Enhancing Autobiographical Memory Fluency & Specificity: Effects of Eye Movements & Eye Closure

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Enhancing Autobiographical Memory Fluency & Specificity: Effects of Eye Movements & Eye Closure

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Abstract

Research has demonstrated that performing a sequence of saccadic horizontal eye movements (SEMs) prior to retrieval or closing one's eyes during retrieval facilitates episodic memory. The research in this thesis is concerned with increasing the recall of episodic autobiographical memory in old (Experiment 1) and younger (Experiment 1-3) individuals with the use SEMs (Experiments 1-3) and eye-closure (Experiments 2-3).

Experiment 1 extends previous research by examining the effects of SEMs in older and younger adults. Autobiographical episodic and semantic memory fluency was assessed in younger and older participants following saccadic (vs. fixation control) manipulations. Eye movements enhanced episodic fluency in both age groups. Semantic autobiographical memory showed a main effect of age (greater fluency in younger participants), whereas general semantic memory showed no effect of age or eye movement.

Experiment 2 extended the first study by the inclusion of eye-closure. The experiment also changed how memories were elicited by use of the Galton Crovitz technique using concrete and abstract words. Recall was measured by the specificity of recall and its associated phenomenological qualities. The experiment found concrete cues to enhance both the specificity of recall and phenomenological qualities. Eye movements increased memory specificity but not phenomenological qualities. Eye closure effects were only found on the phenomenological qualities of 'seeing' and 'hearing'.

Experiment 3 made changes to both manipulations and measurements. Eye-closure was altered from between to within subjects and dynamic visual noise (DVN) was included to increase distraction with eyes open. As before, SEMs was manipulated between-subjects. Regarding measurements, participants indicated whether memories were recalled directly or after more effortful generation. A significant effect of eye-closure/distraction was found (except direct vs generative recall which only showed effects of DVN) showing an advantage in the eye closure condition. Cue-type produced similar findings to Experiment 2 but SEM effects produced only numerical differences. This is the first-time eye-closure and DVN effects have been shown in autobiographical memory using the cue-word technique.

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Statement of original Authorship

This thesis comprises the candidate's own original work and has not been submitted previously or simultaneously to this or any other University for a degree. All experiments were designed and conducted by the candidate under supervision Dr Andrew Parker and Dr Neil Dagnall. Part of the data from this thesis has been previously presented in the published journal article outlined below (full copy of the paper can be found in appendix 6).

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Chapter 1: General Introduction

General Scope of the PhD and Introductory Terminology

Autobiographical memory is personal memory and encompasses both abstract knowledge of oneself and specific details of one's experience in time and space (Conway, 2005; Conway, & Pleydell-Pearce, 2000; Levine, 2004). Abstract knowledge refers to self-knowledge and includes beliefs about one's opinions, evaluations, attitudes, personality or indeed any self-defining characteristics. Collectively, this form of personal knowledge is called semantic autobiographical memory to emphasise its more general nature (like semantic memory) and its personal core. The specific details of one's experience that includes the unique character of remembered episodes such as sensory, emotional & contextual information is defined as episodic autobiographical memory. It is this form of personal memory that provides the basis for mental time-travel and reliving aspects of ones' personal past.

Autobiographical memory is important as it is through this that a sense of mental continuity across time is possible (Bluck, 2003; Bluck, et al., 2005; Leist, Ferring, & Filipp, 2010; Rasmussen & Berntsen, 2009). Indeed, the loss of personal memories leads to a disconnection between oneself in the present and the past and enables individuals to retain a clear appraisal of their own identity (Meléndez, Torres, Redondo, Mayordomo, & Sales, 2016). Autobiographical memory is also of importance in terms of directing ongoing behaviour and regulating emotions (Williams, 1996; Williams & Broadbent, 1986).

Impairment in the ability to recall specific and detailed autobiographical memories is related to depression (Wilson, & Gregory, 2018). More practically, impaired social problem solving (Beaman, Pushkar, Etezadi, Bye, & Conway, 2007; Leahy, Ridout, Mushtaq, & Holland, 2018), and reduced personal independence (Holland, Boukouvalas, Wallis, Clarkesmith, Cooke, Liddell et al., 2017; Leahy et al., 2018).

Accordingly, acquiring and developing means to enhance episodic autobiographical memory is important. Previously, a number of techniques have been used especially with older individuals, those with emotional disorders, and neurological disease. One of these is Memory Specificity Training (MeST) (e.g., Martens, Takano, Barry, Goedleven, Van den Meutter, & Raes, 2019). Briefly, MeST involves the recall of event-specific memories of personal experiences to cues on a repetitive basis over several treatment sessions. Research has shown this technique to hold promise as, compared to control conditions, the degree of detail recalled increases over sessions (e.g., Barry, Hallford, Hitchcock, Takano, & Raes, 2021). Other techniques include reminiscence therapy (Meléndez et al., 2015), and life review (Gonçalves, Albuquerque, & Paúl, 2009).

The research in this thesis is primarily concerned with increasing the recall of episodic autobiographical memory in old (Experiment 1) and young (Experiments 1-3) individuals with the use of relatively novel techniques including saccadic horizontal eye movements (Experiments 1-3) and eye-closure (Experiments 2-3). Different procedures are used to elicit memory including autobiographical fluency (Experiment 1) and the cue-word technique (Experiments 2-3). These are employed with different measures of memory including number of memories per unit of time (Experiment 1) and memory specificity with subjective rating scales (Experiments 2-3).

Prior to the experiments, this introduction provides the general background to all three experiments by outlining the theoretical and empirical basis of **(i)** autobiographical memory structure and processes, and **(ii)** eye movements and eye-closure effects.

Characteristics of Autobiographical Memory.

The features of autobiographical memory can be characterised in multiple ways. For example, in relation to the self (Wright, Moody, Browne, & Cather, 2022), coherence (Vanderveren, Bijttebier, & Hermans, 2019), emotionality (Schulkind, & Woldorf, 2005), their temporal nature (Janssen, Chessa, & Murre, 2005), or more generally in terms of hierarchies and dimensions (Rubin, 2019). In this thesis, some characteristics have been selected as being of primary importance as they relate most closely to the experiments reported and the development of the research in terms of memory enhancement. In addition, the selected ideas are more general and cut across many different research threads in autobiographical memory research. The characteristics that are most pertinent are memory specificity, fluency, and the subjective qualities of personal autobiographical recall.

Autobiographical Memory Specificity.

Specific autobiographical memories refer to those in which precise details of the experienced episode are retrieved and often include reference to people, contexts, time, perceptual information, and emotions. When these forms of information are absent, the memories are characterised as Over General Memories (OGM). Some individuals experience ongoing and trait-like difficulties in retrieving specific and detailed information from their past (Sumner, Griffith, & Mineka, 2010). Most of us at some point will experience the inability to retrieve specific memories because of lack of appropriate cues or contexts (e.g., Dijkstra, & Kaup, 2005; Mazzoni, Vannucci, & Batool, 2014).

Theoretical accounts of OGMs often refer to the structure of the autobiographical knowledge base as outlined by Conway (2005). In particular, OGMs result can result from (i) the inability to access event-specific knowledge, (ii) the loss of event-specific knowledge, or (iii) the termination of search processes higher in the ABM knowledge base (Cabeza & St

Jacques, 2007; Haj, Antoine, Nandrino, & Kapogiannis, 2015; Mangels, Gershberg, Shimamura, & Knight, 1996; Williams, 2006).

Such accounts of OGMs have often been developed within a particular domain to account for memory impairment in particular groups of individuals. For example, individuals with depression, typically recall personal memories that lack precise event-specific details (Williams, & Scott, 1988). This has been explained by the CaRFAX model (e.g., Dalgleish, & Werner-Seidler, 2014; Williams, 2006). According to this account, reduced memory specificity is explained by a number of component processes working on concert. These include: (i) Capture and rumination (CaR), (ii) functional avoidance (FA), and (iii) executive control dysfunction (X).

Capture and rumination relate to the notion that self-relevant (and negative) information 'captures' cognitive / attentional resources. This then leads to rumination about negative aspects of the self. Functional avoidance (FA) refers to self-regulatory strategies that result in avoiding specific autobiographical memories that might increase negative emotions. Finally, executive control (X), refers to the deficits in executive (top-down) control that are important for accessing event-specific details. In this current thesis, not all these component processes are likely to apply, and a more general account is required.

In this context a more general account is required. For instance, Barry, Chiu, Raes, Ricarte, & Lau, (2018) provide an explanation of reduced autobiographical memory specificity that combines work from both cognitive and neurobiological findings. In particular, the role of frontal regions (involved in both top-down control and self-referential processing), play an important part. In particular (see Figure 1), frontal regions associated with top-down control are responsible for accessing more detailed and specific information in the autobiographical knowledge base (stored in more posterior regions and involving the medial temporal lobes).

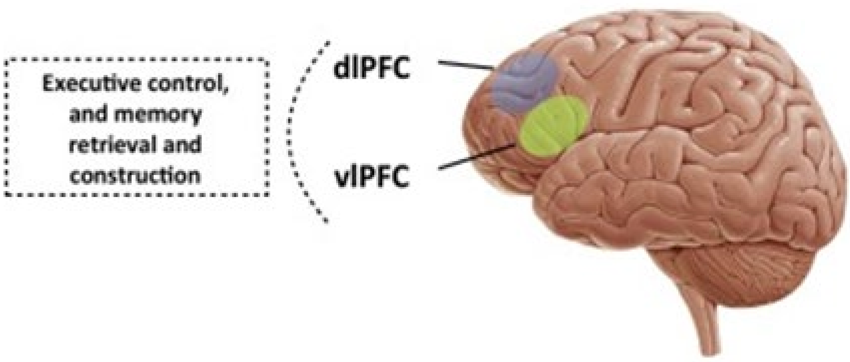

Figure 1 - Executive control and memory retrieval and construction diagram taken from Barry, Chiu, Raes, Ricarte, & Lau. (2018).

Autobiographical Memory Fluency and Retrieval Speed.

Autobiographical memory fluency refers to the number of memories recalled of a particular type (e.g., episodic, or semantic) within a given period of time (e.g., Dritschel, Williams, Baddeley, & Nimmo-Smith, 1992). Retrieval speed refers to the response time to recall a particular memory in response to a cue (e.g., Uzer, 2016). Although differing in the precise details of their measurements (number of memories per unit of time vs. reaction time in milliseconds / second), they are both similar to the extent they represent memorial accessibility.

Accessibility pertains to the ease with which information can be recalled from memory and is important because such memories can be used to shape our own self-conceptions and define our own unique self-appraisals (e.g., Ross, & Wang, 2010; Sutin, Luchetti, Aschwanden, Stephan, & Terracciano, 2021).

Autobiographical fluency has been used on numerous occasions to assess the structure of autobiographical memory (Dritschel, Williams, Baddeley, & Nimmo-Smith, 1992), changes in the accessibility of personally relevant information as a function of disease (Addis, & Tippett, 2004), or in in autism (Crane, & Goddard, 2008), to assess the working-self

(Rathbone & Moulin, 2017) and also in memory enhancement (Parker, Parkin & Dagnall, 2013).

Response speed has been used to assess the structure of the autobiographical knowledge base (e.g., Kemp, Burt, & Malinen, 2009), the cognitive basis of self-reference effects (Klein, & Kihlstrom, 1986), and the processes underpinning self-inferences more generally (Klein, & Nelson, 2014).

In this thesis, autobiographical fluency is measured in Experiment 1 to both follow on from and extend previous work examining SIRE effects in autobiographical memory. The specific details for this can be found in the introduction and method section for the first experiment.

Autobiographical Recollection.

One of the most important qualities associated with autobiographical memory is the sense of recollection. In autobiographical memory this refers to the phenomenological experience that arises during the recall of personally experienced events (Conway, 2001). It is argued that recollection is what sets aside personal remembering from other forms of episodic memory (Brewer, 1996; Conway, 1990; Rubin, 1998). Through recollection individuals are able to partly relive past experiences and engage in a form of mental time travel (Tulving, 1985).

Forming the basis of reliving is the retrieval of sensory information from different modalities and the recall of event-specific knowledge (Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2003; Greenberg, Eacott, Brechin, & Rubin, 2005; Willander Sikström, & Karlsson, 2015). Consequently, autobiographical memory involves the recovery and reconstruction, of multiple forms of encoded information such as perceptual information (visual, auditory, and even olfactory), contextual information and emotional responses (Cabeza & St Jacques, 2007; Gilmore, Quach, Kalinowski, Gotts, Schacter, & Martin, 2021; Greenberg & Rubin, 2003).

Given the nature of autobiographical recollection, its measurement often relies on self-report methods. One such approach is adapted from laboratory studies of episodic memory and makes use of the ‘remember-know’ technique. This requires participants to indicates their subjective state of awareness for each memory by providing either a ‘remember’ or ‘know’ response. A ‘remember’ response indicates the retrieval of associative and contextual details for the recalled memory (e.g., multimodal information). In contrast study, a ‘know’ response indicates confidence that the memory is true, but lacks detailed recollective qualities (Gardiner, 1998; Tulving 1983; Yonelinas, 2002). For example, Piolino, Desgranges, Clarys, Guillery-Girard, Taconnat, Isingrini, & Eustache, (2006), found a decrease in ‘remember’ responses and an increase in know responses in older individuals.

Another technique is the Autobiographical Memory Questionnaire or AMQ (Rubin, Schrauf, & Greenberg, 2003). The AMQ comprises several statements against which the subjective qualities of memory can be rated on Likert type scales. For example, “As I remember the event, I feel as though I am reliving the original event” or “I can see the event in my mind”. The statements were created based on theoretical accounts of autobiographical memory. They encompass statements that relate to the sensory nature of personal memories as well emotion, and meta-characteristics such as belief in the veridically of the memory and its importance in relation to the life of the individual.

A more recent technique is the Autobiographical Recollection Test (ART) (Berntsen, Hoyle, & Rubin, 2019). Like the AMQ, this also measures the multicomponent nature of personal recollection. Although in this case, the emphasis has been centred on the development of a measurement instrument that can be used to assess individual differences in autobiographical recollection. It has been demonstrated that ART scores not only show consistency over time (high reliability) but correlate with autobiographical recollection of specific memories (Gehrt, Nielsen, Hoyle, Rubin, & Berntsen, 2021). Consequently, the ART represents a promising technique for use in future research on memory recollection and specificity.

In the present thesis, autobiographical recollection was measured by the AMQ as this has been used on multiple occasions across the research literature (and thus provides a basis for broader comparisons) and in relation to SIRE effects (e.g., Parker & Dagnall, 2010). It is used in Experiments 2 and 3. Experiment 1, does not assess recollection directly, but rather makes use of an autobiographical memory fluency task (Dritschel et al. 1992), in which participants recall as many personal episodic memories and personal semantic memories from their own life in 90 seconds (see section on ABM methods). In this instance, it is assumed that recollection will be higher for personal episodic (vs. semantic memories) (Dritschel et al. 1992).

Methods of Assessing Autobiographical Memory

Numerous techniques have been developed for the assessment of autobiographical memory. Outlined below is a description and evaluation of the techniques most relevant to this thesis followed by a shorter overview of some of the other often-used procedures.

Memory Retrieval Fluency Techniques

Retrieval fluency refers to how readily information can be retrieved from LTM to working memory or conscious awareness (Benjamin, & Bjork, 1996). This can be measured by reaction times or by the number of memories retrieved per unit of time. These techniques have often been used to explore the structural components of ABM.

In relation to the latter, Dritschel, et al, (1992) required participants to recall as many instances as possible of personal episodic, semantic, and general semantic memories within 90 seconds. Definitions and examples of these categories were provided, and the results made use of cluster analysis. This technique allows the assessment of the extent to which memories recalled can be combined into groups (clusters) that represent greater similarity within (vs. between) groups. The findings revealed a dissociation between the episodic and semantic components of memory and was explained in terms of structural and retrieval differences between these different forms of memory. This technique has been further evaluated and has shown to be sensitive to a range of group differences including autism (Crane, & Goddard, 2008), mild cognitive impairment (Tomadesso et al., 2015), those at risk to Alzheimer's dementia (Grilli, Wank, Huentelman, & Ryan, 2021), and age (Martinelli, Anssens, Sperduti, & Piolono, 2013; Mevel et al., 2013).

In relation to eye movements and ABM fluency tasks, Parker, Parkin, and Dagnall, (2013), required participants to retrieve personal episodic events, personal semantic information (the names of friends and teachers) and general semantic information (taxonomic semantic categories). It was found that only episodic ABM fluency was enhanced by eye movements.

The general notion of ABM fluency has been extended by other research that makes explicit the hierarchical structure of ABM. For instance, Piolino et al (2010) sought developed the ‘Verbal Autobiographical Fluency’ task. This task maps onto Conway’s (2005) & Conway & Pleydell-Pearce’s (2000) model of autobiographical memory and asks participants to recall memories from each of the four main domains in order; Lifetime periods or Verbal Autobiographical Fluency 1 (VAF1), General events (VAF2), specific events (VAF3) & specific singular details (VAF4). Thus, VAF 1 to 4 relates to “descending” through the structural hierarchy from the general to event-specific knowledge.

In practical use, participants are given two minutes to list as many events as they can from VAF1 and can include any ongoing and large periods of a person’s life (living on baker street or going to university). Once this is complete the participant selects one of the time periods produced in VAF1 and in turn generates as many general events as possible (VAF2) which have occurred in this specific lifetime period, again in a two-minute period. This zooming effect then repeats for specific events (VAF3) and again to specific singular incidents (VAF4). This method therefore helps illustrate autobiographical fluency while also exploring each level of the autobiographical memory at the same time.

Use of this technique has shown age related impairments in the ability to access VAF 4 levels of specificity (Piolino et al., 2010). Similarly, access to VAF 4 levels is compromised in those with Alzheimer’s dementia with such access being mediated the retrieval of relevant higher levels (VAF 1-3) of representations (Benjamin, Cifelli, Garrard, Caine, & Jones, 2015). Traumatic brain injury is also associated with the impaired ability to retrieve event-specific knowledge that characterises VAF 4 and is further associated with measures of executive functioning across a number of ABM levels (Coste, Agar, Petitfour, Quinette, Guillery-Girard, Azouvi, & Piolino, 2011).

A strength of the Dritschel, et al (1992) fluency method is that it can provide a measure of the different components on ABM structure that map onto more general distinctions between episodic and semantic memory. Additionally, the responses generated by participants are relatively unambiguous and do not require complex scoring protocols. A strength of the Piolino et al (2010) method is that it can provide an assessment of ABM functioning based on the *nested* nature of ABM structure founded in theoretical models (e.g., Conway, 2005). Both methods are somewhat limited to the extent the experimenter is unable to probe any predefined aspects of an individual's life or vary the nature of the retrieval cues to assess how these might interact with the ABM knowledge base.

In this thesis, the Dritschel, et al (1992) fluency method will be employed in Experiment 1 as it provides a clear measurement of episodic and semantic ABM on different retrieval trials and to extend prior work on eye movements effects (Parker et al., 2013).

Cue-word Technique (Autobiographical Memory Test – AMT)

The cue method technique was originally coined by the Sir Francis Galton (1879) and is often referred to as 'Galton-Crovitz method' as the method was popularised and revived by Crovitz and Schiffman's (1974) research on autobiographical episodic memory. This technique is arguably the most used method to study voluntarily autobiographical memory recall (Otani & Schwartz, 2018).

Using this method, participants are presented with a series of words or other stimuli e.g., odours (Chu, & Downes, 2000; Herz & Schooler, 2002; Willander & Larsson, 2006), or visual images (Ridout, Dritschel, Matthews & O'Carroll, 2016). In some instances, no "stimuli" as such are used but the general instruction given to recall "50 events of your life... just let your mind wonder" (Rubin, 1982). Irrespective of the precise nature of the cueing technique, the participant responds with the first autobiographical memories that come to mind. As such, this method is essentially a form of free association task and can provide memories distributed throughout the participant's lifetime.

Once a memory has been recalled, participants are usually asked to date the memories provided (Wenzel & Rubin, 2005). This process usually happens at the end of the recall to prevent time-based fixation or bias and can be done in a variety of different ways such as asking for a specific date or how old the participant was at the time of occurrence. The pros and cons of different dating techniques have been debated in research with many free association memories being from the recent past the age of the occurrence is not always beneficial, but exact date generation is often estimated and highly cognitively and time demanding (Bernsten & Rubin, 2002).

One of the main benefits of the cue-word technique is the level of flexibility and adaptability to different needs and research aims via manipulating the cue presented. One example of this manipulation is the use of emotional cues (e.g., positive, negative, or neutral) (Holland, Ridout, Walford & Geraghty, 2012; Bunnell, Legerski, & Herting, 2018) and has been used to explore areas such as overgeneral memory and depression (Williams, et al, 2007). Another manipulation which has been explored is the level of imaginability in the presented cue word (Guler & Mackovichova, 2019; Rasmussen, & Berntsen, 2014). In this variation the researchers use either highly visualisable (or concrete) terms such as “Table”, “Chair” and “Cup” in comparison to low visualisable (or abstract) terms such as “Moral”, “Wisdom” and “Obedience”. Rubin (1980) outlined a battery of 125 words rated on 51 different linguistic and cognitive properties, use of these terms over the years has been refined and helped control for issues such as reaction times, levels of specificity and memory omissions in participants.

One of the biggest strengths of this methodology when compared to other methods available is that a researcher can collect a relatively large amount of data from each participant with relative ease. For example, Rubin & Schulkind (1997) generated as many as 900 individual memories from one individual. Another advantage is that participants do not need to complete any form of explicit preparation, such as completing a diary or seeing a staged event (Otani & Schwartz, 2018).

However, a disadvantage of this method is not being able to have any control whatsoever of the encoding of the specific event or indeed whether the event even occurred at all. Of course, this also applies to the fluency methods outlined above and many other ABM techniques. Another disadvantage of this methodology as outlined by Rabbitt and Winthorpe (1988) who show evidence that responses to cues are less detailed and are less likely to be fully spontaneous when compared to memories collected from free recall techniques. They go on to state that such cues can bias recall to more recent memories even though older ones, with the same level of detail could be available.

This technique will be employed in Experiments 2 and 3 to generalise some of the finding from Experiment 1, extend previous work used in conjunction with eye movements (Parker & Dagnall, 2010) and to assess some of the theoretical aspects of eye movement effects by additional experimental manipulations and measurements.

Other Methods

This section provides a brief overview of other techniques used in ABM research that encompass the recording of ABM events, different ways of cueing, and more extended tests that employ interview style questioning. The coverage is not intended to be exhaustive but provides a flavour of approaches to ABM measurement alternative to those used in this thesis.

Diary Method.

The diary method requires participants to keep a record of the events that have happened to them over a period of time. This could be anywhere from a few days (Mace & Atkinson, 2009), up to several years (Linton, 1975; White, 1982). The early dairy studies, especially the ones completed over long periods of time such as Linton (1975,1986) & White (1982), were mostly all projects based upon a single participant, who also happened to be the study researcher. It was several years later in which students and other subjects became the dairy creators and thus popularising and expanding the research methodology (see Thompson et al, 1996 for review).

There are several different variations of the information collected using the dairy technique. The more traditional method simply asked participants to complete a dairy at a fixed point in the day. Other formats focused on more specific recording of data such as 'who, what, where and when' or 'who, what & where' (e.g., Wagenaar, 1986) and thus provided structure to the diary entries that could be used for subsequent recall.

The diary method of autobiographical memory recall has a particular advantage in that it is one of the few methods available which allows for *some* level of verification of the information being provided to the experimenter (Eysenck & Keane, 2015). However, the technique does have several disadvantages. For example, the diary entries are often re-read by the reader at later times and can have significant effects upon the level of recollection and forgetting of a memory (Linton, 1975). Additionally, the dairy technique is rather time consuming and studies using specialist diaries can take weeks or months to complete and like all longitudinal studies can suffer from participant attrition (Joslyn & Oakes, 2005).

Sentence-Cue Techniques

The sentence cue technique developed by Raes, Hermans, Williams & Eelen (2007) works in a somewhat similar fashion to the Galton-Crovitz method but rather than presenting the participants with one key word to generate a memory the participants are presented with sentence stems and are asked to complete them. Examples of these sentence stems include "At the time when I…" or "Last year I . . .". Once the sentence is complete the responses are later coded into one of four levels, which are: i) specific memory, ii) categorical memory, iii) extended memory & iv) semantic associate depending on the level of detail in the recalled memory (see Raes et al, 2007 for example of coding).

The rational for this adaptation is that several authors claim that the AMT is not sufficiently sensitive in detecting overgeneral memories. For example, De Beer, Hermans and Raes, (2005) & Raes & Hermans, (2002) completed the ATM on students and discuss how low the level of overgeneral memories were detected was significantly lower in a population known as a risk factor for depression and overgeneral memories. The Sentence Completion for Events from the Past Test (SCEPT) however has been shown to be far more sensitive to detecting overgeneral memories in students (Raes et al, 2007), participants with depressive vulnerability (Raes, Williams & Hermans, 2009), grieving individuals (Eisma et al, 2015) & adolescents in out-of-home care (Jimena, Latorre & Cantero, 2021).

Interview Methods

The autobiographical memory interview (AMI) was developed by Kopelman, Wilson and Baddeley (1989, 1990) and consists of a series of questions probing successive life stages (Rubin & Wenzel, 2005). The core methodological difference between the AMI and other methods mentioned above is that the AMI helps show what participants *can remember* rather than what they *select to remember* due to the probing and additional information requested by the experimenters.

This method uses a formal interview technique with the researchers traditionally splitting the subject's autobiographical past into core subsections. For example, Childhood, Early adult life, and Recent Events. Prompts are used during the interview to encourage participants to provide as much information as possible about each memory retrieved. An example incident to be recalled could be a memory about primary school (ages 5 – 11 years) and the suggested prompts could be asking for a participants first memory, information the friends involved in the memory or did the memory recalled have any teachers present etc.

A related method called the Autobiographical Interview (AI) was later developed by Levine, Svoboda, Hay, Winocur, and Moscovitch (2002) which separated the lifespan into five separate areas (Early Childhood, Teenage Years, Early Adulthood, Middle Age, and the Previous Year) rather than three. Typically, the participants are asked one question from each of the time periods, but this can be modified due to the age of the participant. In a similar fashion to the AMI the participants are prompted to provide additional detail using questions from a modified version of the memory characteristics questionnaire (Johnson, Foley, Suengas, & Raye, 1988).

Both the interview methods above help the researcher separate the semantic elements of recall from the autobiographical and episodic recall. The main difference is how this information is collected. In the AMI the information is collected using several different specifically designed prompts and questions, whereas in the AI the information is collected in one memory description and coded after the experimental process (for more information about the coding schemes see Piolino, Desgranges, Benali, and Eustache, 2002).

A strength of both the AI and AMI is that they have been shown to be very effective when studying patients with mild cognitive impairment (Barnabe, Whitehead, Pilon, Arsenault-Lapierre, & Chertkow, 2012), healthy aging (Piolino et al, 2002), patients with pre-frontal lesions (Rasmussen & Berntsen, 2016) and traumatic brain injury (Rasmussen & Berntsen, 2012). Importantly these techniques have also shown to be effective when testing the general population (Otani & Schwartz, 2018). The method has also been shown to be useful when testing groups of multiple people (such as families or people who witnessed the same event) to help triangulate different elements and levels of recall (Rasmussen & Berntsen, 2016).

Concluding Remarks

Autobiographical memory has been researched several techniques. As with other forms of empirical investigation, it is important that results are not tied to any one method unless there is some theoretical justification for this. As noted above, this thesis makes use of two of these methods to both extend past work and to assess whether findings generalise from one measure to another.

Autobiographical Memory: Systems & Processes.

Long-term memory has been conceptualised in numerous ways. From the perspective of structure and systems accounts these have encompassed distinctions between declarative vs. procedural (Cohen & Squire, 1980), episodic vs. semantic (Tulving, 1983, 1985), and explicit vs. implicit (Graf & Schacter, 1985). From more functionalist perspectives, the emphasis has been on processing (Morris, Bransford, & Franks, 1977) and the distinction between perceptual vs. conceptual operations (Roediger, 1990).

Although many of these types of distinctions can be found in research on ABM, the most often used theoretical framework is that of episodic vs. semantic memory. The distinction between these two systems (forms) of memory is the former retains information about particular experiences and maintains details that include spatial and temporal reference and a sense or remembering or reliving the past (Dere et al, 2006). Semantic memory on the other hand retains abstract and categorical knowledge. Retrieval from semantic memory thus does not preserve the details of prior experiences.

In ABM, the episodic component (episodic autobiographical memory) is defined as memory for event-specific personal experiences. Such memories preserve the spatio-temporal context of the encoded experience. Subjectively, this form of remembering is accompanied by autonoetic awareness (Dere et al, 2006) and the sense of, in part at least, reliving aspects of the past. It is typically accompanied by the retrieval of perceptual and contextual information and can involve reexperiencing the original emotions (Markowitsch & Staniloiu, 2011).

The semantic component (semantic autobiographical memory) is defined as memory for personal facts and abstracted knowledge about oneself (Conway, 2005; Tulving, 2002). This includes knowledge of one's identity, personal characteristics, historical data, and facts supporting awareness of personal past events (Levine, 2004). Subjectively, recalling such memories does not involve the retrieval of event-specific details (which might be irrecoverable or simply no longer available to awareness). Thus, a person can retrieve general facts about personal information without re-experiencing the specific context. Essentially, individuals can recall general facts about their own personal events accompanied by a sense of simply ‘knowing’ them to be correct without any contextual or supporting details. Consequently, unlike episodic memory, semantic memory is time-independent and functions in a noetic manner (Vandekerckhove, 2019).

These distinctions are not mere theoretical conjectures but have empirical foundations and are based on observations of dissociations between them. For example, systems of autobiographical memory can be differentially affected by ageing (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino, Desgranges, Benali, & Eustache, 2002; Spreng, Lockrow, DuPre, Setton, Spreng, & Turner, 2018), developmental amnesia (Baddeley, Vargha-Khadem, & Mishkin, 2001; Elward & Vargha-Khadem, 2018), dementia (Greene, Hodges, & Baddeley, 1995; Smith, Souchay, & Conway, 2010), and neuroimaging activations (Martinelli, Sperduti, & Piolino, 2012).

Despite such differences, the argument that these subsystems of ABM are entirely independent is indefensible as research shows interactions between them (De Brigard, Umanath, & Irish, 2022). In everyday life, it is likely that the relative contributions of episodic and semantic memory to various memory tasks vary according to multiple factors (Renoult, Irish, Moscovitch, & Rugg, 2019). Thus, it is primarily in experimental situations in which one can observe distinctions between forms of memory. In this thesis, the primary focus will be on the episodic component of ABM. Where necessary of course, this may involve comparisons or contrast to semantic memory.

Autobiographical Memory Structure

The distinction between episodic and semantic ABM is actualised in the structural model of personal memory as described by Conway (2005). The model is presented in a partonomic hierarchical structure (Conway, 2003, 2005) which ranges from highly abstract at the top of the hierarchy and encompasses increasingly detailed representations with event-specific (episodic) information at the lowest level. This is illustrated in Figure 2 below.

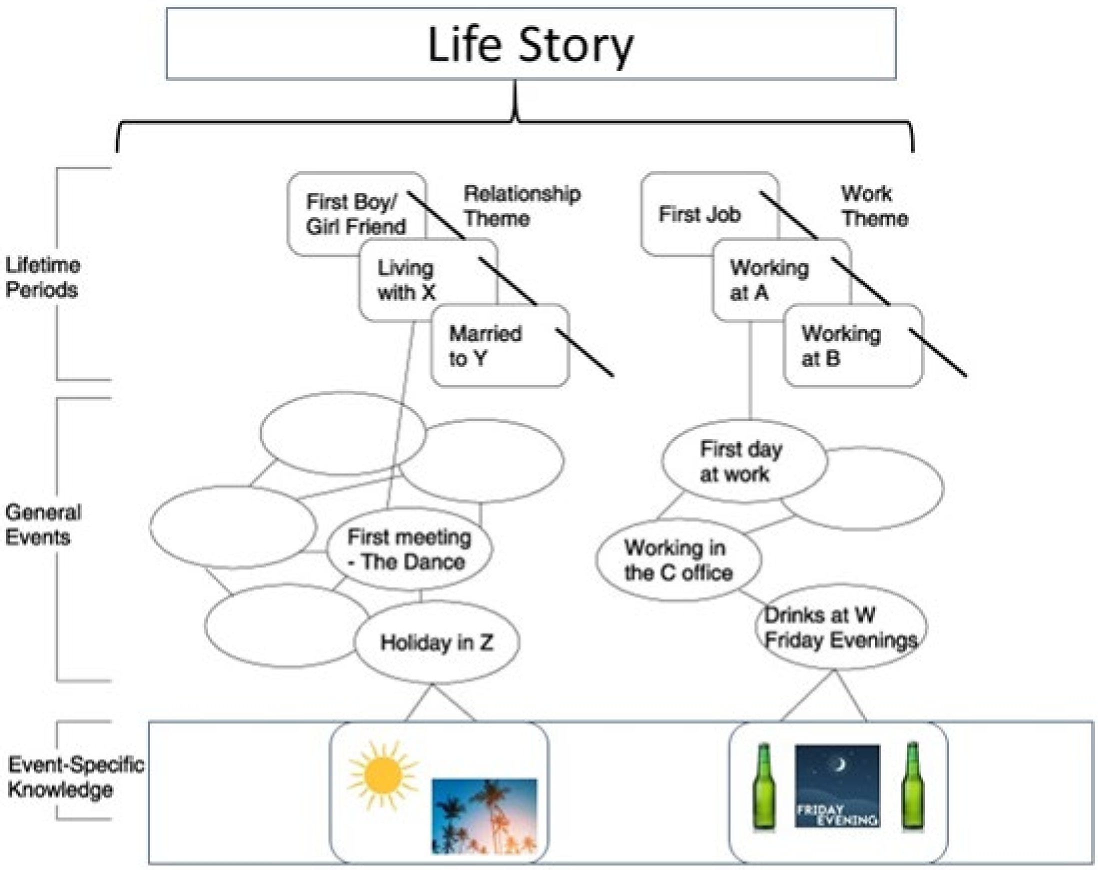

Figure 2– The structural model of autobiographical memory hierarchy adapted from Conway and Pleydell-Pearce (2000).

The 'life story' of the individual is the most abstract representation and contains general factual and evaluative knowledge about the individual (Conway & Singer, 2004) This includes self-images that divide the individual into different identities. These selves comprise cues to more specific representations that form themes from the person's life. For example, in Figure 2, the individual has separate memory-based themes for work life and relationships.

The themes are typically represented as lifetime periods which in turn act as retrieval routes to general events. According to Conway (2005) this level of knowledge includes more specific memories that can include repeated or categorical events (Williams, 1996), extended events (Conway, 1996) or even miniature histories (e.g., learning to drive a car, Robinson, 1992). The level of knowledge forms the basis of gist representations. It is at this level where an individual can provide general basic overviews of personal memories without the need to access specific events or ideas. For example, a person can tell a researcher that they remember going to university without the need to access specific episodic memories such as being late on the first day.

The lowest level of the model is event-specific knowledge (ESK). This the personal episodic autobiographical memory store (higher levels form increasing more semanticised representations). It is at this level where specific perceptual, contextual, and temporal information is stored. Further, it is at this level where 'Autonoetic Consciousness' is experienced. This is the ability of a person to subjectively relive certain events and experiences again in a form of mental time travel (Tulving., 1972; 1985; 2002).

Piolino et al (2002) elaborates upon autobiographical episodic memory and states these representations have several core characteristics. Firstly, episodic memories are unique and person events which contain presuppose phenomenological details (e.g., perceptual, cognitive, and affective details). Secondly, the memories will have some form of self-relevance and are told from a personal and egotistical perspective (Brewer, 1996). Thirdly, when an episode is remembered it is usual for there to be accompanying visual (Greenberg & Rubin, 2003) and emotional (Berntsen & Rubin, 2004) elements.

