1036.38	242.74	1702.57	620.54	1192.28	286.05
Distractor Lag 16	1064.90	313.97	1896.73	822.54	1323.74	430.29
Target Lag 0	601.01	174.69	897.87	201.34	798.53	156.34
Target Lag 4	868.22	150.73	1237.40	334.14	1072.29	245.17
Target Lag 16	799.40	169.51	1126.44	357.49	1131.94	351.15

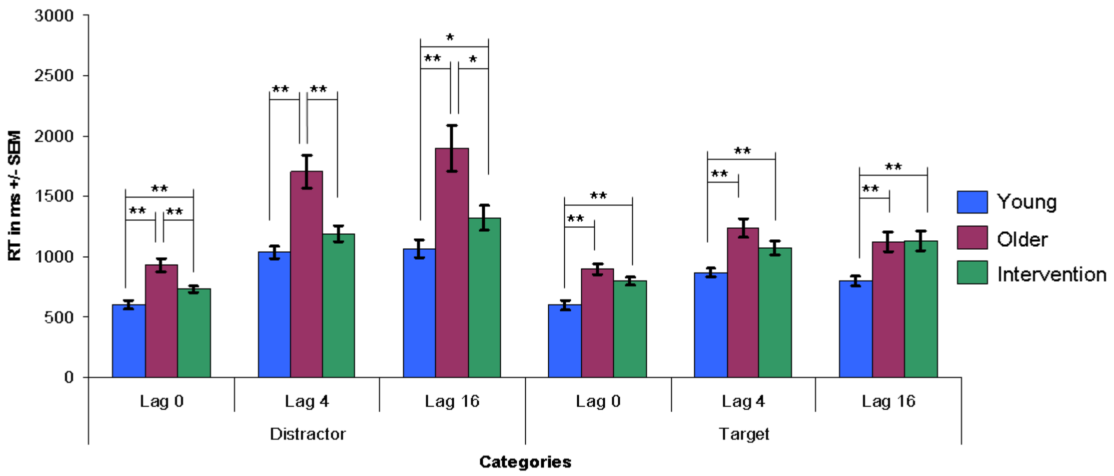


Figure 6.4: Mean response times +/- SEM for the young, older and intervention group on Distractor and Target words at Lags 0, 4 and 16 for the Opposition task for correct responses
*(*p < 0.05, **p < 0.01)*

6.3.2 Where-Who-What (WWW) Task

6.3.2.1 Accuracy.

All means and standard deviations can be seen in Table 6.3 below for the Young, Older and Intervention groups. A 2×3×3 Mixed Factorial ANOVA was conducted on these data for accuracy for the WWW task and found significant main effects for Stimulus Type [F (1, 51) = 13.579, p < 0.01], Pair Type [F (2, 102) = 11.204, p < 0.01] where accuracy was higher on a selection of stimuli types and Group [F (2, 51) = 18.609, p < 0.01]. Tukey post-hoc tests revealed that the group differences were found between the Young and Older, the Young and Intervention, and the Older and Intervention groups [all p < 0.01] where the Intervention group had higher accuracies than the Young and Older groups and the Young group had higher accuracies than the Older group (see Figure 6.5). The interaction effect of Stimulus Type by Group was non-significant but the interactions of Pair Type by Group [F (4, 102) = 7.370, p < 0.01] and Stimulus Type × Pair Type [F (2, 102) = 3.137, p < 0.05] were statistically significant. The three-way interaction of Stimulus Type × Pair Type × Group was not statistically significant.

Independent t-tests between the Young and Older adults showed significant differences for each category [all $t > 2.315$, all $p < 0.05$] except the False BW pairs, where the Young group had higher accuracies than the Older group (see Figure 6.6). Independent t-tests revealed significant differences between the Young and Intervention groups for True BW pairs [$(38) = -4.030$, $p < 0.01$] and False BW pairs [$t\ (36) = -4.924$, $p < 0.01$] where the Intervention group had higher accuracies. No other differences were significant between the Young and Intervention groups [all $t < 1.790$, all $p > 0.05$] (see Figure 6.6). The Intervention group had higher accuracies than the Older group on each condition [all $t > 2.482$, all $p < 0.01$] except the True FW pairs (see Figure 6.5).

Bonferroni-corrected dependent t-tests were conducted within each of the groups to determine if there were any differences within the pair types. The Young group (see Figure 6.6a) had a significant difference within False BF and False BW pairs [$t\ (19) = 2.926$, $p < 0.01$] were accuracy was higher for False BF pairs. Accuracy for the False BF pairs was higher than the False FW pairs for the Young group [$t\ (19) = 3.153$, $p < 0.01$]. No other within group differences were significant for the Young group [all $t < 1.000$, all $p > 0.05$]. The only within group difference seen for the Older group was within False BW and False FW pairs [$t\ (19) = 3.263$, $p < 0.05$] where accuracy was higher for False BW pairs. No other differences were significant [all $t < 1.432$, all $p > 0.05$] (Figure 6.6b). The Intervention group had significantly lower accuracies for True BF compared to True BW pairs [$t\ (19) = -5.180$, $p < 0.01$] (Figure 6.6c). Significantly higher accuracies were seen for True BW than True FW pairs [$t\ (17) = 4.350$, $p < 0.01$]. Accuracy was higher for False BF pairs than for False FW pairs [$t\ (18) = 4.025$, $p < 0.01$] for the Intervention group. Accuracy on False BW pairs compared to False FW pairs were significantly higher [t (16) = 5.800, p < 0.01]. The Intervention group had no other significant within group differences [all t < 2.557, all p > 0.05].

Table 6.4: Means and standard deviations for the Young, Older and Intervention groups for True and False Pairs for accuracy on the WWW task.

	Young		Older		Intervention	
	Mean	SD	Mean	SD	Mean	SD
True BF	6.30	1.38	4.75	1.55	5.90	1.37
True BW	5.95	1.64	4.53	1.54	7.55	0.69
True FW	6.20	1.32	4.85	1.87	5.83	1.58
False BF	6.95	1.19	5.37	1.95	7.20	0.95
False BW	5.90	1.77	5.90	1.55	7.89	0.32
False FW	5.80	1.36	4.65	1.76	6.47	0.96

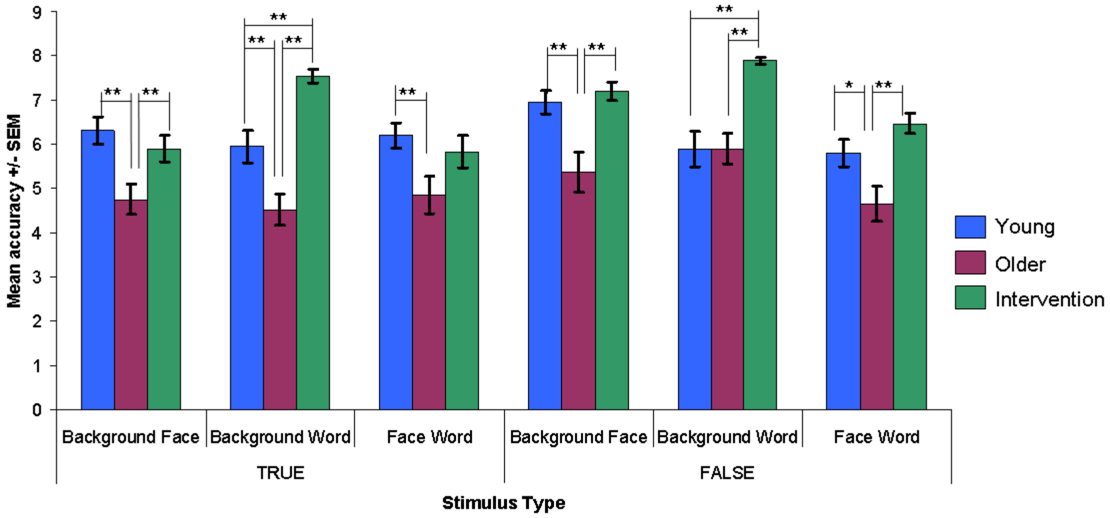


*Figure 6.5: Mean total accuracy +/- SEM for the young, older and intervention groups on True and False Background-Face, Background-Word and Face-Word pairs (*p < 0.05, **p < 0.01)*