Semantic (general) autobiographical memory is not directly mentioned in the Conway (2005) model of autobiographical model. However, Martinelli et al, (2012) states that even though the model does not have a direct label per-se, general events knowledge is ". . . generated by the representation of similar events producing a shift from knowledge about specific to general events, that is, from episodic memory to general memory". Thus, as noted above, memories higher in the structural hierarchy are more semantic in nature.

Like the conception of episodic and semantic memory more generally, the autobiographical forms of these interact and display dynamism between them. For instance, a novel experience of traveling in an aeroplane for the first time would retain event-specific details. However, frequent flying trips would lead to the semanticisation of individual ESKs with these becoming increasing abstract over time (Conway, 2005). It has been postulated by several researchers (See Cabeza & St Jacques, 2007 for full review) that very long-term memory loses episodic details and causes a 'remember-to-know' shift over time. This shift relates to the transformation of autonoetic to noetic awareness that typically accompanies episodic vs. semantic memory respectively.

The primary focus of this thesis is with episodic autobiographical memory. In particular, the lowest level in the structural hierarchy in the form of event-specific knowledge and the specific details associated with this level of representation. To be more precise, the experiments presented here focus on improving access to ESK using recently established techniques that include saccadic horizontal eye movements (experiments 1-3) and eye closure (experiments 2-3).

Autobiographical Memory Retrieval

So far, autobiographical memory has been discussed with reference only to its structural characteristics. This is somewhat incomplete as no viable account of memory is possible without consideration of retrieval processes. Like other forms of memory, autobiographical retrieval is cue-dependent (Davis, Loftus, Rubin, & Wixted, 2007 as cited within Roediger, Dudai & Fitzpatrick, 2007). Within this context, Uzer et al. (2012) proposed ABMs can be recalled by either direct or generative retrieval processes. This dual-strategy account is based on earlier formulations of retrieval mechanisms (e.g.., Conway, & Pleydell-Pearce, 2000; Reiser, Black, & Abelson, 1985; Williams, & Hollan, 1981) and has been incorporated into more recent theorising about personal memory (e.g., Addis, Knapp, Roberts, & Schacter, 2012; Harris O'Connor, & Sutton, 2015).

The distinction is illustrated in Figure 3 together with additional details derived from other accounts of autobiographical memory that refer to different retrieval modes and possible neural underpinning (Moscovitch, & Winocur, 2002; Sekeres, Winocur, & Moscovitch, 2018).

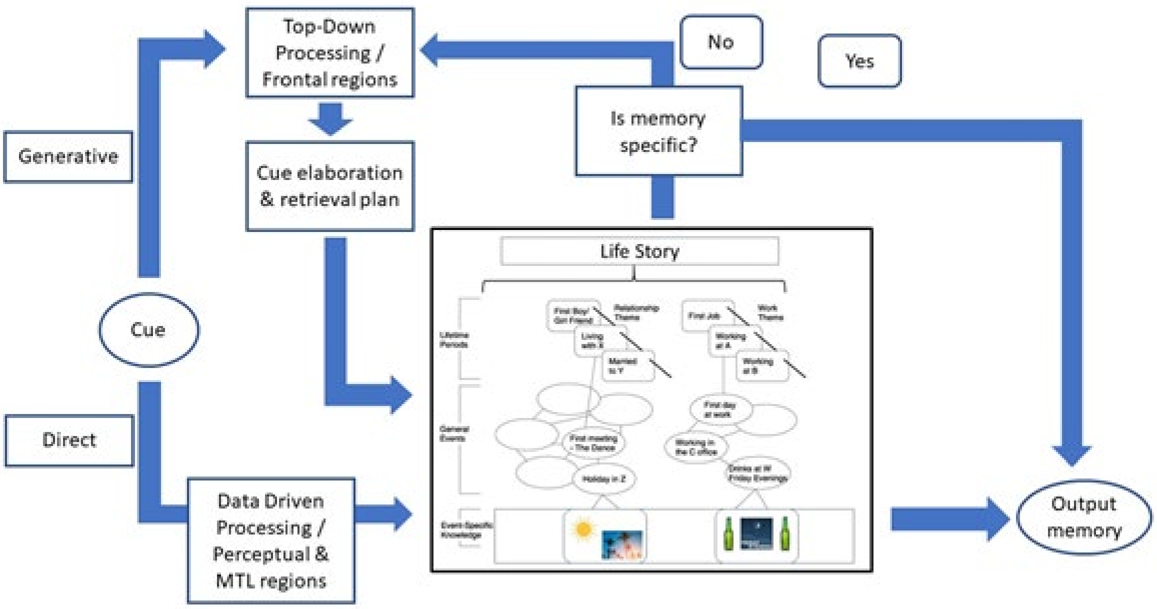

Figure 3– Illustration of the distinction between direct and generative retrieval in autobiographical memory.

The figure illustrates the two mechanisms and shows the potential sequence of processes when presented with a cue and asked to produce an event-specific memory. If the cue is sufficiently detailed, then the recall of a personal event memory can take place via the direct route. In this case, the cue activates perceptual systems and the medial temporal lobes (MTLs) that in turn access an ESK representation in the autobiographical knowledge base. This memory can then be reported.

However, on other occasions, the memory might contain insufficient detail and be rather vague. In this instance, generative retrieval takes place. This involves top-down processing in which the cue is further elaborated upon, and a retrieval plan formed. This elaborated cue is then used to interrogate the autobiographical knowledge base. If an ESK representation is accessed, then this can be output. If not, the retrieval cycle is reiterated until a memory or no matching representation is found. Sometimes, retrieval comes to a halt at higher levels in the hierarchy and the result is an over general memory.

This conception has been useful to the extent that different retrieval routes are associated with different reaction times (Uzer et al., 2012,), phenomenological characteristics (Harris, O'Connor, Sutton, 2015), neural activations (Addis et al., 2012), and are differentially affected by age (Wank, Andrews-Hanna, & Grilli, 2021).

Memory Enhancement in Everyday Memory

Autobiographical memory involves thinking about the past and one’s own presence in the past. In this sense it provides a perspective of the self-extended across time (Neisser, 1988). Pillemer (1992) contended that autobiographical memory serves several functions related to the self (self-integrity and continuity), communication (allowing social exchange and bonding), and future orientation (that is directive, and allowing for prospective thought and planning. This conception was echoed by Bluck (2003) who also argued for a range of autobiographical memory functions encompassing personal, social, and directive functions. Although this thesis is not concerned with autobiographical memory functions in the aforementioned sense, it is clear that the ability to recall and use personal memories to allow ourselves to connect with the past, with others, and orient with future selves is of fundamental importance.

As autobiographical memories fade, because of the mere passage of time, ageing, neurological disease or inappropriate cues, there remains the danger that we lose part of ourselves. To the extent autobiographical memories serve key functions in everyday life, it is important that we find ways to maintain contact with our past by enhancing recall abilities. In this section, two techniques are presented that have shown promise in assisting with recall for both laboratory and everyday life memories. These techniques are defined and described to provide a basis for their application and evaluation in the experiments in this thesis.

Saccadic Induced Retrieval Enhancement (SIRE) effects

Saccade Induced Retrieval Enhancement (SIRE) effects (a term coined by Lyle & Martin, (2010)) refer to the influence of pre-retrieval horizontal (bilateral) saccadic eye movements (EMs) on subsequent memory performance. Although effects on other tasks have been documented (e.g., creativity (Shobe, Ross, & Fleck, 2009), convergent thinking (Fleck & Braun, 2015) and attention Edlin & Lyle, 2013)), the focus in this thesis is on memory. The typical finding is that performing a sequence of horizontal saccades increases subsequent memory accuracy for information encoded before the eye movements.

The effect was originally documented in early research by Christman, Garvey, Propper, & Phaneuf, (2003). In this, participants first encoded a list of unrelated words and then following a short delay were given a pre-retrieval task that involved: (i) horizontal saccadic EMs, (ii) horizontal smooth pursuit EMs, (iii) vertical saccadic EMs, (iv) vertical smooth pursuit EMs and (v) no Eye movements. Each task lasted for thirty seconds and followed by a recognition memory test. The purpose of other types of EM was to control for any non-specific effects of arousal or eye-movement activity (the theoretical significance of this is dealt with below).

It was found that recognition memory accuracy (*d'*) was enhanced, but only following horizontal saccades. This was related to both an increase in the hit rate (correct 'yes' responses to studied items) and a decrease in the false alarm rate (incorrect 'yes' responses to unstudied items).

Additionally, implicit memory was tested using word-fragment completion. This task requires responding to partial words (e.g., T_B_E) with the first real word that pops to mind (e.g., TABLE). Episodic memory is not needed to complete the fragments as this can be achieved solely by reference to lexical memory. However, it has been shown that prior exposure to the words (e.g., TABLE) improves fragment completion performance even in the absence of episodic memory and is called priming (e.g., Tulving, Hayman, & Macdonald, 1991). It was found that horizontal eye movements had no effect on this task. Consequently, it was concluded that horizontal saccades dissociated episodic from implicit memory and provided a potential means to enhance episodic memory without increasing responses bias or errors.

Extending SIRE Research

Later work has extended the original finding across a range of experimental paradigms including associative false memory, eye-witness memory, scene recognition, face recognition and emotional stimuli.

Associative false memory has been studied using the Deese-Roediger-McDermott (DRM paradigm) (Roediger & McDermott, 1995). This technique involves the presentation lists of associated words, all of which strongly relate to a non-studied word. For example, the word list “thread, pin, eye, sew and sharp” are associated to the word needle (e.g., Roediger & McDermott, 1995; Thapar & McDermott, 2001). Typically, individuals falsely recall and recognise the non-studied words and believe then to have been present in the studied lists.

Using this method, Christman, Propper, and Dion, (2004) found that horizontal eye movements reduced the false recall of highly associated words. This was later extended to recognition memory by Parker and Dagnall (2007) who found a decrease in the false alarm rate in addition to an increase in memory for studied list words.

Scene recognition was studied by Brunyé, Mahoney, Augustyn, & Taylor, (2009), during encoding a series of aerial Landsat type images were presented. The recognition test consisted of both studied images and ones that had been digitally manipulated. Eye movements were manipulated either before encoding or before retrieval. It was found that horizontal saccades increased recognition accuracy but only when implemented prior to retrieval.

SIRE effects on eye-witness memory have also been studied in the context of the misinformation paradigm. This involves the study of an event-type scenario in which a sequence of actions are described to the participant. Following this, misleading (false) information about the scenario is provided either explicitly or by misleading questions. Later, memory for the original scenario event is tested (e.g., Loftus, Miller & Burns, 1978). Usually, information that was presented as misleading is accepted as true. Making use of this procedure, Parker, Buckley, & Dagnall (2009) found horizontal EMs to reduce the extent to which misleading information was falsely recognised as pertaining to the original scenario. Similar effects have also been found in other work eye-witness type research (e.g., Kelley & Lyle, 2021; Lyle, 2018; Lyle & Jacobs, 2010).

Other research has extended these findings further to include associative recognition (Lyle, Hanaver-Torrez, Hackländer, & Edlin, 2012; Parker, Relph & Dagnall, 2008), recognition memory in children (Parker & Dagnall, 2012), explicit (vs. implicit memory) (Parker, Powell & Dagnall, 2018), face recognition and classification (Lee, et al., 2016; Lyle & Orsborne, 2011), and some non-memory tasks such as the attentional network test (Edlin & Lyle, 2013) and creative thinking (Fleck & Braun, 2015; Shobe, Ross, & Fleck, 2009; Fleck & Braun, 2015). Most importantly, SIRE effects appear to manifest themselves in terms of the ability to retrieve specific details and in autobiographical memory.

SIRE and the Recall of Specific Details.

Some of the work reviewed above indicates that SIRE effects appear to influence the retrieval of studied details. For example, in relation to associative false memory, the rejection of highly associated, but non-studied information can be achieved by the retrieval of information that pertains to the items source or perceptual characteristics (e.g., Koutstaal, 2006). When source or perceptual information is not retrieved, then the item might not have been studied.

More direct evidence for the notion that eye movements influence the ability to recall specific details comes from experiments in which participants provide responses concerning their state of awareness (using the remember-know procedure) or the retrieval of such details is a requirement for responding.

In relation to the former, the remember-know procedure (e.g., Tulving, 1985; Gardiner & Richardson-Klavehn, 2000), requires participants to indicate whether memory is accompanied by the retrieval of highly specific information, such as associations, source, or position of an item of a list (Remember responses) or merely seems familiar in the context of the experiment without any associated details (Know responses). In previous experiments it has been found that eye movements typically increase 'remember' responses (e.g., Parker et al., 2008; 2009).

In other experiments, the retrieval of highly specific information is required for accurate responses. For example, Parker, Poole, & Dagnall (2020) made use of a perceptual recognition paradigm in which some recognition test items had the same verbal label as a studied item, but differed in precise visual details (e.g., two slightly different pictures of an acorn). Usually, the false recognition rate for perceptually similar items is high. However, this can be reduced by using a recall-to-reject strategy in which non-studied similar items can be rejected by the accurate retrieval of the perceptual details of the corresponding studied item. Parker et al (2020), found that eye movements prior to the recognition test both increased the hit rate and reduced the false alarm rate for highly similar pictures.

In summary, eye movements may operate by increasing the ability to recover specific and often perceptual information about a study episode.

SIRE and Autobiographical Memory

Autobiographical memory was studied in the second experiment of Christman et al., (2003) using the diary technique. Participants kept a dairy of personal events over a six-day period. After two weeks, free recall memory for the diary entries was assessed after a pre-retrieval eye-movement or fixation task. Higher memory accuracy was found in the eye movement condition with no difference if response bias.

In a later experiment, Christman, Propper, & Brown, (2006) asked participants to recall an event in their childhood from before 8 years old. They were asked to provide as much detail as possible and then provide a date for that memory. Prior to retrieval, they were given a horizontal or fixation EM task. It was found that eye movements led to the recall of earlier childhood memories.

The subjective recollective qualities of autobiographical memory has also been assessed in SIRE experiments. For example, making use of the Galton-Crovitz cue word technique, Parker and Dagnall (2010) had participants recall personal memories to emotional and neutral cue-words. Following each recall, the qualities of the memory were rated using the scales from the Autobiographical Memory Questionnaire (Rubin, Schrauf, & Greenberg, 2003). It was found that horizontal saccades (vs fixation) led to higher levels of subjective recollection in terms of sensory details such as feelings of seeing and hearing components of the memory together with a heightened sense of reliving and experiencing the memory from a first-person perspective.

Using the autobiographical fluency task, Parker, Parkin, & Dagnall, (2013) found eye movements to increase the recall of episodic autobiographical memory across two time periods (5-11 and 12-28 years). However, eye movements had no effect on semantic autobiographical memory or general semantic memory. In addition, using the Sentence Completion for Events from the Past Test (SCEPT) (Raes, Hermans, Williams, & Eelen, 2007), Parker Parkin and Dagnall (2017), found eye movements led to the recall of more specific (vs. categorical or extended) memories.

Taken together, these findings show SIRE effects for “real-life” personal memories and complement those found in laboratory-based work. Furthermore, similar to laboratory acquired memories, it appears that eye movements enhance the retrieval of detailed and more specific information. In relation to ABM theories, this can be explained by eye movements initially potentiating retrieval processing. Consequently, leading to greater access to event-specific knowledge and sensory episodic information lower in the hierarchy of the autobiographical knowledge base.

The research presented in this thesis aimed to extend this work further by the use of different participant groups, and different manipulations to assess the applied and theoretical value of SIRE effects in cognitive enhancement.

Theories

Two prominent explanations have been put forward to account for SIRE effects: The Hemispheric Encoding and Retrieval Asymmetry (HERA) account and the top-down processing explanation. Each of these will be outlined followed by an evaluation.

The original explanation was based on the Hemispheric Encoding and Retrieval Asymmetry (HERA) explanation of a range of neuroimaging findings (Christman et al., 2003; Christman & Propper, 2010). A range of neuroimaging findings found a distinct asymmetry in pre-frontal activations during encoding and retrieval (Babiloni et al., 2006; Gagnon, Blanchet, Grondin, & Schneider, 2010; Habib, Nyberg, & Tulving, 2003; Nyberg, Cabeza, & Tulving, 1996; Tulving, Kapur, Craik, Markowitsch, & Houle, 1994). Particularly, encoding (vs. retrieval) comparisons showed a left pre-frontal bias and retrieval (vs. encoding) comparisons showed a right pre-frontal bias (see Figure 4). This was explained as a greater engagement of left-based semantic processing during encoding and a right-based processing during retrieval thought to reflect recall attempts, search and monitoring.

According to the HERA account of SIRE effects, horizontal eye movements are related to an increase in activation in the hemisphere contralateral to the eye movement (e.g., Dean, Crowley, & Platt, 2004; Kastner, et al., 2007). The idea is that performing a succession of horizontal eye movements results in activation of both hemispheres. This brings about more equalized activation of the hemispheres and enables more efficient interhemispheric communication (Christman et al., 2003; Christman & Propper, 2010).

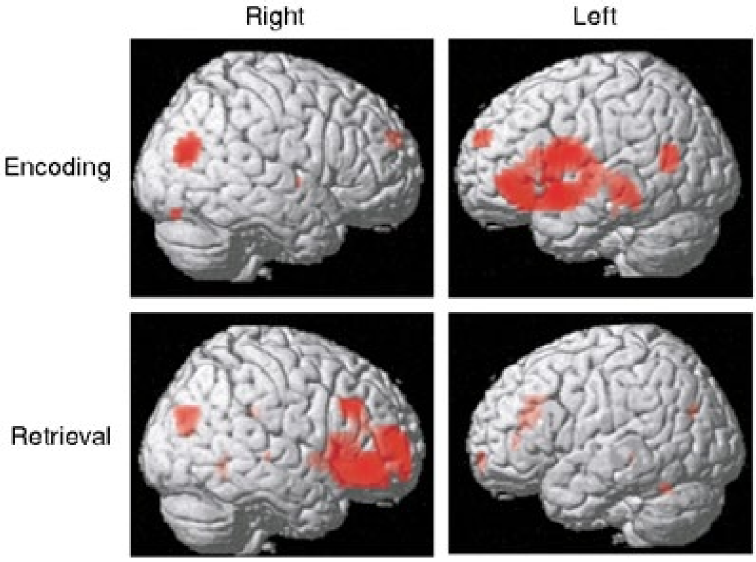

Figure 4- Summary of activation regions showing the HERA pattern of results adapted from Habib, Nyberg & Tulving, (2003).

As this account goes, the proposal is that episodic memory is influenced by a combination of both left (encoding) and right (retrieval) processing. Consequently, enhancing communication between the hemispheres improves processing that is dependent on such activity, including episodic memory.

Some indirect evidence that bears upon the possible importance of bihemispheric activations was found by Nieuwenhuis et al. (2013). They compared a number of right-left alternating tasks including eye movements, auditory listening and tactile stimulation. It was found that both eye movements and alternating tactile stimulation (but not alternating auditory stimulation) improved memory. This was explained by reference to the fact that the visuomotor (eyes) and somatosensory (tactile) systems have a greater degree of contralateral organization compared to the auditory system. This was hypothesized to lead to greater interhemispheric activation during the eye and tactile tasks and thus an improvement of cognitive performance as outlined by the HERA account.

Unfortunately, experiments in which more direct assessment of brain activations have been measured have been somewhat inconclusive. Using EEG coherence measurements (as a proxy for interhemispheric communication) Propper, Pierce, Geisler, Christman, and Bellorado, (2007), found horizontal eye movements led to a decrease (as opposed to the hypothesized increase) in frontal EEG coherence. Later work has also found little support for the idea that EEG coherence is influenced by eye movements (Samara et al., 2011).

In the theorising of Christman and colleagues, it was claimed only horizontal saccades should increase hemispheric interaction and therefore episodic memory. This was based on the idea that horizontal eye movements bring about the greatest changes in alternating right-left neural activity. Some work has supported this idea and found only horizontal saccades produce SIRE effects (e.g., Brunyé, Mahoney, Augustyn, & Taylor, (2009). In contrast other work has shown vertical eye movements can also enhance memory (Lyle, Logan, & Roediger, 2008). A recent meta-analysis found only horizontal eye movements have appreciable and significant effect sizes in relation to memory (Qin, Yang, Cui, Ye, & Wang, 2021). This could be interpreted cautiously as providing support for the HERA account, although more direct evidence would be welcome.

As opposed to appealing to interhemispheric processing to explain SIRE effects, a more recent theory refers to the possible influence of top-down processing (Edlin & Lyle, 2013; Lyle & Edlin, 2015). From a cognitive perspective, this account claims the eye movement task to require a degree of top-down attentional control to maintain focus on the moving target on the screen. This activity then exerts processing aftereffects. Effectively, top-down activity does not cease once the eye movement task is over. Rather, this activity continues to influence subsequent performance including the allocation of attentional resources. The reasoning is that any following task that requires a degree of top-down control is then potentiated. With regard to memory, this would involve a range of operations such as strategic retrieval and post-retrieval monitoring.

Although the neurobiological foundations of this are not fully specified by Lyle and colleagues, reference is made to neuroimaging work in related fields of investigation. In particular, work that illustrates interactions between the dorsal pre-frontal (PFC) and dorsal parietal cortex (Cabeza, 2008; Corbetta & Shulman, 2002). To outline, it has been hypothesised that top-down signals originating in the dorsal PFC are received by the dorsal parietal cortex and apportions attentional resources based on these signals accordingly (see Figure 5).

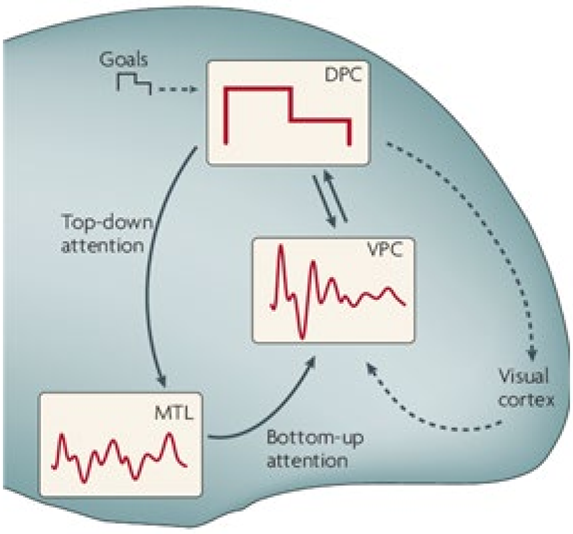

Figure 5– Illustrations of the interaction between frontal and posterior region during top-down control on memory adapted from Cabeza, Ciaramelli, Olson, Moscovitch, (2008).

The top-down signal would likely originate in the frontal eye-fields (FEFs) and subsequently influences activity in the parietal, and eventually visual regions. In this case, performing eye movements prior to episodic retrieval activates a fronto-parietal network and up-modulates memory representations making them accessible.

Evidence consistent with this account comes from behavioural, EEG and some neuroimaging work. In relation to the former, it has been found that SIRE effects are larger when the memory task requires some degree of strategic control. For example, Lyle and Edlin (2015) hypothesised that eye movements would have a greater effect in enhancing memories when the memoranda are less accessible. In this experiment, accessibility was manipulated by the repeated retrieval of some items (more accessible) compared to non-practiced items (less accessible). Eye movement effects were found only for the less accessible information. Additionally, Lyle (2018) found SIRE effects for free recall but not recognition. A result claimed to support the top-down account as strategic processing is more likely to be required for retrieval with minimal cues (but see the work on SIRE effects and recognition memory).

Regarding EEG research, Fleck et al., (2018), found greater delta-band coherence between frontal and posterior electrode sites following thirty seconds of horizontal eye movements (compared to fixation). They explained this as arising from the engagement of attentional control processes extending across time following the cessation of eye movements. That is, the continued influence of top-down control after horizontal saccades.

A relatively recent *f*MRI experiment examined the contributions of the frontoparietal network with eye movements and during retrieval (Harricharan, et al., 2019). The results showed increased connectivity with frontal regions (including the frontal eye fields, supplementary eye fields and the right dorsolateral prefrontal context and more anterior regions including the parietal cortex and the insula). This was explained in the context of the top-down regulation of memory retrieval in association with eye movements.

SIRE Effects and Handedness

Findings on SIRE effects have sometimes been related to the degree of personal handedness. This refers to the degree to which individuals have a preference to use a particular hand to perform a range of manual activities (e.g., using scissors or brushing teeth).

Some work has shown that individuals who are mixed or inconsistently-handed (showing no strong preference for the use of the right or left hand) outperform individuals who are strongly right-handed (or consistent-handers) (e.g., Christman et al., 2006; Lyle, McCabe & Roediger, 2008; Propper et al., 2005). This has been interpreted as due to mixed-handers possessing a larger corpus callosum and show greater hemispheric interaction (Christman & Propper, 2010). This results in superior episodic memory in accordance with the HERA account as outlined above.

In this context, strongly right- (consistently) handed individuals, are hypothesized to possess *lower* levels of hemispheric interaction and thus are *more* likely to benefit from an increase in such interactions. If this is correct, then according to the HERA explanation, SIRE effects would be predicted to be larger for strongly right- (consistently) handed individuals. Some work has indeed found this (e.g., Brunyé, et al., 2009; Lyle et al., 2008). Consequently, these findings can be seen as providing some further support for the HERA account of SIRE effects. However, the findings more generally have been inconclusive with other work failing to find a dependency of eye movement effects on handedness (e.g., Lyle & Jacobs, 2010). The research presented in this thesis also measures handedness in an attempt to further examine the issues outlined above.

Eye Closure effects

Definition & Original Work

The environment can be detrimental to information processing to the extent that incoming visual information can impair a range of cognitive tasks including memory retrieval. Eye-closure effects refer to the influence of voluntary or instructed eye-closure on cognition (Vredeveldt, Hitch, & Baddeley, 2011).

In some of the original work, Glenberg, et al., (1998), found that gaze aversion was related to the ability to recall recent autobiographical events (e.g., what did you have for breakfast?). That is, greater gaze aversion was associated with better memory. Similar effects were also found for answering general knowledge questions. Using instructed eye-closure, Glenberg et al., found eye-closure to facilitate performance in answering general knowledge questions and mathematics problems.

This research, although influential, did not address the effects of eye-closure on episodic memory. However, later experiments extended the above findings more comprehensively and demonstrated that eye-closure can facilitate the retrieval of episodic information.

Extending Eye-Closure Research

Much of the work on eye-closure effects has been performed with complex stimuli in the form of visual events or scenarios of an “eye-witness” form. For example, Wagstaff et al. (2004) assessed the effects of eye-closure (experiment 2) on memory for a public event; the funeral of the Princess of Wales which occurred in 1997. The results showed closing one’s eyes during recall enhanced true memory without an increase in false recall. The latter point is important as it demonstrates the findings are not due to a more liberal response bias, in the eyes-closed group.

Other work has exercised more control over encoding and the stimuli presented. For instance, Perfect et al. (2008) performed a series of experiments involving a simulated robbery (using a videotaped event), a local UK news bulletin, a television programme (from an unfamiliar UK TV series "The Family at War"), and a real-life staged event (in which an experimental stooge performed a pre-determined script). Memory for these various scenarios were tested with eyes open or closed. Despite some differences between the experiments, the results generally showed that eye-closure improved episodic memory for both the visual and auditory information without an increase in false memory.

Eye-closure effects have also been found with children. For instance, Mastroberardino and Vredeveldt (2014) has children between 8 and 12 view a short video featuring a theft. Later, memory was tested in an interview in which the children were given a set of open-ended questions about the details of the video. It was found that those in the eye-closure condition recalled more studied information and produced fewer false recalls about the event.

Older individuals have also shown eye-closure effects, although the research is more limited. For example, Wais, Martin, and Gazzaley, (2012) has participants encode a series of pictures of objects (e.g., a pumpkin). It was found that eye-closure improved recognition accuracy and that the effects were more pronounced in older individuals.

Although the previous experiment made use of a list-learning type paradigm, there has been a more limited range of research using this procedure. An example includes, Einstein, Earles, and Collins (2002) who found eye-closure to enhance *recall* for lists comprising related and unrelated pairs and both concrete and abstract items. In contrast, Uchiyama and Mitsudo, (2019) found no effects of eye-closure on *recognition* memory for words. However, in this experiment, eye-closure was manipulated *before* the recognition test which took place with eyes open for all participants. When eye-closure was manipulated on a trial-by-trial basis, recognition memory (for pictures) was enhanced (Parker & Dagnall, 2020).

Eye-Closure and the Recall of Specific Details.

The question here is whether eye-closure influences the retrieval of memory in a more “general” sense without specific features (i.e., familiarity or ‘know’ responses), or for precise details (i.e., recollection or ‘remember’ responses). The research suggests that eye-closure can be especially beneficial in aiding the latter. For example, in the Wais, et al., (2012) experiment outlined above, participants studied pictures in which some trials were of a single object and other trials of four pictures of an identical object. During retrieval, fine-grained or specific memory was tested by asking participants not only to indicate if the object was studied (“global” memory), but how many pictures had been presented (specific memory). Eye-closure was found to assist with the retrieval of more fine-grained or specific information.

Using the remember-know paradigm, Parker and Dagnall (2020) found intermittent eye-closure to improve recognition accuracy studied items while decreasing false recognition for perceptually similar unstudied items. The effects were typically associated with changes to ‘remember’ responses. Again, indicating that eye-closure appears to assist with the retrieval of more specific information.

The research on eye-witness memory can also be interpreted as being congruent with the above conclusions to the extent that the tests required answering questions about specific details of the experienced events.

In summary, eye-closure, like eye movements, appears to facilitate the ability to retrieve specific and often perceptual information about a study episode.

Eye-Closure and Autobiographical Memory

Given the amount of work on eye-closure effects and eye-witness memory, it is surprising that no research has been done that examines these effects on personal memories from one’s own life. Although eyewitness and autobiographical memory may differ in the extent to which the encoded episodes are personal, there is some between these fields as both forms of memory often entail the retrieval of event-related information (Pezdek, 2003; Rubin, & Umanath, 2015). This overlap is more fully explored in Experiments 2 and 3 of this thesis.

<u>Theories</u>

Closing one's eye in an interview type situation can reduce interpersonal anxiety and discomfort when face to face with an interrogator (Vredeveldt & Penrod, 2013). Thus, social factors may, in part, explain some of the beneficial effects of eye-closure, although it is unlikely to account for the whole range and pattern of effects found. Additionally, in some instances closing one's eyes in such situations might increase interpersonal discomfort (Nash, Nash, Morris & Smith, 2016). However, in this thesis, explanations based on changes in cognitive activity are evaluated and later considered in the context of autobiographical memory enhancement.

In this context, two primary theories have been advanced. The first, variously labelled the domain-general or cognitive load hypothesis, is based on the idea of a limited central capacity of attentional resources (e.g., Norman, & Bobrow, 1975). The second, the domain- or modality-specific hypothesis, is premised on the notion of separate attentional resources for each modality (e.g., Alais, Morrone, & Burr, 2006).

The domain-general account explains the eye-closure effects as arising because retrieving memories with open eyes is accompanied by interference between retrieval and monitoring the environment (Glenberg et al., 1998). If interference is sufficiently high, then the limited pool of attention will be unable to perform both tasks simultaneously and memory will be impaired. In models of working memory (Baddeley, 2010; Baddeley & Hitch, 1974) this modality general pool of resources can be taken to refer to the central executive (Baddeley, 1986). Evidence for this comes from research that shows the beneficial effects of eye closure extend across more than just the visual modality. For example, Perfect et al., (2008) found enhanced memory for both visual and auditory information. Perfect, Andrade, and Eagan,

(2011) also found evidence consistent with the domain-general account in that eye closure reduced the number of recall errors equally for both visual and auditory information.

The domain-specific hypothesis explains eye-closure effects as resulting from interference at the level of modality specific subsystems or processes (Baddeley, 1986). From a working memory perspective, these subsystems comprise the visuospatial sketchpad and the phonological loop. Accordingly, interference only arises when tasks compete for the same resources *within* a particular modality. Evidence that favours this account come from work in which eye-closure effects are limited to the recall of visual details (e.g., Vredeveldt et al., 2012, 2014).

It is also of interest to consider these accounts in relation to a possible mediating role of mental imagery. For example, closing one's eyes could assist with generating mental visual images of a past event or stimulus. Neuroimaging work has shown that eye-closure can lead to increased activations in regions such as the lateral occipital cortex that were used to initially encode a stimulus (Wais, Rubens, Boccanfuso, & Gazzaley, 2010). Thus, excluding new incoming sensory information (closed eyes) could provide a basis for *re*-engaging the cognitive processes used during encoding and leading to a more successful attempt to generate a vivid mental image. This experiment also revealed increased activations in the hippocampus (important for episodic memory) during eye-closure and greater connectivity between memory and visual regions (see Figure 6). This could be explained in terms of the domain-specific account of eye-closure.

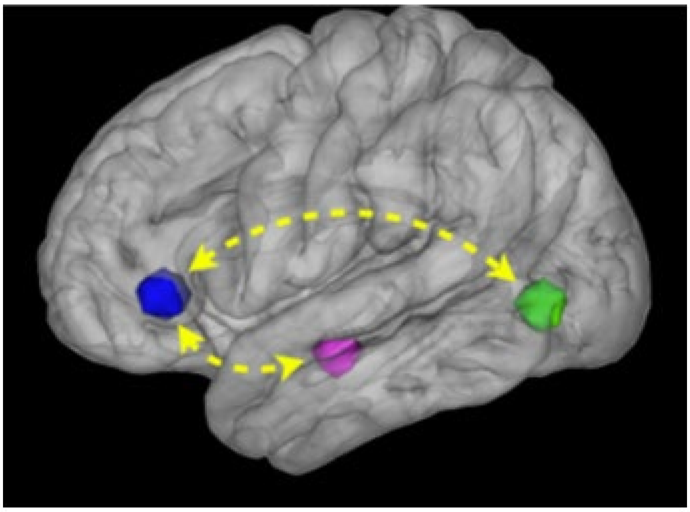

Figure 6- Illustration of the interactions between frontal regions (the left inferior frontal gyrus – blue), the hippocampus (violet) and occipital cortex (green). Adapted from Wais, Rubens, Boccanfuso & Gazzaley (2010).

However, the work by Wais et al., (2010) also found eye-closure to be associated with prefrontal activations. Furthermore, disrupting prefrontal activity with repetitive Transcranial Magnetic Stimulation (rTMS) impaired retrieval with eyes closed. Together, these findings were explained in terms of a combination of both top-down control (domain-general) mechanisms interacting with bottom-up (domain-specific) influences to influence memory. In this context it is likely that both explanations have something to offer (Vredeveldt Hitch, & Baddeley, 2011) but the conditions under which any process is dominant is, as yet, unclear and remains to be determined.

General Summary

Autobiographical memories are personal records and constructions of our lived experience (Conway, 2005; Conway, & Pleydell-Pearce, 2000; Levine, 2004). There are different forms of personal memories and range from those that are highly semanticised or abstract, to those that are specific and detailed. This thesis is primarily concerned with the latter and by assessing such memories by retrieval fluency and the cue-word technique. Autobiographical memories are important as they play a role in forming our identity, enabling mental time travel, and regulating behaviour and emotions (Meléndez et al., 2016; Rasmussen & Berntsen, 2009). Consequently, techniques that can promote or enhance the recall of personal memories are worthy of research. The background research covered in the introduction dealt with two procedures for enhancing memory: eye movements and eye-closure. Both have been shown to enhance memory at *retrieval* and are thus useful as the importance of memories (especially autobiographical ones) cannot always be known or predicted during encoding.

Regarding eye movements, short periods of pre-retrieval horizontal saccades has been demonstrated to improve episodic memory for information acquired during the laboratory and in real life (Christman et al., 2003). Theoretically, this has been explained as resulting from increased hemispheric interaction (the HERA model) or by facilitated top-down processing. The evidence relating to these accounts has been somewhat indirect and mainly reliant on behavioural experiments. The HERA model has not fared as well as originally anticipated (Samara et al., 2011). The top-down account has garnered some behavioural evidence in its favour together with some suggestive imaging work (Fleck et al., 2018; Harricharan, et al., 2019).

Regarding eye-closure, shutting ones eyes during retrieval has also been found to improve episodic memory (Vredeveldt et al., 2011). To date, this has been found in mainly laboratory tasks and for eye-witness memory (Perfect et al. 2008). No work has examined eye-closure effects on autobiographical memory. The explanation for eye-closure effects has, in part, also referred to top-down processing. Principally, closing one's eyes is predicted to free executive/attentional resources that can be then used to perform retrieval more effectively. An alternative explanation is that eye-closure works in a bottom-up fashion by freeing visual attentional resources. Existing work has found evidence for both these accounts, and it is best to conclude that these theories should not be considered mutually exclusive.

Plan of PhD, Aims & Experiments

This thesis consists of three experiments each assessing the extent to which eye movements (Experiments 1-3) and eye-closure (Experiments 2-3) can enhance the retrieval of autobiographical memories. Outlined below is a summary plan of the thesis combined with the rationale behind the experiments. Aspects of the latter were altered because of the COVID-19 pandemic. Accordingly, the basic aims, rationale and specific experiments are outlined both before and after the changes were made. See page 81 for further details on how the Pandemic altered the direction of this PhD.

Prior to the COVID-19 Pandemic.

The initial rationale was to assess the effectiveness of retrieval-based techniques for improving episodic personal memory in the elderly and younger individuals. Within this context, the planned research had both an applied and a more theoretical strand.

From an applied perspective, the aim of the first experiment was to determine the effect of saccadic horizontal eye movements on the recall of episodic autobiographical memory, semantic autobiographical memory, and general semantic memory in both older and younger participants. To do this, autobiographical fluency task (Dritschel, Williams, Baddeley, & Nimmo-Smith, 1992) was employed. As this had been used in previous work with younger participants (Parker, Parkin &

Dagnall, 2013) it was reasoned that this would be a good starting point by extending to an older population.

From a more theoretical perspective, different types of memory were measured as these not only related to existing work in autobiographical research, but to conceptions about the mechanisms of SIRE effects. Principally, the largest eye movement effects were expected to be found on the recall of specific autobiographical incidents (personal episodic memory) in comparison to personal semantic and general semantic memory.

If this thesis had continued to assess autobiographical memory in older participants, subsequent experiments were planned to: **(i)** determine the generality of SIRE effects across different types of autobiographical tests, **(ii)** use different types of cues and, **(iii)** combine eye movements with other retrieval-based techniques (i.e., eye closure) to assess if such combinations produce interactive or main effects.

After COVID-19 Pandemic.

Because of the lack of access to older participants, the aims of this thesis necessarily changed somewhat. The applied aspect, as related to older participants, was therefore dropped. Focus instead was on younger individuals. Despite this, and to maintain continuity, many aspects of the original plan were incorporated. These included, assessing generalisability of enhancement effects across tests and dependent variables, the use of different methods to cue autobiographical memory and additional memory enhancement techniques.

In this context, Experiment 2 aimed to extend and refine the finding of Experiment 1 with focus on younger subjects. To generalise across different measurements, the Autobiographical Memory Test (AMT) was used together with measurements of memory specificity and phenomenal ratings of memory qualities. To extend past work and the theoretical aspects of the thesis, concrete (imageable) and abstract (less imageable) cues were used. This was done to assess the role of top-down as predicted by one of the main theoretical accounts of SIRE effects and used here in ABM work for the first time. This manipulation was based on the notion that different types of cue bring about different retrieval strategies of which some were predicted to be more likely to initiate top-down processing. This is discussed more fully in the introduction to Experiment 2.

Additionally, to extend past work further, eye-closure was manipulated alongside eye movements. The rationale for this was to contribute to the applied aims of the thesis (to facilitate ABM retrieval) and consider eye-closure effects within a theoretical context. The latter is if interest as eye-closure (like SIRE) effects have often been considered in terms of top-down processing (as outlined earlier in this introduction). If both eye movements and eye-closure are underpinned by similar (vs. independent) mechanisms, then the combined use of the two techniques would produce interactive (vs. additive) effects. In Experiment 2, memories were recalled and recorded after 30 seconds of eye movement (vs. fixation control) with eyes either open or closed. Both IVs were manipulated between-subjects. Memories were rated by the participants for their subjective characteristics and the recall protocol scored for memory specificity.

The aim of the third experiment was to refine the findings from Experiment 2. This was achieved by manipulating eye-closure on a within-subjects basis and adding an additional level to this factor, that of perceptual interference with a dynamic visual noise field. Thus eye-closure consisted of three within-subject levels: eyes closed, eyes open without perceptual interference and eyes open with perceptual interference. In addition to measuring memory specificity and the subjective qualities of each recall, participants were also asked to indicate *how* they retrieved each memory. Two options were provided (direct vs. generative) based on past work (Harris, O'Connor, and Sutton (2015). Manipulation of eye movements was kept between-subjects and imaginable vs. less imaginable cues were again manipulated within-subjects.

Thus, the overarching rationale of the thesis was to: **(i)** Extend previous research by assessing the applied or practical value of using retrieval-based manipulations to enhance ABM in older (Exp 1) and younger (Exp's 1-3) individuals. This is an important goal because recall failures of autobiographical memory can have negative consequences for individuals for both their own sense of self-identity and in terms of facilitating interpersonal relationships. **(ii)** Evaluate the theoretical nature of retrieval-based enhancement techniques by use of manipulations, combinations of variables and measurements that provide some insight into the contributions of types of processing that might underpin such enhancement procedures.

Chapter 2: Experiment 1 – Effects of Saccadic Eye Movements on Episodic & Semantic Memory Fluency in Older and Younger Participants.

Introduction

General Introduction to Experiment 1

As noted in the general introduction, memory enhancement has been the focus of much psychological research and encompasses a range of procedures known to improve performance, such as depth of processing (Craik & Tulving, 1975), spacing (Cepeda, Rohrer, Wixted, & Pashler, 2008) or expanding retrieval (Karpicke, & Roediger, 2007). The principal aim of Experiment 1 is to assess whether saccadic eye movements can enhance autobiographical memory in the elderly. To date, research has only addressed this question in younger adults. Finding a SIRE effect in older participants will be of immense practical value given impairments of episodic memory are associated with increased age. In this context, the autobiographical fluency task (see research methods section of general introduction) will be used with both younger and older individuals to measure both episodic and semantic personal memory, together with general semantic memory following a sequence of horizontal saccades. To place this work in a broader context, an outline of the decline of personal memory in the elderly is first considered.

Autobiographical memory and ageing

Prior research has shown that age has a differential impact on episodic and semantic components of memory (Meléndez, Agusti, Satorres, & Pitarque, 2018; Piolino et al., 2002). Typically, ageing is associated with a decrease in the accuracy and overall number of episodic details recalled (Piolino et al., 2010; St Jacques & Levine, 2007). This is especially the case with unsupported effortful retrieval (Levine, 2002) and has been evidenced in subjects from at the ages of 55 years old with subjects showing a greater emphasis upon semantic autobiographical recall over episodic recall (Frankenberg et al, 2022).

This decrease in the accessibility of episodic details can be conceptualised in theoretical models of autobiographical memory that were outlined in the general introduction. To reiterate, personal memory is theorised to be organised in a hierarchical manner. In this conceptualisation the most abstract representations cover lifetime periods that include temporal and thematic information spanning large periods in one's life (Conway, 2005). Below this is general event knowledge that depicts single, repeated, and extended events. Both forms of representations are types of personal semantic knowledge (Conway, & Pleydell-Pearce, 2000; Coste, Navarro, Vallat-Azouvi, Brami, Azouvi, & Piolino, 2015). Finally, event-specific knowledge (ESK) represents information that possesses direct reference to place, events, people, and time (Conway, & Pleydell-Pearce, 2000).

The reduction in the ability to recall specific episodes has several important consequences for older individuals. Particularly, the loss of specific autobiographical memories can lead to a disconnection between current and past selves and the ability to retain a clear appraisal for one's personal identity (Meléndez, Torres, Redondo, Mayordomo, & Sales, 2015). Reduced memory specificity is also associated with increased depression in the elderly (Wilson, & Gregory, 2018). More practically, impaired social problem solving (Beaman, Pushkar, Etezadi, Bye, & Conway, 2007; Leahy, Ridout, Mushtaq, & Holland, 2018), and reduced personal independence (Holland, Boukouvalas, Wallis, Clarkesmith, Cooke, Liddell et al., 2017; Leahy et al., 2018) can also result from the inability to retrieve specific autobiographical information.

Consequently, developing techniques to enhance the accessibility of specific memories in older individuals is an important goal. Previously, several procedures have been employed that have shown positive outcomes. These include reminiscence therapy (Meléndez et al., 2015), memory specificity training (Martens, Takano, Barry, Goedleven, Van den Meutter, & Raes, 2019) and life review (Gonçalves, Albuquerque, & Paúl, 2009). To add to this list, Experiment 1 assessed the use of pre-retrieval saccadic eye movements in the enhancement of autobiographical memory.

The Current Experiment

Experiment 1 assessed the effects of eye movements on episodic and semantic personal memory by use of the autobiographical fluency task (Dritschel, Williams, Baddeley, & Nimmo-Smith, 1992). As described in the general introduction, this task requires the production of as many examples as possible of personal episodic, semantic, and general semantic memories within 90 seconds.

The task has been utilised to assess memory performance as a function of saccadic eye movements (Parker, Parkin, & Dagnall, 2013). In this, pre-retrieval horizontal saccades enhanced episodic autobiographical, but not semantic autobiographical memory fluency. Principally, horizontal eye movements increased the number of personal memories for episodic events over two lifetime periods of 5-11 and 12-18. Conversely, memory for the names of friends and teachers (personal semantic memory) and of semantic categories (general semantic memory) were uninfluenced by eye movements. However, this experiment did not use older individuals. Consequently, the aim of Experiment 1 is to replicate the work with younger persons and extend to more elderly individuals.

In the first experiment, saccadic eye movements (vs. fixation) task was implemented prior to the recall of personal episodic memory, personal semantic memory, and general semantic memory for both older and younger individuals. The episodic memories recalled were from 5-11 and 12-18 to maintain consistency with previous work and to facilitate comparisons with prior results. Tentative predictions are derived from the SIRE explanations outlined in the general introduction. From perspective of the hemispheric interaction (HERA) account, it is known that ageing is associated with a decrease in the size and structural integrity of the corpus callosum (e.g., Cowell et al., 1992; McLaughlin, Paul, Grieve, Williams, Laidlaw et al., 2007; Weis et al., 1993). As this is the major pathway by which interhemispheric communication takes place, ageing should bring about a decrease in the degree of interaction (Delvenne & Castronovo, 2018; Duffy, McAnulty, & Albert, 1996; Lyle, McCabe, & Roediger, 2008). Indeed, neuroimaging work has shown a reduced HERA signature to be associated with impaired episodic memory in older individuals (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Cabeza, Daselaar, Dolcos, Prince, Budde, & Nyberg, 2004; Johansson, Salami, Lundquist, Wåhlin, Andersson, & Nyberg, 2020). Consequently, a possible enhancement of interhemispheric communication, via horizontal saccades, could serve to increase episodic autobiographical memory performance in both older and younger individuals.

Regarding the top-down explanation, research indicates that top-down processing is impaired in older adults (e.g., Amer, Campbell, & Hasher, 2016; Braver & Barch, 2002; Lee, Crawford, Henry, Trollor, Kochan, Wright, Ames, Brodaty, & Sachdev, 2012). Furthermore, this impairment has been found to impact performance on tests of episodic and autobiographical episodic memory (e.g., Piolino Coste & Martinelli et al., 2010). In the context of the top-down account, the result of eye movement induced increases in controlled processing would lead to the activation of mnemonic representations and the facilitation of their retrieval (Lyle & Orsborn, 2011). This is hypothesised to take place by the upmodulation of target representations making them more accessible and reducing interference from non-target competitors (Kelley & Lyle, 2021; Lyle & Edlin, 2015).

Hypotheses

Based on the work reviewed above several predictions are made, thus:

H1. It is predicted that older (vs. younger) subjects will show a reduction in the number of episodic autobiographical memories recalled over 90 seconds.

H2. As semantic memory is generally more preserved in older individuals, it is predicted that age differences will be smaller or non-existent for both personal semantic and general semantic memory.

H3. It is predicted that horizontal saccades (vs. fixation) will increase the number of episodic autobiographical memories recalled over 90 seconds.

H4. In line with prior work, it is predicted that eye movements will have no effect on the recall of semantic memories. In other words, a dissociation is predicted between episodic and semantic memory as a function of eye movements.

What is more difficult to predict is whether the magnitude of the SIRE effect will differ across older and younger participants. It could be argued that if hemispheric interaction is reduced in older participants, then eye movements could provide a particularly valuable boost to recall and thus the size of the SIRE effect could be larger. A similar argument could be made from the perspective of the top-down account as top-down processing is deficient in older subjects, eye movements should enhance retrieval. If this is correct, then:

H5. An interaction between age group and eye movements is predicted. Particularly, older participants will show a greater benefit from eye movements compared to younger participants in the recall of episodic autobiographical memories.

Method

Design

The experiment had two between-subject variables; eye movement task (horizontal vs. fixation) and age of the individual (older vs. younger). The episodic autobiographical memory condition also contained a within-subject variable which was the age of the recalled memory (ages 5 – 11 years old vs 12 – 18 years old). The dependent variables were the number of examples generated for each of the memory categories. These included: (i) personal episodic memory (episodic events from 5-11 years and 12-18 years), (ii) personal semantic memory (names of teachers and names of friends, both from 5-18) and (iii) general semantic memory (names of vegetables and animals).

Participants

One-hundred and twenty participants took part in the experiment. Eighty younger adults (age range 18-34, mean = 22.50), and 40 older adults (age range 55-87, mean = 70.35) were recruited using opportunity snowball sampling. Participants were randomly allocated to each eye movement condition (59 in the horizontal condition and 61 in the fixation condition) by the data collection team. The participants in the younger condition were primarily recruited from the university and surrounding facilities and had to be at least 18 years of age. The older participants were all community dwelling and autonomous individuals who were recruited from several community establishments, such as local churches and community centres. The exclusion criteria were: (i) presence of neurological or psychiatric medical history, (ii) current or past memory complaints, (iii) taking any medication known to impair memory.

Sample size was based on similar previous work (e.g., Parker et al., 2013, Dijkstra & Janssen., 2013 & Holland et al., 2012) and a sample size analysis performed in MorePower 6.0 (Campbell, & Thompson, 2012). For a main effect and interaction effect size of η_p^2 = .063, with α = .05, and for 80% power, the estimated total sample size was 120

Materials & Apparatus.

Materials included an experimental booklet that consisted of three main sections. The first contained the participant information sheet, consent form, and spaces to record demographic information such as the participant age. The second section contained a modified version of the 'Edinburgh Handedness Inventory' (Oldfield, 1971). Several different versions of the scale have been used in the past (Edlin et al, 2015). In the present work, a total of ten activities (e.g., writing, drawing, & throwing) were used as described by Lyle et al. (2008). For each activity, the participant placed a check at one of the five points of a Likert scale to indicate handedness preference for each of the ten activities. The five points were defined as always left (-10), usually left (-5), no preference (0), usually right (+5) and always right (+10). An example question from the scale asks, "What hand do you write with?" or "When brushing your teeth, what hand do you use?"

The third section contained the experimental instructions pertaining to the recall of episodic autobiographical memory, semantic autobiographical memory, and general semantic memory. Each sub-section of the test contained explicit instructions and examples for the experimenters to follow.

A digital timer was used to time the 90 seconds given for each memory recall trial and an audio program on a portable PC was used to record all responses provided by the participants. Finally, computer program was used to initiate eye movements. This was done by flashing a black circle against a white background from side to side (horizontal condition), or on and off in the center of the screen (fixation condition). The circle moved once every 500ms and in the eye movement conditions was located approximately 27° of visual angle apart.

Procedure.

Participants were tested individually. Each participant was assigned randomly to one of the eye movement conditions. The participants where then asked to read the participant information sheet and if they had no questions complete the provided consent forms and participant codes.

Next, the participants were asked to complete the Edinburgh Handedness Inventory. Once this was completed, the participants gave back the booklet to the experimenter and was asked to relax and face the computer monitor. At this point, all the instructions were presented verbally, and responses recorded by the audio recording software. The participants were then told the experiment would consist of several phases. In each phase, they were asked to view a moving or stationary dot on the screen for 30 seconds. Participants were in the same eye movement condition for all the phases of the experiment. Compliance with the eye movement instructions was monitored by the experimenter as in previous studies. After the eye movement (vs. fixation) task, standardised instructions were read to the participants based on those described by Dritschel et al., (1992).

For the test of episodic autobiographical memory, the instructions were "For this test, I would like you to recall as many personal memories as possible of events from two periods in your life. The first period is between 5-11 years old, and the second period is between 12-18 years old. For each of these periods I would like you to recall as many memories as you can within 90 seconds. Please try to name specific memories of events that relate to particular and single occurrences such as "the time I beat my best friend in the school swimming competition" rather than general memories, such as "having a paper round". Please do not go into detail about each memory, just state each one as it comes to mind and then move onto the next". Participants were provided with additional examples where required and were told that they did not have to reveal any memories they were not comfortable with disclosing. The task progressed only when the instructions were understood.

For the test of semantic autobiographical memory, the instructions were “For this test, I would like you to recall as many autobiographical facts as you can from two periods in your life. The first period is between 5-11 years old, and the second period is between 12-18 years old. For each of these periods I would like you to recall as many autobiographical facts as you can within 90 seconds. By autobiographical facts, in this case I mean names of school friends (vs. teachers). You do not need to tell me each memory in detail, just try to recall as many facts as you can about your life.” The task progressed only when the instructions were understood.

For the test of general semantic memory, the instructions were “For this test, I would like you to generate as many examples from two semantic categories as you can. I will give you 90 seconds to generate from each semantic category. By generating examples from semantic categories what I mean is this, if I were to say “transport” then I would like you to say as many examples of transport that you can such as cars, trains, boats, ships etc. Just state out loud the examples that come to mind. You do not need to tell me about each example in detail, just try to generate as many examples as you can.” Following the presentation of these instructions, either animals or vegetables was read aloud in a randomized order and the recall period commenced. Once the recall period for one category had elapsed, the next category was presented, and the second recall period commenced.

After presenting the appropriate instructions, the timer was set to 90 seconds and the recall trial began. Following Dritschel et al. (1992), the recall of episodic memory always started with earlier autobiographical period. After each recall trial, there was a short pause of a few minutes before the next set of eye movements (vs. fixation) and recall trial. The order in which episodic autobiographical, semantic autobiographical (friends and teachers names) and general semantic memories were tested was counterbalanced.

Once the experimental procedure was completed the participant and the experimenter would listen back to the recording of the sessions and check the provided data for any anomalies or replications which may have occurred (e.g., If a forename was stated more than once the experimenter would check each is a valid unique response).

Once the study was complete the participants were debriefed and reminded of their ethical rights.

Results

The handedness scores were not used in the analyses as this produced too few participants in each of the conditions. For completeness, the number of consistent (vs. inconsistent handed) individuals in each condition can be found in the appendix (section 2) together with the relevant descriptive statistics. This of course represents a limitation of the current experiment and is dealt with in the discussion. However, to provide some assessment of the possible contribution of handedness an ANCOVA was performed with the handedness scores as a covariate using the same factors and fluency scores as described in the results section. This did not alter the pattern of findings of main effects and handedness was found not to relate to any of the fluency scores. The conclusion drawn from this is that in this sample at least, handedness does not moderate the effects of eye movements.

The number of memories recalled (minus repetitions or irrelevant / incorrect information) for each memory type were scored separately. These were then entered into separate univariate ANOVAs for each DV. The descriptive statistics for all tests can be found in Table 1.

Table 1- Mean (SD) Number of memories recalled for each memory type as a function of eye movement condition and age group.

	Eye Movement condition								
	Horizontal *n* = 59			Fixation *n* = 61			Total *n* = 120		
Age group	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
Episodic ABM 5-11									
Younger	37	11.68	(3.53)	43	10.53	(2.87)	80	11.62	(3.22)
Older	22	10.45	(2.18)	18	8.33	(3.40)	40	9.50	(2.95)
Total	59	11.22	(3.13)	61	9.89	(3.17)	120	10.54	(3.21)
Episodic ABM 12-18									
Younger	37	13.73	(3.72)	43	10.77	(2.87)	80	12.14	(3.72)
Older	22	10.64	(2.17)	18	9.06	(3.19.)	40	9.93	(2.79)
Total	59	12.58	(3.55)	61	10.26	(3.23)	120	11.40	(3.57)
Personal semantic memory									
Younger	37	19.81	(5.84)	43	18.99	(6.45)	80	19.37	(6.15)
Older	22	10.32	(3.15)	18	9.67	(5.89)	40	10.03	(5.54)
Total	59	16.27	(6.80)	61	16.24	(7.57)	120	16.25	(7.17)
General Semantic memory									
Younger	37	23.88	(5.37)	43	23.02	(5.87)	80	23.41	(5.63)
Older	22	18.05	(3.44)	18	17.86	(4.51)	40	17.96	(3.90)
Total	59	21.70	(5.50)	61	21.50	(5.96)	120	21.60	(5.72)

Episodic Autobiographical Memory.

The cumulative number of specific autobiographical memories were placed in a 2 (Eye Movements: Horizontal vs. Fixation) between-subjects by 2(Age Group: Young vs. Old) between-subjects by 2(Lifetime Period: 5-11 vs. 12-18) within-subject mixed factorial ANOVA. This revealed a significant main effect of participant age group, $F(1,116) = 16.53$, $p < .001$, $\eta_p^2 = .125$, indicating more episodic memories recalled for the younger group ($M = 11.67$) compared to the older participants ($M = 9.20$). The main effect of eye movement was significant, $F(1,116) = 14.88$, $p < .001$, $\eta_p^2 = .114$, indicating that participants in the horizontal group ($M = 11.62$) scored significantly higher than the fixation group ($M = 9.67$). The main effect of lifetime period was also significant, $F(1,116) = 5.50$, $p = .021$, $\eta_p^2 = .045$, showing more memories for 12-18 ($M = 11.05$) compared to 5-11 ($M = 10.25$).

The interaction between eye movement and lifetime period was not significant, $F(1,116) = 0.87$, $p = .35$, $\eta_p^2 = .008$. The interaction between age and lifetime period was not significant, $F(1,116) = 1.03$, $p = .31$, $\eta_p^2 = .009$. The interaction between eye movement and age was not significant, $F(1,116) = 0.39$, $p = .84$, $\eta_p^2 < .001$. Finally, the three way interaction was not significant, $F(1,116) = 3.01$, $p = .09$, $\eta_p^2 = .025$

The absence of an interaction is inconclusive regarding support for the null hypothesis. However, the use of Bayesian analyses can be used to assess the relative degree of support for the null (vs. alternative) (Rouder, Morey, Speckman, & Province, 2012). Bayesian hypothesis testing has been proposed as a replacement to traditional frequentist hypothesis testing (e.g., Wagenmakers, 2007). It has also been suggested as a supplement to such analyses to evaluate the relative evidence in support of the null hypothesis when the outcome of frequentist statistics is not significant (e.g., Dienes, 2014; Rouder et al., 2012).

Bayesian analyses were performed using JASP software (JASP Team, 2018) using a Cauchy distribution with .5 on the prior (Rouder, Morey, Speckman, & Province, 2012; Wagenmakers et al., 2018) and BF_{01} (Bayes factor) values reported.

This Bayes factor represents the ratio of the probabilities in the data set to support the null vs. alternative hypothesis. A Bayes factor of 1 indicates equal support for the null and the alternative hypothesis. A Bayes factor of 1 and above indicates more support for the null hypothesis (Morey, Romeijn, & Rouder, 2016). However, although Bayesian evidence is continuous, standard thresholds are sometimes reported and provide a more categorical interpretation of the findings. For these, values of between 3 and 0.33 are taken to indicate the results are indeterminate (Lee, & Wagenmakers, 2014). These reporting thresholds are included below.

Consequently, Bayesian ANOVAs were performed in which the significant main effects were combined into the null model and the unique contribution of the two-way and the three-way outcomes were assessed. The interaction between eye movement and lifetime period produced a BF_{01} of 1.93, indicating this finding is somewhat inconclusive and more work needs to be done to assess the likelihood of an interaction between eye movements and lifetime period. The Bayes factor for the interaction between eye movement and age was BF_{01} of 3.24, showing moderate evidence in favour of the absence of an interaction. The interaction between age and lifetime period produced a BF_{01} of 3.25, also showing evidence of the absence of an interaction. The three-way interaction resulted in a BF_{01} of 1.18, showing somewhat inconclusive evidence for the absence of an interaction between all factors.

Personal Semantic Memory

The cumulative number of personal semantic memory indicated a significant main effect of participant age group, $F(1,116) = 71.90$, $p < .001$, $\eta_p^2 = .383$, showing more personal semantic memories recalled for the younger group ($M = 19.37$) compared to the older participants (M = 10.03). The main effect of eye movement was not significant, F(1,116) = .441, p = .508, η_p^2 = .004. The interaction between the two variables was also not significant, F(1,116) = .006, p = .939, $\eta_p^2 < .001$. Bayes factors were computed for the null effects eye movement and the interaction. For the main effect of eye movement, the BF_{01} was 5.26, showing moderate evidence in favour of the null hypothesis for an absence of a SIRE effect. For the interaction, the BF_{01} was 3.70, showing moderate evidence for the absence of an interaction between eye movements and age. Thus, support was found for only the main effect of age.

General Semantic Memory

The cumulative number of general semantic memories produced a significant main effect of participant age group, F(1,116) = 30.10, $p < .001$, η_p^2 = .206, indicating more general semantic memories recalled for the younger group (M = 23.41) compared to the older participants (M = 17.96). The main effect of eye movement was not significant, F(1,116) = .441, p = .269, η_p^2 = .002. The interaction between the two variables was not significant, F(1,116) = .112, p = .738, η_p^2 = .001. Bayes factors were computed for the null effects eye movement and the interaction. For the main effect of eye movement, the BF_{01} was 5.00, showing moderate evidence for the absence of a SIRE effect. For the interaction, the BF_{01} was 3.57, showing moderate evidence for the absence of an interaction between eye movements and age. Consequently, support was found for only the main effect of age.

General Summary

Horizontal saccades enhanced autobiographical memory fluency but only when this required the recollection of episodic information. Age had a significant main effect in all three of the recollection categories showing that the older participants recalled significantly less information in the provided 90 second time windows.

Discussion

The current experiment demonstrated that SIRE effects for autobiographical episodic memory can be found in both younger and older participants. The effect for younger participants replicates the findings from Parker et al. (2013). The novel finding is that similar SIRE effects can be found for older individuals. Additionally, the fact that no interaction occurred showed the magnitude of the SIRE effect was similar for both age groups (although the absolute number of memories produced was lower for older participants).

The current findings in the context of theory & related work

The current experiment was not designed to tease apart theoretical accounts of SIRE effects. Consequently, both the HERA and top-down descriptions can explain the current outcomes. Regarding the HERA account, horizontal saccades enhance hemispheric interaction and allow right-hemisphere retrieval processes to more effectively access left-hemisphere encoded representations (Christman et al., 2003; Christman & Propper, 2010). This is only for episodic (vs. semantic) memories only as these are considered to be dependent on hemispheric interaction. Consequently, the finding that only episodic fluency was enhanced by eye movements is consistent with this account.

Another explanation claims that eye movements potentiate top-down processes that are then more readily employed to perform subsequent tasks that also require such processes. This includes episodic memory retrieval and attentional tasks (e.g., Edlin & Lyle, 2013). Within this framework it has been proposed that SIRE effects are more likely to be found for less accessible information, as this requires more top-down support for successful recall (Lyle & Edlin, 2015). One possible prediction arising form this is that less accessible older memories (5-11) would benefit more from eye movements compared to more accessible recent memories (12-18). However, this conjecture was not supported and deserves further consideration in future work.

In this experiment, eye movements did not interact with age (thus rejecting hypothesis five). Although this should not yet be taken as a general expectation, the lack of an interaction indicates that episodic autobiographical fluency can be enhanced to a similar degree in older as well as younger participants (see the limitations below in relation to the choice of lifetime periods). This is a good pragmatic outcome if eye movements are to be considered useful as a means of memory improvement in older people and used alongside other techniques for enhancing memory in the elderly such as reminiscence therapy, memory specificity training, and life review (Gonçalves et al., 2009; Martens et al., 2019; Meléndez et al., 2015). Although the practical significance is clear, the theoretical importance of the lack of an interaction is more difficult to assess. It was earlier conjectured that SIRE effects could be larger in older participants if hemispheric interaction or top-down processing were less that optimal (but still available for implementation). Of course, too much remains unknown about the precise mechanisms of SIRE and exploration of this issue remains for future work.

In this experiment, the effects of eye movements have been depicted in terms of memory facilitation. An alternative explanation is the fixation condition *reduced* memory performance. For example, prior research has shown that instructed eye fixation on an area of a screen can impair the recall of visual and auditory scene descriptions (Johansson Holsanova, Dewhurst, & Holmqvist, 2012), the vividness of a staged visual tour (Armson, Diamond, Levesque, Ryan, & Levine, 2021), and detailed episodic autobiographical memories (Lenoble, Janssen, & El Haj, 2019). However, in these and similar studies, the fixation task is implemented *during* retrieval and thus disrupts spontaneous eye movements that may have a functional role during accessing memory. In contrast to SIRE work, the manipulation takes place *prior* to retrieval and thus eye movements are unconstrained during the recall period itself. In addition, Lyle, Logan and Roediger (2008) directly compared horizontal, fixation and free eye movements prior to retrieval and found only pre-task saccades to increase memory. The fixation condition produced equivalent performance to spontaneous free eye movements. Thus, it is reasonable to conclude that the SIRE effects found here are due to eye movement enhancement as opposed to fixation induced impairment.

The outcomes of the current work can also be examined in a broader context on the episodic-semantic distinction and ageing. Aging has a greater impact on episodic (vs. semantic) memory in both traditional laboratory measures of these concepts (e.g., Bäckman, & Nilsson, 1996; Verhaegen, Borchelt, & Smith, 2003) and in autobiographical memory (e.g., Meléndez, Agusti, Satorres, & Pitarque, 2018; Piolino et al., 2002). In relation to general semantic memory, the current results showed fewer items recalled in older (vs. younger) individuals. However, previous work has revealed older individuals to perform to equivalent standards on tests that require the use of semantic memory such as naming, lexical decisions, or semantic priming (e.g., Allen et al., 1993; Balota & Ferraro, 1996; Laver & Burke, 1993; Mitchell, 1989).

Conclusive reasons for differences between the past and current work are beyond the scope of the present paper but one explanation could relate to differences in task demands. Often, tasks that require verification of responses as opposed to overt production show smaller age differences because of reduced response competition or the involvement of frontal-executive processes (Geraci, 2006; Light, Prull, LaVoie, & Healy, 2000). As the semantic fluency task used here required response production, this could have exaggerated or produced age differences that relate less to semantic knowledge and more to task demands. Relatedly, the lower scores for the older age group across all the DVs may indicate that the latter age group found the fluency tasks more difficult (e.g., Ivanoiu et al., 2006; Piolino et al., 2010). Future work could assess this by varying the level of difficulty across tasks or matching performance between older and younger individuals in some other baseline tasks.

Additionally, it is possible that the older participants were less familiar with experimental participation. Accordingly, it might be useful for later work to assess this following the experiment and probing details of their experience of taking part in the study.

Differences in personal semantic (vs. episodic) memory are eliminated or much reduced in older individuals using autobiographical interview techniques (e.g., Frankenberg, Knebel, Degen, Siebert, Wahl, & Schröder, 2022; Levine, et al., 2002). In the present experiment, a main effect of age was found for personal semantic memory as measured by the recall of names of teachers and friends. As autobiographical interview techniques likely require production demands greater than that in the current experiment, the production differences are unlikely to explain the age reduction found here. However, one reason for the disparity might relate to younger individuals possessing larger social networks compared to older persons (e.g., Wrzus, Hänel, Wagner, & Neyer, 2013). If so, then the age difference might be more apparent than real and simply represent a larger memory set size for younger persons.

Limitations

There are several limitations to the current work that could be addressed in subsequent research. Firstly, although handedness data was collected, the number of subjects per cell was too low to allow for this to be incorporated as a variable. As some previous work has shown SIRE effects are more robust for consistently-handed (mainly strongly right-handed) persons (e.g., Lyle et al., 2008), it would have been ideal to incorporate handedness as a factor. Past work on autobiographical cognition has also considered eye movements and handedness in separate studies (Parker & Dagnall, 2010, Parker et al., 2017). Consequently, there is a need to assess the joint influence of both eye movements and consistency of hand usage in one experiment. Despite this, the current work has at least shown the existence of SIRE effects even when consistent and inconsistently-handed persons are combined into one group.

The lifetime periods assessed in the present experiment covered childhood and adolescence. The reason for this was to maintain consistency with prior experiments (e.g., Parker et al., 2013). However, one drawback is that the age of the memory was not matched between the groups and such memories were necessarily older for the elder group. Older memories are presumably less accessible (indicated by a main effect of age) and thus could be more likely to benefit from eye movements according to the top-down account. Although the absence of an interaction would seem to go against this idea, it would be clearly advantageous to have a within-subject comparison of the remoteness of the memory. Thus, to achieve this, future work could attempt to match the age range of memories by the inclusion of a more recent lifetime period. For example, recall of personal episodic and semantic memories over the past 10 years. It is possible that a different pattern of findings might result compared to the ones observed here.

The present experiment made use of a fluency task to assess autobiographical retrieval and the episodic-semantic distinction. This could be extended to include other important measures of these concepts. One example is the cue-word technique or the Galton-Crovitz test (see general introduction). Benefits of this technique are the level of flexibility and adaptability it affords to various research aims. For example, cues can be verbal, visual, or olfactory (Chu & Downes, 2000; Herz & Cupchik, 1992), different emotions (Holland, Ridout, Walford & Geraghty., 2012; Kyung, Yane-Lukin & Roberts., 2016), or different levels of abstraction/imaginability (e.g., (Rasmussen, & Berntsen, 2014; Williams, Healy, & Ellis, 1999). In this thesis, the latter is of importance in Experiments 2 and 3. As autobiographical memory is highly cue-dependent the use of low imaginable cues is theorised to be more reliant upon top-down processing to generate a relative autobiographical memory (Harris, O'Connor, & Sutton, 2015). This is of particular importance when studying saccadic induced retrieval enhancement techniques as Lyle & Edlin, (2015) state that when a task requiring the similar exertion of top-down control as saccadic bilateral eye movements, that task will benefit. Thus, pre-task eye-movements should be particularly beneficial in aiding access to event-specific knowledge when the cues are more abstract.

Conclusion

Eye movements were shown to improve episodic autobiographical memory fluency whilst having no effect on semantic or general autobiographical memory. This is a novel finding and the first demonstration of episodic memory enhancement in elderly individuals initiated by eye movements. This finding holds promise for future work aiming to enhance memory in older individuals where personal recollection can be important for either maintaining or improving the quality of life of those individuals.

SARS-CoV-2: Adjustments in methodology due to health and safety.

With the emergence of Covid-19 in the United Kingdom at the start of March 2020 the current research project was adjusted to allow for reasonable and appropriate health and safety to be made. In this section each of the adjustments and rationales will be very briefly outlined.

Online data collection

From early 2020 it was government policy to “avoid all non-essential face to face contact with anybody outside of an individual’s immediate family”. For this reason and for the safety of the researcher and participants the final two studies were completed entirely online using Microsoft Teams. This is a platform provided by Manchester Metropolitan University and has been accepted as a safe and secure online platform to collect online data. This platform allowed for two-way verbal and visual communication and did not need the participant to download any third-party applications. The experimenter was also able to ensure that all experimental instructions were followed via webcams and able to answer any questions in a similar manner to any face-to-face research experiment.