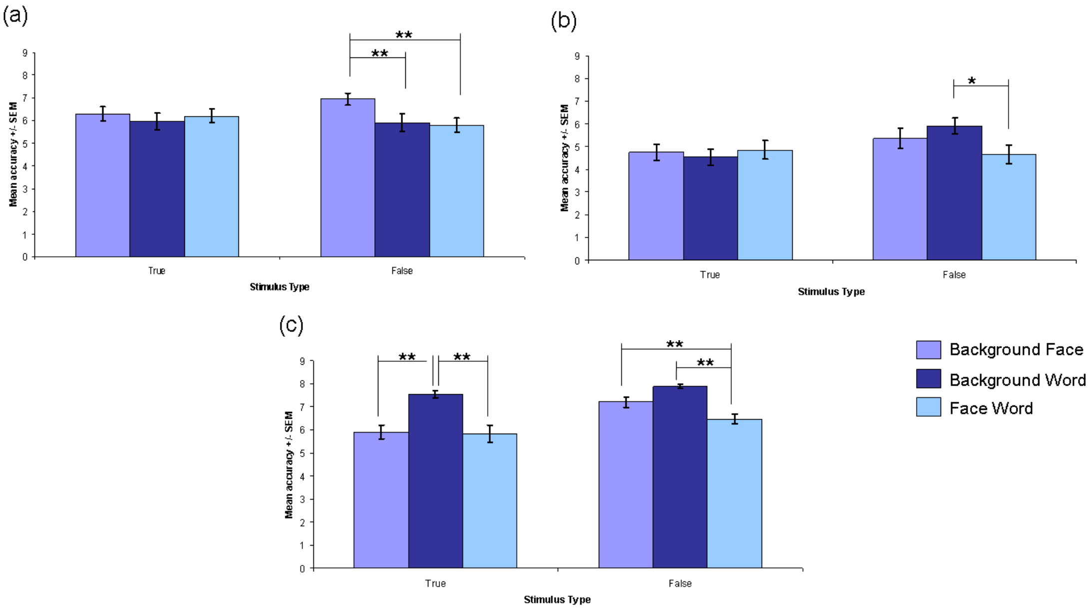


Figure 6.6: Mean accuracy +/- SEM on the WWW task within True and False Background-Face, Background-Word and Face-Word pairs for (a) the young, (b) the older and (c) the intervention groups
*(*p < 0.05, **p < 0.01)*

6.3.2.2 Response Times for Correct Responses.

See Table 6.4 for the means and standard deviations for the three groups on each of the conditions of the WWW task. The 2×3×3 Mixed Factorial ANOVA revealed that the main effects of Stimulus Type [F (1, 47) = 12.493, p < 0.01], Pair Type [F (2, 94) = 18.961, p < 0.01] and Group [F (2, 47) = 10.307, p < 0.01] were significant with response times being faster on a selection of stimuli pairs. Post-hoc tests showed that the Young group responded significantly faster than both the Older and Intervention groups [p < 0.01] but no difference was found between the Older and Intervention groups [p > 0.05] (see Figure 6.7). The only interaction which was significant was Stimulus Type by Pair Type [F (2, 94) = 8.549, p < 0.01]. All other interactions were non-significant.

Independent t-tests showed that there was a significant difference between the Young and Older group for True BF pairs [t (37) = -4.134, p < 0.01], True BW pairs [t (35) = -2.803, p < 0.01], False BF pairs [t (37) = -5.200, p < 0.01] and False FW pairs [t

(38) = -2.777, $p < 0.01$] where the Young group responded faster (see Figure 6.7). No other differences were significant between the Young and Older groups [all $t < 1.854$, all $p > 0.05$]. The Young group responded significantly faster than the Intervention group on each condition except True FW pair (see Figure 6.7) [all $t > 2.242$, all $p < 0.05$]. No significant differences were found between the Older and Intervention groups for response times when correct for any comparison [all $t < 1.279$, all $p > 0.05$] (see Figure 6.7).

Table 6.5: Means and SDs for the Young, Older and Intervention groups for Response times on True and False pairs for the WWW task.

	Young		Older		Intervention	
	Mean	SD	Mean	SD	Mean	SD
True BF	1471.19	614.27	3459.82	2009.36	3153.24	1779.04
True BW	1219.96	419.16	1842.51	867.16	1912.98	1096.78
True FW	1615.82	934.73	1701.91	768.01	2065.55	972.07
False BF	893.60	332.98	2211.66	1056.02	2535.22	1128.11
False BW	1146.35	466.81	1431.35	480.54	1709.24	1015.48
False FW	1364.24	728.18	2216.74	1164.09	2448.23	1426.88

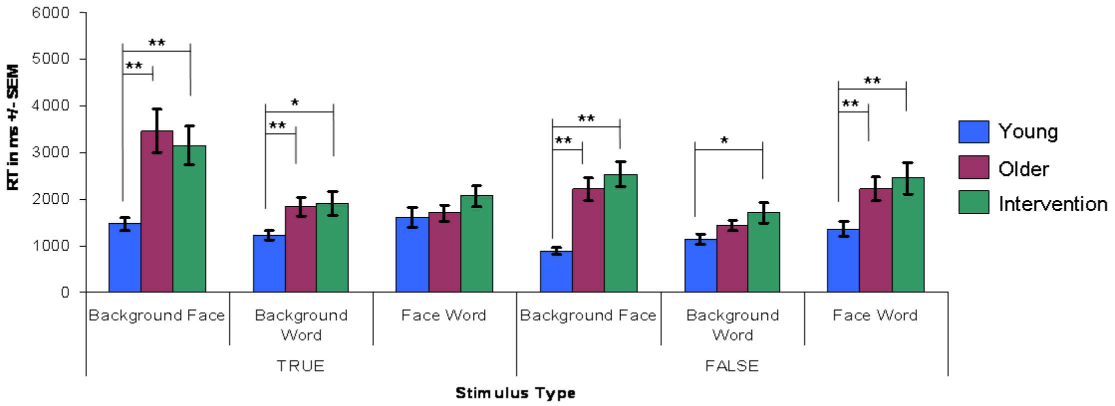


Figure 6.7: Response times +/- SEM for young, older and intervention groups on True and False Background-Face, Background-Word and Face-Word pairs for correct responses
($p < 0.05$, **$p < 0.01$)*

6.4 Discussion

It was apparent that the Older control group were more affected by source memory failures than both the Young and Intervention groups, while the Intervention group appeared to show few source memory failures as they performed with superior accuracy to both the Young and Older Control groups on both the Opposition and WWW tasks. This may suggest that deeper processing allowed for better recall than shallow processing. However, this enhanced memory accuracy due to the use of a strategy did not yield the same pattern of results for response times. The Young group generally had faster response times than both older groups, and the Older Intervention group showed response times that were either faster than or equivalent to those of Older Control adults. Therefore, it can be inferred that an intervention of deeper processing enhances source memory accuracy in older adults and that it may also aid response times for particular conditions of source memory recall.

The Opposition task showed that the Young group performed better than the Older Control group on Distractor words (new) at Lag 4 and Lag 16 while no differences were evident for Target words. The results indicate that older adults show a decrement in source memory that was not seen in younger adults and this decrement was seen for longer lag lengths on new words. This may suggest that when the time delay between repeated new items is longer, the more likely older adults were to misidentify items as previously encountered. This pattern was also seen across Chapters 3-5 which showed that Older adults were more impaired on Distractor words at longer lag lengths. This indicates that older adults have a larger discrepancy with correctly judging the time estimation of the occurrence of an event (Jennings & Jacoby, 1993, 1997).