Aging based research

Due to the increased vulnerability of the elderly to the Covid-19 virus, especially at a time when there were no vaccines or effective viral testing regimes in the UK, it was considered too impractical to continue collecting data from older participants exclusively. This was especially so when many of the established recruitment sites (such as activity centres and local churches) had either temporary or permanently closed their facilities. Additionally, the need to collect data via computer at a distance, also posed a problem due to generally lower technological literacy among older individuals. Consequently, the decision was made to shift the focus away from age as a primary variable (as was initially conceived) to dealing with memory enhancement from a broader scope. This did not mean that older participants were preclude from taking part in the current research, but rather age was no longer considered a core independent variable for the next two experimental projects.

Chapter 3: Experiment 2 – The effects of eye movement, eye closure and handedness upon the autobiographical memory test.

Introduction

General Introduction to Experiment 2

Experiment 1 found eye-movements to increase autobiographical fluency for episodic information. This occurred for both younger and older adults, indicating its potential to improve the amount of information recalled across a range of age groups. There was no effect of eye-movements on personal semantic memory or semantic memory more generally. This could be taken to indicate the effects are limited to the retrieval of event-specific knowledge from the autobiographical knowledge base.

The second experiment aimed to extend this work by: **(i)** incorporating another memory enhancing technique, (eye-closure), **(ii)** the use of a different cueing technique (the Galton Crovitz word-cue test), and **(iii)** the use of different dependent variables to measure both the objective specificity of recall and its associated phenomenological qualities.
Some of these details were outlined in the general introduction. They are now reintroduced here in a contextualised manner to prepare for the second experiment.

Eye Closure & Memory

As noted in the general introduction, instructed eye-closure has been found to benefit episodic memory. In some instances, this has been found in traditional list-learning type experiments (e.g., Einstein, Earles, & Collins, 2002: Parker & Dagnall, 2020). However, most of the work has been conducted for eye-witness memory. Typically, in eye-witness experiments, memory for recently encoded events, such as staged crimes are measured. In such studies, eye-closure has been found to increase the retrieval of encoded information without a loss in accuracy as evidenced by no or fewer false memories (Perfect et al., 2008; Vredeveldt & Penrod, 2012). To our awareness, eye-closure effects have not been studied in relation to autobiographical memory. Although this type of research characteristically involves the recall of more personally significant and private information, there is some potential overlap with eye-witness research (Bruce & Read, 1998; Pezdek, 2003). In part, this can arise to the extent that both types of memory research often require the retrieval event-related information (Rubin, & Umanath, 2015). Additionally, some of the concerns of both forms of research strands are similar and encompass similar themes such as accuracy, affect, imagery, development, methods, and theory (Bruce & Read, 1998).

Given the above, it is perhaps surprising that autobiographical researchers have not made use of eye-closure as a means of enhancing personal memory. Most probably, it would be predicted that eye-closure would improve the recall of more specific autobiographical details in the form of event-related knowledge. As these forms of representation are also experience-near (Conway, 2005) then it would also be expected that memories recalled with one's eyes closed would be richer in sensory detail.

In Experiment 2, eye-closure is used alongside eye movements to assess the extent to which these techniques when combined produce additive or interactive effects on the specificity of autobiographical recall and its associated phenomenal qualities such as vividness.

Cue-Type, Executive Functions and Autobiographical Memory

Like other forms of long-term memory, autobiographical memory is cue-dependent (Conway, 2005). These cues interact with the autobiographical knowledge base and provide a basis for the retrieval of event-specific knowledge or episodic elements (Conway, 2005). The Galton-Crovitz test employs cues (typically words) to elicit the free-recall of personal memories associated or prompted by the cue (see general introduction).

The cues themselves come in many forms and differ on several dimensions (e.g., Willander, Sikström, & Karlsson, 2015). One specific example is cue-imaginability. When the cues are verbal, the referents can be concrete and highly imageable, such as "table", or abstract and more difficult to picture such as "moral". Previous research has shown that highly imageable cues elicit more specific personal memories with shorter response times and fewer omissions (e.g., Rasmussen, & Berntsen, 2014; Williams, Healy, & Ellis, 1999). One reason for this is that highly imageable cues interact with the retrieval process by permitting access to information lower in the hierarchy of the ABM knowledge base (Williams et al., 2009). Particularly, imagistic information is used to direct search processes and because they comprise of rich perpetual information act as more potent cues and more readily activate specific event-related representations that form the basis of autobiographical recollection.

Further theorising about the mechanisms for this has proposed a role for the central executive. For example, Williams et al (2006), claim that highly imageable cues are more likely to lead to *direct* retrieval of episodic elements. As noted in the general introduction, this form of recall is bottom-up and driven by shared perceptual features between the cue and the to-be-recalled information (Harris, O'Connor, & Sutton, 2015). A match between the cue and the mnemonic representation leads to ecphory (Tulving, 1983) and efficient recall. For cues that are more abstract, *generative* retrieval is required (Harris, O'Connor, & Sutton, 2015). The latter involves a greater degree of top-down or executive processing that necessitates more extended searches through the autobiographical knowledge base involving the nested hierarchies that form the basis of self-knowledge. This often entails iterative retrieval comprising multiple searches and evaluation cycles until the recovered content meets retrieval goals.

To provide some additional context to the above, executive functioning comprises a range of high-level activities including planning, monitoring, searching, sequencing, and the inhibition of goal directed information processing (Diamond, 2013). Such functions require the allocation of attentional resources and require effort and intention to perform these. Retrieval from memory can require such executive resources when the to-be-recalled information is less accessible (e.g., Craik, Eftekhari, Bialystok, & Anderson, 2018; Lyle & Edlin, 2015), poorly specified by a retrieval cue (e.g., Moscovitch & Winocur, 2002; Taconnat, Clarys, Vanneste, Bouazzaoui, & Isingrini, 2007) and in the face of interference (e.g., Kane & Engle, 2000).

In the context of autobiographical memory, impaired or poorly implemented executive processes can lead to the recall of memories that lack specificity (Barry, Chiu, Raes, Ricarte, & Lau, 2018). That is, recall might terminate at higher and more abstract levels within the autobiographical knowledge base. Some research has indeed shown that executive functioning is related to more general and less specific personal memories in clinical populations such as those with depression, (Valentino, Bridgett, Hayden, & Nuttall, 2012; Williams et al., 2007), or Alzheimer's dementia (Benjamin, Cifelli, Garrard, Caine, & Jones, 2015). Similar findings have also been obtained in non-clinical elderly participants (Holland, Ridout, Walford, & Geraghty, 2012), and young participants with no clinical history (Sumner, et al., 2014).

To return to cue imageability and the possible role of executive functioning, these are of both applied and theoretical importance within the context of this thesis. From an applied perspective, as cues differ regarding their ability to support the more effective recall of specific autobiographical information, this fits with the general thread of the current experiments whose aim is to examine and evaluate techniques to enhance personal memory. From the latter perspective to the extent that cues differ in the types of retrieval mechanisms they engage, this has relevance to both SIRE and eye-closure effects.

As outlined in the general introduction, the top-down account of SIRE effects (Edlin & Lyle, 2013; Lyle & Edlin, 2015), theorises the eye-movement task to comprise a minimal attentional control activity. This is because participants need to engage a small amount of top-down influence to keep attentional focus on the moving target. SIRE effects arise as a consequence, or after-effect, of this on certain types of cognitive activity that follow. When a subsequent task requires the similar exertion of top-down control, that task will benefit from eye-movements. When cues in an ABM task are low in imaginability, top-down generative retrieval is more likely to be required to access a specific memory. Thus, pre-task eye-movements should be particularly beneficial in aiding access to event-specific knowledge when the cues are more abstract.

Regarding eye-closure, both modality independent (top-down) and modality specific theories have been advanced (Vredeveldt, Baddeley, & Hitch, 2012). To the extent, eye-closure effects arise because of modality-free resources, these would then be free to participate in search and evaluation processes within the autobiographical knowledge base. Consequently, eye-closure would presumably be more important when using low imageable cues to access memory.

Qualities of Autobiographical Memory and Specificity

Autobiographical memories vary along several dimensions as noted in the general introduction. One of these is specificity and refers to the amount of detail in the memory. Typically, the amount of detail recalled is measured in relation to the event such as what happened, the occasion, the time and place, who was present, and any other relevant associated details. Another refers to the subjective or phenomenological characteristics of the memory including among other things its vividness, auditory qualities, sense of reliving and coherence. This type of information can be measured using appropriate rating scales (Rubin, Schrauf, & Greenberg, 2003). Such scales represent an attempt to assess the more personal aspects of autobiographical recollection in terms of autonoetic consciousness. As defined by Tulving (1983), this involves the rememberer becoming consciously aware of a prior personal experience and in some part, reengaging or reliving that in the form of “mental time travel”.

In Experiment 2, the scales developed by Rubin et al., were adapted and used to assess the subjective qualities of autobiographical remembering after the participant had recalled a memory in response to a cue. This approach has in part, been used previously in the context of eye-movements (Parker & Dagnall, 2010). It was found that eye-movements increased the vividness and sense of reliving for both neutral and emotional memories. That experiment however, did not measure mnemonic specify or use eye-closure. Thus, the second experiment aimed to extend this work by incorporating both different manipulations and measures.

The Current Experiment

Experiment two required participants to recall personal memories to both high and low imageable cues after engaging in an eye-movement task or fixation. Recall was spoken and took place with either eyes open or closed. Memories were then rated for their subjective qualities (again with eyes open or closed). The recall protocols were scored for level of specificity and this, together with the subjective ratings were used as the primary DVs.

The principal aims were to: **(i)** assess the practical or applied value of combining different memory enhancing techniques to autobiographical recall and **(ii)** evaluate theoretical predictions for these effects as founded in extant accounts of both eye-movements and eye-closure effects.

Hypotheses

Both main effect and interaction effects were specified. The predictions were set within a broader context in experimental psychology in which interactions (vs. main effects) of two variables are taken to be indicative of similar (vs. separate) processing stages (e.g., Balota, Aschenbrenner, & Yap, 2013; Gabales, & Birney, 2011: Sternberg, 1969). If two variables are dependent on similar cognitive activity or the same processing stage stages, then interactions are predicted. However, if the variables influence separate processes or stages then additivity or separate main effects are predicted.

Main effects eye movements

H1a. It was predicted that eye-movements (vs. fixation) will increase the recall of specific details (higher specificity scores following eye-movements).

H1b. It was predicted that eye-movements (vs. fixation) will enhance the subjective qualities of memory recalls.

The above predictions are based on prior work (e.g., Parker & Dagnall, 2010) and simply extend them here to recall specificity that was not covered in the latter experiment.

Main effects handedness

H2a. It was predicted that inconsistent handed participants (vs. consistent handed) will increase the recall of specific details.

H2b. It was predicted that inconsistent handed participants (vs. consistent handed) will enhance the subjective qualities of memory recalls.

The above predictions are based upon prior work in both lab-based and real world-based research which shows inconsistent handed individuals superior recall when compared to consistent handed individuals (Christman and Butler, 2011). See also the general introduction and to the section on SIRE effects in which handedness is also presented.

Main effects eye-closure

H3a. It was predicted that eye-closure (vs. eyes open) will increase the recall of specific details (higher specificity scores following eye-closure).

H3b. It was predicted that eye-closure (vs. eyes open) will enhance the subjective qualities of memory recalls.

The above predictions are based on prior work involving eye-closure in an eye-witness context and extend them here to autobiographical memory. Similar predictions are advanced for both memory specificity and phenomenology as the former is considered a basis for the latter. That is, the more specific and detailed a memory, the greater the degree of subjective vividness and reliving etc. (Vredeveldt & Penrod, 2013).

Main effects cue-type

H4a. It was predicted that high (vs. low) imageable cues will increase the recall of specific details (higher specificity scores to highly imageable cues).

H4b. It was predicted that high (vs. low) imageable cues will enhance the subjective qualities of memory recalls.

These predictions are based on prior work involving the use of cues differing in imageability (e.g., Williams et al., 1999).

Interactions: eye movement & cue-type

H5a. It was predicted that cue-type will interact with eye-movements such that eye-movements will increase memory specificity to a greater extent for low imageable cues.

This prediction is derived from the top-down account of SIRE effects (Edlin & Lyle, 2013; Lyle & Edlin, 2015) and the hypothesis that cue imageability is dependent on executive resources (Williams et al., 2006). Thus, cues with low imageability are more likely to lead to generative retrieval and the engagement of top-down processes for the search and evaluation of recovered information. Consequently, to the extent eye-movements momentarily prompt top-down processing, the continued aftereffects of this will be available for autobiographical retrieval especially when requiring extended search and evaluation processes.

H5b. It was predicted that cue-type will interact with eye-movements such that eye-movements will increase ratings for low imageable cues.

This prediction is derived in a similar manner to H4a. It is extended here to subjective ratings for the reasons outlined for H2b. Further, to the extent that eye-movement effects are moderated by handedness consistency, this interaction may only be found for consistently-handed participants resulting in a possible three-way interaction between eye-movements, cue-type and handedness.

Interactions: eye-closure & cue-type

H6a. It was predicted that cue-type will interact with eye-closure such that closing one's eyes will increase memory specificity to a greater extent for low imageable cues.

This prediction is derived from the domain-general account of eye-closure effects (see general introduction). In brief, this explanation takes as its basis the notion that individuals have limited attentional (executive) processing capacities (Baddeley, 2012; Kane, Conway, Hambrick, & Engle, 2007). Retrieving information from memory makes use of these limited resources. At the same time, external and interfering visual information can draw attention away from retrieval and reduce the efficiency of the retrieval process (Glenberg et al., 1998). Consequently, closing one's eyes is removes interference and frees attentional resources to focus on retrieval. As cues with low imageability are hypothesised to be more dependent on executive resources (Williams et al., 2006), there will be more to gain from the freeing of these resources.

This prediction is more nuanced as an alternative account of eye-closure effects is based on domain-specific processing (Craik, 2014). This explanation claims the beneficial effect of eye-closure arises by reducing only visual interference and thus freeing modality-specific processing resources. If this is correct, it is not clear that eye-closure and cue-type would interact. One possibility is that eye-closure will increase specificity as a main effect.

H6b. It was predicted that cue-type will interact with eye-closure such that closing one's eyes will increase ratings for memory recalls.

This prediction is derived in a similar manner to H4a. It is extended here to subjective ratings for the reasons outlined for H2b. An additional possibility, based on the domain-specific account, is that eye-closure will increase ratings for the scales measuring perceptual detail.

Interactions: eye-movements & eye-closure

H7a. If eye movements and eye-closure work by similar mechanisms (i.e., top-down processing / domain-general resources) then an interaction was predicted such that memory specificity will be the highest in the horizontal eye movement condition with eyes closed. If eye-closure effects are dependent on domain-specific resources, then additivity or separate main effects were predicted.

H7b. If eye movements and eye-closure work by similar mechanisms (i.e., top-down processing / domain general resources) then an interaction was predicted such that subjective ratings will be the highest in the horizontal eye movement condition with eyes closed. If eye-closure effects are dependent on domain-specific resources, then separate main effects were predicted.

Higher order interaction between eye-movements, eye-closure and cue-type.

The specification of a three-way interaction is difficult and should be regarded as more exploratory. Nevertheless, a tentative prediction is that the two-way interaction between eye movement and eye-closure will be dependent upon cue-type. Thus, the greatest effect on specificity and ratings is predicted to be following eye movements with eyes closed in response to low imageability cues. This prediction is based on the assumption that both eye movements and closure influence a common mechanism, that is, top-down processing.

Method

Design

The current experiment had three between-subject variables; Eye movement task (Bilateral vs. Fixation), Eye Closure (Open vs. Closed) and Handedness (Consistent vs. Inconsistent). The experiment also had one within-subject variable; Imaginability (Concrete vs. Abstract). The dependent variable in the study was the level of verbal specificity provided in the 'Autobiographical Memory Test' and five separate Likert scale questions taken from the AMQ (1 disagree – 7 agree) assessing the recollection and component processes of the recall provided.

Participants

The sample size was determined in a similar manner to Experiment 1 using past research (Parker & Dagnall, 2010 & Bunnell, Legerski, & Herting, 2018) and a sample size analysis performed in MorePower 6.0 (Campbell, & Thompson, 2012). For a main effect and interaction effect size of $\eta_p^2 = .05$, with $\alpha = .05$, and for 80% power, the estimated total sample size was 160.

One hundred and ninety participants took part in the current research experiment (ninety-four males and ninety-six females) and were recruited using opportunity snowball sampling from Manchester Metropolitan University and the surrounding local area. The sample age ranged from eighteen years old to seventy-nine years old (Mean: 32.03 SD: 17.19) and all participants were able to complete and pass the brief cognitive assessment tool 'Sweet 16' (Fong et al, 2011) before taking part in the research.

Participants were asked to self-exclude from the research if any of the following applied to them: **(i)** A history of neurological disorders, **(ii)** Any significant psychiatric disorders, **(iii)** A history of abusing illicit substances, **(iv)** Any medical disorders known to affect cognitive functioning, **(v)** Any none-corrected visual impairments. Participants did not have to declare which specific reason they are excluding from the study and the researchers would not ask for any elaboration.

Out of the sample, nineteen participants were removed from the sample due to incomplete data sets being provided. The remaining sample was allocated randomly into one of the four experimental conditions, these were: eye movement & eyes open (N = 48 mean age = 29.69, SD = 16.75), eye movement & eyes closed (N = 55 mean age = 33.55, SD = 17.32), eye fixation & eyes open (N = 45 mean age = 33.16 SD = 18.00) and eye fixation and eye closed (N = 42 mean age = 31.52, SD = 16.93). The allocation for the handedness condition depended upon the Edinburgh handedness scale scores (one hundred and eleven in the consistent group vs sixty-five in the inconsistent group). There was no significant differences between the age of the participants in each of the between subject conditions (see appendix 4A).

Materials and Apparatus

Sweet 16 (S-16) (Fong et al, 2011)

The Sweet-16 (S-16) is a simple and quick assessment tool to screen for cognitive impairment which are often unrecognised among older adults (Fong et al, 2011). The scale is scored from 0 – 16 (with 16 being the best score). The scale includes eight orientation items (temporal and special orientation), three registration items (registration), four-digit span items (sustained attention) and three recall items (short-term memory), each of the items receives one point (except the first two-digit span activities). The cut off score for the current experiment was less than fourteen out of sixteen points.

Edinburgh handedness Inventory (EHI) (Oldfield, 1971)

The EHI is a self-report measure that asks participants to indicate their handed preference on ten separately presented activities (e.g., Brushing teeth, combing hair, and opening a jar lid). Responses are categorised as either 'Always right hand' (+10 points), 'usually right hand' (+5 points), 'no preference' (Zero points), 'usually left hand' (-5 points) & 'always left hand (-10 points). Thus, the scores range from -100 to +100. Participants scoring between -75 and +75 were classified as mixed handed, while subjects scoring outside of this bracket were classed as strongly handed. This scoring scheme (as opposed to the original EHI scoring scheme) is in-line with another previous research on this topic area (e.g., Edlin et al, 2013, 2015 & Lyle et al, 2008).

Eye movement program

A computer program was used to initiate eye movements. This was done by flashing a black dot against a while background bilaterally or flashing centrally for the fixation condition. The circle moved (flashed) once every 500ms and in the eye movement conditions was located approximately 27° of visual angle apart. The average size of the computer monitors used in this research was 22 inches (56cm) with the viewing distance adjusted to maintain the 27-degree visual angle.

Autobiographical memory test (AMT) (Williams & Broadbent, 1986)

The standard Autobiographical memory test methodology was employed as described by Williams & Broadbent (1986) and participants were asked to recall a specific memory connected to each given keyword. The participants were asked to respond to the keywords verbally and the response was recorded using Microsoft Teams for later encoding and data entry.

The current version of the procedure included eleven keyword prompts (1 practice trial and 10 experimental cues) and was split into five high imaginable words (wisdom, obedience, boredom, attitude & moral) and five low imaginable words (mountain, butterfly, fire, house & cloud) as based upon previous research by Williams et al., (2006) & Guler & Mackovichova., (2019).

The AMT was coded based upon the level of specificity provided in the participants responses using a four-point scale (Baddeley & Wilson, 1986). Based upon previous research (Piolino et al., (2007, 2009) & Danion et al., (2005)) the following scoring parameters were set for the current study: Four points were scored for memories for a very specific episodic incident or event that occurred on a particular day including features such as **(i)** what happened **(ii)** occasion or time **(iii)** when appropriate a place or location **(iv)** appropriate objects or things **(v)** if appropriate relevant other people. Three points were allocated to less specific episodic memories which may be similar to above but lack some of the listed cues and details. Two points were allocated to more general memories which included repeated events or general categories (e.g., 'going out for coffee with friends' or 'we always go on holiday') or extended events (e.g., 'The three years I spent at university' or 'my holiday in France two years ago'). One point was scored for memories that are effectively semantic in nature and relate to definitions of words or concepts. A score of zero was given to participants if they were unable to generate a memory to match the keyword.

Recollection and Component Processes Likert scales (Rubin et al, 2003)

Following the administration of the AMT a set of five follow up questions were presented to assess the participants recollection and component processes associated with ABM (Rubin et al., 2003). These questions were marked on a 1 (disagree) to 7 (agree) Likert scale. The following two questions 'I feel that I am reliving the original event' and 'I travel back to the time when it happened' are part of the recollection section. The following three questions 'I can see and/or hearing it in my mind', 'I can recall the setting where it occurred' and 'It comes to me as a coherent story' are part of the component processes section. Some of the scale items were omitted from the current experiment as they were not deemed directly relevant to the current research hypothesises in a similar way to Parker and Dagnall (2010), for example "would you be confident enough to testify in a court of law?" or "To what extent is your memory of the event distorted by your beliefs and motives and expectations.

Research booklet and demographical information

A research booklet was constructed to help develop a fixed structure and to ensure a same experimental procedure was followed by the data collector. The booklet also included two basic demographical questions (Age & Gender). A copy of the experimental booklet and all the scales used within this experiment can be found in the appendix section 4.

Procedure

Participants who showed in the interest in the project were invited to a one-to-one Microsoft team meeting at a time which suited them and were sent a copy of the participant information sheet. During the Microsoft teams meeting the participants were first asked to switch on their webcams and microphones and the participant information sheet was summarised and the consent form completed. Following this, participants were informed that the TEAMs meeting recording function would be activated from this point.

Once recording had started, participants were asked to complete the demographical information questions verbally and the booklet was completed by the experimenter. The Sweet 16 (S-16) questions were answered by the participant while guided by the researcher. The experimenter did not need to transcribe or store the scores of the scale as long as the participant scored above the set point threshold, potential participants who did not pass this threshold were taken directly to the debrief form.

Next, the participants were asked to complete the Edinburgh Handedness Inventory. The researcher shared their screen so the participant could see the scale and read the instructions provided. These stated "*Please indicate your preferences in the use of hands in the following activities. Please answer all the questions, and only leave a blank if you have no experience at all with the object or task.*". The researcher then stated the ten tasks and highlighted the participants responses for later totalling and coding.

The next stage of the experiment was the Autobiographical Memory Test (AMT) that consisted of one practice trial and ten recorded trials. The participants were randomly allocated to one of the four between subject conditions (Eye closure; open vs closed & Eye movement; Bilateral vs fixation). At the start of the AMT participants were asked to read (or would have read to them if requested) the following instructions "*In the next section of the experiment, you will be presented with a key word and asked to provide a personal memory. The retrieved memory can be something what has happened recently or a long time ago but must be at least a week old. It does not matter if the memory recalled is something trivial or important if the memory is autobiographical and about your individual past.*".

For the practice cue the participants were then asked the following question "*Can you describe one specific moment or event that the word [Keyword] reminds you of?*". The researcher did not set any time limits for this recall and did not offer any prompts. If the participant could not think of a memory an alternative practice cue was provided.

Once the practice was completed the researcher provided an overview of the next stage; this varied according to the experimental condition. Before each cue the participants were asked to watch a thirty second manipulation task. This was either a dot that moved side to side, subtending a visual angle to the participant of approximately 27 degrees, (horizontal condition) or flashed on and off in the centre of the screen (fixation condition). In the former, participants were asked to move their eyes to follow the dot while keeping their heads stationary. In the latter, participants were asked to focus their attention on the dot while keeping both eyes and head stationary. Following this, half of the participants were asked to close their eyes or keep their eyes open. The researcher would then read aloud the memory cue and the participant was asked to speak out aloud the memory that came to mind. Then, after the recall, the researcher read aloud each of the five Likert scales statements and ask for the participant to respond. The recall was audio recorded and Likert scale responses entered into a response sheet. Once this section was completed the participants in the eye closure condition were invited to open their eyes. This procedure is repeated for all 10 experimental trials.

Finally, once all the trials were completed, the recording was stopped, and the participants were fully debriefed and reminded of their ethical rights and their option to receive an overview of the study findings if requested at a later date.

Results

Overview.

The specificity and rating scores were analyses in separate univariate ANOVAs using eye-movement, eye-closure, and handedness as between-subject variables and cue-type as a within-subject variable. The findings from the Autobiographical Memory (AMQ) scales were analysed separately for each response type to consider the effects of the independent variables on each component of autobiographical memory as in previous work (e.g., Parker & Dagnall, 2010; Rubin et al, 2003). Two-way interactions were assessed further by simple main effects. Higher order interactions were analyses initially by simple interaction effects followed by additional follow-up tests when required.

Results of Specificity Scores.

The recall verbal recall protocols were scored by two independent raters in accordance with the scheme outlined in the method section. A random selection of 20% of the protocols were then assessed for interrater reliability. Interrater agreement was assessed using Cohen's Kappa. This produced a value of 0.847 and indicated very good and substantial agreement between the scorers. Any disagreements were resolved by discussion between the markers.

The specificity scores were then entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 2(eye-closure: open vs. closed) between-subjects by 2(handedness: consistent vs. inconsistent) between-subjects by 2(cue-type: high vs. low imageable) within-subjects mixed-ANOVA. The descriptive statistics can be found in table 2 below.

Table 2 - Mean (SD) specificity scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 92			Fixation *n* = 79			Total *n* = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Open									
Consistent	25	2.96	(.43)	26	2.95	(.52)	51	2.96	(.47)
Inconsistent	17	3.24	(.55)	14	2.60	(.41)	31	2.95	(.59)
Closed									
Consistent	36	2.97	(.60)	22	2.87	(.57)	58	2.93	(.59)
Inconsistent	14	3.00	(.30)	17	2.85	(.54)	31	2.92	(.45)
Total									
Consistent	61	2.96	(.54)	48	2.91	(.54)	109	2.94	(.54)
Inconsistent	31	3.16	(.47)	31	2.74	(.50)	62	2.94	(.52)
Low-imaginability Cues									
Open									
Consistent	25	2.56	(.55)	26	2.58	(.42)	51	2.57	(.48)
Inconsistent	17	2.86	(.70)	14	2.38	(.51)	31	2.64	(.66)
Closed									
Consistent	36	2.74	(.54)	22	2.43	(.56)	58	2.63	(.56)
Inconsistent	14	2.67	(.55)	17	2.47	(.45)	31	2.56	(.50)
Total									
Consistent	61	2.66	(.55)	48	2.51	(.48)	109	2.60	(.52)
Inconsistent	31	2.77	(.63)	31	2.43	(.48)	62	2.60	(.58)

Main effects. The main effect of cue-type was significant, $F(1,163) = 63.38$, $p < .001$, $\eta_{p2} = .299$, indicating more specific memories recalled for highly imaginable cues ($M = 2.93$) compared to the low imaginable cues ($M = 2.59$). The main effect of eye movement was also significant $F(1,163) = 9.88$, $p = .002$, $\eta_{p2} = .057$, indicating more specific memories recalled for the horizontal group ($M = 2.87$) compared to the fixation group ($M = 2.64$). However, the main effect of handedness was not significant $F(1,163) = .001$, $p = .980$, $\eta_{p2} < .001$, nor was the main effect of eye closure, $F(1,163) = .035$, $p = .852$, $\eta_{p2} < .001$.

Two-way interactions. The interaction between cue-type and handedness was not significant $F(1,163) = .144$, $p = .705$, $\eta_{p2} = .001$. The interaction between cue type and eye movement was also non-significant $F(1,163) = .307$, $p = .848$, $\eta_{p2} < .001$. The interaction between cue type and eye closure was also non-significant $F(1,163) = .005$, $p = .946$, $\eta_{p2} < .001$. The interaction between handedness and eye movement was also non-significant $F(1,163) = 3.404$, $p = .067$, $\eta_{p2} = .020$. The interaction between handedness and eye closure was also non-significant $F(1,163) = .007$, $p = .933$, $\eta_{p2} = .003$. The interaction between eye closure and eye movement was also non-significant $F(1,163) = .429$, $p = .513$, $\eta_{p2} = .003$.

Three-way Interactions. The three-way interaction between eye movement, eye-closure and handedness just achieved significance, $F(1,163) = 4.168$, $p = .043$, $\eta_{p2} = .025$. This was assessed further by simple interaction effects at each level of handedness. The inconsistent handed ANOVA showed a significant main effect for eye movement $F(1,58) = 10.36$, $p = .002$, $\eta_{p2} = .152$, with the fixation group (M = 2.58) scoring significantly lower than the horizontal group (M = 2.94). The main effect of eye closure however was not significant $F(1,58) = .031$, $p = .862$, $\eta_{p2} = .001$. The interaction between eye movement and eye closure was also non-significant $F(1,58) = 3.026$, $p = .087$, $\eta_{p2} = .050$. The constant handed ANOVA showed no significant main effects of eye movement $F(1,109) = 1.117$, $p = .293$, $\eta_{p2} = .011$ or eye closure $F(1,109) = .007$, $p = .934$, $\eta_{p2} < .001$. The interaction was also not significant $F(1,109) = 1.271$, $p = .262$, $\eta_{p2} = .012$.

The interaction between cue type, handedness and eye movement was non-significant $F(1,163) = .866$, $p = .353$, $\eta_{p}^{2} = .005$. The interaction between cue type, handedness and eye closure was non-significant $F(1,163) = .442$, $p = .507$, $\eta_{p}^{2} = .003$. The interaction between cue type, eye closure and eye movement was non-significant $F(1,163) = 1.822$, $p = .179$, $\eta_{p}^{2} = .011$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant $F(1,163) = .006$, $p = .939$, $\eta_{p}^{2} < .001$.

Reliving the Original event

The descriptive statistics for the reliving the event likert scale can be found in table 3 below:

Table 3 - Mean (SD) Reliving scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal n = 92			Fixation n = 79			Total n = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-Imaginability Cues									
Open									
consistent	25	4.79	(1.45)	26	4.87	(1.64)	51	4.83	(1.53)
inconsistent	17	5.22	(1.16)	14	5.33	(.91)	31	5.27	(1.03)
Closed									
consistent	36	5.39	(1.21)	22	5.14	(1.24)	58	5.29	(1.22)
inconsistent	14	5.66	(.90)	17	5.43	(1.15)	31	5.53	(1.03)
Total									
Consistent	61	5.14	(1.33)	48	4.99	(1.46)	109	5.07	(1.39)
Inconsistent	31	5.42	(1.05)	31	5.38	(1.03)	62	5.40	(1.03)
Low-Imaginability Cues									
Open									
Consistent	25	4.34	(1.39)	26	4.70	(1.36)	51	4.52	(1.37)
Inconsistent	17	4.71	(1.46)	14	5.17	(1.36)	31	4.91	(1.27)
Closed									
consistent	36	5.06	(1.34)	22	4.64	(1.07)	58	4.90	(1.25)
inconsistent	14	5.20	(1.22)	17	4.82	(1.17)	31	4.99	(1.19)
Total									
Consistent	61	4.76	(1.40)	48	4.67	(1.22)	109	4.72	(1.31)
Inconsistent	31	4.93	(1.36)	31	4.98	(1.08)	62	4.95	(1.22)

Main effects. The main effect of cue type was significant $F(1,163) = 25.349$, $p < .001$, $\eta_{p2} = .135$, indicating more reliving of events scores for the more highly imaginable cue ($M = 5.23$) compared to the low imaginability cue group ($M = 4.83$). The main effect of eye movement was not significant $F(1,163) = .034$, $p = .855$, $\eta_{p2} < .001$. The main effect of eye closure was also non-significant $F(1,163) = 2.121$, $p = .147$, $\eta_{p}^{2} = .013$. The main effect of handedness was also non-significant $F(1,163) = 2.966$, $p = .087$, $\eta_{p}^{2} = .018$.

*Two-way interactions***.** The Interaction between cue type and handedness was not significant $F(1,163) = .225$, $p = .636$, $\eta_{p}^{2} = .001$. The interaction between cue type and eye movement was also non-significant $F(1,163) = .247$, $p = .620$, $\eta_{p}^{2} = .002$. The interaction between cue type and eye closure was also non-significant $F(1,163) = .867$, $p = .353$, $\eta_{p}^{2} = .005$. The interaction between handedness and eye movement was also non-significant $F(1,163) = .016$, $p = .899$, $\eta_{p}^{2} < .001$. The interaction between handedness and eye closure was also non-significant $F(1,163) = .313$, $p = .557$, $\eta_{p}^{2} = .002$. The interaction between eye closure and eye movement was also non-significant $F(1,163) = 2.275$, $p = .133$, $\eta_{p}^{2} = .014$.

Three-way Interactions. The interaction between cue type, eye movement and eye closure was not significant $F(1,163) = 2.291$, $p = .132$, $\eta_{p}^{2} = .014$. The Interaction between cue type, eye movement and handedness was also non-significant $F(1,163) =.020$, $p = .888$, $\eta_{p}^{2} < .001$. The interaction between cue type, eye closure and handedness was also non-significant $F(1,163) = .090$, $p = .764$, $\eta_{p}^{2} = .001$. The interaction between eye movement, eye closure and handedness was also non-significant $F(1,163) = .002$, $p = .962$, $\eta_{p}^{2} < .001$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant $F(1,163) = .010$, $p = .921$, $\eta_{p}^{2} < .001$.

Traveling back to the time the event happened.

The descriptive statistics for the traveling back to the time the event happened likert scale can be found in table 4 below:

Table 4 Mean (SD) Traveling back in time scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 92			Fixation *n* = 79			Total *n* = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-Imaginability Cues									
Open									
Consistent	25	4.87	(1.40)	26	4.79	(1.64)	51	4.83	(1.51)
Inconsistent	17	5.40	(1.25)	14	5.44	(.99)	31	5.42	(1.12)
Closed									
Consistent	36	5.44	(1.28)	22	5.09	(1.19)	58	5.31	(1.25)
inconsistent	14	5.77	(1.13)	17	5.64	(1.17)	31	5.70	(1.12)
Total									
Consistent	61	5.21	(1.35)	48	4.92	(1.45)	109	5.09	(1.39)
Inconsistent	31	5.57	(1.20)	31	5.55	(1.06)	62	5.56	(1.12)
Low-Imaginability Cues									
Open									
consistent	25	4.34	(1.44)	26	4.67	(1.63)	51	4.51	(1.53)
inconsistent	17	4.81	(1.44)	14	5.15	(.93)	31	4.96	(1.23)
Closed									
Consistent	36	5.01	(1.49)	22	4.71	(1.18)	58	4.90	(1.37)
Inconsistent	14	5.22	(1.39)	17	5.09	(.95)	31	5.13	(1.16)
Total									
Consistent	61	4.73	(1.49)	48	4.69	(1.43)	109	4.72	(1.45)
Inconsistent	31	4.99	(1.42)	31	5.10	(.93)	62	5.05	(1.18)

Main effects. The main effect of cue type was significant $F(1,163) = 35.433$, $p < .001$, $\eta_p^2 = .179$, indicating more mental time travel mean scores recalled for the more highly imaginable cues ($M = 5.307$) compared to the low imaginability cue group ($M = 4.87$). The main effect of eye movement was not significant $F(1,163) = .037$, $p = .849$, $\eta_p^2 < .001$. The main effect of eye closure was also non-significant $F(1,163) = 2.235$, $p = .129$, $\eta_p^2 = .029$. The main effect of handedness however was significant $F(1,163) = 4.877$, $p = .029$, $\eta_p^2 = .029$, indicating inconsistently handed (M = 5.31) participants scored higher on travelling back in time compared to consistently handed participants (M = 4.87).

*Two-way interactions***.** The interaction between cue type and handedness was not significant $F(1,163) = .915$, $p = .340$, $\eta_p^2 = .006$. The interaction between cue type and eye movement was also non-significant $F(1,163) = 1.488$, $p = .224$, $\eta_p^2 = .009$. The interaction between cue type and eye closure was also non-significant $F(1,163) = .490$, $p = .485$, $\eta_p^2 = .003$. The interaction between handedness and eye movement was also non-significant $F(1,163) = .095$, $p = .758$, $\eta_p^2 = .001$. The interaction between handedness and eye closure was also non-significant $F(1,163) = .182$, $p = .670$, $\eta_p^2 = .001$. The interaction between eye closure and eye movement was also non-significant $F(1,163) = .924$, $p = .338$, $\eta_p^2 = .006$.

Three-way Interactions. The interaction between cue type, eye movement and eye closure was not significant $F(1,163) = 1.291$, $p = .257$, $\eta_p^2 = .008$. The interaction between cue type, eye movement and handedness was also non-significant $F(1,163) =.117$, $p = .732$, $\eta_p^2= .001$. The interaction between cue type, eye closure and handedness was also non-significant $F(1,163) = .025$, $p = .875$, $\eta_p^2 < .001$. The interaction between eye movement, eye closure and handedness was also non-significant $F(1,163) = .016$, $p = .899$, $\eta_p^2 < .001$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant $F(1,163) < .001$, $p = .986$, $\eta_{p}^{2} < .001$.

Seeing and/or hearing the event in their mind.

The descriptive statistics for the seeing and or hearing the event likert scale can be found in table 5 below:

Table 5. Mean (SD) See / Hear scores as a function of eye movement, eye-closure, handedness, and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 92			Fixation *n* = 79			Total *n* = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-Imaginability Cues									
Open									
Consistent	25	5.37	(1.28)	26	5.20	(1.40)	51	5.28	(1.34)
Inconsistent	17	5.78	(1.16)	14	5.69	(.68)	31	5.74	(1.04)
Closed									
Consistent	36	5.80	(1.04)	22	5.66	(1.00)	58	5.75	(1.02)
Inconsistent	14	6.16	(.81)	17	5.98	(.83)	31	6.05	(.81)
Total									
Consistent	61	5.62	(1.17)	48	5.41	(1.25)	109	5.53	(1.21)
Inconsistent	31	5.95	(1.10)	31	5.85	(.77)	62	5.90	(.94)
low-Imaginability Cues									
Open									
Consistent	25	5.11	(1.00)	26	5.09	(1.28)	51	5.46	(1.16)
Inconsistent	17	5.34	(1.20)	14	5.50	(.84)	31	5.70	(.73)
Closed									
Consistent	36	5.65	(1.14)	22	5.16	(1.09)	58	5.10	(1.14)
Inconsistent	14	5.94	(.74)	17	5.50	(.68)	31	5.41	(1.04)
Total									
Consistent	61	5.43	(1.11)	48	5.12	(1.18)	109	5.30	(1.15)
Inconsistent	31	5.61	(1.05)	31	5.50	(.74)	62	5.56	(.90)

Main effects. The main effect of cue type was significant $F(1,163) = 21.500$, $p < .001$, $\eta_{p2} = .117$, indicating more seeing or hearing of the event recalled for the more highly imaginable cues ($M = 5.71$) compared to the low imaginability cue group ($M = 5.41$). The main effect of eye closure was also significant $F(1,163) = 4.52$, $p = .035$, $\eta_{p2} = .027$, indicating more seeing or hearing of the event recalled for the eye closed group (M = 5.73) when compared to the eye open group (M = 5.39).The main effect of handedness was also significant $F(1,163) = 4.752$, $p = .031$, $\eta_{p2} = .028$, indicating more seeing or hearing of the event recalled for the more inconsistent handed group (M = 5.74) when compare to consistent handed group (M = 5.38). The main effect of eye movement was not significant $F(1,163) = 1.10$, $p = .295$, $\eta_{p2} = .007$.

*Two-way interactions***.** The Interaction between cue type and handedness was not significant $F(1,163) = .359$, $p = .550$, $\eta_{p2} = .002$. The interaction between cue type and eye movement was also non-significant $F(1,163) = .196$, $p = .658$, $\eta_{p2} = .001$. The interaction between cue type and eye closure was also non-significant $F(1,163) = .511$, $p = .476$, $\eta_{p2} = .003$. The interaction between handedness and eye movement was also non-significant $F(1,163) = .043$, $p = .836$, $\eta_{p2} < .001$. The interaction between handedness and eye closure was also non-significant $F(1,163) = .032$, $p = .585$, $\eta_{p2} < .001$. The interaction between eye closure and eye movement was also non-significant $F(1,163) = .770$, $p = .382$, $\eta_{p2} = .005$.

Three-way Interactions. The interaction between cue type, eye movement and eye closure was significant $F(1,163) = 3.976$, $p = .048$, $\eta_{p2} = .024$. This was assessed further by simple interaction effects at each level of cue type. A two way between-subjects ANOVA was completed for eye closure and eye movement upon high imaginability cues and low imaginability cues. For the high imaginability cue there was a significant main effect of eye closure $F(1,167) = 5.565$, $p = .022$, $\eta_{p2} = .031$, with the closure group (M = 5.85) scoring significantly higher than the open group (M = 5.45). The main effect of eye movement was non-significant $F(1,167) = .585$, $p = .446$, $\eta_{p2} = .003$. The interaction was also non-significant

F(1,167) = .029, *p* = .864, $\eta_{p2} < .001$. For the low imaginability group there was no main effect of eye closure *F*(1,167) = 1.477, *p* = .226, $\eta_{p2} = .009$. There was also no main effect of eye movement (1,167) = 1.477, *p* = .226, $\eta_{p2} = .020$ and no significant interaction between eye movement and eye closure (1,167) = 1.996, *p* = .163, $\eta_{p2} = .012$.

The Interaction between cue type, eye movement and handedness was also non-significant *F*(1,163) =.133, *p* = .716, $\eta_{p2} = .001$. The interaction between cue type, eye closure and handedness was also non-significant *F*(1,163) = .217, *p* = .642, $\eta_{p2} = .001$. The interaction between eye movement, eye closure and handedness was also non-significant *F*(1,163) = .039, *p* = .844, $\eta_{p2} < .001$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant *F*(1,163) < .001, *p* = .993, $\eta_{p2} < .001$.

Recalling the setting of the memory

The descriptive statistics for the memory setting the memory occurred likert scale can be found in table 6 below:

Table 6 Mean (SD) Setting scores as a function of eye movement, eye-closure, handedness, and cue-type

	Eye Movement Condition								
	Horizontal *n* = 92			Fixation *n* = 79			Total *n* = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
				High-Imaginability Cues					
Open									
Consistent	25	6.03	(.93)	26	5.88	(1.07)	51	5.95	(1.00)
Inconsistent	17	6.09	(.91)	14	6.10	(.65)	31	6.10	(.79)
Closed									
Consistent	36	6.38	(.90)	22	6.17	(.68)	58	6.30	(.82)
Inconsistent	14	6.29	(.53)	17	5.98	(.54)	31	6.12	(.55)
Total									
Consistent	61	6.23	(.92)	48	6.01	(.92)	109	6.14	(.92)
Inconsistent	31	6.18	(.76)	31	6.04	(.59)	62	6.10	(.68)
				low-Imaginability Cues					
Open									
Consistent	25	6.04	(.74)	26	6.14	(.87)	51	6.09	(.81)
Inconsistent	17	5.56	(.95)	14	5.61	(.86)	31	5.59	(.90)
Closed									
Consistent	36	6.06	(.95)	22	5.94	(1.00)	58	6.01	(.97)
Inconsistent	14	5.73	(.82)	17	5.74	(.57)	31	5.74	(.68)
Total									
Consistent	61	6.05	(.87)	48	6.05	(.93)	109	6.05	(.89)
Inconsistent	31	5.64	(.88)	31	5.69	(.70)	62	5.66	(.79)

Main effects. The main effect of cue type was significant $F(1,163) = 17.096$, $p < .001$, $\eta_{p}2 = .095$, indicating the mean setting score of the memory was higher for the highly imaginable cues ($M = 6.12$) compared to the low imaginability cue group ($M = 5.83$). The main effect of eye closure was non-significant $F(1,163) = .705$, $p = .402$, $\eta_{p}2 = .004$. The main effect of handedness was also non-significant $F(1,163) = 2.432$, $p = .121$, $\eta_{p}2 = .015$. The main effect of eye movement was not significant $F(1,163) = 395$, $p = .531$, $\eta_{p}2 = .002$.

Two-way interactions. The Interaction between cue type and handedness was significant $F(1,163) = 9.168$, $p = .003$, $\eta_{p}2 = .053$. This was assessed further by simple main effects at each level of handedness. The analysis indicated a significant difference between highly imaginable cues (M = 6.11) when compared to low imaginability cues (M = 5.66) for the inconsistent handed condition $t(61) = 6.132$, $p < .001$, $d = .604$. However there was no significant difference between high imaginability (M = 6.14) scores and low imaginability (M = 6.05) scores in the consistent handedness group $t(108) = 1.013$, $p = .313$, d = .097.

The interaction between cue type and eye movement was non-significant $F(1,163) = 1.894$, $p = .171$, $\eta_{p}2 = .011$. The interaction between cue type and eye closure was also non-significant $F(1,163) = 1.380$, $p = .242$, $\eta_{p}2 = .008$. The interaction between handedness and eye movement was also non-significant $F(1,163) = .023$, $p = .880$, $\eta_{p}2 < .001$. The interaction between handedness and eye closure was also non-significant $F(1,163) = .007$, $p = .932$, $\eta_{p}2 < .001$. The interaction between eye closure and eye movement was also non-significant $F(1,163) = .382$, $p = .538$, $\eta_{p}2 = .002$.

Three-way Interactions. The interaction between cue type, handedness and eye closure was significant $F(1,163) = 4.389$, $p = .038$, $\eta_{p}2 = .026$. This was assessed further by simple interaction effects at each level of cue type. A two way between-subject ANOVA was completed for eye closure and handedness upon high imaginability cues and low imaginability cues. For the high imaginability ANOVA there was no significant main effect of eye closure $F(1,167) = 1.882$, $p = .172$, $\eta_{p}^{2} = .011$. There was also no main effect of handedness $F(1,167) = 0.17$, $p = .895$, $\eta_{p}^{2} < .001$. There was also no interaction between the two variables $F(1,167) = 1.504$, $p = .222$, $\eta_{p}^{2} = .009$. For the low imaginability ANOVA there was a main effect for handedness $F(1,167) = 8.082$, $p = .005$, $\eta_{p}^{2} = .046$, with the consistent handed individuals (M = 6.05) scoring significantly higher than the inconsistent handed individuals (M = 5.66). The main effect of eye closure was non-significant $F(1,167) = .070$, $p = .792$, $\eta_{p}^{2} < .001$. The interaction between the two variables was also not significant $F(1,167) = .730$, $p = .394$, $\eta_{p}^{2} = .004$.

The Interaction between cue type, eye movement and eye closure was non-significant $F(1,163) = .060$, $p = .807$, $\eta_{p}^{2} < .001$. The interaction between cue type, eye movement and handedness was also non-significant $F(1,163) = .003$, $p = .958$, $\eta_{p}^{2} < .001$. The interaction between eye movement, eye closure and handedness was also non-significant $F(1,163) = .008$, $p = .931$, $\eta_{p}^{2} < .001$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant $F(1,163) = .800$, $p = .372$, $\eta_{p}^{2} = .005$.

Recalling a coherent story

The descriptive statistics for the coherent story likert scale can be found in table 7 below:

Table 3.5. Mean (SD) Coherent story scores as a function of eye movement, eye-closure, handedness, and cue-type.

Table 7. Mean (SD) Coherent story scores as a function of eye movement, eye-closure, handedness, and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 92			Fixation *n* = 79			Total *n* = 171		
Eye Closure & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-Imaginability Cues									
Open									
Consistent	25	4.82	(1.04)	26	5.34	(1.26)	51	5.09	(1.17)
Inconsistent	17	5.38	(.99)	14	5.25	(.66)	31	5.32	(.84)
Closed									
Consistent	36	5.56	(1.09)	22	4.84	(1.42)	58	5.29	(1.26)
Inconsistent	14	5.26	(1.28)	17	4.91	(1.34)	31	5.07	(1.30)
Total									
Consistent	61	5.26	(1.12)	48	5.11	(1.35)	109	5.19	(1.22)
Inconsistent	31	5.32	(1.11)	31	5.06	(1.08)	62	5.19	(1.09)
Low-Imaginability Cues									
Open									
Consistent	25	4.65	(1.25)	26	5.20	(1.08)	51	4.93	(1.19)
Inconsistent	17	4.80	(1.02)	14	5.02	(1.11)	31	4.90	(1.05)
Closed									
Consistent	36	5.40	(1.19)	22	4.86	(1.11)	58	5.19	(1.18)
Inconsistent	14	5.11	(1.32)	17	4.63	(1.07)	31	4.85	(1.19)
Total									
Consistent	61	5.09	(1.26)	48	5.04	(1.10)	109	5.07	(1.18)
Inconsistent	31	4.94	(1.16)	31	4.81	(1.09)	62	4.87	(1.12)

Main effects. The main effect of cue type was significant *F*(1,163) = 7.678, *p* = .006, η_{p2} = .045, indicating more coherent stories recalled for the more highly imaginable cues (*M* = 5.17) compared to the low imaginability cue group (*M* = 4.96). The main effect of eye movement was not significant *F*(1,163) = .0478, *p* = .490, η_{p2} = .003. The main effect of eye closure was also non-significant *F*(1,163) = .006, *p* = .939, η_{p2} < .001. The main effect of handedness was also non-significant *F*(1,163) = .52, *p* = .820, η_{p2} < .001.

*Two-way interactions***.** The Interaction between eye closure and eye movement was significant *F*(1,163) = 5.790, *p* = .017, η_{p2} = .034 (see figure 7 below). This was assessed further by simple main effects at each level of eye movement. The analysis indicated a significant difference between the eyes open (M = 4.88) and eye closed (M = 5.40) in the horizontal group *t*(90) = 2.835, *p* = .019, d = .510. However there was no significant difference between eyes open (M = 5.22) scores and eye closed (M = 4.81) scores in the consistent fixation group *t*(77) = 1.718, *p* = .090, d = .390.

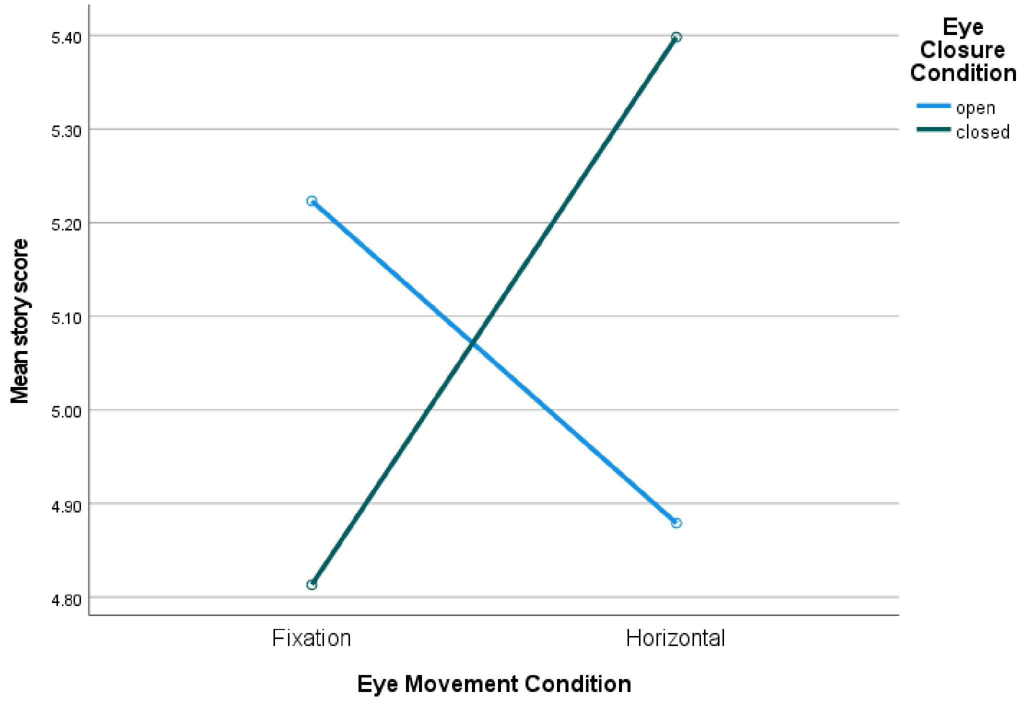

Figure 7 - Experiment Two - The effects of eye movement and eye closure upon mean story scores.

The interaction between cue type and eye movement was not significant $F(1,163) = .506$, $p = .478$, $\eta_{p2} = .003$. The interaction between cue type and eye closure was also non-significant $F(1,163) = .799$, $p = .373$, $\eta_{p2} = .005$. The interaction between cue type and handedness was also non-significant $F(1,163) = 1.614$, $p = .206$, $\eta_{p2} = .010$. The Interaction between eye movement and handedness was also non-significant $F(1,163) = .155$, $p = .694$, $\eta_{p2} = .001$. The Interaction between eye closure and handedness was also non-significant $F(1,163) = .753$ $p = .387$, $\eta_{p2} = .007$.

Three-way Interactions. The three-way interaction between cue type, eye movement and eye closure was not significant $F(1,163) = .308$ $p = .580$, $\eta_{p2} = .002$. The interaction between cue type, eye movement and handedness was also non-significant $F(1,163) = .753$ $p = .001$, $\eta_{p2} = .979$. The interaction between cue type, eye closure and handedness was also non-significant $F(1,163) = .125$ $p = .724$, $\eta_p^2 = .001$. The interaction between eye movement, eye closure and handedness was also non-significant $F(1,163) = 1.082$ $p = .300$, $\eta_p^2 = .007$.

Four-way Interaction. The four way interaction between cue type, eye movement, eye closure and handedness was also non-significant $F(1,163) = 1.095$, $p = .297$, $\eta_p^2 = .007$.

Further Analyses of the Autobiographical Memory Questionnaire Responses: Assessing Highly Specific Memories.

In the overall analyses, the rating scale responses were assessed separately for each Likert scale questions. This was done by averaging across all memories *irrespective* of their specificity score. Additionally, some research has made more *selective* use of recalled information by defining only the most *detailed* and specific memories as *truly* episodic or *strictly* episodic (e.g., Piolino, Desgranges, Benali, & Eustache, 2002; Piolino, Hisland, Ruffeveille, Matuszewski, Jambaqué, & Eustache, 2007). That is, using memories with specificity scores of only four. Distinguishing between types of memory in this manner may reveal differences obscured by the overall average. As the effects predicted pertain to episodic memory, it was considered useful to reanalyse the data making use of a stricter scoring criteria. To this end, memories whose specificity score was 4 were analysed separately and added to the appendix (see appendix 4C). Specifically, ratings associated with memories with a specificity score of four were entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 2(eye-closure: open vs. closed) between-subjects by 2(handedness: consistent vs. inconsistent) between-subjects by 2(cue-type: high vs. low imageable) within-subjects mixed-ANOVA.

In a brief summary of the findings, it was discovered that the main effects of eye closure, eye movement and handedness were identical to the overall analyses. The only effect to change by this adjustment was that of cue type. This could be expected as cue type was predicted to effect memory specificity (Rubin, 1980 – see general introduction page 24). Thus, is only very specific memories are included, the effect of this factor is essentially removed thus little effect of the variable upon the data.

The main difference between the two analyses was a significant interaction between eye movement and cue type for the DV of the setting of the memory (i.e., recalling location or situation). This interaction was unpicked with a series of within-subject t-tests and showed that cue type produced a significant main effect in the fixation but not in the horizontal eye movement group. Thus, the eye movement control group experienced a stronger significant positives effect of recalling abstract cues when compared to concrete cues.

Discussion

Overview of Discussion.

The results from the current experiment are considered below. This is done with regard to the hypothesised main effects and interactions to maintain continuity with the results section and to provide general structure for understanding of the main findings. Significant outcomes are considered in the "Review and Discussion of Current Findings" below. These are explained in the context of theories and conjectures as discussed in the general introduction to this thesis and the introduction for the current experiment. Where predictions were not borne out, possible shortcomings are assessed. This can be found in the section on "Consideration of Problems and Planning for Experiment 3".

Review & Discussion of the Current Findings.

Main effects

The most robust result from Experiment 2 was the main effect of cue-type. Highly imageable cues led to the recall of more specific autobiographical memories, were associated with higher levels of belief/recollection and component processes as measured by the Rubin et al scales. These findings support H4a & H4b and replicate similar past work (e.g., Rasmussen, & Berntsen, 2014; Williams, Healy, & Ellis, 1999), and can be explained by such cues providing more effective access to lower levels of the autobiographical knowledge base in the form of event-specific knowledge.

As predicted by H1a, memory specificity was also increased by eye movements. This is the first demonstration of this using the cue-word technique. Past work has shown an enhancement of memory specificity using the sentence fragment procedure (Parker, Parkin, & Dagnall, 2017) or recognition accuracy using the diary procedure (Christman et al., 2006). Thus, the current work extends these outcomes to a different ABM elicitation method. The increase in memory specificity can be explained by top-down processing and the consequent effect of this on improving access to specific memory details that would otherwise have remained inaccessible (at least on the retrieval attempts performed within the time restrains imposed in Experiment 2). The HERA account would also be in a position to explain the main effect of eye movements by increasing hemispheric interactions between the right and left pre-frontal cortex. Particularly, the right having greater access to specific episodic memories encoded by the left pre-frontal cortex (Christman & Propper, 2010).

However, the main effect of eye movements did not extend to subjective ratings of autobiographical recollection or associated component processes. This stands in contrast to Parker and Dagnall (2010) who found horizontal eye movements to enhance the phenomenological experience of episodic autobiographical memory. Thus, a dissociation was found between objectively scored memory specificity and the first-person experience as rated by the participants. It is not clear why this was found as it was expected that both specificity and subjective experience would be related. This point is taken up further below.

Handedness produced two significant effects with inconsistent handedness being associated with an increase in the subjective experience of travelling back in time and the sensory reliving (seeing/hearing) of information associated with the memory. This in part replicates Parker and Dagnall (2010), but in a more limited manner as the latter found effects across a broader range of the AMQ scales. One account of handedness effects, as noted previously (see the general introduction on SIRE effects), is related to the finding that inconsistent handers have a larger corpus callosum (Kompus et al, 2011). Thus, like the HERA hypothesis of eye movements, this facilitates hemispheric interaction and improves memory. In this case the subjective experience of some of the components of autobiographical remembering. Why handedness effects this did not extend across the AMQ scales is unclear. Observation of the *pattern* of effects offers no clarification as in some cases, the means were either the same or higher for the consistently handed individuals (albeit non-significantly).

Eye-closure produced only one significant main effect. This was for the subjective experience of seeing/hearing the memory. This could be accounted for by eye-closure blocking external interference and enabling the reimagining or reconstruction of sensory details. It is difficult to be more precise given the lack of differences for memory specificity or the other AMQ scales. These findings stand in contrast to much previous work on eye-witness testimony. Given the similarity between autobiographical and eye-witness recall (Bruce & Read, 1998; Pezdek, 2003; Rubin, & Umanath, 2015), this outcome is surprising and thus does not provide support for either of the main theoretical descriptions of eye-closure effects. Possible reasons for this are taken up below.

Interactions

The contention that cue-type and eye movements would interact was not found. This hypothesis was based on the idea that eye movements potentiate top-down control and thus would provide a basis for more successful access to event-specific knowledge when cues required additional top-down support (i.e., low-imaginable cues, Williams et al (2006).

For the most part, eye movements did not interact with eye-closure. This prediction was based on the idea that eye movements and eye-closure might be dependent on similar mechanisms (e.g., top-down control). The only exception was a two-way interaction for story coherence. For this, eye-closure produced a significant difference after eye movements but not fixation. Perhaps one reason for this is that eye movements increased the amount of event-specific detail recalled and that eye-closure assisted in organising this into a coherent story-like narrative. However, caution must be exercised with this post-hoc interpretation given the non-significant interactions for the other scales.

There was a similar failure to find an interaction between eye-closure and cue-type. Again, this was hypothesised based on the claim that low-imageability cues are more likely to depend on top-down processing resources. Thus, freeing such resources (by eye-closure) should have a greater effect on recall with such cues.

Handedness did not interact with eye movements as might be expected given the HERA model. That is, consistent handers would be expected to show a greater effect of horizontal saccades as their baseline level of hemispheric interaction would be expected to be lower (because of a smaller corpus callosum) and thus have more room for improvement. In past work, this form of interaction has been inconsistently observed (Edlin & Lyle, 2013; Roberts, Fernandes & MacLeod, 2020). Consequently, its absence here just adds to this. Of course, it does not explain why these interactions are sometimes observed or not and existing theorising provides no clear grounds for the conditions under which they will be found.

However, handedness did interact with cue-type, but for only one of the AMQ scales (recalling the setting). It was found that cue-type was important for only inconsistent-handers (higher scores for high-imageability cues). For consistent-handers, cue-type had no effect.

Higher-order interactions

A three-way interaction between eye movement, eye closure, and handedness was found for memory specificity. Subsequent analyses indicated this to be due to a significant main effect of eye -movement (higher after horizontal saccades) for *inconsistent*-handers. This is not what would be expected based on the HERA account as consistent-handers would be expected to benefit more from a boost to eye movement induced hemispheric interaction.

A three-way interaction was also found between eye movement, eye-closure, and cue-type for seeing/hearing. Further examination at each level of cue-type was assessed. This showed this to be due to a main effect of eye-closure for highly-imageable cues. That is, such cues enhanced the ability to reexperience sensory information but only when eyes were closed.

Consideration of Problems and Planning for Experiment 3.

The findings of Experiment 2 provided only limited support for the hypotheses. The upcoming section will outline and evaluate the findings with links to relevant research.

Lack of consistent effects of eye-closure.

The outcomes for eye-closure were surprising given the wealth of positive findings in the eye-witness testimony research. One reason for this is that is that autobiographical recall and eye-witness memory are distinct and do not share any common processes. However, this seems rather unlikely to the extent that the latter can be considered a form of autobiographical memory for public events (e.g., Lindsay, 2007; Peterson, 2012). More generally, both often entail the retrieval of information about events, the reconstruction of narratives and memory for very precise sensory details from past experiences.

Another reason for the lack of consistent eye-closure effects could be due to the possible limited effect of excluding distracting sensory information under controlled experimental conditions. In the latter, the degree of external interference is likely to be low, especially compared to other settings such as outdoors on a busy street (e.g., Vredeveldt & Penrod, 2013). Thus, if the amount of external distraction is low, then the gains from closing one's eyes might not be sufficiently high to produce an observable effect.

Consequently, more robust effects of eye-closure might be easier to detect across a range of measures (e.g., specificity and the AMQ scales), if the amount of distraction was increased. Experiment 3 sought to assess this by the use of a Dynamic Visual Noise (DVN) display. Previous work has shown that interfering with memory encoding and retrieval by the viewing of a random changing pattern of pixels can reduce memory (Chubala, Surprenant, Neath, & Quinlan, 2018; Parker & Dagnall, 2009; Quinn, & McConnell, 2006). This is expanded upon in the introduction to the third experiment.

Additionally, the absence of eye-closure effects on subjective experience might also have been due to the lack of an appropriate comparison standard. That is, making judgements (such as the vividness of a memory) requires the use of appropriate contextual information in order to anchor one's judgement or provide a criterion by which to assess the degree of vividness (e.g., Folville, Cheriet, Geurten, Willems, D'Argembeau, & Bastin, 2020; Tourangeau, & Rasinski, 1988). This may have been difficult for the participants in Experiment 2 as the eye-closure manipulation was between-subjects. However, if the same participant can experience a difference between open and closed conditions, this may facilitate comparisons between these and result in a difference in ratings between the two conditions. This is taken up in the introduction to Experiment 3.

Finding eye movement effects limited to memory specificity.

Eye movement main effects were limited to memory specificity scores and did not extend to the AMQ ratings. This is inconsistent with the findings of Parker and Dagnall (2010). A difference between this and Experiment 2 was that Parker and Dagnall used only strongly right-handed (consistent) subjects. This was premised on some findings that show stronger eye movement effects for consistently handed persons (Lyle & Orsborn, 2011). However, this does not fully explain the current findings because if this were true, then an interaction between eye movements and handedness would have been found. Thus, the dissociation between memory specificity and the AMQ scores is difficult to explain. Important here is experimental replicability. Experiment 3 sought to assess further whether the results from Parker and Dagnall (2010) can be reproduced or not (as in Experiment 2).

Limited range of important interactions.

The predicted interaction between eye movements and cue-type assumed that top-down processing plays a key role in potentiating memory retrieval and accessing memory to less-imageable cues. Regarding eye movements, the potential role of top-down control is supported by some work that shows eye movements to enhance less accessible information (Lyle & Edlin, 2015), influences attention (Edlin & Lyle, 2013), is associated with tasks and measures that assume a degree of control (Lyle, 2018; Parker et al., 2008) and EEG work (Fleck et al., 2018). Regarding cue-type, less imageable cues do lead to the recall of less specific information (Experient 2; Crane, Pring, Jukes, & Goddard, 2012; Williams et al., 1999) and are likely need a greater degree of executive influence to access more particular information (Hoffman, Jefferies, & Ralph, 2010; Williams et al., 1996).

When cues do not provide direct access to specific autobiographical memories, a process of generative retrieval is engaged to retrieve the desired information. As previously noted, (see general introduction), generative retrieval involves an effortful and iterative search through the autobiographical knowledge base until a cue is constructed that activates a specific memory (Conway, 2005; Conway & Loveday, 2010).

Experiment 2 did not assess the retrieval strategies employed by the participants and so the extent to which cues or eye movements deploy generative, and therefore top-down, retrieval strategies is not known. This is examined in Experiment 3 in which the contention that different types of cue and eye movements are associated with different retrieval operations are measured.

The absence of interactions between eye movements and eye-closure (except for story coherence) could be taken to indicate these manipulations influence separate processes. However, the lack of main effects on several DVs possibly argues against this. Given these techniques have demonstrable effectiveness in memory enhancement in previous work it is was considered that it would be beneficial to combine these again in Experiment 3 with the different manipulation for eye-closure (within-subject), the introduction of external distraction, and measures (of direct vs. generative retrieval).

As noted above, the lack of interaction between eye movements and handedness adds to the inconsistences often seen in previous research. Although it is not apparent why this is so, Experiment 3 incorporates handedness as variable to further address the role handedness might play in autobiographical memory in the revised experimental design.

Chapter 4: Experiment 3 – Effects of saccadic eye movements, handedness & distraction (eye closure and dynamic visual noise) upon the autobiographical memory test.

Introduction

Overview of Experiment 3

The aim of Experiment 3 was to further the results of the second experiment through a set of methodological changes to the manipulations and some of the measurements. Experiment 2 produced some unexpected null findings. Possible reasons for these are considered together with proposed experimental adaptions and the rationale for these changes. Principally, these relate to **(i)** an absence of a broad effect of eye-closure (except for seeing/hearing), **(ii)** no interaction between eye movement and cue-type.

Absence of Effects of Eye-Closure

In the discussion to the second experiment, two reasons were offered to explain the lack of consistent effects of eye-closure on ABM. Firstly, as participants in the eyes-open condition were allowed to freely move their eye, it is possible that they were able to minimise the effects of any external interference. For example, by directing attention to regions in the environment where perceptual input is less cluttered, they may have been able to regulate the degree of interference and thus reduce the impact of eye-closure. In this sense, the open and closed conditions may have differed only minimally.

In some previous work on eye-closure, the open condition has been more tightly controlled by introducing a viewing task in which participants are required to attend to the presentation of distractor stimuli. For example, Wais, Rubens, Boccanfuso, and Gazzaley (2010), compared the effects of closing one's eyes to enforced viewing of a grey screen (minimal distraction) and pictures of outdoor scenes (maximal distraction). Eye-closure effects produced the greatest recognition accuracy (as measured by *d'*) with the visual distraction task the lowest and the grey screen in-between. Similar effects have also been found with auditory distraction with ambient noises from a busy café reducing the retrieval of visual information (Wais & Gazzaley, 2011). The authors asked participants to recognize the previously viewed images. However, eye-closure was not manipulated in this experiment.

Another manner to create distracting visual input is Dynamic Visual Noise (DVN) task (Quinn & McConnell, 1996). This task involves the presentation of a matrix of a randomly changing arrangement of black and white squares on a screen. Early work demonstrated that the DVN display disrupts the processing of imagistic visual information. For instance, recall memory for a list of words was reduced by DVN when encoded with a visual mnemonic (Quinn & McConnell, 1996). However, no disruptive effects of distraction were found when participants were asked to use a non-imagery mnemonic.

Other work has shown that DVN can bring about interfering effects when presented at encoding or retrieval (Quinn and McConnell, 2006), reduce recognition memory confidence (Kemps & Andrade, 2012), impair the recall and recognition of concrete (vs. abstract) words (Chubala, Surprenant, Neath, & Quinlan, 2018; Parker & Dagnall, 2009), and reduce the specificity of autobiographical memories (Anderson, Dewhurst, & Dean, 2017). Dynamic visual noise can also influence processing in non-episodic memory tests that necessitate the use of visual imagery (Dean, Dewhurst, Morris, & Whittaker, 2005).

Theoretically, one explanation of these results is that DVN gains obligatory entry to one STM visual subsystem labelled the passive visual store or visual buffer (Quinn & McConnell, 1996; 2006). This subsystem maintains imagery and visual information in an active state to subserve on-going processing goals that require such information. When a dynamic noise field is presented, interference effects are observed, and imagistic representations degraded. As this task does not require the use of recognisable visual images, it provides a good means to disrupt imagery processing at a purely visual level without any additional interference that might arise from semantic codes if recognisable pictures were used. Consequently, the DVN task was selected for use in Experiment 3 and compared to an eye-closure condition. In addition, another condition was implemented that involved minimal perceptual input, like Wais et al., and involved a blank screen.

Another reason for the lack of consistent eye-closure effects on ABM (and especially their associated subjective qualities) might also have arisen because of the absence of an appropriate comparison standard. Typically, making subjective judgments about the magnitude of a stimulus or a representation of that stimulus requires the use of relevant contextual information. This is needed in order to ‘anchor’ the judgement or rating as it can provide a criterion by which to assess the target of the current decision (e.g., Folville, Cheriet, Geurten, Willems, D'Argembeau, & Bastin, 2020; Tourangeau, & Rasinski, 1988). When computing judgments that involve the subjective qualities (ratings) of the memory, participants rely on information that is most easily accessible (e.g., Higgins, 1996). When this is available and relevant, the judgment can be influenced by the anchor point.

In the second experiment, the availability of an appropriate anchor may not have been readily apparent. One reason for this is that the eye-closure manipulation was between-subjects. However, if the same participant can use the representations in one condition (e.g., eyes open) and experience a difference to another condition (e.g., eyes closed), this may facilitate comparisons between these and result in a difference in ratings between the two conditions. Thus, in the third experiment the eye-closure manipulation (closed vs. open with DVN vs. open with blank screen) is manipulated within-subjects.

The Finding of Eye Movement Effects and Memory Specificity

As noted in the discussion to Experiment 2, eye movement main effects were limited to memory specificity scores and did not extend to the AMQ ratings. This is inconsistent with the findings of Parker and Dagnall (2010). Additionally, there was no interaction between eye movements and handedness as has been found in some, but not all studies (c.f., Brunyé, et al., 2009; Lyle et al., 2008; Lyle & Jacobs, 2010). There is no clear reason for the difference between the current and past findings as they were similar along many important dimensions. However, one difference was the stimuli used as word cues. Whether this was of significance is uncertain, but it seems unlikely that SIRE effects should be limited to only the stimuli used in past work. Another difference is that memories were rated silently in Parker and Dagnall (2010) with no requirement to say them aloud. Although this may have produced differencing outcomes there is no obvious rationale for this in any theoretical account of SIRE effects. Irrespective of these problems, the third Experiment sought to assess the reproducibility of the observed eye movement effects on memory specificity. In this respect, no alterations were made to the experimental design.