However, the older adults using the intervention not only performed with better accuracies than the Older Control group, but also than the Young group with the exception of Target Lag 16 words. As this category consists of study words with a long interval between presentations, it is likely that the young and older adults perform well as such words may appear more familiar. For example, when an error response is made to the initial presentation of the word, it may then appear more familiar at the longer lag lengths, rectifying the initial response to a correct one as discussed in Chapter 3. However, as the Older Intervention group performed with higher accuracies than the Young and Older Control groups for each other category, this would suggest that by putting study words into sentences, the older adults in this group engaged in a deeper level of processing than the other groups. However, an issue with using this type of strategy lies in individual differences on the exact method used in the sentence formation. Some participants may have been able to utilise such a strategy better than others leading to a deep a level of processing and therefore may have benefitted more from such a strategy. As a result there may have been a large variance in the group as to whether the participants actively engaged in deep processing. Jacoby, Shimizu, Daniels et al. (2005) investigated a depth of processing strategy which required participants to either rate the pleasantness of words (deep) or merely hear words (shallow), and found that recall increased where encoding was deep. Furthering these results, Jacoby, Shimizu, Velanova et al. (2005) used a similar approach with older participants who were requested to make either judgements on the pleasantness of words (deep) or the vowels in words (shallow). Participants were required to engage with the word in the deep condition and the authors concluded that recall due to deep processing increased in older adults and the results of the current chapter support these findings. Sentence formation may have created a semantic link to the words as the meaning of the word must be identified in order to generate a sentence. As such, this may have led to semantic analysis of the meaning of the item, which is necessary for deep processing to occur (Craik & Lockhart, 1972; Craik, 2002). This may have provided the Older Intervention adults with greater retention of items as the words were processed on a deep level leading to better accuracy on the Opposition task and reduced impairments in source memory performance.

However, the response times indicate an interesting pattern between the three groups. The response times show that the Young group responded faster than the Older Control and this pattern has been seen across Chapters 3-5 and has replicated the previous results within the thesis. However, the Young group also responded faster than the Older Intervention group indicating that, although this type of intervention allows for better identification of items, it does not enable speeds of processing that are equivalent to those of young adults. This suggests that the Older Intervention group required more time than the Young when identifying items; this may have been due to the Older Intervention group having to access the semantic link that they created for identifying these items before they could make a response. However, the Older Intervention group in turn had faster response times than the older control group possibly indicating that, although the intervention of deeper processing did not allow for similar response times to Young adults, it did confer a slight speed advantage over Older Control adults. This may imply that while Older Controls required more time to correctly identify items, the intervention allowed for relatively faster processing. This may indicate that, despite the requirement to access semantic links, the intervention still yields faster response times than Older Controls recalling normally. The results from Craik and Tulving (1975) indicated that deeper processing required more time for participants compared to shallow processing. However, the authors did not differentiate between age, leaving it more difficult to generalise their findings to the current results. The processing involved in Craik and Tulving's experiment involved answering questions, whereas in the current study processing involved putting words into sentences. This process may have led to faster response times here as participants may have been recalling the mere method of putting the word into a sentence rather than recalling the entire formed sentence.

The WWW task showed that the older adults generally performed with poorer accuracy than the young adults. This supports findings of others indicating that older adults have poorer recall for face-scene pairs (Dennis, Hayes, et al., 2008) and auditory words (Harris, Dubno, Keren, Ahlstrom, & Eckert, 2009), and is consistent with the findings of the previous chapter (Chapter 5) replicating the results of the previous cohort. This apparent impairment in older adults on this task implies that source memory for the context of learning information declines with ageing. It also indicates that older adults are more likely than younger to misidentify items which have been previously linked, in turn suggesting that older adults are impaired in their ability to identify the source in which they acquired information. The results of the WWW task indicated that False face-word pairs (i.e. recombined faces and words) generally had the lowest accuracies for each of the groups. An explanation for this may be similar to the well documented phenomenon of recognising faces but forgetting names (Burton & Bruce, 1992; D. M. Harris & Kay, 1995; Rahman, Sommer, & Olada, 2004; Scanlan & Johnston, 1997; Yarmey, 1973). Therefore, participants may be recognising the face but when it is recombined with a single word, the word may be acting similarly to a name as seen in the face-name phenomenon, and participants may misrecognise the pair as a result of this. This pattern was generally seen in Chapter 5 also, particularly in young adults.

However, when older adults were given an intervention to use in order to create links between the three elements (i.e. story generation), they performed with improved accuracy. However, a problem with this technique lies in individual differences on how elaborate the story is and therefore how strong the links between the different items of context are. As such this may have led to a large variance within the Intervention group whereby participants are using different levels of depth which may have affected the accuracy performance of some participants. The Intervention groups performance was comparable to the Young group for all categories but two, where the Intervention group's performance was better, suggesting that the intervention allowed the older adults to have superior identification of paired items. For both True and False Background-Word pairs, the intervention group performed with greater accuracy than the Young group, possibly suggesting that this strategy engendered stronger links between *where* something was acquired and *what* was acquired. It was also apparent that story generation led to better recall for the Background-Word pairs than the other pairs. This may have been due to linking the word to the location in the story, while binding faces to other items may be more complex as, according to Bruce and Young (1986) semantic information can only be retrieved when a face is familiar, i.e. known to the person (Pfütze et al., 2002). As such, participants may be able to recognise that they have previously seen the face, but may have difficulty in retrieving the other semantic information related to the face (i.e. the location or word). In addition, the intervention in older adults generally produced better recall than the Older Control group on nearly each category. This may suggest that the process of story generation can create stronger links between items which can result in improved accuracy. Previous research has indicated that forming associations or links between items can increase recall in older adults (Dennis, Daselaar, et al., 2007; M. W. Eysenck, 1974; Osorio, Ballesteros, Fay,

& Pouthas, 2009) and the current results supports these studies. Elaborative processing can involve associations and stories and is considered a deeper level of processing than shallow (Craik & Lockhart, 1972). As the method of story generation relied on creating associations it may be considered as elaborative processing which remains deeper than shallow although it is not considered as deep as semantic analysis (Craik & Lockhart, 1972) which was utilised in the sentence generation in the Opposition task. However, despite this, the Intervention group performed with a high level of retention in the WWW task and it may be concluded that elaborative processing can lead to a reduction in source memory impairments.

Response times indicated that the Young group usually showed faster RTs than the Older Control group replicating the RT data on the task from the previous chapter. In addition, the Young group responded faster than the Older Intervention group, suggesting that the strategy did not allow for response times equivalent to those of Young adults at recall. This may have been due to the Older Intervention group needing longer to access the links created during acquisition of the items. However, there were no differences between the Older Control and Older Intervention groups on response times, which may suggest that the faster response times of Young adults compared to both older groups may simply reflect the well-documented age-related slowing in speed of processing. This corresponds with the results of the previous samples of older adults within the thesis and the with the speed theory proposed by Salthouse stating that older adults show a reduction in the speed at which they process information (Salthouse, 1993, 1996a). The theory further posits that this slowing accounts for cognitive deficits in older adults (Salthouse, 1996a; 1996b). However, as the intervention led to better accuracy performance than young adults, this is not the case for these particular older adults, indicating that, contrary to the speed theory, slowing in older adults may have an indirect role in the impairment in memory.

This study contains a few confounds which some alterations could have rectified. The first issue lies within comparing the two older groups. This study randomly assigned participants to either the older control or older intervention group and compared the groups' overall performance. However, by using this method it may have occurred that older adults with poorer memory performance were in the control group and higher performers ended up in the intervention group thus, skewing the data and making it appear as though a difference occurs between the two older groups when one does not. A way to rectify this issue may have been to match the individuals as closely as possible on performance on the control tasks and then assign participants to either the control or intervention group and thus, determine if a difference then exists.

Another issue regarding the results is again with the intervention group. It may be speculated that the intervention did not engender high accuracy scores as this group of adults are high performers based on the results of the control tasks. As such to remedy this issue participants could have been tested both with and without the intervention at different times in order to develop a baseline of performance for the source memory tasks and to then determine if the intervention allowed for better performance for the source memory tasks. One issue with this method is task learning; therefore, the order of the tasks would have to be counterbalanced and two separate versions of the task would have to be used to reduce the effects of task learning.

As stated above a final confound within the study is the use of a depth of processing intervention and individual differences on what is considered deep for each participant. To counter this problem each sentence and story could have been given to the participants who where then asked to repeat these so that each participant used the same technique. However, as the purpose was to investigate self-initiated techniques for memory retention, such a technique for investigation was not utilised in this experiment.