The Limited Range of Important Interactions

The hypothesised interaction between eye movements and cue-type assumes top-down processing plays a key role in potentiating memory and retrieving less accessible information (Edlin & Lyle, 2013). That is, SIRE effects would be greater for more abstract cues. Past work has shown that more abstract cues do lead to the recall of less specific information (experiment 2; Crane, Pring, Jukes, & Goddard, 2012; Williams et al., 1999) and are likely need a greater degree of top-down influence to access more particular information (Hoffman, Jefferies, & Ralph, 2010; Williams et al., 1996). Top-down control is most needed when cues are insufficient to provide direct access to a memory and generative retrieval is required. This involves an iterative search through autobiographical memory until access to a specific memory is found (Conway, 2005; Conway & Loveday, 2010).

Greater understanding of any interaction (or lack thereof) between eye movements ad cue-type would be achieved if the type of retrieval strategies employed during autobiographical memory search were measured. This was not done in Experiment 2 and thus the third experiment sought to remedy this through the measurement of the nature of the retrieval attempts. Direct and generative recall can be assessed in several ways. One is through the measurement of retrieval latencies as recall via generative processes is slower than direct access for example, the median response time difference being between 4 to 14 seconds (Uzer, Lee & Brown, 2012). Another is by measurement of neural activity. Addis Knapp, Roberts, & Schacter, (2012) found generative retrieval preferentially engaged regions typically associated with executive control, including the lateral prefrontal cortex.

Self-reports of retrieval strategy have also been used successfully. For instance, Harris, O'Connor, and Sutton (2015) had subjects indicate whether recalled memories were associated with the experience of being directly triggered by a cue or if the cue required additional information to be generated before recalling a specific memory. It was found that the characteristics of directly retrieved memories differed from generatively retrieved memories in terms of field perspective and retrieval time. Experiment 3 implemented this procedure to assess whether the type of retrieval strategy differs as a function of cue-type and whether eye movements or eye-closure effect the type of retrieval strategy selected. The results arising from the influence of cue-type would be particularly informative in addressing whether less imageable cues recruit generative processing and thus more likely to demand the involvement of top-down control.

That eye movements and eye-closure did not interact (except for story coherence) could be taken to indicate these manipulations influence separate processes. However, the lack of consistent effects across several variables makes this difficult to assess. Ideally, both need to show some degree of influence within a DV and across several DVs for this to be answered in a more thorough manner. As noted earlier, by changing eye-closure to a within-subject manipulation it was hoped to bring about stronger and more consistent effects of this factor. Given both eye movements and closure have been demonstrated to have significant effects in previous work it is was considered that it would be beneficial to combine these once more in Experiment 3 with the different manipulation for eye-closure (within-subject), the introduction of external distraction, and measures (of direct vs. generative retrieval).

The Current Study

Similar to the second experiment, Experiment 3 required participants to recall personal memories to both high and low imageable cues after engaging in an eye-movement task or fixation (between-subjects). Recall was spoken and took place with eyes closed, eyes open with DVN and eyes open with a blank screen (within-subjects). Memories were then rated for their subjective qualities under each of the three conditions. Additionally, participants were informed that the recall of personal memories can take place in different ways, and they were provided with definitions and examples of direct and generative retrieval. Participants were asked which strategy best described their strategy for each memory recalled.

As in Experiment 2, the recall protocols were scored for level of specificity and this, the subjective ratings and recall strategy were used as the primary DVs. The principal aims were to: **(i)** assess the practical or applied value of combining different memory enhancing techniques to autobiographical recall and **(ii)** evaluate theoretical predictions for these effects as founded in extant accounts of both eye-movements and eye-closure effects.

Hypotheses Regarding Dynamic Visual Noise

The hypotheses are broadly the same as Experiment 2. This is because the change in the design (from between to within-subjects and the use of DVN) is considered to be a more stringent test of the eye-closure hypotheses as outlined in the second experiment. However, the inclusion of DVN also permits some additional predictions to be made to accommodate any effects of visual noise on the DVs. The numbers used for the hypotheses carry on from those in the second experiment. Thus, it is predicted that:

H8a. Autobiographical memory specificity be reduced by the presence of DVN with the order of levels of specificity being eyes-closed > eyes-open > DVN.

H8b. Subjective ratings relating to episodic recollection will be reduced by the presence of DVN with the order of the magnitude of ratings being eyes-closed > eyes-open > DVN.

Both these predictions follow from earlier work in which DVN reduced both measures of ABM in comparison to a blank screen (Anderson et al., 2017). The novel prediction relates to the inclusion of an eyes closed condition. These predictions are expected for both types of cues as the latter did not interact with the presence of visual distraction in previous work (Anderson et al., 2017).

Hypotheses Regarding Type of Retrieval Strategy

The type of retrieval strategy is expected to vary according to the type of cue and will provide a test of the assumption made if Experiment 2 that less imaginable cues will be more likely to engage top-down retrieval. This is because less imaginable cues are less likely to provide direct access to specific autobiographical memories (Harris & Berntsen, 2019; Williams, Chan, Crane, Barnhofer, Eade, & Healy, 2006). Less imaginable cues will require more extensive searches, cue-elaboration and iterative attempts before a detailed memory is activated, thus:

H9a. It is predicted that less imaginable cues will be associated with a greater number of generative retrieval responses.

The link between cue-type and retrieval strategy is of course not expected to be perfect, as indeed has been shown in other work (e.g., Harris & Berntsen, 2019). Consequently, both types of cues are expected to bring about a combination of both types of retrieval strategy depending on the idiosyncratic nature of the cue for each participant. This enables additional analyses based on the use of type of retrieval (as opposed to cue-type) as a grouping factor (see below for details).

It is less clear whether eye movements will affect the type of retrieval strategy deployed. The top-down account claims eye movements to potentiate less accessible memories making them more likely to be recalled. This could imply either (i) the generative retrieval process becomes more effective and perhaps leading to fewer iterative retrieval attempts or, (ii) for some subset of memories, they become more readily accessible to direct retrieval. If the latter is correct, then a tentative hypothesis is:

> **H9b.** It is predicted that eye movements will increase the number of memories directly recalled. Whether this relates to both or only one type of cue is a question for exploration.

There are no clear predications for the effects of eye-closure or handedness on the use of retrieval strategy and these are left as open questions.

Method

Design

Experiment 3 had two between-subject variables; eye movement task (horizontal vs. fixation) and handedness (consistent vs. inconsistent). The experiment also had two within-subject variables; imaginability (concrete vs. abstract) & distraction (dynamic visual noise vs. control vs. eye closure).

The dependent variable in the study was the level of verbal specificity provided in the 'Autobiographical Memory Test' and five separate Likert scale questions taken from the AMQ (1 disagree – 7 agree) assessing the recollection and component processes of the recall provided. The final dependent variable was the 'direct vs generative recall score'. Participants were allocated one point per response accredited to direct recall and zero points for generative recall.

Participants

The sample size was determined in a similar manner to Experiment 1 & 2 using past research (Parker & Dagnall, 2010 & Bunnell, Legerski, & Herting, 2018) and a sample size analysis performed in MorePower 6.0 (Campbell, & Thompson, 2012). For a main effect and interaction effect size of $\eta_p^2 = .06$, with $\alpha = .05$, and for 80% power, the estimated total sample size was around 114.

One hundred and fifteen participants took part in the current research experiment (fifty-nine males and fifty-six females) and were recruited using opportunity snowball sampling from Manchester Metropolitan University and the surrounding local area. The sample age ranged from eighteen years old to seventy-three years old (Mean: 24.78 SD: 9.43) and all participants were able to complete and pass the brief cognitive assessment tool ‘Sweet 16’ before taking part in the research.

Participants were asked to self-exclude from the research if any of the following applied to them: **(i)** A history of neurological disorders, **(ii)** Any significant psychiatric disorders, **(iii)** A history of abusing illicit substances, **(iv)** Any medical disorders known to affect cognitive functioning, **(v)** Any none-corrected visual impairments. Participants did not have to declare which specific reason they are excluding from the study and the researchers would not ask for any elaboration.

The sample was allocated randomly into both the eye movement (fifty-eight subjects in the bilateral group (mean age = 25.19, SD = 9.64) vs fifty-seven in the fixation group (mean age = 24.37, SD = 9.27). No significant difference of age were found in the between subjects groups of the participants, the full analysis can be found in appendix 5A.

The allocation for the handedness condition depended upon the Edinburgh handedness scale scores (sixty-four in the consistent group vs fifty-one in the inconsistent group).

Materials and Apparatus

Sweet 16 (S-16) (Fong et al, 2011)

The Sweet-16 (S-16) is a simple and quick assessment tool to screen for cognitive impairment which are often unrecognised among older adults (Fong et al, 2011). The scale is scored from 0 – 16 (with 16 being the best score). The scale includes eight orientation items (temporal and special orientation), three registration items (registration), four-digit span items (sustained attention) and three recall items (short-term memory), each of the items receives one point (except the first two-digit span activities). The cut off score for the current experiment was less than fourteen out of sixteen points.

Edinburgh handedness Inventory (EHI) (Oldfield, 1971)

The EHI is a self-report measure that asks participants to indicate their handed preference on ten separately presented activities (e.g., Brushing teeth, combing hair, and opening a jar lid). Responses are categorised as ‘Always right hand’ (+10 points), ‘usually right hand’ (+5 points), ‘no preference’ (Zero points), ‘usually left hand’ (-5 points) & ‘always left hand (-10 points). Thus, the scores range from -100 to +100. Participants scoring between -75 and +75 were classified as mixed handed, while subjects scoring outside of this bracket were classed as strongly handed. This scoring scheme (as opposed to the original EHI scoring scheme) is in-line with another previous research on this topic area (e.g., Edlin et al, 2013, 2015 & Lyle et al, 2008).

Eye movement program

A computer program was used to initiate eye movements. This was done by flashing a black dot against a while background horizontally or flashing centrally for the fixation condition. The circle moved (flashed) once every 500ms and in the eye movement conditions was located approximately 27° of visual angle apart. The average size of the computer monitors used in this research was 22 inches (56cm) with the viewing distance adjusted to maintain the 27-degree visual angle.

Autobiographical memory test (AMT) (Williams & Broadbent, 1986)

The standard Autobiographical memory test methodology was employed as described by Williams & Broadbent (1986) and participants were asked to recall a specific memory connected to each given keyword. The participants were asked to respond to the keywords verbally and the response was recorded using Microsoft Teams for later encoding and data entry.

The current version of the procedure included eighteen keyword prompts and was split into three sections of six responses. Each of the six sections contained six cues with three highly imaginable terms (Block 1 – Frog, Mountain & Butterfly. Block 2 – fire, house & apple. Block 3 – ambulance, cake & boat) and three low imaginability terms (Block 1 – wisdom, obedience & boredom. Block 2 – attitude, morality & philosophy. Block 3 – virtue inspiration & irony) as based upon previous research by Williams et al., (2006) & Guler & Mackovichova., (2019). The blocks of cue words were randomly allocated to each participant for each experimental condition (dynamic visual noise, control & eye closure).

The AMT was coded based upon the level of specificity provided in the participants responses using a four-point scale (Baddeley & Wilson, 1986). Based upon previous research (Piolino et al., 2007, 2009; Danion et al., 2005) the following scoring parameters were set for the current study: Four points were scored for memories for a very specific episodic incident or event that occurred on a particular day including features such as **(i)** what happened **(ii)** occasion or time **(iii)** when appropriate a place or location **(iv)** appropriate objects or things **(v)** if appropriate relevant other people. Three points were allocated to less specific episodic memories which may be similar to above but lack some of the listed cues and details. Two points were allocated to more general memories which included repeated events or general categories (e.g., 'going out for coffee with friends' or 'we always go on holiday') or extended events (e.g., 'The three years I spent at university' or 'my holiday in France two years ago'). One point was scored for memories that are effectively semantic in nature and relate to definitions of words or concepts. A score of zero was given to participants if they were unable to generate a memory to match the keyword.

Recollection and Component Processes Likert scales (Rubin et al, 2003)

Following the administration of the ATM a set of six follow up questions were presented to assess the participants recollection and component processes associated with ABM (Rubin et al., 2003). These questions were marked on a 1 (disagree) to 7 (agree) Likert scale. The following two questions 'I feel that I am reliving the original event' and 'I travel back to the time when it happened' are part of the recollection section. The following three questions 'I can see and/or hearing it in my mind', 'I can recall the setting where it occurred' and 'It comes to me as a coherent story' are part of the component processes section. Some of the scale items were omitted from the current experiment as they were not deemed directly relevant to the current research hypothesises in a similar way to Parker and Dagnall (2010, for example "would you be confident enough to testify in a court of law?" or "To what extent is your memory of the event distorted by your believes and motives and expectations".

Research booklet and demographical information

A research booklet was constructed to help develop a fixed structure and to ensure a same experimental procedure was followed by the data collector. The booklet also included two basic demographical questions (Age & Gender). The booklet also included two basic demographical questions (Age & Gender). A copy of the experimental booklet and all the scales used within this experiment can be found in the appendix section 5.

Dynamic visual noise program

The dynamic visual noise program was based upon the works of Quinn & McConnell (1996) and Parker & Dagnall (2010). The program was written and operated in visual basic and consisted of 120 x 120 black and white dots each measuring 3mm x 4 mm distributed 50:50

on the display screen. The screen refresh rate was set to 0.25 seconds and changed 50% of the dots in a random manner per cycle following the recommendations from Dean et al (2005).

Procedure

Participants were invited to a one-to-one Microsoft team meeting at a time which suited them and were sent a copy of the participant information sheet. During the Microsoft teams meeting the participants were first asked to switch on their webcams and microphones and the participant information sheet was summarised and the consent form completed. Following this, participants were informed that the TEAMs meeting recording function would be activated from this point.

Once recording had started, participants were asked to complete the demographical information questions verbally and the booklet was completed by the experimenter. The Sweet 16 (S-16) questions were answered by the participant while guided by the researcher. The experimenter did not need to transcribe or store the scores of the scale as long as the participant scored above the thirteen-point threshold, potential participants who did not pass this threshold were taken directly to the debrief form.

Next, the participants were asked to complete the Edinburgh Handedness Inventory. The researcher shared their screen so the participant could see the scale and read the instructions provided. These stated "*Please indicate your preferences in the use of hands in the following activities. Please answer all the questions, and only leave a blank if you have no experience at all with the object or task*.". The researcher then stated the ten tasks and highlighted the participants responses for later totalling and coding.

The next stage of the experiment was the Autobiographical Memory Test (AMT) that consisted of eighteen recorded trials split into three sections of six questions. Each of the sections was randomly allocated to one of the three distraction variable levels (dynamic visual noise, control & eye closure). This was manipulated in a blocked manner such that participants were run through each level of the factor in turn. The participants were also randomly allocated to the between subject conditions (eye movement; horizontal vs fixation).

Depending upon the condition the participants were allocated to they were asked to watch a thirty second visual manipulation task. This was either a dot that moved side to side, subtending a visual angle to the participant of approximately 27 degrees, (horizontal condition) or flashed on and off in the centre of the screen (fixation condition). In the former, participants were asked to move their eyes to follow the dot while keeping their heads stationary. In the latter, participants were asked to focus their attention on the dot while keeping both eyes and head stationary. This manipulation was completed eighteen times before each of the specificity prompts outlined below.

At the start of the AMT participants were asked to read (or would have read to them if requested) the following instructions "*In the next section of the experiment, you will be presented with a key word and asked to provide a personal memory. The retrieved memory can be something what has happened recently or a long time ago but must be at least a week old. It does not matter if the memory recalled is something trivial or important if the memory is autobiographical and about your individual past*.".

Once the instructions for the AMT and the eye movement manipulations were completed the researcher allocated the participant to one of the three distraction conditions (dynamic visual noise, control or eye closure). For the control condition no additional instructions were presented, and the participant were asked to recall information for the presented cues. For the eye closure condition participants were asked to close their eyes until asked to open them again. For the DVN condition participants were asked to look and their computer monitors during recall, where the researchers would share their screen and the DVN program.

Once the condition was set the researcher then read aloud the memory cue and the participant was asked to speak out aloud the memory that came to mind, no time limit was given for this recall. Then, after the recall, the researcher read aloud each of the five Likert `scales statements and ask for the participant to respond on a one to seven scale. The recall was audio recorded and Likert scale responses entered into a response sheet.

The final question asked of the participants was to label their recall as either direct recall or generative recall. At the start of the AMT participants are provided the following instructions "*There are two ways that people can retrieve memories, when asked to recall personal events in response to cues: The first is when the cue directly triggers a memory, and no additional information needs to be thought about. The second is when the cue does not directly trigger a memory so additional information from one's life is thought about in order to arrive at a specific memory. When thinking of the memory to be recalled try to note of how the retrieval occurs.*". Participants were reminded of the definition of both direct recall and generative recall if needed throughout the experiment.

Once the three blocks of six memory recollections and follow up questions were completed the participants were fully briefed and provided an opportunity to ask any questions.

Results

Overview.

The specificity and rating scores were analyses in separate univariate ANOVAs using eye-movement, eye-closure, and handedness as between-subject variables and cue-type as a within-subject variable. The findings from the Autobiographical Memory (AMQ) scales were analysed separately for each response type to consider the effects of the independent variables on each component of autobiographical memory as in previous work (e.g., Parker & Dagnall, 2010; Rubin et al, 2003). Two-way interactions were assessed further by simple main effects. Higher order interactions were analyses initially by simple interaction effects followed by additional follow-up tests when required.

Results of Specificity Scores.

The verbal recall protocols were scored by two independent raters in accordance with the scheme outlined in the method section and Experiment 2. A random selection of 20% (23 responses) of the protocols were assessed for interrater reliability. The Interrater agreement was assessed using Cohen's Kappa. This produced a value of 0.847 and indicated very good and substantial agreement between the scorers. Any disagreements were resolved by discussion between the markers.

The specificity scores were then entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 3(distraction: eye closed vs. control vs. DVN) within-subjects by 2(cue-type: high vs. low imageable) within-subjects by 2(handedness: consistent vs.

inconsistent) between-subjects mixed-ANOVA. The descriptive statistics can be found in Table 8 below.

Violations of Mauchly's test of sphericity was also outlined within the statistics below. Based upon the recommendations of Field (2013). If the Greenhouse-Geisser estimate (ε) is >.75 then the Huynh-Feldt correction was implemented and if the Greenhouse-Geisser estimate (ε) is <.75 then the Green-Geisser estimate was used.

Table 8. Mean (SD) specificity scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	3.22	(.48)	31	3.23	(.41)	64	3.24	(.44)
Inconsistent	25	3.01	(.49)	26	3.22	(.39)	51	3.12	(.45)
Control									
Consistent	33	2.99	(.62)	31	3.11	(.66)	64	3.05	(.64)
Inconsistent	25	2.80	(.58)	26	2.82	(.54)	51	2.81	(.55)
DVN									
Consistent	33	2.79	(.72)	31	2.60	(.78)	64	2.69	(.75)
Inconsistent	25	2.59	(.90)	26	2.53	(.78)	51	2.56	(.83)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	2.45	(1.50)	31	2.23	(.91)	64	2.35	(.86)
Inconsistent	25	2.45	(1.15)	26	2.53	(.77)	51	2.49	(.83)
Control									
Consistent	33	2.16	(.60)	31	2.26	(.61)	64	2.21	(.60)
Inconsistent	25	2.23	(.81)	26	2.04	(.44)	51	2.13	(.65)
DVN									
Consistent	33	2.05	(.61)	31	2.05	(.78)	64	2.05	(.70)
Inconsistent	25	1.84	(.69)	26	1.73	(.45)	51	1.78	(.58)

Sphericity. For the distraction variable Mauchly's test indicated violation of the sphericity assumption, $\chi2(2) = 36.924$, $\varepsilon = .778$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi2(2) = .492$, $\varepsilon = .996$, $p = .782$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 168.819$, $p < .001$, $\eta_{p2} = .603$, indicating more specific memories recalled for highly imaginable cues ($M = 2.91$) compared to the low imaginable cues ($M = 2.17$). The main effect of distraction was also significant, $F(1.617, 179.485) = 33.90$, $p < .001$, $\eta_{p2} = .234$ Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant, difference between all three levels of the variables with DVN scoring the lowest (M = 2.27), followed by the control group (M = 2.55), followed by the highest score of eye closure (M = 2.80). The main effect of handedness was not significant, $F(1,111) = 3.04$, $p = .054$, $\eta_{p2} = .27$. The effect of eye movement was also non-significant, $F(1,111) = .078$, $p = .781$, $\eta_{p2} = .001$.

*Two-way interactions***.** The interaction between cue type and eye movement was not significant, $F(1,111) = .461$, $p = .499$, $\eta_{p2} = .004$. The interaction between cue type and handedness was also non-significant, $F(1,111) = .750$, $p = .388$, $\eta_{p2} = .007$. The interaction between distraction and eye movement was not significant, $F(1.617, 179.48) = .461$, $p = .898$, $\eta_{p2} = .004$. The interaction between distraction and handedness was not significant, $F(1.617, 179.48) = 1.502$, $p = .227$, $\eta_{p2} = .013$. The interaction between distraction and cue type was not significant, $F(2,222) = .233$, $p = .793$, $\eta_{p2} = .002$. Finally, the interaction between eye movement and handedness was not significant, $F(1, 111) = .900$, $p = .900$, $\eta_{p2} < .001$.

Three-way Interactions. The interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .211$, $p = .647$, $\eta_{p2} = .002$. The interaction between distraction, eye movement and handedness was not significant, $F(1.617, 179.485) = 1.348$, $p = .260$, $\eta_p^2 = .012$. The interaction between cue type, distraction and eye movement was not significant, $F(2, 222) = 1.094$, $p = .337$, $\eta_p^2 = .010$. The interaction between cue type, distraction and handedness was not significant, $F(2, 222) = 2.474$, $p = .087$, $\eta_p^2 = .022$.

Four-way Interaction. The four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(2, 222) = .562$, $p = .571$, $\eta_p^2 = .005$.

Results of the Autobiographical Memory Questionnaire.

The rating scale responses were assessed separately for each scale. The responses were entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 3(distraction: eye closed vs. control vs. DVN) within-subjects by 2(cue-type: high vs. low imageable) within-subjects by 2(handedness: consistent vs. inconsistent) between-subjects mixed-ANOVA.

I feel that I am reliving the original event.

The descriptive statistics for the reliving the event Likert scale can be found in table 9 below:

Table 9. Mean (SD) Reliving scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	5.12	(.93)	31	5.28	(.80)	64	5.20	(.86)
Inconsistent	25	5.13	(.89)	26	5.14	(.58)	51	5.14	(.74)
Control									
Consistent	33	5.06	(1.11)	31	4.88	(1.08)	64	4.97	(1.09)
Inconsistent	25	4.83	(.93)	26	4.54	(.96)	51	4.68	(.95)
DVN									
Consistent	33	4.25	(1.43)	31	3.96	(1.19)	64	4.10	(1.31)
Inconsistent	25	4.16	(1.77)	26	4.00	(1.46)	51	4.08	(1.61)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	3.85	(1.59)	31	3.48	(1.63)	64	3.67	(1.61)
Inconsistent	25	4.03	(1.67)	26	3.69	(1.44)	51	3.86	(1.55)
Control									
Consistent	33	3.31	(1.32)	31	3.33	(1.07)	64	3.33	(1.10)
Inconsistent	25	3.48	(1.22)	26	3.26	(.93)	51	3.34	(1.13)
DVN									
Consistent	33	2.83	(1.14)	31	2.85	(1.05)	64	2.84	(1.09)
Inconsistent	25	2.85	(1.23)	26	2.59	(.91)	51	2.72	(1.07)

Sphericity. For the distraction variable Mauchly's test indicated violation of the sphericity assumption, $\chi2(2) = 45.967$, $\varepsilon = .745$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi2(2) = .413$, $\varepsilon = .984$, $p = .984$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 153.260$, $p < .001$, $\eta_{p2} = .580$, indicating greater recall for highly imaginable cues ($M = 5.70$) compared to the low imaginable cues ($M = 3.30$). The main effect of distraction was also significant, $F(1.491, 165.479) = 36.304$, $p < .001$, $\eta_{p2} = .246$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant difference between all three levels of the variables with DVN scoring the lowest (M = 3.44), followed by the control group (M = 4.09), followed by the highest score of eye closure (M = 4.46). The main effect of handedness was not significant, $F(1,111) = .198$, $p = .106$, $\eta_{p2} = .002$. The effect of eye movement was also not significant, $F(1,111) = .273$, $p = .602$, $\eta_{p2} = .002$.

*Two-way interactions***.** The interaction between cue type and eye movement was not significant, $F(1,111) = .086$, $p = .770$, $\eta_{p2} = .001$. The interaction between cue type and handedness was not significant, $F(1,111) = .528$, $p = .469$, $\eta_{p2} = .005$. The interaction between distraction and eye movement was not significant, $F(1.491, 165.479) = .018$, $p = .957$, $\eta_{p2} < .001$. The interaction between distraction and handedness was not significant, $F(1.491, 165.479) = .316$, $p = .665$, $\eta_{p2} = .003$. The interaction between distraction and cue type was not significant, $F(2,222) = .507$, $p = .603$, $\eta_{p2} = .005$. The interaction between eye movement and handedness was not significant, $F(1, 111) = .273$, $p = .602$, $\eta_{p2} = .002$.

Three-way Interactions. The interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .072$, $p = .789$, $\eta_{p2} = .001$. The interaction between distraction, eye movement and handedness was not significant, $F(1.491, 165.479) = .316$, $p = .665$, $\eta_{p2} = .003$. The interaction between cue type, distraction and eye movement was not significant, $F(1.969, 218.516) = 1.727$, $p = .181$, $\eta_{p2} = .015$. The interaction between cue type, distraction and handedness was not significant, $F(1.969, 218.516) = .906$, $p = .404$, $\eta_{p2} = .008$.

Four-way Interaction. The four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(1969, 218.516) = .375$, $p = .684$, $\eta_p^2 = .003$.

I travel back to the time when it happened.

The descriptive statistics for 'I travel back to the time when it happened' likert scale can be found in Table 10 below:

Table 10. Mean (SD) Travel back to the time when it happened scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	5.24	(.93)	31	5.42	(.81)	64	5.33	(.87)
Inconsistent	25	5.35	(.77)	26	5.24	(.57)	51	5.29	(.67)
Control									
Consistent	33	5.06	(1.17)	31	5.14	(.93)	64	5.10	(1.05)
Inconsistent	25	4.85	(1.06)	26	4.87	(.89)	51	4.86	(.97)
DVN									
Consistent	33	4.18	(1.52)	31	4.11	(1.26)	64	4.15	(1.39)
Inconsistent	25	4.20	(1.66)	26	4.19	(1.54)	51	4.20	(1.58)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	3.81	(1.15)	31	3.66	(1.77)	64	3.73	(1.61)
Inconsistent	25	3.99	(1.52)	26	3.82	(1.28)	51	3.90	(1.39)
Control									
Consistent	33	3.47	(1.20)	31	3.41	(1.03)	64	3.44	(1.11)
Inconsistent	25	3.76	(1.35)	26	3.44	(1.03)	51	3.59	(1.20)
DVN									
Consistent	33	3.03	(1.21)	31	3.08	(1.29)	64	3.05	(1.24)
Inconsistent	25	2.88	(1.25)	26	2.65	(.90)	51	2.76	(1.08)

Sphericity. For the distraction variable Mauchly's test indicated violation of the sphericity assumption, $\chi 2(2) = 53.048$, $\varepsilon = .750$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi 2(2) = .529$, $\varepsilon = .995$, $p = .767$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 165.735$, $p < .001$, $\eta_{p2} = .599$, indicating greater recall for highly imaginable cues ($M = 4.82$) compared to the low imaginable cues ($M = 3.41$). The main effect of distraction was also significant, $F(1.447, 160.566) = 35.130$, $p < .001$, $\eta_{p2} = .240$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant, difference between all three levels of the variables with DVN scoring the lowest (M = 3.54), followed by the control group (M = 4.25), followed by the highest score of eye closure (M = 4.56). The main effect of handedness was not significant, $F(1,111) = .091$, $p = .764$, $\eta_{p2} = .001$. The effect of eye movement was also not significant, $F(1,111) = .454$, $p = .502$, $\eta_{p2} = .004$.

*Two-way interactions***.** The interaction between cue type and eye movement was not significant, $F(1,111) = .570$, $p = .452$, $\eta_{p2} = .005$. The interaction between cue type and handedness was not significant, $F(1,111) = .169$, $p = .682$, $\eta_{p2} = .002$. The interaction between distraction and eye movement was not significant, $F(1.447, 160.566) = .001$, $p = .993$, $\eta_{p2} < .001$. The interaction between distraction and handedness was not significant, $F(1.447, 160.566) = .284$, $p = .680$, $\eta_{p2} = .003$. The interaction between distraction and cue type was not significant, $F(1.990, 220.939) = 1.117$, $p = .329$, $\eta_{p2} = .010$. The interaction between eye movement and handedness was not significant, $F(1, 111) = .454$, $p = .502$, $\eta_{p2} = .004$.

Three-way Interactions. The Interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .039$, $p = .844$, $\eta_{p2} < .001$. The Interaction between distraction, eye movement and handedness was not significant, $F(1.447, 160.566) = .006$, $p = .979$, $\eta_p^2 < .001$. The interaction between cue type, distraction and eye movement was not significant, $F(1.990, 220.939) = .172$, $p = .842$, $\eta_p^2 = .002$. The interaction between cue type, distraction and handedness was not significant, $F(1.990, 220.939) = 2.525$, $p = .083$, $\eta_p^2 = .022$.

Four-way Interaction. The Four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(1.990, 220.939) = .432$, $p = .649$, $\eta_p^2 = .004$.

I can see and/or hearing it in my mind.

The descriptive statistics for 'I can see and/or hearing it in my mind.' Likert scale can be found in table 11 below:

Table 11. Mean (SD) I can see and or hear it in my mind scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	5.78	(.86)	31	6.09	(.77)	64	5.93	(.83)
Inconsistent	25	5.77	(.72)	26	5.79	(.69)	51	5.78	(.70)
Control									
Consistent	33	5.44	(1.12)	31	5.56	(1.12)	64	5.50	(1.11)
Inconsistent	25	5.27	(1.17)	26	5.24	(1.18)	51	5.25	(1.17)
DVN									
Consistent	33	4.70	(1.66)	31	4.71	(1.51)	64	4.70	(1.58)
Inconsistent	25	4.65	(1.81)	26	4.68	(1.80)	51	4.66	(1.79)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	4.21	(1.42)	31	4.10	(1.69)	64	4.16	(1.54)
Inconsistent	25	4.53	(1.38)	26	4.29	(1.08)	51	4.41	(1.24)
Control									
Consistent	33	3.77	(1.21)	31	3.72	(1.10)	64	3.75	(1.15)
Inconsistent	25	4.17	(1.27)	26	3.99	(.83)	51	4.08	(1.07)
DVN									
Consistent	33	3.18	(1.33)	31	3.47	(1.44)	64	3.32	(1.38)
Inconsistent	25	3.37	(1.19)	26	3.03	(1.10)	51	3.20	(1.14)

Sphericity. For the distraction variable Mauchly's test indicated violation of the sphericity assumption, $\chi 2(2) = 46.091$, $\varepsilon = .745$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi 2(2) = .1.650$ $\varepsilon = .985$, $p = .438$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 182.395$, $p < .001$, $\eta_{p2} = .622$, indicating greater recall for highly imaginable cues ($M = 5.30$) compared to the low imaginable cues ($M = 3.82$). The main effect of distraction was also significant, $F(1.490, 165.387) = 39.169$, $p < .001$, $\eta_{p2} = .261$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant difference between all three levels of the variables with DVN scoring the lowest (M = 3.97), followed by the control group (M = 4.65), followed by the highest score of eye closure (M = 5.07). The main effect of handedness was not significant, $F(1,111) = .002$, $p = .966$, $\eta_{p2} < .001$. The effect of eye movement was also not significant, $F(1,111) = 771$, $p = .382$, $\eta_{p2} = .007$.

*Two-way interactions***.** The interaction between cue type and eye movement was not significant, $F(1,111) = .712$, $p = .401$, $\eta_{p2} = .006$. The interaction between cue type and handedness was not significant, $F(1,111) = 1.834$, $p = .178$, $\eta_{p2} = .016$. The interaction between distraction and eye movement was not significant, $F(1.490, 165.387) = .11$, $p = .969$, $\eta_{p2} < .001$. The interaction between distraction and handedness was not significant, $F(1.490, 165.387) = .168$, $p = .765$, $\eta_{p2} = .002$. The interaction between distraction and cue type was not significant, $F(2, 222) = .467$, $p = .628$, $\eta_{p2} = .004$. The interaction between eye movement and handedness was not significant, $F(1, 111) = .771$, $p = .382$, $\eta_{p2} = .007$.

Three-way Interactions. The Interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .132$, $p = .717$, $\eta_{p2} = .001$. The interaction between distraction, eye movement and handedness was not significant, $F(1.490, 165.387) = .065$, $p = .888$, $\eta_p^2 = .001$. The interaction between cue type, distraction and eye movement was not significant, $F(1.971, 218.743) = .413$, $p = .659$, $\eta_p^2 = .004$. The Interaction between cue type, distraction and handedness was not significant, $F(1.971, 218.743) = 2.281$, $p = .105$, $\eta_p^2 = .020$.

Four-way Interaction. The four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(1.971, 218.743) = .887$, $p = .412$, $\eta_p^2 = .008$.

I can recall the setting where it occurred.

The descriptive statistics for 'I can recall the setting where it occurred.' Likert scale can be found in table 12 below:

Table 12. Mean (SD) I can recall the setting it occurred scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	6.30	(.71)	31	6.44	(.74)	64	6.36	(.72)
Inconsistent	25	5.97	(.74)	26	6.09	(.77)	51	6.03	(.75)
Control									
Consistent	33	5.80	(1.28)	31	6.00	(1.21)	64	5.90	(1.24)
Inconsistent	25	5.42	(1.31)	26	5.62	(1.29)	51	5.52	(1.29)
DVN									
Consistent	33	5.18	(1.79)	31	5.16	(1.79)	64	5.19	(1.77)
Inconsistent	25	5.21	(1.91)	26	4.88	(2.00)	51	5.05	(1.95)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	5.00	(1.32)	31	4.68	(1.65)	64	4.84	(1.49)
Inconsistent	25	5.14	(1.11)	26	4.97	(.91)	51	5.06	(1.01)
Control									
Consistent	33	4.29	(1.51)	31	4.68	(1.29)	64	4.48	(1.41)
Inconsistent	25	4.65	(1.36)	26	4.54	(1.09)	51	4.59	(1.22)
DVN									
Consistent	33	3.94	(1.71)	31	4.11	(1.65)	64	4.02	(1.67)
Inconsistent	25	3.95	(1.56)	26	3.55	(1.37)	51	3.74	(1.46)

Sphericity. For the distraction variable Mauchly's test indicated violation of the sphericity assumption, $\chi2(2) = 29.165$, $\varepsilon = .811$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi2(2) = .2.230$ $\varepsilon = .980$, $p = .328$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 138.795$, $p < .001$, $\eta_{p}^{2} = .559$, indicating more specific memories recalled for highly imaginable cues ($M = 5.67$) compared to the low imaginable cues ($M = 4.46$). The main effect of distraction was also significant, $F(1.687, 187.289) = 38.053$, $p < .001$, $\eta_{p}^{2} = .255$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant difference between all three levels of the variables with DVN scoring the lowest (M = 4.50), followed by the control group (M = 5.16), followed by the highest score of eye closure (M = 5.57). The main effect of handedness was not significant, $F(1,111) = .579$, $p = .448$, $\eta_{p}^{2} = .005$. The effect of eye movement was also not significant, $F(1,111) = 006$, $p = .938$, $\eta_{p}^{2} < .001$.

Two-way interactions. The interaction between cue type and eye movement was not significant, $F(1,111) = .345$, $p = .558$, $\eta_{p}^{2} = .003$. The interaction between cue type and handedness was not significant, $F(1,111) = 2.109$, $p = .149$, $\eta_{p}^{2} = .019$. The interaction between distraction and eye movement was not significant, $F(1.687, 187.289) = .835$, $p = .414$, $\eta_{p}^{2} = .007$. The interaction between distraction and handedness was not significant, $F(1.687, 187.289) = .171$, $p = .807$, $\eta_{p}^{2} = .002$. The interaction between distraction and cue type was not significant, $F(2, 222) = .133$, $p = .876$, $\eta_{p}^{2} = .001$. The interaction between eye movement and handedness was not significant, $F(1, 111) = .382$, $p = .538$, $\eta_{p}^{2} = .003$.

Three-way Interactions. The Interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .228$, $p = .634$, $\eta_{p}^{2} = .002$. The Interaction between distraction, eye movement and handedness was not significant, $F(1687, 187.289) = .525$, $p = .562$, $\eta_{p}^{2} = .005$. The interaction between cue type, distraction and eye movement was not significant, $F(1.\ 2, 222) = 905$, $p = .406$, $\eta_{p}^{2} = .008$. The interaction between cue type, distraction and handedness was not significant, $F(2, 222) = 2.911$, $p = .057$, $\eta_{p}^{2} = .026$.

Four-way Interaction. The four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(1.971, 218.743) = .491$, $p = .613$, $\eta_p^2 = .004$.

It comes to me as a coherent story.

The descriptive statistics for ‘It comes to me as a coherent story.’ likert scale can be found in table 13 below:

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Table 13. Mean (SD) It comes to me as a coherent story score as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
High-imaginability Cues									
Eyes Closed									
Consistent	33	5.44	(.98)	31	5.47	(1.10)	64	5.46	(.88)
Inconsistent	25	5.43	(.85)	26	5.54	(.54)	51	5.48	(1.03)
Control									
Consistent	33	5.25	(1.07)	31	5.19	(.96)	64	5.22	(1.01)
Inconsistent	25	5.00	(1.21)	26	4.90	(.95)	51	4.95	(1.09)
DVN									
Consistent	33	4.36	(1.44)	31	4.22	(1.48)	64	4.30	(1.45)
Inconsistent	25	4.48	(1.68)	26	4.35	(1.70)	51	4.41	(1.67)
Low-imaginability Cues									
Eyes Closed									
Consistent	33	3.62	(1.41)	31	3.56	(1.62)	64	3.60	(1.50)
Inconsistent	25	3.73	(1.59)	26	3.82	(1.45)	51	3.77	(1.50)
Control									
Consistent	33	3.41	(1.18)	31	3.11	(1.10)	64	3.27	(1.14)
Inconsistent	25	3.66	(1.45)	26	3.18	(1.16)	51	3.41	(1.32)
DVN									
Consistent	33	3.09	(1.25)	31	2.72	(1.06)	64	2.91	(1.17)
Inconsistent	25	2.64	(1.37)	26	2.40	(.92)	51	2.52	(1.16)

Sphericity. For the distraction variable Mauchly’s test indicated violation of the sphericity assumption, $\chi2(2) = 36.924$, $\varepsilon = .778$, $p < 0.01$. The interaction between distraction and cue type was not significant, $\chi2(2) = 1.474$ $\varepsilon = .879$, $p = .987$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 252.117$, $p < .001$, $\eta_{p2} = .694$, indicating more specific memories recalled for highly imaginable cues ($M = 4.97$) compared to the low imaginable cues ($M = 3.25$). The main effect of distraction was also significant, $F(1.617, 179.485) = 35.083$, $p < .001$, $\eta_{p2} = .240$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant, difference between all three levels of the variables with DVN scoring the lowest (M = 3.53), followed by the control group (M = 4.21), followed by the highest score of eye closure (M = 5.78). The main effect of handedness was not significant, $F(1,111) = .060$, $p = .807$, $\eta_{p2} = .001$. The effect of eye movement was also not significant, $F(1,111) = 1.553$, $p = .215$, $\eta_{p2} < .014$.

*Two-way interactions***.** The interaction between cue type and eye movement was not significant, $F(1,111) = .643$, $p = .424$, $\eta_{p2} = .006$. The interaction between cue type and handedness was not significant, $F(1,111) = .020$, $p = .424$, $\eta_{p2} = .006$. The interaction between distraction and eye movement was not significant, $F(1.617, 179.485) = .775$, $p = .437$, $\eta_{p2} = .007$. The interaction between distraction and handedness was not significant, $F(1.617, 179.485) = .443$, $p = .601$, $\eta_{p2} = .004$. The interaction between distraction and cue type was not significant, $F(2, 222) = .372$, $p = .690$, $\eta_{p2} = .003$. The interaction between eye movement and handedness was not significant, $F(1, 111) = .012$, $p = .914$, $\eta_{p2} < .001$.

Three-way Interactions. The interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .001$, $p = .979$, $\eta_{p2} < .001$. The interaction between distraction, eye movement and handedness was not significant, $F(1.617, 179.485) = .118$, $p = .847$, $\eta_{p2} = .001$. The interaction between cue type, distraction and eye movement was not significant, $F(1. 2, 222) = .256$, $p = .775$, $\eta_{p2} = .002$. The interaction between cue type, distraction and handedness was significant, $F(2, 222) = 3.607$, $p = .029$, $\eta_{p2} = .031$.

Simple interaction effects. This was assessed further by simple interaction effects at each level of handedness creating a 2(cue type; consistent vs inconsistent) by 3(distraction; DVN vs control vs eye closure) repeated measures ANOVA.

For the consistent handed group Mauchly's test indicated violation of the sphericity assumption for the distraction variable, $\chi2(2) = 22.621$, $\varepsilon = .766$, $p < 0.01$. The was no significant violation of the sphericity assumption for the interaction between cue type and distraction variable $\chi2(2) = 2.418$, $\varepsilon = .963$, $p = .298$.

The main effect of cue type was significant, $F(1, 63) = 166.595$, $p < .001$, $\eta_{p2} = .726$. With the concrete cues (M = 4.99) scoring significantly higher than the abstract cues (M = 3.26). The main effect of distraction was significant, $F(1.562, 98.424) = 15.340$, $p < .001$, $\eta_{p2} = .196$. The interaction between cue type and distraction was also significant, $F(2, 126) = 3.295$, $p = .004$, $\eta_{p2} = .050$. see figure X below.

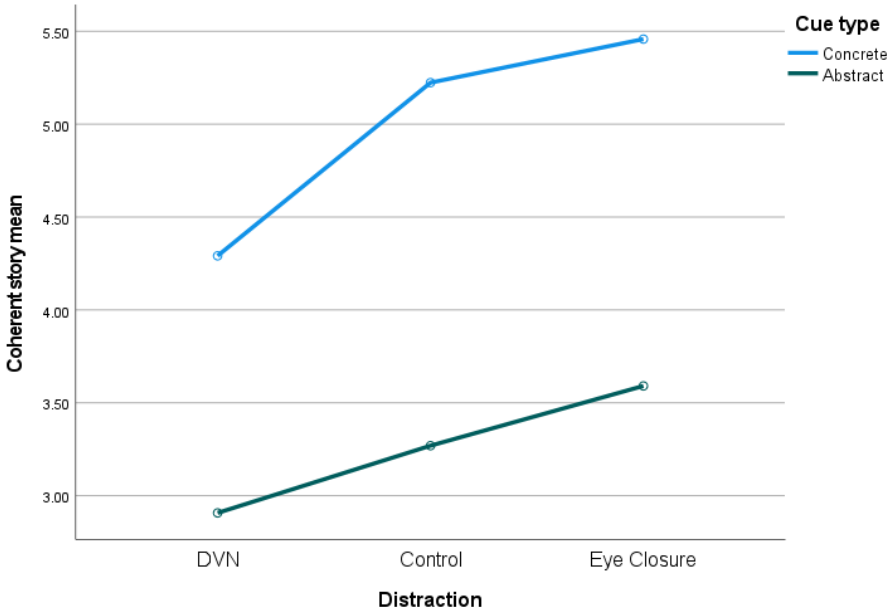

Figure 8 - Experiment Three - The interaction between cue type and distraction in consistent handed individuals.

Simple main effects using Bonferroni corrections were used to unpick the interaction using three within subjects t-tests. The difference between DVN concrete cues (M = 4.29) and DVN abstract cues (M = 2.91) was significant, $t(63) = 8.359$, $p < .001$, d = 1.132. The difference between control concrete cues (M = 5.22) and control abstract cues (M = 3.27) group was significant, $t(63) = 10.182$, $p < .001$, d = 1.54. The difference between eye closure concrete cues (M = 5.46) and eye closure abstract cues (M = 3.59) group was significant, $t(63) = 8.590$, $p < .001$, d = 1.74.

For the inconsistent handed group Mauchly's test indicated violation of the sphericity assumption for the distraction variable, $\chi2(2) = 14.315$, $\varepsilon = .798$, $p < 0.01$. The was no significant violation of the sphericity assumption for the interaction between cue type and distraction variable $\chi2(2) = .442$, $\varepsilon = .991$, $p = .802$.

The main effect of cue type was significant, $F(1, 50) = 96.682$, $p < .001$, $\eta_{p2} = .661$. With the concrete cues (M = 4.95) scoring significantly higher than the abstract cues (M = 3.24). The main effect of distraction was significantly different $F(1.640, 82.00) = 20.629$, $p < .001$, $\eta_{p2} = .292$. The main effect was assessed using Bonferroni adjusted comparisons. There was a significant difference between DVN group (M = 3.47) and the control group (M = 4.18) (***p*** < .001, 95% *CI* of the difference = .609 to 1.718). There was a significant difference between DVN group (M = 3.47) and the eye closure group (M = 4.63**)** (***p*** < .001, 95% *CI* of the difference = .057 to 842). There was also significant difference between the control group (M = 4.18) and the eye closure group (M = 4.633) (***p*** = .020, 95% *CI* of the difference = -.057 to .842)**.** The interaction between cue type and distraction was not significant, $F(2, 100) = .952$, $p = .390$, $\eta_{p2} = .019$.

Four-way Interaction. The four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(2, 222) = .073$, $p = .930$, $\eta_{p2} = .001$.

Direct vs generative recall

In this final analysis section, the responses of direct recall vs generative recall. The scores were coded by give a point to the participants for direct retrieval and no points for generative retrieval, each participant's total was then calculated for each condition. The scores were then entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 3(distraction: eye closed vs. control vs. DVN) within-subjects by 2(cue-type: high vs. low imageable) within-subjects by 2(handedness: consistent vs. inconsistent) between-subjects mixed-ANOVA.

The descriptive statistics for 'direct vs generative recall' can be found in table 14 below:

Table 14. Mean (SD) directive vs generative scores as a function of eye movement, eye-closure, handedness and cue-type.

	Eye Movement Condition								
	Horizontal *n* = 58			Fixation *n* = 57			Total *n* = 115		
Distraction & Handedness	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
				High-imaginability Cues					
Eyes Closed									
Consistent	33	2.21	(.93)	31	2.06	(.85)	64	2.14	(.89)
Inconsistent	25	2.04	(.73)	26	1.92	(.84)	51	1.98	(.79)
Control									
Consistent	33	2.15	(.80)	31	2.26	(.85)	64	2.20	(.82)
Inconsistent	25	2.04	(.89)	26	2.12	(.91)	51	2.07	(.89)
DVN									
Consistent	33	2.00	(.79)	31	1.84	(.100)	64	1.92	(.90)
Inconsistent	25	1.92	(.86)	26	1.88	(.99)	51	1.90	(.51)
				Low-imaginability Cues					
Eyes Closed									
Consistent	33	1.03	(.85)	31	.90	(.70)	64	.96	(.77)
Inconsistent	25	1.04	(1.02)	26	1.19	(.89)	51	1.12	(.95)
Control									
Consistent	33	1.12	(.99)	31	1.03	(1.02)	64	1.08	(1.00)
Inconsistent	25	1.08	(1.04)	26	.96	(.72)	51	1.02	(.88)
DVN									
Consistent	33	1.02	(.81)	31	1.00	(.89)	64	1.02	(.85)
Inconsistent	25	1.08	(1.00)	26	.65	(.69)	51	.68	(.87)

Sphericity. For the distraction variable Mauchly's test indicated no violation of the sphericity assumption, $\chi 2(2) = 4.117$, $\varepsilon = .965$, $p = .128$. The interaction between distraction and cue type was also not significant, $\chi 2(2) = .734$, $\varepsilon = .993$, $p = .693$.

Main effects. The main effect of cue-type was significant, $F(1,111) = 150.732$, $p < .001$, $\eta_{p2} = .576$, indicating more direct recall for highly imaginable cues ($M = 2.04$) compared to the low imaginable cues ($M = 1.01$). The main effect of distraction was also significant, $F(2, 222) = 3.301$, $p = .039$, $\eta_{p2} = .029$. Follow up tests using Bonferroni corrections were used to unpick the main effect. There was a significant effect between DVN group (M = 1.43) and the control group (M = 1.60) (p = .047, 95% CI of the difference = -.336 to -.002). However, the difference between DVN (M = 1.43) and the eye closure group (M = 1.55) was not significant (p = .267, 95% CI of the difference = -.303 to .054). The difference between the control group (M = 1.60) and the eye closure group (M = 1.55) was also non-significant (p = .1.00, 95% CI of the difference = -.195 to .106). The main effect of handedness was not significant, $F(1,111) = .864$ $p = .473$, $\eta_{p2} = .005$. The effect of eye movement was also not significant, $F(1,111) = .864$, $p = .335$, $\eta_{p2} = .008$.

Two-way interactions. The interaction between cue type and eye movement was not significant, $F(1,111) = .128$, $p = .721$, $\eta_{p2} < .001$. The interaction between distraction and eye movement was not significant, $F(2, 222) = .683$, $p = .506$, $\eta_{p2} = .006$. The interaction between distraction and handedness was not significant, $F(2, 222) = .251$, $p = .778$, $\eta_{p2} = .002$. The interaction between distraction and cue type was not significant, $F(2,222) = .339$, $p = .713$, $\eta_{p2} = .003$. The interaction between eye movement and handedness was not significant, $F(1, 111) < .001$, $p = .983$, $\eta_{p2} < .001$. The interaction between Cue type and handedness was also not significant, $F(1,111) = .241$, $p = .625$, $\eta_{p2} = .002$.

Three-way Interactions. The interaction between cue type, eye movement and handedness was not significant, $F(1, 111) = .073$, $p = .787$, $\eta_{p2} = .001$. The interaction between distraction, eye movement and handedness was not significant, $F(2, 222) = .579$, $p = .561$, $\eta_{p2} = .005$. The interaction between cue type, distraction and eye movement was not significant, $F(2, 222) = .721$, $p = .487$, $\eta_{p2} = .003$. The interaction between cue type, distraction and handedness was not significant, $F(2, 222) = 1.063$, $p = .347$, $\eta_{p2} = .009$.

Four-way Interaction. The Four-way interaction between cue type, distraction, eye movement and handedness was also not significant, $F(2, 222) = .859$, $p = .425$, $\eta_{p2} = .008$.

Further Analyses of the Autobiographical Memory Questionnaire Responses: Assessing Highly Specific Memories.

In a similar manner to experiment two, the research also attempted to explore the effects of the independent variables on truly episodic scores (AMT scores of only maximum value of 4). Unfortunately, due to the adjustments in the methodology (adjustments to within-subject variables) and the lower percentage of max AMT scores, this led to the removal of 68% of the concrete responses and 78% of the abstract responses. Consequently, it was not possible to complete the exact inferential statistics due to missing cells.

However, it was possible to run a version of the analysis with the concrete and abstract scores averaged to give an overview of some potential findings. The full analysis and outputs can be found in the appendix (see appendix 5b, page 313) and show that none of the experimental manipulations had any significant effects upon the variety of dependent variables.

This outcome was rather unexpected and does not match with the presented literature presented above (please see general introduction). However, there are several potential methodological explanations which could account for these findings. Firstly, a significant number of responses have been removed from the original data set leaving some cells with very few data samples, with some groups having only two subjects per cell being compared with comparable cells of 38 subjects. Secondly and a somewhat related factor is that several of the cells are reporting very close to ceiling effects with means of the maximum available scores with zero deviation from these scores presented. Both factors are related to a breach in the core assumptions of the ANOVA analysis and therefore mean the findings and results are very unreliable (Field, 2013).

Discussion

Overview of Discussion.

The results from the current experiment are considered below. This is done with regard to the hypothesised main effects and interactions to maintain continuity with the results section and to provide general structure for understanding of the main findings. Significant outcomes are considered in the "Review and Discussion of Current Findings" below. These are explained in the context of theories and conjectures as discussed in the general introduction to this thesis and the introduction for the current experiment. Where predictions were not borne out, possible shortcomings are assessed.

Review & Discussion of the Current Findings.

Main effects

The most robust result from Experiment three was yet again the main effect of cue-type in a very similar way to Experiment two. Highly imageable cues led to the recall of more specific autobiographical memories, were associated with higher levels of belief/recollection & component processes as measured by the Rubin et al scales. These findings support H4a & H4b and replicate similar past work (e.g., Rasmussen, & Berntsen, 2014; Williams, Healy, & Ellis, 1999), and can be explained by such cues providing more effective access to lower levels of the autobiographical knowledge base in the form of event-specific knowledge.

The main effect of distraction was also significant. The adjustments to Experiment two, from a between to a within-subjects design, the current experiment found evidence supporting both hypothesis H8a and H8b with eyes-closed > eyes-open > DVN in every dependent variable. This effect therefore replicates and expands the findings of previous research (e.g., Anderson et al., 2017) in which both high and low imaginability cues were affected by the presence of dynamic visual noise. However, this experiment expands the current research by adding an eye closure variable to the experimental design. The only exception to this finding was that of the direct vs generative dependent variable in which the only effect was of the DVN condition scoring lower than the eye open group. However, as stated in the introduction the link between the retrieval strategy and the other outlined variables was not expected to be as clear and perfect as the other dependent variables (e.g., Harris & Berntsen., 2019).

The effects of eye movements were not significant for either the specific qualities of the recalled event or in the subjective qualities of the memories recalled. Therefore, both hypothesis H2a and H2b are rejected in the current experiment. There is no clear reason for the difference between the current and Experiment two as they were practically identical along many important dimensions, as in study two hypotheses H2a was accepted even when H2b was rejected. This type of inconsistent effect appears to follow the same pattern as Roberts, Fernandes & MacLeod., (2019) who also found inconsistent findings when completing a series of conceptual replications of previous research studies.

The main effects of handedness were not significant in either the specific qualities of the recalled event or in the subjective qualities of the memories recalled. There is no apparent reason for this lack of significant effects, especially when main effects were seen in Experiment 2 for both of the 'subjective experience' category of questions which consisted of '[I] travel back to the time when it happened' and 'I can see and/or hearing it in my mind'. This lack of replication within eye movement-based research is something which has been outlined by Roberts, Fernandes & MacLeod., (2020) and will be outlined in more detail in the general discussion of the project.

Interactions

The current research experiment did not find any significant two-way interaction effects between any of the variables. This is somewhat unexpected as outlined in the introduction and based upon the findings of Experiment 2 which showed a significant two-way interaction between handedness and cue-type on the setting of the recall and between eye movement and eye closure on the story-like narrative dependent variable.

The non-significant interaction between eye movement and cue-type does not support the top-down hypothesis as outlined in the introduction. This was somewhat unexpected due to the large body of literature supporting the top-down hypothesis (Edlin & Lyle, 2013; Lyle & Edlin, 2015). The section which evidences the lack of support for the top-down model of processing in autobiographical recall the most comes from the direct vs generative dependent variable where participants scored higher for reporting direct recall and lower for generative recall. The lack of interaction between eye movement and cue-type on this category of recall is even more unexpected as it was hypothesised that generative recall would be less imaginable and therefore benefit more from top-down processing.

One potential development for future research in this area would be to record response times when completing the data collection. This is based upon research by Uzer, Lee & Brown., (2012) and could help filter and classify direct or generative recall. For example, the reported the median response time for direct recall was around four seconds and the median recall time for generative recall was around fourteen seconds. Values which are significantly different from these reported averages could be filtered out to ensure the reported retrieval method was likely the correctly used one. This said however, there have been recent reports which state that direct and generative recall are two sides of the same coin and that the differences between them are just a statistical anomaly (Gatti, Somos, Mazzoni & Jellema., 2022).

The lack of interaction between eye movement and eye closure in Experiment 2 (except in the story coherence condition) as well as in this current experiment offers more support for the concept that these manipulations influence separate cognitive processes. However, the lack of consistent effects of eye movements (absent in Experiment 3) and eye-closure (absent in Experiment 2) makes this difficult to assess.

Handedness did not interact with eye movements in this study or in study two as might be expected given the HERA model. That is, consistent handers would be expected to show a greater effect of horizontal saccades as their baseline level of hemispheric interaction would be expected to be lower (because of a smaller corpus callosum) and thus have more room for improvement. In past work, this form of interaction has been inconsistently observed (e.g., Edlin & Lyle, 2013; Roberts, Fernandes & MacLeod, 2020).

Higher-order interactions

A three-way interaction was found between handedness, cue-type, and distraction for the 'It comes to me as a coherent story' dependent variable. This interaction shown that when split by handedness, the consistent-handed individuals showed significant main effects of distraction and cue-type plus a significant interaction with when further unpicked showed significant differences at each level of the three within subjects t-tests exploring each level of distraction by cue type. The interesting part of this finding was that the effect sizes were larger as the levels of distraction were lowered. This finding is consistent with prior work that shows DVN to reduce concreteness effects in episodic memory, at least for word lists (Chubala, Surprenant, Neath, & Quinlan, 2018; Parker & Dagnall, 2010). Here, the results suggest that story coherence is reduced by DVN when recalling memories to concrete cues. This could be due to distraction impairing the use of imagery. The result that eye-closure further increases story coherence would also be consistent with the use of imagery in this respect. The new finding here is that this effect was dependent on handedness. The inconsistent-handed group, while showing significant main effects of eye closure and distraction showed no interaction between distraction and cue type.

However, caution must be exercised when interpreting this three-way interaction. The fact that none of the other similar dependent variables showed signs of significant two- or three-way interactions as well as none of the current research showing any main effects of handedness are cautionary signs that more additional research is needed.

Chapter 5: General discussion

Introduction

In this section of the thesis a general discussion of the current research findings will be overviewed, and contributions to current research field will be outlined. Finally, concepts for future research and development for this area of research will be explored based upon the outlined evaluation points.

Major Findings from Experiments one to three

Experiment 1

This experiment extends previous research by examining the effects of saccadic eye movements in older and younger adults. Autobiographical episodic and semantic memory fluency was assessed in younger (age range 18-35, mean = 22.50), and older (age range 55-87, mean = 70.35) participants following saccadic (vs. fixation control) manipulations. Main effects of eye movements and age were found for episodic autobiographical memory (greater fluency after eye movements and in younger participants). Semantic autobiographical memory showed a main effect of age (greater fluency in younger participants), whereas general semantic memory showed no effect of age or eye movement.

The unique contributions of Experiment 1 are that **(i)** saccadic horizontal eye movements can enhance episodic personal memory in older individuals, **(ii)** a dissociation between episodic and semantic (personal and general) was found as a function of eye movements in the elderly and extends that found with younger subjects (e.g., Parker et al., 2013).

Experiment 2

As there were no effects of eye-movements upon personal semantic memory or general semantic memory in Experiment 1, this could have been taken to indicate the effects are limited to the retrieval of event-specific knowledge from the autobiographical knowledge base. Additionally, the effects were found using only one memory enhancing technique (eye movements) and were limited to the use of only one ABM task. Therefore Experiment 2 was designed to extend this work by a second memory enhancement technique of eye closure. The experiment also adjusted the dependent variable from memory fluency to the Galton Crovitz word-cue test to variables to measure both the objective specificity of recall and its associated phenomenological qualities. Finally, the cue words used in the experiment were also manipulated to be half concrete and highly imaginable terms while the other half were less imaginable and abstract.

The experiment found consistent effects of cue-type on both the specificity of recall and its associated phenomenological qualities with the concrete cues providing a significantly higher score. The effects of eye movements were observed on the specificity of the recalled memory, but not on the associated phenomenological qualities. Finally, the effects of eye closure were only found upon the seeing and hearing category of recall.

The unique contributions of Experiment 2 are that eye movements had a significant main effect upon autobiographical memory specificity. It was also discovered that cue-type had a significant effect upon specificity and the associated phenomenological aspects of the recalled memory.

Experiment 3

As Experiment 2 produced some unexpected null findings (lack of interactions and main effects of eye closure & eye movement), the aim of Experiment 3 was to further the results of the second experiment through a set of methodological changes to the manipulations and some of the measurements. The study was adjusted from a between-subjects design to a within-subjects design and a new variable of dynamic visual noise was added. Therefore, within this experiment each participant was placed randomly into each of the three distraction conditions (DVN, Control & eye closure), participants were still place between subjects for the eye movement conditions.

The experiment found there was still a consistent effect of cue type with concrete cues again still scoring significantly higher in the specificity of the recalled memory, but not on the associated phenomenological qualities. However, this time there was a significant effect of a distraction with all variables (except direct vs generative recall which only showed the negative effects of DVN) showing significant differences (eye closure > control > DVN). This is the first-time eye-closure and DVN distraction effects have been shown in autobiographical memory using the cue-word technique. The most somewhat unexpected finding of the study however was the lack of eye movement effects in all experimental conditions (which is overviewed in the section below).

General issues in the current research

Inconsistent eye movement findings

The current set of three experiments sought to increase and enhance episodic autobiographical recall in the healthy public (Experiments 1-3) and in the elderly (Experiment 1) using a range of relatively novel techniques such as saccadic horizontal eye movements (Experiments 1-3) and eye-closure (Experiments 2-3).

The findings of the research experiments did not find as clear-cut findings as hypothesised. Study 1 was able to find significant main effects of aging and eye movements upon episodic autobiographical memory using memory fluency techniques as was hypothesised. However, the results were only partially replicated using cue-word techniques in Experiment 2 (memory specificity) and found no significant effects at all in study 3 when using the AMT with repeated measures designs.

The finding of null results in saccadic induced retrieval enhancement research is not unheard off. Matzke et al., (2015) failed to produce SIRE effects when following the procedures outlined by Lyle et al (2008). However, the validity and reliability of such research replications has been strongly critiqued by writers such as Phaf (2016) who stated that the writers of the replication were more focused upon creating a statistical hypothesis and satisfying *P* values rather than exploring the mechanisms relevant to memory enhancement. Phaf (2016) warns that by solely following *P* values reported in studies and not the trends, outcomes and meta-analyses there is a risk of not seeing the bigger picture.

Roberts, Fernandes & McLeod., (2020) have also provided findings similar to those reported here (Experiments 1-3) by presenting a two-study experiment set replicating the work of Chrisman et al., (2003). The researchers presented only weak but significant results for the direct manipulation (study 1) and found non-significant effects when horizontal and vertical eye movements conditions were manipulated separately (study 2).

These findings are of particular relevance to the current research as even though they were replication studies, rather than more investigative research as exemplified in the current set of experiments, they have also found mixed results. Finally, it should also be mentioned that due to publication bias with null results there may also be other such findings of mixed or null results which are similar in nature to the current research experiment that have failed to be published (Kepes, Banks & Oh., 2012).

Lack of interaction effects

One of the main observations from all three of the research experiments is the lack of predicted interactions between key variables. There were no two-way interactions (or covariance effects) reported in study one and only a few sporadic interactions reported in Experiment 2 (two two-way interactions and one three-way interaction) and Experiment 3 (only one two-way interaction, which was not consistent with study 2).

The most unexpected missing interaction effect was that of eye movement and handedness as many previous research papers have outlined the link between SIRE and consistently handed or strongly right-handed individuals (see general introduction, SIRE effects). Research by Qin et al., (2021) overviews the standard observable strength of this effect in other research projects by using moderation analysis upon a selection of twenty-two recent research papers and found significant evidence to support the conclusion that handedness was a significant moderator of the SIRE effect. In a somewhat similar manner, it was also expected that there would be interactions between eye movement and eye closure effects, especially if both effects are regulated by top-down processing mechanisms.

Though the current study did find a few sporadic interaction effects, the infrequency of the effects as well as difference in outcomes between the studies suggest these findings require further research.

Theoretical implications & issues

SIRE effects

Regarding the top-down account, some evidence could be taken to support the main claims of this theory. For example, the increase in the number of specific memories recalled and the increase in memory fluency are both consistent with the involvement of enhanced top-down processing. However, this conclusion is made more nuanced by the fact that eye movements did not interact with cue-type. Fully understanding the precise significance of this is for future work and needs to consider the use of measures of executive functioning and how (or if) different cues (such as the ones used in Experiments 2 and 3) actually do instigate different processes. See the sections “SIRE, experimental design & top-down processing” and “The use of concrete and abstract cue types” below.

Regarding HERA, the absence of interactions between eye movements and handedness is notable. In section on “SIRE and handedness” in the general introduction, it was hypothesised that SIRE effects should be larger in consistent and especially strongly right-handed individuals. This is because the degree of hemispheric interaction is considered to be lower in such people and therefore, they have more to gain by receiving a boost in hemispheric interaction via eye movements. As this was not found, this goes against the HERA account. It is not clear why this was so, but past work has been somewhat inconsistent in terms of this findings (see Brunyé, et al., (2009) and Lyle & Jacobs, (2010) for differences). Clearly, this demands additional investigation about the conditions under which handedness moderates the effects for eye movements.

Eye-closure effects

The findings for the eye closure research are somewhat mixed with the clear and consistent findings in Experiment 3 and the somewhat lack of main effects and interactions in Experiment 2. However, from these findings there are still a few implications which can be taken and used as a basis for future research.

There appears to be a good level of support for the domain-general account of eye closure as when participants were asked to close their eyes in Experiment 3 the level of recall significantly increased in all conditions, this is congruent with research such as Glenberg et al., (1998) who theorised that freeing up attentional resources would help increase the level of recall. This was a lot easier to control and compare when using a within-subject methodology compared to a between-subjects methodology as the location of the participants was not fully controlled due to covid-19 pandemic and some locations may have been more naturally stimulating than others creating a unintended confounding variable.

There also appears to be a good level of support for the domain specific theory of eye closure as each of the study's dependent variables showed a significant negative main effect of DVN and a significant positive effect of eye closure. As outlined in the general introduction, activities which vie for control of the module specific subsystems of working memory (visuospatial sketchpad, phonological loop & Episodic buffer, Baddeley, (1986)) are theorised to lower episodic recall. DVN is theorised to be disruptive to visualisation-based tasks (Quinn & McConnell, 1996) whereas eye closure is theorised to help free up these systems and aid the recall of visual details (Vredeveldt et al., 2012, 2014).

This said however, the current experiments were not designed to unpick the theoretical explanations of eye closure effects and therefore these implications are simply a starting point for future research and experimental study. There is also the fact that Experiment 2 found far less clear evidence of eye closure effects, which are evaluated in the next section of this report but cannot be ignored.

Limitations and future research

SIRE, experimental design & top-down processing

The current research (Experiments 2 and 3) only found effects of eye movements when the eye-closure was manipulated between-subjects. This is not something which is currently explicable by existing research literature. These findings therefore need to be assessed in future research by a full factorial manipulation of both eye movement and eye-closure as both between and within-subject variables. This would allow random allocation of subjects to each of the conditions, and thus avoid the pitfalls of across experiment comparisons. Additionally, it would permit an evaluation of the extent to which the nature of the experimental design influences the outcomes of these variables.

In subsequent research, it would also be beneficial to further address the possible role of top-down processing In SIRE effects. For example, Lyle and Edlin (2015) used a retrieval practice paradigm or Lyle (2018) used a free vs. cued recall paradigm when exploring eyewitness testimony. In both these examples, manipulations and tests were used to vary the extent to which the contribution of top-down control would be required for retrieval. One way this type of work could be advanced is by incorporating individual difference measures of executive functioning into the experiment. For example, by comparison of individuals who differ in their level of executive skills as assessed by tasks that measure inhibitory control, planning, attentional flexibility. One prediction arising from this would be that eye movements would interact with executive control such that greater SIRE effects would be more likely observed for those lower in such abilities.

Although this thesis did not aim to distinguish between alternate theoretical accounts of SIRE effects, it did make use of manipulations (i.e., cue-type) that were premised on the top-down account. Future work should focus more specifically on the design of experiments that tease apart the top-down from the HERA account. This means designing situations in which the predictions of these explanations can be differentiated. One relatively straightforward design would incorporate additional eye movement conditions as HERA makes the prediction that only bilateral-horizontal saccades should produce enhancement effects. Thus, prior to recall, participants would be required to make either horizontal or vertical saccades (compared to fixation). Although this has been done in previous work (e.g., Christman et al., 2003; Parker & Dagnall, 2007), this has not yet been performed with autobiographical memories.

Additionally, the top-down explanation makes the prediction that enhancement effects would be more pronounced in situations where retrieval was more demanding (Lyle & Edlin, 2015). Of course, this reasoning underpinned the manipulation of cue-type. However, there are other ways in which the demands on retrieval could be varied experimentally (as opposed to considering individual differences as mentioned above). For example, requesting recall from different time periods. Based on the notion that recall from more distant time periods is more attentionally demanding (e.g., Haj, Boutoleau-Bretonnière, & Janssen, 2021), the top-down account would predict larger enhancement effects from such periods.

These suggestions could be combined and assessed in either a behavioural experiment or one in which neural activity is monitored. Surprisingly little work has been done in this regard (to my knowledge, all of the existing ones which were outlined in the introduction) and fMRI would be suited to this endeavour. The important pattern of activations would be those after eye movements during recall. Principally, HERA-like activations (Habib, Nyberg, & Tulving, 2003; Johansson et al., 2020) would be predicted during recall following only horizontal saccades and positively correlated with retrieval success or specificity measures of episodic detail. The top-down account would expect similar activations in both horizontal and vertical saccade conditions. It would also predict regional interactions and enhanced functional connectivity between anterior and posterior neural sites. Based on the attention to memory hypothesis (AtoM) (Burianová, Ciaramelli, Grady, & Moscovitch, 2012; Ciaramelli, Grady, & Moscovitch, 2008), that has been integrated with the top-down account of SIRE effects (Lyle & Edlin, 2015), this would involve the dorsal frontal and dorsal parietal regions. This would be predicted to be mediated by the degree of retrieval effort (vs. direction of eye movement) and greater for memories that are more difficult to retrieve (i.e., more distant memories in the example used here). Of course, only future work will be able to assess these predictions and the utility of these models.

Eye-closure effects & experimental design

In a similar manner to SIRE effects, the influence of eye closure was also different between Experiment 2 and 3. Experiment 2 only found significant main effects of eye closure of hearing and seeing the event in one’s mind (see discussion section of Experiment 2 for overview) when testing was between-subjects. However, when testing within-subjects Experiment 3 found significant main effects for distraction in all experimental conditions and following the hypothesised order of eye closure > control > DVN (except in the case of direct vs generative which found only control groups significantly higher than DVN conditions).

It was hypothesised that lack of EC effects found in experiment two may have been caused by the participants not having an appropriate comparison standard between the eyes open and eye closed conditions as they did in within Experiment 3. Of course, this explanation relies on a cross-experiment comparison. Ideally a between vs. within-subject comparison would be done within a single design. One potential route for future research therefore could be to directly compare experimental designs. Additionally, it would be valuable to more directly assess if and how participants adjust their responses across EC/interference conditions (i.e., if their responses are biased or changed by a shift from and eyes open to closed conditions).

The use of concrete and abstract cue types.