These results suggest that with the use of an intervention, accuracy scores can be enhanced to levels similar to those of young adults. This intervention may have resulted in an increase in accuracy for a number of reasons other than deeper processing. Firstly, this increase may have been seen as items had been bound together in memory allowing for easier access, and thus, increasing the amount of processing resources being used in older adults (Craik & Byrd, 1982; Craik et al., 1983; Craik, 1986). A second explanation may be that the use of an intervention required older adults to pay more attention to the items as they had to link them or put them into a sentence; this may have resulted in less interference for the items allowing only relevant information, i.e. the particular study items, to be entered into memory (Hasher & Zacks, 1988; Zacks et al., 2000).

Thirdly, as the intervention required participants to create semantic links to the items, this may have created cues for participants, and thus, enhanced any monitoring of such cues to recall the context of the items; as such it may be the case that the use of this intervention allowed for easier monitoring in older adults (Dodson & Johnson, 1996; M. Johnson et al., 1993; Mitchell & Johnson, 2009). Additionally, the use of an intervention produced heightened accuracy scores on source memory tasks which may have been due to an enhancement in binding the units of information together leading to a reduction in the breakdown of the links between the units (Naveh-Benjamin et al., 2004, 2003; Naveh-Benjamin, 2000). Finally, as there is not such a large decrement in familiarity due to ageing compared to recollection (Hasher & Zacks, 1979; Jacoby, 1991; Jennings & Jacoby, 1993), the intervention may have allowed for increased familiarity as participants had to concentrate on the items in order to create semantic links to them during the study which may have allowed for heightened accuracy when the item was presented.

Previous studies have found that the use of strategies can enhance memory performance in the elderly (Ball et al., 2002; Best, Hamlett, & Davis, 1992; Verhaeghen, Marcoen, & Goossens, 1992). Studies (Eysenck & Eysenck, 1980; Moscovitch & Craik, 1976) have indicated that deep processing is particularly beneficial for enhancing memory performance, and researchers have found that a deeper level of processing can have significant benefits for memory recall in older adults (Froger, Taconnat, Landré, Beigneux, & Isingrini, 2008; Jacoby, Shimizu, Velanova, et al., 2005). As the Older Intervention group performed with superior accuracies than the Older Control group, this would suggest that the use of an intervention at acquisition can have a significant benefit for older adults' source memory recall. As the Young group responded faster than both older groups, this implies that there is an age-related reduction in speed of processing, and while an intervention can counteract the decrement in performance accuracies, it appears as though it cannot totally negate the reduction in the speed at which older adults process information. The current study supports the levels of processing framework (Craik & Tulving, 1975; Craik & Lockhart, 1972) and further suggests that deeper processing can ameliorate the age-related accuracy impairment that is apparent in these particular source memory tasks.

Chapter VII

General Discussion

7.1 Overview of Results

The main objective of this thesis involved examining the effects of normal ageing on associative and source memory tasks using both electrophysiological and behavioural measures. An additional aim of the thesis was to investigate the importance of contextual information in the cognitive neuroscience of ageing. The current thesis resulted in four main findings. The first is an age-related decline in memory accuracy and slowing of speed of processing. This was evident across each of the experimental chapters where older adults generally had poorer accuracy than young on tasks of associative and source memory, and they also responded more slowly than the young adults. In general, these results suggest that different aspects of memory (i.e. source, associative and episodic) are related, and that they may rely on similar resources and processes, such as binding and association. The second main finding of the thesis is that a depth of processing intervention in older adults can enhance memory to be equivalent or superior to that of young adults. The results from Chapter 6 indicate that memory strategies, such as deeper levels of processing, can greatly enhance older adults' performance to exceed those of control older adults and allowing for performance to be more similar to those of young adults. Additionally, evidence which may suggest a compensation mechanism in older adults was found which appeared to occur at approximately 200ms. This compensation appeared in two forms; either as overactivity or as a shift in positive ERP waveforms from posterior to anterior scalp. The ERP analysis of Chapters 4 and 5 indicated that young adults show greater electrical activity than older. However, at approximately 200ms older adults generally displayed increased mean amplitudes, either positive or negative, and increased frontal activity, indicating a possible compensatory function which appears to only be evident at 200ms and may reflect an increase in attentional resources to counteract for a deficit in sensory perceptual processing. Finally, these findings offer support for the CRUNCH (Reuter-Lorenz & Cappell, 2008) and PASA (S. W. Davis et al., 2008) models which are predominant in the ageing literature, and which postulate a compensatory mechanism within older adults.

7.2 Implications of Findings

7.2.1 Memory and Normal Ageing

The current thesis showed that there is a general behavioural decline in memory due to the ageing process. This behavioural decline can be seen in a variety of types of memory including associative memory, episodic memory and predominantly in different contextual aspects of source memory. However, in light of these results, the role of executive function and attention must be discussed as these changes in memory could actually reflect decreases in executive function and/or attention. Executive function plays a vital role in memory, particularly in episodic-related memory (M. C. Davidson, Amso, Anderson, & Diamond, 2006; Shallice et al., 1994; Tulving, Markowitsch, Kapur, Habib, & Houle, 1994). Both encoding and retrieval of episodic memory relies on executive function (Kapur et al., 1994) as it is needed for assimilating information and preserving a sequence for events (Baddeley, 2000). Additionally, attention is necessary for both encoding and retrieval of episodic memories (Muzzio, Kentros, & Kandel, 2009). Encoding is determined by attending to and selecting particularly relevant information (Chun & Turk-Browne, 2007) and focusing attention on internal representations may result in the retrieval of memories (Cabeza, 2008; Chun & Turk-Browne, 2007; Muzzio et al., 2009). As such memory cannot be considered independent in its entirety as it is contingent on intact executive function and attention. Many previous studies have indicated an age-related decline in both executive function

(Gunning-Dixon & Raz, 2003; Libon et al., 1994; Salthouse, Atkinson, & Berish, 2003; Van Petten et al., 2004) and attention (N. D. Anderson, Craik, & Naveh-Benjamin, 1998; Dywan et al., 2001; Kok, 2000; Milham et al., 2002). As each of these types of cognitive processes may be related and rely on one another in some manner, it is impossible to entirely separate them. While the deficit may actually be attentional or executive dysfunctional, these cognitive functions are contingent upon one another; therefore, a decline in one aspect may reflect and result in a decline in another function. Consequently, the age-related decline in memory could result due to impairments in executive function or attention as it is impossible to separate the processes entirely. Therefore, within the ageing literature, it is possible that the age-related memory decline is as a result of a decline across numerous domains of cognition including memory, and consequently, a deficit in one aspect can incidentally impair another domain of cognition.

Testing adults from the age of 55 years may be considered as a young age group in comparison to some studies. This leads to the question of what is considered "older" in the context of the ageing literature. There is a large discrepancy within the literature as to what exactly is considered "old" within the context of ageing. Some researchers have included ages 55 years and over as part of a older group (for example: Cansino et al., 2013; Hultsch, Hertzog, & Dixon, 1990; Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992; Mattay et al., 2006), while others have included 60 and over as older (for example: Craik, Morris, Morris, & Loewen, 1990; Hutchens et al., 2012; Osorio, Ballesteros, Fay, & Pouthas, 2009; G. Smith, Della Sala, Logie, & Maylor, 2000), while >65 years is included as older for other researchers (for example: Duverne, Motamedinia, & Rugg, 2009; Lawson, Guo, & Jiang, 2007; Spencer & Raz, 1994; Viscogliosi, Desrosiers, Belleville, Caron, & Ska, 2011). As a result of these differences across the literature it is difficult to determine at what age exactly one should consider when it comes to testing memory in older adults. However, more recent research suggests that cognitive functions may begin to decline as early as the 40s (Singh-Manoux et al., 2012) and Metzler-Baddeley, Jones, Belaroussi, Aggleton and O'Sullivan (2011) indicated that episodic memory performance has a negative correlation with age beginning in the mid 50s. Additionally, long established studies have indicated that memory substantially declines from the mid 50 and onwards (Albert, Duffy, & Naeser, 1987; Albert, 1997). Therefore, as some cognitive functions may decline as early as ages 40, and studies indicate that memory in particular may begin to deteriorate from mid 50s onwards, adults aged 55 years and over may be considered as a prime cohort for age-related memory decline research, and it is this age group that was utilised within the current research studies.

In conclusion, the results of the current thesis suggest that the processes involved in source memory include identifying contextual information, binding the contextual information to the item or content which is then represented in memory. This contextual information may then act as a cue in order for the content memory to be retrieved. This may be apparent as young adults perform better than older on source memory tasks and previous research has indicated that older adults are more impaired on recalling the source of the information rather than the content (Schacter et al., 1991; Siedlecki et al., 2005; Simons et al., 2004). The current thesis further suggests that this reduction in source memory may reflect an inability to bind the contextual information to the content information, supporting suggestions by other researchers (Glisky & Kong, 2008; Henkel et al., 1998; Kessels et al., 2007). This can be inferred, as when older adults are given a strategy to help them bind information in memory, this decrement virtually disappears, corroborating the results indicated by other researchers (Glisky et al., 2001). Additionally, the results of the current thesis correspond with the predictions of the CRUNCH and PASA models, as overactivations were apparent in older adults at certain time points and scalp topographies indicated a shift in positive ERP activity from the posterior to the anterior. Additionally, both types of compensation appear to be occurring concurrently and, as previously discussed, may be compensating with increased attentional processes in order to balance out the potential reduction in early perceptual processing (see Chapter 4 and 5 for discussion). As such, the current results may indicate a compensatory function of the ageing brain to counteract the cognitive deficits seen in ageing.

7.2.2 Context

The current thesis has implicated the importance of context in memory, especially in source memory which is regarded as memory for the entire context of an item, i.e. *where, when, how* it was acquired and any other aspects of context associated with the memory (Glisky & Kong, 2008; Jacoby, Shimizu, Daniels, et al., 2005; M. Johnson et al., 1993; Schacter et al., 1994; Schmitter-Edgecombe et al., 2009). The current thesis offered evidence mainly for the importance of intrinsic context in associative and source memory tasks, i.e. automatically processed information which is relevant to an item in memory (Mckenzie & Tiberghien, 2004). Contextual information was provided in different tasks within the current thesis, i.e. backgrounds in the VPAc task, time of presentation in the Opposition task, and background, face and word triplets in the WWW task. Previous research has indicated that if contextual cues at recall remain similar to those at the time of acquisition, recollection can be facilitated (Boywitt & Meiser, 2012; Davis, Lockhart, & Thomson, 1972; Ecker, Zimmer, & Groh-Border, 2007; Light & Carter-Sobell, 1970; Tulving & Thomson, 1973). However, within the current thesis the only task which manipulated context in such a way was the VPAc task, and the results from this task generally support the suggestion that contextual consistency aids memory recall. Although both source memory tasks also rely on context, the context within was not manipulated in this manner, as the contextual dependency effect was not the phenomenon under investigation. However, as the studies mentioned above have indicated that this is the case, it may be inferred that consistency within context may have facilitated memory somewhat in these tasks.

As indicated above, context is a very important feature when encoding items to memory and can enhance or impede memory recall depending on whether the context remains the same or changes compared to the time of acquisition. The current thesis has indicated that increasing attention to the contextual cues at the time of acquisition for the WWW task allowed for increased recall in older adults. Cohen's computational model of context suggests that context has an attentional function (Cohen et al., 1999, 1996; Cohen & Servan-Schreiber, 1992) and this intervention increased attention to contextual information allowing for improved memory recall in older adults. This was established by using an intervention which involved deeper processing giving meanings, implications and semantic links to the information (Craik & Lockhart, 1972; Craik, 2002). As such, additional contextual information was created for older adults which may have led to increased source memory performance. The intervention used for the Opposition task increased semantic binding of items in memory and therefore, cannot be discussed in terms of context here.

In conclusion, contextual information is a very important and necessary component of memory, and can be used to both enhance and impede memory performance. The hippocampus plays a crucial role in processing the context of information, and deficits in contextual processing may result from impaired functioning of the hippocampus. As source memory relies on the recall of the context of a memory, manipulations to the contexts of source memory tasks may therefore result in poorer memory performance for such tasks. However, by providing additional context to items, and instructing attention to the context with the use of strategies, memory can be enhanced with the use of these contextual cues.

7.3 Limitations

There are number of limitations within the current thesis. The first limitation to be considered relates to the types of participants tested in the studies. The current research relied on young and older adults volunteering for the particular research studies and as such participants consisted of individuals with an interest in the area of memory. Due to this the sample may not have been representative of the population as participants may have tried harder given their interest, and individuals who considered they had a poor memory capacity may not have volunteered for such research.

A second limitation pertains to the source memory tasks. Both tasks (Opposition and WWW tasks) had a low number of trials in each condition; as such this may have led to noisy data regarding electrophysiology. It may have also allowed for exaggerated accuracy performances in the groups as fewer items had to be correctly identified. However, the preparation for EEG usually took an hour, and along with the control and computer tasks, testing usually lasted a total of two hours. As such additional trials in the tasks would have increased the overall duration of testing and would not have fallen within the ethical remits of the study. Additionally, the WWW task is very difficult so poor performance may reflect task difficulty rather than source memory deficits. Future research may be needed to further investigate this particular task to establish if impairments in memory have been distorted by the difficulty of the task.

Another aspect of the research that could have been adjusted would have been to include a full IQ test instead of the NART in order to obtain more accurate results rather than estimates IQ. However, the NART is a widely accepted and frequently used test that correlates highly with premorbid intelligence, is quick to administer and is considered a useful test for healthy participants (Crawford, Parker, Stewart, Besson, & Lacey, 1989; Franzen, Burgess, & Smith-Seemiller, 1997; Frick, Wahlin, Pachana, & Byrne, 2011). It is for these reasons that this test was used rather than a full IQ test. A further criticism is in the use of the CFQ as a control measure. The results of the CFQ throughout the thesis reported similar scores for both young and older adults. Researchers have indicated that age-related differences within the CFQ are weak (Rast, Zimprich, Van Boxtel, & Jolles, 2009), corresponding with the results from the current thesis. However, they have suggested that by categorising the questionnaire into distractibility, forgetfulness and false triggering, different patterns of change can be seen across the lifespan, suggesting that there are different rates of change for the various elements of cognitive failures (Rast et al., 2009). As such, it may be considered useful to use this structure for any future research involving the CFQ.

Thirdly, regarding the analyses, a large number of dependent t-tests were carried out to investigate within-group differences in the tasks, these had to be Bonferroni-corrected in order to reduce the instance of Type I error. However, due to this, some within group differences were rendered non-significant which this may have not been correct (Type II error). A larger N of participants and trials should counteract this limitation for future research. Additionally, as the main focus of the research was to determine age-related differences in memory, independent t-tests alone could have established significant differences between the groups. However, using this type of analysis alone would not have yielded as many interesting and varied results within the tasks. Additionally, using a larger N within each of the experiments could have potentially led to less chance of the behavioural and electrophysiological results being underpowered. It is possible that a real effect was missed by not having enough data. For example, this could have been the issue with the False Memory task, and a larger sample of participants may have led to significant differences between the groups. Additionally, this could have also been the issue for a fewer number of significant differences between the groups on the mean amplitudes of the ERP components and a larger N could have yielded different results. As such, for future studies, it would be pertinent to include a larger sample of participants for more confidence in the experimental power.

A final adjustment which could have been made to the study would have been to include a third group, aged 35-50 years to further compare age-related differences in memory and to determine at which ages such impairments begin to emerge. In addition, the intervention study could have also employed the intervention in young adults to determine if older adults' memory would be equivalent to those of young adults using the same intervention, or if age-related impairments existed despite the use of a memory strategy. However, as the young adults were included as a control group this was not carried out within the current study.

7.4 Future Directions

Further studies which are of interest include imaging studies using fMRI for both the Opposition and WWW tasks. This type of study would be especially interesting in normal and pathological ageing, in particular with Mild Cognitive Impairment, Alzheimer's Disease and Vascular Dementia. It would be of interest to determine how detrimental these types of dementia would be for behavioural performance on these tasks, to determine which regions of the brain are activated during them and to examine whether an age-related deficit is associated with such regions. In addition, research into different memory strategies for source memory decline in normal and pathological ageing are of interest. In particular, a longitudinal study to determine if a depth of processing strategy can alleviate or enhance everyday memory in normal and pathological ageing and if this enhances the already apparent compensatory function in the brain in older adults would be revealing. Additionally, a future study of interest is a correlational study to develop a sensitive source memory questionnaire, along with norms for a population, which could be used to identify early source memory deficits in normal and pathological ageing. Ultimately, any further research would focus primarily on imaging in normal and pathological ageing in source memory, and on any novel techniques which may impede such deficits.

7.5 Concluding Remarks

The results in the current thesis manifested four main findings. First, a decline in accuracy and slowing of response times appears to be age-related. Secondly this age-related decline in accuracy can be negated with a depth of processing strategy in older adults. Third, ERP analysis indicated age-related overactivity or a shift in positive activity at approximately 200ms, which may reflect a compensatory function in older adults. Finally, these compensation mechanisms offer support for the well documented CRUNCH (Reuter-Lorenz & Cappell, 2008) and PASA models (S. W. Davis et al., 2008).

This discussion has indicated that different aspects of memory are related. However, as relationships were not apparent between all conditions of these tasks, this indicates that while source, associative and episodic memory utilise the same or similar cognitive resources, they may not use these in the same way or at the same level. Furthermore, additional neural and cognitive resources may also function in different aspects of these types of memory, and this may have not allowed for each of the conditions to be correlated.

As the WWW task showed correlations with the Opposition task, which is long established (Jennings & Jacoby, 1993, 1997), this may suggest that this task is a useful measure of source memory. Additionally, as older adults found this task particularly difficult, and previous research indicates that older adults are particularly impaired on source memory tasks (Siedlecki et al., 2005; Spencer & Raz, 1994; Zacks et al., 2000), this also indicates that this task may be quite sensitive to source memory deficits in older adults. This may be the case as this task uses a variety of contexts and previous studies have indicated that older adults may have a deficit when required to bind the context of an item to the specific content (Glisky & Kong, 2008; Henkel et al., 1998; Kessels et al., 2007). As such, this task provides further evidence that there may be a decrement in binding the different contexts of items within memory together. However, the current thesis further suggests that this decrement can be reduced by using a depth of processing strategy to help create semantic links between such contextual items. This was also apparent for judging the timing of presentation of stimuli, as measured by the Opposition task.

Finally, the current thesis provides additional support for the PASA (S. W. Davis et al., 2008) and CRUNCH (Reuter-Lorenz & Cappell, 2008) models. As both models were established with the use of neuroimaging, the current research enhances knowledge of these models of normal ageing as the results were established with electrophysiology, and based on current knowledge of the literature, no studies using electrophysiology with source memory have indicated support for these models to date.

In conclusion, the current thesis reports four experiments which involved a total of 170 participants (76 young; 94 older) tested on a variety of memory tasks. Results suggest that older adults are more impaired than young in memory performance on a variety of tasks, and predominantly source memory tasks. However, this behavioural decrement can be alleviated with the use of a depth of processing strategy. However, the most notable finding of this thesis is the support for a compensatory function in the brains of older adults which may be an automatic process. Additionally, this compensatory function offers support for the CRUNCH (Reuter-Lorenz & Cappell, 2008) and PASA (S. W. Davis et al., 2008) models. Further studies to determine if this function can be enhanced with the use of a depth of processing strategy are needed.

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Appendices

Appendix A: Rey Auditory Verbal Learning Test

Appendix B: National Adult Reading

Appendix C: Digit Span

Appendix D: Cognitive Failures Questionnaire

Appendix E: Source Memory Questionnaire

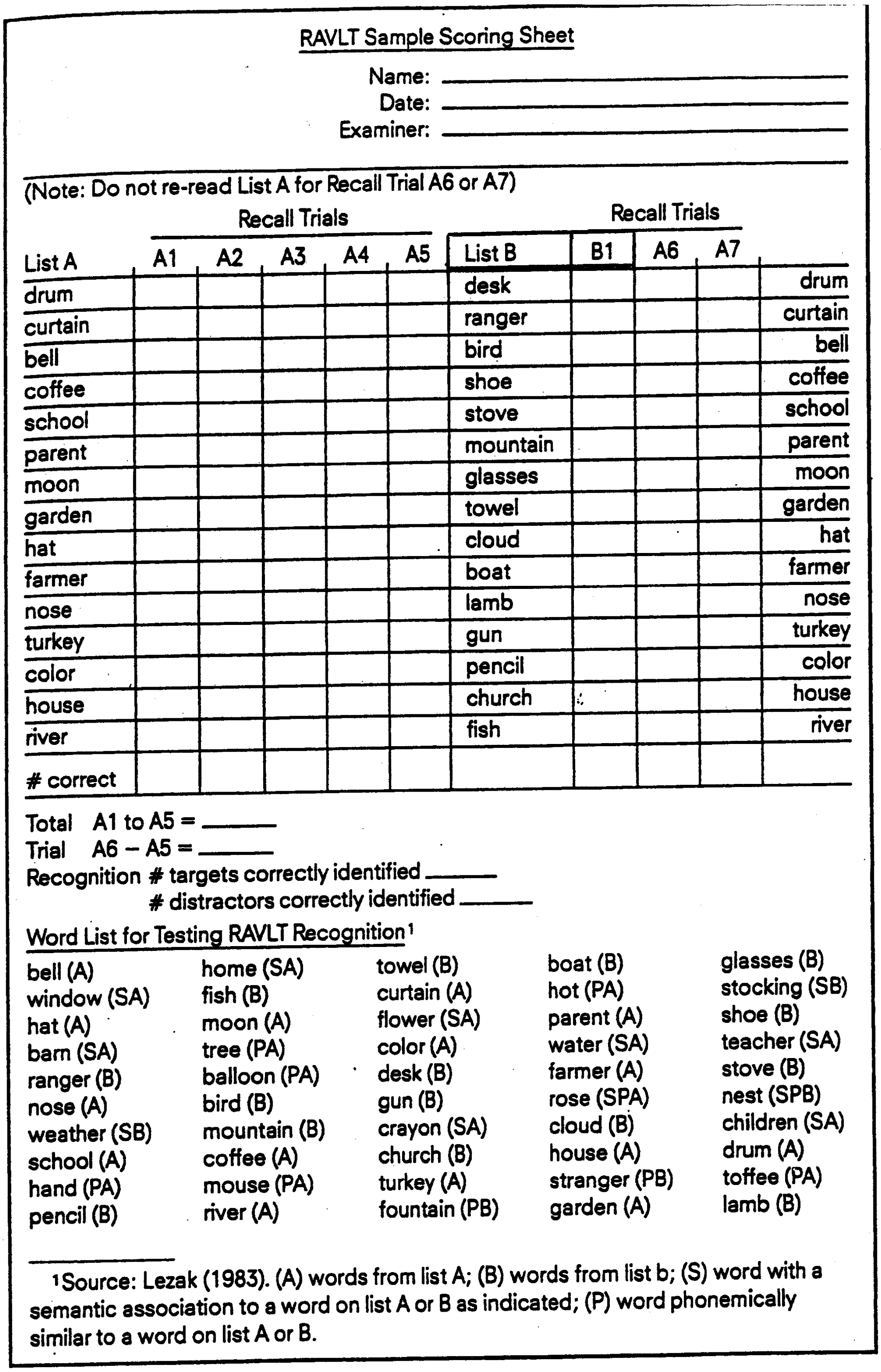
Appendix F: Informed Consent (Chapter 3)

Appendix G: Informed Consent (Chapter 4)

Appendix H: Informed Consent (Chapter 5)

Appendix I: Informed Consent (Chapter 6)

Appendix A



RAVLT Sample Scoring Sheet

Name: ____________________

Date: ____________________

Examiner: ____________________

(Note: Do not re-read List A for Recall Trial A6 or A7)

	Recall Trials						Recall Trials			
List A	A1	A2	A3	A4	A5	List B	B1	A6	A7	
drum						desk				drum
curtain						ranger				curtain
bell						bird				bell
coffee						shoe				coffee
school						stove				school
parent						mountain				parent
moon						glasses				moon
garden						towel				garden
hat						cloud				hat
farmer						boat				farmer
nose						lamb				nose
turkey						gun				turkey
color						pencil				color
house						church				house
river						fish				river
# correct										

Total A1 to A5 = ______

Trial A6 – A5 = ______

Recognition # targets correctly identified ______

distractors correctly identified ______

Word List for Testing RAVLT Recognition[1]

bell (A)
window (SA)
hat (A)
barn (SA)
ranger (B)
nose (A)
weather (SB)
school (A)
hand (PA)
pencil (B)

home (SA)
fish (B)
moon (A)
tree (PA)
balloon (PA)
bird (B)
mountain (B)
coffee (A)
mouse (PA)
river (A)

towel (B)
curtain (A)
flower (SA)
color (A)
desk (B)
gun (B)
crayon (SA)
church (B)
turkey (A)
fountain (PB)

boat (B)
hot (PA)
parent (A)
water (SA)
farmer (A)
rose (SPA)
cloud (B)
house (A)
stranger (PB)
garden (A)

glasses (B)
stocking (SB)
shoe (B)
teacher (SA)
stove (B)
nest (SPB)
children (SA)
drum (A)
toffee (PA)
lamb (B)

---

[1] Source: Lezak (1983). (A) words from list A; (B) words from list b; (S) word with a semantic association to a word on list A or B as indicated; (P) word phonemically similar to a word on list A or B.

Appendix B

National Adult Reading Test

Ache
Debt
Psalm
Depot
Chord
Bouquet
Deny
Capon
Heir
Aisle
Subtle
Nausea
Equivocal
Naïve
Thyme
Courteous
Gaoled
Procreate
Quadruped
Catacomb
Superfluous
Radix
Assignate
Gist
Hiatus
Simile
Aeon
Cellist
Zealot
Abstemious
Gouge
Placebo
Façade
Aver
Leviathan
Chagrin
Détente
Gauche
Drachm
Idyll
Beatify
Banal
Sidereal
Puerperal
Topiary
Desmesne
Labile
Phlegm
Syncope
Prelate

FOR EXPERIMENTER’S USE

NART pronunciation and definitions

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

FOR EXPERIMENTER'S USE ONLY

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

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

Appendix C

11. Digit Span (Optional)

DISCONTINUE RULE:
After scores of 0 on both trials of any item.
For both Digits Forward & Backward, administer both trials of each item even if Trial 1 is passed.

RECORDING:
All responses verbatim.

SCORING RULE:
0–1 pt. for each response

Digits Forward

Item/Trial		Response	Score 0 or 1
1.	Trial 1	1 - 7	
	Trial 2	6 - 3	
2.	Trial 1	5 - 8 - 2	
	Trial 2	6 - 9 - 4	
3.	Trial 1	6 - 4 - 3 - 9	
	Trial 2	7 - 2 - 8 - 6	
4.	Trial 1	4 - 2 - 7 - 3 - 1	
	Trial 2	7 - 5 - 8 - 3 - 6	
5.	Trial 1	6 - 1 - 9 - 4 - 7 - 3	
	Trial 2	3 - 9 - 2 - 4 - 8 - 7	
6.	Trial 1	5 - 9 - 1 - 7 - 4 - 2 - 8	
	Trial 2	4 - 1 - 7 - 9 - 3 - 8 - 6	
7.	Trial 1	5 - 8 - 1 - 9 - 2 - 6 - 4 - 7	
	Trial 2	3 - 8 - 2 - 9 - 5 - 1 - 7 - 4	
8.	Trial 1	2 - 7 - 5 - 8 - 6 - 2 - 5 - 8 - 4	
	Trial 2	7 - 1 - 3 - 9 - 4 - 2 - 5 - 6 - 8	

Forward Total Score
Range = 0 to 16 ☐

Digits Backward

Item/Trial		(Correct Response)/Response	Score 0 or 1
1.	Trial 1	2 - 4 (4 - 2)	
	Trial 2	5 - 7 (7 - 5)	
2.	Trial 1	6 - 2 - 9 (9 - 2 - 6)	
	Trial 2	4 - 1 - 5 (5 - 1 - 4)	
3.	Trial 1	3 - 2 - 7 - 9 (9 - 7 - 2 - 3)	
	Trial 2	4 - 9 - 6 - 8 (8 - 6 - 9 - 4)	
4.	Trial 1	1 - 5 - 2 - 8 - 6 (6 - 8 - 2 - 5 - 1)	
	Trial 2	6 - 1 - 8 - 4 - 3 (3 - 4 - 8 - 1 - 6)	
5.	Trial 1	5 - 3 - 9 - 4 - 1 - 8 (8 - 1 - 4 - 9 - 3 - 5)	
	Trial 2	7 - 2 - 4 - 8 - 5 - 6 (6 - 5 - 8 - 4 - 2 - 7)	
6.	Trial 1	8 - 1 - 2 - 9 - 3 - 6 - 5 (5 - 6 - 3 - 9 - 2 - 1 - 8)	
	Trial 2	4 - 7 - 3 - 9 - 1 - 2 - 8 (8 - 2 - 1 - 9 - 3 - 7 - 4)	
7.	Trial 1	9 - 4 - 3 - 7 - 6 - 2 - 5 - 8 (8 - 5 - 2 - 6 - 7 - 3 - 4 - 9)	
	Trial 2	7 - 2 - 8 - 1 - 9 - 6 - 5 - 3 (3 - 5 - 6 - 9 - 1 - 8 - 2 - 7)	

Backward Total Score
Range = 0 to 14 ☐

Total Score
Range = 0 to 30 ☐

(Sum Forward Total Score & Backward Total Score)

Appendix D

CFQ

Name ....   Date...........

....

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

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

	Very often	Quite often	Occasio-nally	Very rarely	Never
Do you find yourself suddenly wondering whether you've used a word correctly?	4	3	2	1	0
Do you have trouble making up your mind?	4	3	2	1	0
Do you find you forget appointments?	4	3	2	1	0
Do you forget where you put something like a newspaper or a book?	4	3	2	1	0
Do you find you accidentally throw away the thing you want and keep what you meant to throw away as in the example of throwing away the matchbox and putting the used match in your pocket?	4	3	2	1	0
Do you daydream when you ought to be listening to something?	4	3	2	1	0
Do you find you forget people's names?	4	3	2	1	0
Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	4	3	2	1	0
Do you find you can't quite remember something although it's 'on the tip of your tongue'?	4	3	2	1	0
Do you find you forget what you came to the shops to buy?	4	3	2	1	0
Do you drop things?	4	3	2	1	0
Do you find you can't think of anything to say?	4	3	2	1	0

Appendix E

Source Memory Questionnaire

Below are some examples of things that happen to people in everyday life. We want to know how often these things may have happened to you. Please circle the appropriate number.

Very Often	Quite Often	Occasionally	Rarely	Never
4	3	2	1	0

Do you read something and find that you haven't been thinking about it and must read it again?

4 3 2 1 0

Do you find you forget why you went from one part of the house to another?

4 3 2 1 0

Do you find that you forget whether you've turned of a light or a fire or locked the door?

4 3 2 1 0

Do you fail to hear people speaking to you when you are doing something else?

4 3 2 1 0

Do you leave important letters unanswered for days?

4 3 2 1 0

Do you find you forget which way to turn on a road you know well byt rarely use?

4 3 2 1 0

Do you find you forget appointments?

4 3 2 1 0

Do you forget where you put something like a newspaper or a book?

4 3 2 1 0

Do you find that you accidentally throw away the thing you want and keep what you meant to throw away, as in the example of throwing away the box of matches and putting the used match in your pocket?

4 3 2 1 0

Do you find you forget people's names?

4 3 2 1 0

Do you start doing one thing at home and get distracted into doing something else (unintentionally)?

4 3 2 1 0

Very Often	Quite Often	Occasionally	Rarely	Never
4	3	2	1	0

Do you find that you forget what you came to the shops to buy?

4 3 2 1 0

Do you find yourself having to check whether you have done something that you should have done?

4 3 2 1 0

Do you find yourself forgetting when it was that something happened; for example whether it was last week or yesterday?

4 3 2 1 0

Do you find that you forget that you were told something and maybe having to be reminded about it?

4 3 2 1 0

Do you find that you start to read something (a book or an article in a newspaper, or magazine) without realising that you have already read it before?

4 3 2 1 0

Do you fins that you completely forget to do things you said you would do, and things you planned to do?

4 3 2 1 0

Do you forget important details of what you did or what happened to you the day before?

4 3 2 1 0

Do you forget to tell somebody something important, perhaps forget to pass on a message or remind someone of something?

4 3 2 1 0

Do you forget where things are normally kept or look for them in the wrong place?

4 3 2 1 0

Do you repeat to someone what you have just told them or ask someone the same question twice?

4 3 2 1 0

Appendix F

Investigating age-related memory retrieval decline

Researcher:
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Ph 01 708 6311

Supervisor:
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Department of Psychology
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Ph 01 708 6069

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

Your participation is requested in an experimental study taking place in the Department of Psychology at NUI Maynooth examining if a learning strategy will improve source memory accuracy. You will be asked to complete a number of control tasks and questionnaires, and three computer-based memory tasks, an Opposition task and a Visual Paired-Associates task and a False Memory task where you will first complete a study section and then a test section in which you will be asked to respond to stimuli.

The total time for your participation will be approximately 1 hour.

The specific nature of the study will be explained as soon as you have completed your session. The results of each individual's participation will be strictly confidential and will be kept in a locked cabinet in the Psychology Department. The results of your participation will be documented by subject number only. No names or individual identifying information will be recorded. With the exception of the researcher(s) involved in running this study, nobody will be allowed to see or discuss any of the individual responses. Your responses will be combined with many others and reported in group form in a scientific paper, but your own data will be available to you at your discretion. Data will be retained for five years post publication, in accordance with the requirements of most academic journals. You may withdraw from the study at any time or you may withdraw their data up until the work is published.

In the unlikely event that you experience any distress, discomfort or other negative experience as a result of participating in this study, you should contact the Student Counseling Service (708 3554) or Student Health Service (708 3878; both on campus and located very close to the Psychology Department) or contact your own GP.

Finally, we will need to know if you suffer from **any** of the following:

- severe visual impairments;
- history of psychological/neurological impairment;
- severe head trauma resulting in unconsciousness;
- history of epilepsy;
- currently taking psychoactive medication;
- other relevant medical conditions;
- high blood pressure/heart condition;
- history of drug or alcohol problems;
- claustrophobia;
- dyslexia.

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

Participant signature Date

This research project has been approved by the Departmental Ethics Committee.

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

Appendix G

Investigation of different ERP waveforms in young and older adults

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Ph 01 708 6069

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

Your participation is requested in an experimental study taking place in the Department of Psychology at NUI Maynooth examining the role of ageing in memory decline. You will be asked to complete three computer-based memory tasks, an Opposition task, a False Memory task and a Visual Paired Associates task where you will first complete a study section and then a test section in which you will be asked to respond to stimuli. During the experiment, we will record electrical brain waves by placing a cap on your head which will allow us to record electrical signals as your brain engages in the tasks you are doing. This procedure is safe, painless and non-invasive; it does not involve radiation, x-rays, magnetic fields or any other dangerous elements, so you should consider it similar to having your heart-rate or blood-pressure measured. The procedure involves applying a conductive gel to your scalp to help us get a clear signal from the brain, so you will need to wash your hair afterwards – washing and drying facilities will be provided for you.

The total time for your participation will be approximately 2 hours.

The specific nature of the study will be explained as soon as you have completed your session. The results of each individual's participation will be strictly confidential and will be kept in a locked cabinet in the Psychology Department. The results of your participation will be documented by subject number only. No names or individual identifying information will be recorded. With the exception of the researcher(s) involved in running this study, nobody will be allowed to see or discuss any of the individual responses. Your responses will be combined with many others and reported in group form in a scientific paper, but your own data will be available to you at your discretion. You may withdraw from the study at any time or you may withdraw their data up until the work is published.

In the unlikely event that you experience any distress, discomfort or other negative experience as a result of participating in this study, you should contact the Student Counseling Service (708 3554) or Student Health Service (708 3878; both on campus and located very close to the Psychology Department) or contact your own GP.

Finally, we will need to know if you suffer from **any** of the following:

- severe visual impairments;
- history of psychological/neurological impairment;
- severe head trauma resulting in unconsciousness;
- history of epilepsy;
- currently taking psychoactive medication;
- other relevant medical conditions;
- high blood pressure/heart condition;
- history of drug or alcohol problems;
- claustrophobia.

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

______________________________________ __________________

Participant signature Date

This research project has been approved by the Departmental Ethics Committee.

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

Appendix H

An investigation of brain activity in source memory tasks

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Ph 01 708 6069

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

Your participation is requested in an experimental study taking place in the Department of Psychology at NUI Maynooth examining memory decline in ageing and identifying the specific region where such impairment occurs. You will be asked to complete a number of control tasks and questionnaires, and two computer-based memory tasks, an Opposition task and a Where-Who-What where you will first complete a study section and then a test section in which you will be asked to respond to stimuli. During the experiment, we will record electrical brain waves by placing a cap on your head which will allow us to record electrical signals as your brain engages in the tasks you are doing. This procedure is safe, painless and non-invasive; it does not involve radiation, x-rays, magnetic fields or any other dangerous elements, so you should consider it similar to having your heart-rate or blood-pressure measured. The procedure involves applying a conductive gel to your scalp to help us get a clear signal from the brain, so you will need to wash your hair afterwards – washing and drying facilities will be provided for you.

The total time for your participation will be approximately 2 hours.

The specific nature of the study will be explained as soon as you have completed your session. The results of each individual's participation will be strictly confidential and will be kept in a locked cabinet in the Psychology Department. The results of your participation will be documented by subject number only. No names or individual identifying information will be recorded. With the exception of the researcher(s) involved in running this study, nobody will be allowed to see or discuss any of the individual responses. Your responses will be combined with many others and reported in group form in a scientific paper, but your own data will be available to you at your discretion. Data will be retained for five years post publication, in accordance with the requirements of most academic journals. You may withdraw from the study at any time or you may withdraw their data up until the work is published.

In the unlikely event that you experience any distress, discomfort or other negative experience as a result of participating in this study, you should contact the Student Counseling Service (708 3554) or Student Health Service (708 3878; both on campus and located very close to the Psychology Department) or contact your own GP.

Finally, we will need to know if you suffer from **any** of the following:

- severe visual impairments;
- history of psychological/neurological impairment;
- severe head trauma resulting in unconsciousness;
- history of epilepsy;
- currently taking psychoactive medication;
- other relevant medical conditions;
- high blood pressure/heart condition;
- history of drug or alcohol problems;
- claustrophobia.

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

______________________________________ __________________

Participant signature Date

This research project has been approved by the Departmental Ethics Committee.

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

Appendix I

An investigation of a learning strategy on source memory tasks

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

Your participation is requested in an experimental study taking place in the Department of Psychology at NUI Maynooth examining if a learning strategy will improve source memory accuracy. You will be asked to complete a number of control tasks and questionnaires, and two computer-based memory tasks, an Opposition task and a Where-Who-What where you will first complete a study section and then a test section in which you will be asked to respond to stimuli. During the study block of the experiment, we will ask you to use a learning strategy, either putting words into sentences or creating a story.

The total time for your participation will be approximately 1 hour.

The specific nature of the study will be explained as soon as you have completed your session. The results of each individual's participation will be strictly confidential and will be kept in a locked cabinet in the Psychology Department. The results of your participation will be documented by subject number only. No names or individual identifying information will be recorded. With the exception of the researcher(s) involved in running this study, nobody will be allowed to see or discuss any of the individual responses. Your responses will be combined with many others and reported in group form in a scientific paper, but your own data will be available to you at your discretion. Data will be retained for five years post publication, in accordance with the requirements of most academic journals. You may withdraw from the study at any time or you may withdraw their data up until the work is published.

In the unlikely event that you experience any distress, discomfort or other negative experience as a result of participating in this study, you should contact the Student Counseling Service (708 3554) or Student Health Service (708 3878; both on campus and located very close to the Psychology Department) or contact your own GP.

Finally, we will need to know if you suffer from **any** of the following:

- severe visual impairments;
- history of psychological/neurological impairment;
- severe head trauma resulting in unconsciousness;
- history of epilepsy;
- currently taking psychoactive medication;
- other relevant medical conditions;
- high blood pressure/heart condition;
- history of drug or alcohol problems;
- claustrophobia;
- dyslexia.

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

______________________________________ __________________

Participant signature Date

This research project has been approved by the Departmental Ethics Committee.

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