Another expansion upon the current research would be to explore the effects of cue type (abstract vs concrete) when focusing on retrieval based upon executive function. Research by Anderson, Dewhurst & Dean., (2017) showed evidence that disrupting executive resources (e.g., irrelevant picture task) had an effect upon generative recall, to low imagery cues, but not upon direct recall. Thus, supporting the idea that cues with a low imagery value demand the involvement of top-down control. However, later research by Guler & Mackovichova., (2019) found no interaction between measures of executive function, such as flanker inhibitory control (in the form of the attentional network test) (Fan et al., 2002), dimensional change card sort test (DCCS), (Zelazo, 2006) & list sorting working memory test (Mungas, Reed, Crane, Hannn & González, 2004) and word cue type. Instead, participants with higher executive functioning recalled significantly more specific memories compared to the lower participant group irrespective of cue-type.

Consequently, further research needs to clarify how cue-type interacts with retrieval and executive process *manipulations* (via experimental means) and *measures* (though the use of individual difference assessments and classification of individual differences in such functions). Ideally, a combination of these should reveal the extent to which the types of cues used in Experiments 2 and 3 do indeed invoke top-down control and thus provide greater clarity on the results found here and the value of testing the top-down account of SIRE via a manipulation of cue-type. If different types of cues (low vs. high imageability) do lead to a greater (vs. lesser) need for control processes than the top-down account of SIRE effects is clearly not supported by the current findings. On the other hand, if such cues do not lead to different processes, then the manipulation used in Experiments 2 and 3 are not a fair test of the top-down hypothesis and other manipulations are needed.

Aging and the autobiographical memory interview

Experiment 1 made use of a fluency task to assess autobiographical retrieval and the episodic-semantic distinction. This could be extended to include other important measures of these concepts. For example, the autobiographical interview, as noted above (see general introduction), assesses the episodic and semantic components of personal memory *within* a recall protocol as opposed to separate recall trials as done in Experiment 1 (Levine et al., 2002). This technique makes use of a scoring system that quantifies the internal (episodic or event-specific) and external (including semantic) qualities of memory across several lifetime periods.

An advantage of this technique is that is allows for the objective assessment of personal memory elements as they are freely recalled in a natural manner without the need for artificially distinguishing between components of personal memory with separate testing trials. Findings using the autobiographical interview show age to be positively associated with a decline in internal and event-specific detail and a preservation or even increase in semantic recall (Levine et al., 2002; St. Jacques, & Levine, 2007). Use of the autobiographical interview would be particularly valuable in the context of age and SIRE effects for several reasons. Firstly, it would ensure that the current results are not limited to one particular method. Secondly, it would allow an appraisal of how eye movements influence components of *narrative* recall. This is an important consideration especially in an applied context if eye movements were to be used to improve memory in the elderly or other populations.

Another potential explorative pathway for this research is a combination of SIRE effects and other techniques such as reminiscence therapy (Meléndez et al., 2015) or life review (Gonçalves, Albuquerque, & Paúl, 2009) techniques. This more therapeutic programme could focus on if eye movement effects increasing the fluency (Experiment 1) and specificity (Experiment 2) of autobiographical memory could lead to a beneficial impact upon a participant's wellbeing and mental health.

Concluding comments

In summary, this section has provided a detailed overview of each of the three research experiments and their unique contributions to the current research field. Additionally, a discussion of the more general issues with the current research methodology and findings as well as the associated theoretical implications was considered. Based upon these concepts several areas of future research were presented based upon top-down processing, eye closure effects and the future use of abstract vs concrete cues as prompts to recall.

To conclude, this thesis extends past work on memory enhancement and found both eye movements and eye-closure to improve episodic autobiographical recollection. However, the variability in some of the outcomes strongly suggests that the influence of these variables is likely to be moderated by other, and as yet, unidentified factors. In relation to eye movements, this presumably goes beyond any effect accounted for by handedness and may extend to eye-dominance or whether retrieval takes place during the eye-movement phase (Phaf, 2016, 2017; Phaf, Hermans, Krepel, Lieuw-On, Mulder, & Weijland, 2021). As for eye-closure, the possible moderating effect of experimental design has been highlighted here (Cf. Experiments 2 and 3), but this does not account for eye-closure effects in other studies in which memory enhancement have been found with both between- and within-subject designs. Of course, the issue of design could relate to autobiographical memory only, although this would seem unparsimonious, it does not negate the fact that the question requires further investigation in which design is compared within a single experiment.

More generally, the role of top-down influences needs to be more carefully examined in the case of autobiographical retrieval in paradigms where memory enhancement techniques are employed. This would help to not only establish the theoretical underpinnings of memory enhancement techniques, but possibly set boundary conditions on how these can be applied in everyday situations and the populations (e.g., aged individuals) to which they can be applied.

Further work on the topic pursued in the current experiments is of course warranted. This is especially the case given the ease with which eye movements and eye-closure can be implemented and the promise of these techniques to improve one’s ability to access important information about the past.

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Section 1 – Experimental booklet for Experiment One.

Participant Information Sheet

Participant Information Sheet

Researcher's Name: Adam Parkin

University: Manchester Metropolitan University

Course: PHD Psychology

Supervisor's Name: Neil Dagnall, Andrew Parker & Peter Clough

Title of the project: Can 'Saccadic Bilateral Eye Movements' increase autobiographical recall in older non-clinical participants.

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take your time to read the following information carefully and discuss it with others if you wish. Ask the researcher if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Unfortunately, there are no funds available to reimburse any expenses that you may incur for completing this research, however no expense is anticipated for your participation.

The purpose of the research is to test your autobiographical memory recollection based upon memories from your personal past. You have been invited because you match the research criteria and are a healthy consenting adult. You must not take part in this research if you are under the age of 18. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. Please do not complete this research project if you have a history of alcohol or substance abuse (excluding smoking), any major medical illnesses, brain injury or traumas or have taken any psychoactive substances in the past two weeks.

If you agree to take part the researcher will complete the non-invasive experimental process with you in a quiet and controlled location (which will either be an allocated room at Manchester Metropolitan University or a room negotiated between the researcher and participant). The research will involve you focusing upon an eye based fixation point (Changing depending upon the variable) and answering a series of autobiographical questions.

All the information that is collected from you during this research will be kept secure and any identifying material, such as names and addresses will be removed in order to ensure your anonymity. This research project forms part of the researcher's doctoral degree and it is anticipated that the research will be written up into a report which will be assessed. It may also be published at a later date. Your anonymity will be ensured and all the information that has been collected about you will be kept secure. The researcher will keep the anonymised information in a safe and secure mode for a minimum of five years.

If you decide to take part you are still free to withdraw your data from the study after participation. Please note that you can do this until 01/09/2018, after which the researcher will have already conducted the analysis of the data. If you wish to withdraw from the study please contact the researcher at a.parkin@mmu.ac.uk

If after completion of this research you feel negatively affected in any way please contact the Samaritans helpline on 116 123.

If you require any further information about the research please contact the researcher at, a.parkin@mmu.ac.uk or the research supervisor Neil Dagnall at N.dagnall@mmu.ac.uk.

Thank you for reading this information sheet and considering participation in my research. The goal of the research is to develop our knowledge and understanding of human memory throughout an individual's life.

Written Consent Form

Name of Researcher: Adam Parkin

University: Manchester Metropolitan University

Course: PHD

Name of Supervisor(s): Neil Dagnall, Andrew Parker & Peter Clough

Title of Project: Can 'Saccadic Bilateral Eye Movements' increase autobiographical recall in older non-clinical participants.

Thank you for considering taking part in the autobiographical memory research experiment, as part of my doctorial research. Please read through the following questions and indicate your response to each of them. This is to ensure that you are fully aware of the purpose of the research and that you are willing to take part.

1. I have been informed about the purpose of the study and have had the opportunity to ask questions about it if I wished. YES/NO

2. I understand that I can withdraw from the study at any stage up to 01/09/18, without giving a reason and that my data will not be included in the research. YES/NO

3. I understand that I am free to choose not to answer a question without giving a reason why. YES/NO

4. I have been informed that the interview will be audio recorded and I give my consent for this recording to be made. YES/NO

5. I understand that extracts from the recording might be used in the research report and that this may be read by others or published later. YES/NO

6. I understand that if extracts from the recording are used any identifying information about myself and my organisation will be removed and that every attempt will be made to ensure my anonymity. YES/NO

I give my consent to take part in the research by completing the unique code box bellow.

Creating your unique, anonymous personal code:

	Please insert the day of the month on which you were born	Please insert the last two letters of your home postcode (e.g.	Please insert the last two digits of your home telephone

	(e.g., 04 or 12) in the box below	AD or SU) in the box below	number (e.g., 02, or 98) in the box below
Your unique, anonymous personal code is:			
What is your Date of Birth: Number of years in Education: Gender:			

<u>Researcher</u>

Signed ………………………………………..

NAME IN BLOCK LETTERS …..…………………………………….

Date …………………………………………

Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by circling the appropriate option. Please answer all of the questions, and only leave a blank if you have no experience at all with the object or task.

Writing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Drawing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Throwing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Using Scissors

Always Left	Usually Left	No Preference	Usually Right	Always Right

Brushing Teeth

Always Left	Usually Left	No Preference	Usually Right	Always Right

Knife (without fork)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Spoon

Always Left	Usually Left	No Preference	Usually Right	Always Right

PLEASE TURN OVER

Broom (which hand would you place on the upper part of the broom handle)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Striking A Match

Always Left	Usually Left	No Preference	Usually Right	Always Right

Opening box/jar (lid)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Episodic Autobiographical Memory

For this test, I would like you to recall as many personal memories of events from two periods in your life. The first period is between 5-11 years old and the second period is between 12 -18 years old.

For each of these periods I would like you to recall as many memories as you can within 90 seconds.

Please try to name specific event memories, such as "the time I beat my best friend in the school swimming competition" rather than general memories, such as "having a paper round".

Please do not go into detail about each memory, just state each one as it comes to mind and then move onto the next. It does not matter if you cannot remember each memory in great detail just tell me each one as it comes to mind. Do you have any questions?

Part 1

"Your time will now begin. Please recall as many memories for events as you can from 5-11 years old.

Experimenter keep tally of number of events here

Part 2

"Your time will now begin. Please recall as many memories for events as you can from 12-18 years old

Experimenter keep tally of number of events here

Semantic Autobiographical Memory

For this test, I would like you to recall as many autobiographical facts as you can from your life.

For each of these periods I would like you to recall as many autobiographical facts as you can within 90 seconds

By autobiographical facts, I mean names of people, such as school friends and teachers.

You do not need to tell me each memory in detail, just try to recall as many facts as you can about your life. Do you have any questions?"

Part 1

"Your time will now begin. Please recall as many names of friends as you can from 5-18 years old.

Experimenter keep tally of number of names here

Part 2

"Your time will now begin. Please recall as many names of teachers as you can from 5-18 years old.

Experimenter keep tally of number of names here

*"For this test, I would like you to generate as many examples from two semantic categories as you can. I will give you 90 seconds to generate from each semantic category. By generating examples from semantic categories what I mean is this, if I were to say **transport** then I would like you to say as many examples of transport that you can such as cars, trains, boats ships etc.*

Just state out loud the examples that come to mind

You do not need to tell me each example in detail, just try to generate as many examples as you can. Do you have any questions?"

<u>Part 1</u>

"Your time will now begin. Please generate as examples of vegetables as you can".

Experimenter keep tally of number of items here

<u>art 2</u>

"Your time will now begin. Please recall as many examples of animals as you can".

Experimenter keep tally of number of items here

Section 2 - Experiment One – Descriptive statistics for Age Group, Handedness & Eye Movement.

Number of participants in each condition as a function of eye movement condition, age group & handedness

	Eye Movement condition								
Age group & Handedness	Horizontal *n* = 59			Fixation *n* = 61			Total *n* = 120		
				Episodic ABM 5-11					
Younger									
Consistent	23	11.52	(3.36)	32	10.69	(2.67)	55	11.04	(2.97)
Inconsistent	14	11.93	(3.91)	11	10.09	(3.51)	25	11.12	(3.78)
Older									
Consistent	15	11.52	(3.36)	14	8.36	(3.56)	46	9.07	(2.87)
Inconsistent	7	12.00	(2.00)	4	8.25	(3.20)	15	10.64	(3.00)
Total									
Consistent	38	10.82	(2.98)	46	9.98	(3.12)	84	10.36	(3.07)
Inconsistent	21	11.95	(3.34)	15	9.60	(3.41)	36	10.97	(3.53)
				Episodic ABM 12-18					
Younger									
Consistent	23	14.17	(4.30)	32	11.10	(3.78)	55	12.13	(3.96)
Inconsistent	14	13.00	(2.48)	11	10.66	(2.97)	25	12.16	(3.20)
Older									
Consistent	15	10.27	(3.15)	14	9.21	(3.53)	46	9.76	(2.69)
Inconsistent	7	11.43	(2.17)	4	8.50	(1.73)	15	10.36	(3.00)
Total									
Consistent	38	12.63	(3.96)	46	10.22	(3.19)	84	11.31	(3.73)
Inconsistent	21	12.48	(2.75)	15	10.40	(3.50)	36	11.61	(3.21)
				Personal Semantic Memory					
Younger									
Consistent	23	19.76	(6.60)	32	18.39	(5.97)	55	18.96	(6.22)
Inconsistent	14	19.89	(4.56)	11	20.73	(7.72)	25	20.26	(6.02)
Older									
Consistent	15	9.47	(2.58)	14	9.43	(6.71)	46	9.45	(4.92)
Inconsistent	7	12.14	(3.67)	4	10.50	(0.70)	15	11.55	(2.99)

Total									
Consistent	38	15.69	(7.38)	46	15.66	(7.38)	84	15.68	(7.35)
Inconsistent	21	17.31	(5.62)	15	18.00	(5.62)	36	17.60	(6.63)
General Semantic Memory									
Younger									
Consistent	23	23.17	(5.52)	32	22.97	(6.02)	55	23.05	(5.77)
Inconsistent	14	25.04	(5.09)	11	23.18	(5.68)	25	24.22	(5.33)
Older									
Consistent	15	17.83	(3.38)	14	17.57	(4.51)	46	21.33	(6.05)
Inconsistent	7	18.50	(3.79)	4	18.88	(6.05)	15	22.03	(5.86)
Total									
Consistent	38	21.07	(5.43)	46	21.33	(6.05)	84	21.21	(5.74)
Inconsistent	21	22.86	(5.58)	15	22.03	(5.86)	36	22.51	(5.63)

Section 3 – Experiment 1 - ANCOVA Analysis for study one using Participant handedness as covariant.

Encoding: UTF-8.

```
DATASET ACTIVATE DataSet1.
GLM Events_5_11 Events_12_18 BY Eye_movement Holland WITH Handedness
/WSFACTOR=lifeperiod 2 Polynomial
/METHOD=SSTYPE(3)
/EMMEANS=TABLES(OVERALL) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Holland) WITH(Handedness=MEAN)
/EMMEANS=TABLES(lifeperiod) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement*Holland) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement*lifeperiod) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Holland*lifeperiod) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement*Holland*lifeperiod) WITH(Handedness=MEAN)
/PRINT=DESCRIPTIVE ETASQ
/CRITERIA=ALPHA(.05)
/WSDESIGN=lifeperiod
/DESIGN=Handedness Eye_movement Holland Eye_movement*Holland.
```

General Linear Model

Within-SubjectsFactors

Measure: MEASURE_1

lifeperiod	Dependent Variable
1	Events_5_11
2	Events_12_18

Between-Subjects Factors

		Value Label	N
Eye_movement	1.00	Still	61
	3.00	Bilatteral	59
Holland	1.00	Young	80
	2.00	Old	40

Descriptive Statistics

Eye_movement	HollandMean			Std. Deviation	N
Events_5_11	Still	Young	10.5349	2.87310	43
		Old	8.3333	3.39550	18
		Total	9.8852	3.17332	61
	Bilatteral	Young	11.6757	3.52809	37
		Old	10.4545	2.17622	22
		Total	11.2203	3.12977	59
	Total	Young	11.0625	3.22311	80
		Old	9.5000	2.95262	40
		Total	10.5417	3.20948	120
Events_12_18	Still	Young	10.7674	3.15351	43
		Old	9.0556	3.18955	18
		Total	10.2623	3.23472	61
	Bilatteral	Young	13.7297	3.72416	37
		Old	10.6364	2.17224	22
		Total	12.5763	3.54869	59
	Total	Young	12.1375	3.71703	80
		Old	9.9250	2.75855	40
		Total	11.4000	3.57254	120

Multivariate Tests[a]

Effect	Value		F	Hypothesis df	Error df
lifeperiod	Pillai's Trace	.004	.492[b]	1.000	115.000
	Wilks' Lambda	.996	.492[b]	1.000	115.000
	Hotelling's Trace	.004	.492[b]	1.000	115.000
	Roy's Largest Root	.004	.492[b]	1.000	115.000
lifeperiod * Handedness	Pillai's Trace	.010	1.158[b]	1.000	115.000
	Wilks' Lambda	.990	1.158[b]	1.000	115.000
	Hotelling's Trace	.010	1.158[b]	1.000	115.000
	Roy's Largest Root	.010	1.158[b]	1.000	115.000
lifeperiod * Eye_movement	Pillai's Trace	.008	.930[b]	1.000	115.000
	Wilks' Lambda	.992	.930[b]	1.000	115.000
	Hotelling's Trace	.008	.930[b]	1.000	115.000
	Roy's Largest Root	.008	.930[b]	1.000	115.000
lifeperiod * Holland	Pillai's Trace	.009	1.023[b]	1.000	115.000
	Wilks' Lambda	.991	1.023[b]	1.000	115.000
	Hotelling's Trace	.009	1.023[b]	1.000	115.000
	Roy's Largest Root	.009	1.023[b]	1.000	115.000
lifeperiod * Eye_movement * Holland	Pillai's Trace	.025	2.970[b]	1.000	115.000
	Wilks' Lambda	.975	2.970[b]	1.000	115.000
	Hotelling's Trace	.026	2.970[b]	1.000	115.000
	Roy's Largest Root	.026	2.970[b]	1.000	115.000

Multivariate Tests[a]

Effect		Sig.	Partial Eta Squared
lifeperiod	Pillai's Trace	.485	.004
	Wilks' Lambda	.485	.004
	Hotelling's Trace	.485	.004
	Roy's Largest Root	.485	.004
lifeperiod * Handedness	Pillai's Trace	.284	.010
	Wilks' Lambda	.284	.010
	Hotelling's Trace	.284	.010
	Roy's Largest Root	.284	.010
lifeperiod * Eye_movement	Pillai's Trace	.337	.008
	Wilks' Lambda	.337	.008
	Hotelling's Trace	.337	.008
	Roy's Largest Root	.337	.008
lifeperiod * Holland	Pillai's Trace	.314	.009
	Wilks' Lambda	.314	.009
	Hotelling's Trace	.314	.009
	Roy's Largest Root	.314	.009
lifeperiod * Eye_movement * Holland	Pillai's Trace	.087	.025
	Wilks' Lambda	.087	.025
	Hotelling's Trace	.087	.025
	Roy's Largest Root	.087	.025

Design: Intercept + Handedness + Eye_movement + Holland + Eye_movement * HollandWithin Subjects Design: lifeperiod

Exact statistic

Measure: MEASURE_1

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser
lifeperiod	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon[b] Huynh-Feldt	Lower-bound
lifeperiod	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependentvariables is proportional to an identity matrix.

Design: Intercept + Handedness + Eye_movement + Holland + Eye_movement * HollandWithin Subjects Design: lifeperiod

May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square
lifeperiod	Sphericity Assumed	3.003	1	3.003
	Greenhouse-Geisser	3.003	1.000	3.003
	Huynh-Feldt	3.003	1.000	3.003
	Lower-bound	3.003	1.000	3.003
lifeperiod * Handedness	Sphericity Assumed	7.073	1	7.073
	Greenhouse-Geisser	7.073	1.000	7.073
	Huynh-Feldt	7.073	1.000	7.073
	Lower-bound	7.073	1.000	7.073
lifeperiod * Eye_movement	Sphericity Assumed	5.676	1	5.676
	Greenhouse-Geisser	5.676	1.000	5.676
	Huynh-Feldt	5.676	1.000	5.676
	Lower-bound	5.676	1.000	5.676
lifeperiod * Holland	Sphericity Assumed	6.248	1	6.248
	Greenhouse-Geisser	6.248	1.000	6.248
	Huynh-Feldt	6.248	1.000	6.248
	Lower-bound	6.248	1.000	6.248
lifeperiod * Eye_movement	Sphericity Assumed	18.136	1	18.136
	Greenhouse-Geisser	18.136	1.000	18.136

* Holland	Huynh-Feldt	18.136	1.000	18.136
	Lower-bound	18.136	1.000	18.136
Error(lifeperiod)	Sphericity Assumed	702.152	115	6.106
	Greenhouse-Geisser	702.152	115.000	6.106
	Huynh-Feldt	702.152	115.000	6.106
	Lower-bound	702.152	115.000	6.106

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		F	Sig.	Partial Eta Squared
lifeperiod	Sphericity Assumed	.492	.485	.004
	Greenhouse-Geisser	.492	.485	.004
	Huynh-Feldt	.492	.485	.004
	Lower-bound	.492	.485	.004
lifeperiod * Handedness	Sphericity Assumed	1.158	.284	.010
	Greenhouse-Geisser	1.158	.284	.010
	Huynh-Feldt	1.158	.284	.010
	Lower-bound	1.158	.284	.010
lifeperiod * Eye_movement	Sphericity Assumed	.930	.337	.008
	Greenhouse-Geisser	.930	.337	.008
	Huynh-Feldt	.930	.337	.008
	Lower-bound	.930	.337	.008
lifeperiod * Holland	Sphericity Assumed	1.023	.314	.009
	Greenhouse-Geisser	1.023	.314	.009
	Huynh-Feldt	1.023	.314	.009
	Lower-bound	1.023	.314	.009
lifeperiod * Eye_movement * Holland	Sphericity Assumed	2.970	.087	.025
	Greenhouse-Geisser	2.970	.087	.025
	Huynh-Feldt	2.970	.087	.025
	Lower-bound	2.970	.087	.025
Error(lifeperiod)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	lifeperiod	Type III Sum of Squares	df	Mean Square	F
lifeperiod	Linear	3.003	1	3.003	.492
lifeperiod * Handedness	Linear	7.073	1	7.073	1.158
lifeperiod * Eye_movement	Linear	5.676	1	5.676	.930
lifeperiod * Holland	Linear	6.248	1	6.248	1.023
lifeperiod * Eye_movement * Holland	Linear	18.136	1	18.136	2.970
Error(lifeperiod)	Linear	702.152	115	6.106	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	lifeperiod	Sig.	Partial Eta Squared
lifeperiod	Linear	.485	.004
lifeperiod * Handedness	Linear	.284	.010
lifeperiod * Eye_movement	Linear	.337	.008
lifeperiod * Holland	Linear	.314	.009
lifeperiod * Eye_movement * Holland	Linear	.087	.025
Error(lifeperiod)	Linear		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	10210.373	1	10210.373	748.276	.000
Handedness	.844	1	.844	.062	.804
Eye_movement	200.719	1	200.719	14.710	.000
Holland	223.872	1	223.872	16.407	.000
Eye_movement * Holland	.549	1	.549	.040	.841
Error	1569.198	115	13.645		

Measure: MEASURE_1

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Partial Eta Squared
Intercept	.867
Handedness	.001
Eye_movement	.113
Holland	.125
Eye_movement * Holland	.000
Error	

Estimated Marginal Means

Grand Mean

Measure: MEASURE_1

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
10.648[a]	.254	10.145	11.151

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement

Measure: MEASURE_1

Eye_movement	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Still	9.674[a]	.367	8.948	10.400
Bilatteral	11.623[a]	.352	10.926	12.319

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Holland

Measure: MEASURE_1

Holland	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Young	11.677[a]	.293	11.097	12.257
Old	9.620[a]	.415	8.797	10.442

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

lifeperiod

Measure: MEASURE_1

lifeperiod	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	10.249[a]	.299	9.658	10.841
2	11.047[a]	.312	10.428	11.666

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement * Holland

Measure: MEASURE_1

Eye_movement	Holland	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Still	Young	10.652[a]	.398	9.863	11.441
	Old	8.696[a]	.616	7.477	9.916
Bilatteral	Young	12.703[a]	.429	11.852	13.553
	Old	10.543[a]	.557	9.440	11.646

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement * lifeperiod

Measure: MEASURE_1

Eye_movement	lifeperiod	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Still	1	9.439[a]	.431	8.585	10.293
	2	9.909[a]	.451	9.016	10.803
Bilatteral	1	11.060[a]	.413	10.241	11.879
	2	12.186[a]	.433	11.329	13.043

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Holland * lifeperiod

Measure: MEASURE_1

Hollandlifeperiod		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Young	1	11.106[a]	.344	10.425	11.788
	2	12.248[a]	.360	11.534	12.962
Old	1	9.392[a]	.488	8.426	10.359
	2	9.847[a]	.511	8.835	10.858

Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement * Holland * lifeperiod

Measure: MEASURE_1

Eye_movement	Holland	lifeperiod	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Still	Young	1	10.538[a]	.468	9.610	11.465
		2	10.766[a]	.490	9.795	11.737
	Old	1	8.340[a]	.724	6.907	9.773
		2	9.052[a]	.757	7.552	10.553
Bilatteral	Young	1	11.675[a]	.505	10.675	12.675
		2	13.730[a]	.528	12.684	14.777
	Old	1	10.445[a]	.655	9.148	11.742
		2	10.641[a]	.685	9.284	11.998

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

```
UNIANOVA personal_semantic_overall BY Eye_movement Holland WITH Handedness
/METHOD=SSTYPE(3)
/INTERCEPT=INCLUDE
/EMMEANS=TABLES(OVERALL) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Holland) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement*Holland) WITH(Handedness=MEAN)
/PRINT ETASQ DESCRIPTIVE
/CRITERIA=ALPHA(.05)
/DESIGN=Handedness Eye_movement Holland Eye_movement*Holland.
```

Univariate Analysis of Variance

Between-Subjects Factors

Value Label			N
Eye_movement	1.00	Still	61
	3.00	Bilatteral	59
Holland	1.00	Young	80
	2.00	Old	40

Descriptive Statistics

Dependent Variable: personal_semantic_overall

Eye_movement	Holland	Mean	Std. Deviation	N
Still	Young	18.9884	6.44804	43
	Old	9.6667	5.89367	18
	Total	16.2377	7.57111	61
Bilatteral	Young	19.8108	5.84446	37
	Old	10.3182	3.14925	22
	Total	16.2712	6.79904	59
Total	Young	19.3688	6.15143	80
	Old	10.0250	4.53752	40
	Total	16.2542	7.17166	120

Tests of Between-Subjects Effects

Dependent Variable: personal_semantic_overall

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2367.418[a]	4	591.855	18.135	.000
Intercept	10295.703	1	10295.703	315.476	.000
Handedness	21.613	1	21.613	.662	.417
Eye_movement	13.648	1	13.648	.418	.519
Holland	2341.977	1	2341.977	71.762	.000
Eye_movement * Holland	.250	1	.250	.008	.930
Error	3753.080	115	32.635		
Total	37824.250	120			
Corrected Total	6120.498	119			

Tests of Between-Subjects Effects

Dependent Variable: personal_semantic_overall

Source	Partial Eta Squared
Corrected Model	.387
Intercept	.733
Handedness	.006
Eye_movement	.004
Holland	.384
Eye_movement * Holland	.000
Error	
Total	
Corrected Total	

a. R Squared = .387 (Adjusted R Squared = .365)

Estimated Marginal Means

Grand Mean

Dependent Variable: personal_semantic_overall

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
14.696[a]	.556	13.595	15.796

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement

Dependent Variable: personal_semantic_overall

Eye_movement	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Still	14.336[a]	.802	12.748	15.925
Bilatteral	15.055[a]	.769	13.531	16.578

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Holland

Dependent Variable: personal_semantic_overall

Holland	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Young	19.402[a]	.641	18.133	20.670
Old	9.990[a]	.908	8.191	11.788

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement * Holland

Dependent Variable: personal_semantic_overall

Eye_movement	Holland	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Still	Young	18.994[a]	.871	17.268	20.719
	Old	9.679[a]	1.347	7.012	12.346
Bilatteral	Young	19.809[a]	.939	17.949	21.670
	Old	10.300[a]	1.218	7.887	12.713

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

```
UNIANOVA general_semantic_overall BY Eye_movement Holland WITH Handedness
/METHOD=SSTYPE(3)
/INTERCEPT=INCLUDE
/EMMEANS=TABLES(OVERALL) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Holland) WITH(Handedness=MEAN)
/EMMEANS=TABLES(Eye_movement*Holland) WITH(Handedness=MEAN)
/PRINT ETASQ DESCRIPTIVE
/CRITERIA=ALPHA(.05)
/DESIGN=Handedness Eye_movement Holland Eye_movement*Holland.
```

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Eye_movement	1.00	Still	61
	3.00	Bilatteral	59
Holland	1.00	Young	80
	2.00	Old	40

Descriptive Statistics

Dependent Variable: general_semantic_overall

Eye_movement	Holland	Mean	Std. Deviation	N
Still	Young	23.0233	5.87160	43
	Old	17.8611	4.51079	18
	Total	21.5000	5.96098	61
Bilatteral	Young	23.8784	5.36761	37
	Old	18.0455	3.43618	22
	Total	21.7034	5.50009	59

Total	Young	23.4188	5.62513	80
	Old	17.9625	3.90330	40
	Total	21.6000	5.71582	120

Tests of Between-Subjects Effects

Dependent Variable: general_semantic_overall

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	810.814[a]	4	202.704	7.576	.000
Intercept	18729.883	1	18729.883	700.015	.000
Handedness	2.051	1	2.051	.077	.782
Eye_movement	7.295	1	7.295	.273	.603
Holland	798.612	1	798.612	29.848	.000
Eye_movement * Holland	2.909	1	2.909	.109	.742
Error	3076.986	115	26.756		
Total	59875.000	120			
Corrected Total	3887.800	119			

Tests of Between-Subjects Effects

Dependent Variable: general_semantic_overall

Source	Partial Eta Squared
Corrected Model	.209
Intercept	.859
Handedness	.001
Eye_movement	.002
Holland	.206
Eye_movement * Holland	.001
Error	
Total	
Corrected Total	

a. R Squared = .209 (Adjusted R Squared = .181)

Estimated Marginal Means

Grand Mean

Dependent Variable: general_semantic_overall

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
20.702[a]	.503	19.706	21.699

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement

Dependent Variable: general_semantic_overall

Eye_movement	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Still	20.439[a]	.726	19.001	21.878
Bilatteral	20.965[a]	.696	19.585	22.344

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Holland

Dependent Variable: general_semantic_overall

Holland	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Young	23.450[a]	.580	22.301	24.599
Old	17.954[a]	.822	16.326	19.582

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Eye_movement * Holland

Dependent Variable: general_semantic_overall

Eye_movement	Holland	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Still	Young	23.022[a]	.789	21.459	24.584
	Old	17.857[a]	1.219	15.442	20.272
Bilatteral	Young	23.879[a]	.850	22.194	25.563
	Old	18.051[a]	1.103	15.866	20.236

a. Covariates appearing in the model are evaluated at the following values: Handedness = 66.7917.

Section 4A – SPSS output showing no significant differences in age in experiment 2.

Between-Subjects Factors

		Value Label	N
hand_group	1.00	Mixed	69
	2.00	Strong	121
EMcondition	1.00	fixation	87
	2.00	movement	103
ECcondition	1.00	open	93
	2.00	closed	97

Descriptive Statistics

Dependent Variable: Age

hand_group	EMcondition	ECcondition	Mean	Std. Deviation	N
Mixed	fixation	open	34.6875	17.49178	16
		closed	35.4444	18.24739	18
		Total	35.0882	17.62809	34
	movement	open	29.7059	14.92801	17
		closed	33.5556	16.20901	18
		Total	31.6857	15.49340	35
	Total	open	32.1212	16.16276	33
		closed	34.5000	17.03693	36
		Total	33.3623	16.54581	69
Strong	fixation	open	32.3103	18.51853	29
		closed	28.5833	15.61191	24
		Total	30.6226	17.20379	53
	movement	open	29.6774	17.91161	31
		closed	33.5405	18.05331	37
		Total	31.7794	17.95920	68
	Total	open	30.9500	18.10087	60
		closed	31.5902	17.17399	61
		Total	31.2727	17.56891	121
Total	fixation	open	33.1556	17.99616	45
		closed	31.5238	16.92918	42
		Total	32.3678	17.40697	87
	movement	open	29.6875	16.75246	48

	closed	33.5455	17.32031	55
	Total	31.7476	17.08440	103
Total	open	31.3656	17.35799	93
	closed	32.6701	17.09271	97
	Total	32.0316	17.18985	190

Tests of Between-Subjects Effects

Dependent Variable: Age

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	999.951[a]	7	142.850	.474	.853	.018
Intercept	180251.142	1	180251.142	598.122	<.001	.767
hand_group	234.189	1	234.189	.777	.379	.004
EMcondition	56.183	1	56.183	.186	.666	.001
ECcondition	61.145	1	61.145	.203	.653	.001
hand_group * EMcondition	229.821	1	229.821	.763	.384	.004
hand_group * ECcondition	54.328	1	54.328	.180	.672	.001
EMcondition * ECcondition	310.229	1	310.229	1.029	.312	.006
hand_group * EMcondition * ECcondition	54.983	1	54.983	.182	.670	.001
Error	54847.859	182	301.362			
Total	250792.000	190				
Corrected Total	55847.811	189				

a. R Squared = .018 (Adjusted R Squared = -.020)

Section 4B – Experimental booklet for Experiment Two.

Demographical Information

How old are you?

____

How would you describe your gender?

- Male
- Female
- Non-Binary
- Prefer to self-describe (please enter below):

____

- Prefer not to say

How many years of formal education have you completed?

____

Have you any of the following:

- A learning disability (i.e., childhood diagnosis or failure of a grade),
- A history of neurological disorders,
- Any significant psychiatric disorders
- A history of abusing illicit substances
- Any medical disorders known to affect cognitive functioning.
- Any none-corrected visual impairments

Please delete the appropriate option.

Yes

No

Sweet 16 Instrument

- What is the year?
- What is the date?
- What is the day of the week?
- What is the month?
- Can you tell me where we are? The name of the place?
- What city are we in?
- What County are we in?
- What room of the building are we in?
- am going to name 3 objects. After I have said them, I want you to repeat them. Remember what they are because I am going to ask you to name them again in a few minutes.

The three items are: “Apple” ….” Table” ….” Penny”.

[PRESENT WORDS CLEARLY AND SLOWLY. WORDS MAY BE PRESENTED UP TO 4 TIMES, BUT SCORE ONLY ITEMS REPORTED AFTER FIRST PRESENTATION]

Table ________________

Apple________________

Penny________________

- Now I am going to say some numbers. Please repeat them back to me:

2 – 4 – 9

8 – 5 – 2 – 7

Now I am going to say some more numbers but this time, when I stop, I want you to say them backwards. For example, if I say 7-1-9, what would you say?

4-1-5

3-2-7-9

Now, remember the 3 objects I asked you to remember?

  - Apple
  - Table
  - Penny

Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by circling the appropriate option. Please answer all of the questions, and only leave a blank if you have no experience at all with the object or task.

Writing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Drawing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Throwing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Using Scissors

Always Left	Usually Left	No Preference	Usually Right	Always Right

Brushing Teeth

Always Left	Usually Left	No Preference	Usually Right	Always Right

Knife (without fork)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Spoon

Always Left	Usually Left	No Preference	Usually Right	Always Right

Continued Overleaf

Combing Hair

Always Left	Usually Left	No Preference	Usually Right	Always Right

Striking a Match

Always Left	Usually Left	No Preference	Usually Right	Always Right

Opening box/jar (lid)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Now wait for instructions from the experimenter

Autobiographical Memory Test (AMT)

In the next section of the experiment, you will be presented with a key word and asked to provide a personal memory. The retrieved memory can be something what has happened recently or a long time ago but must be at least a week old. It does not matter if the memory recalled is something trivial or important if the memory is autobiographical and about your individual past.

Practice term: Can you describe one specific moment or event that the word Frog reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q1. Can you describe one specific moment or event that the word Wisdom reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q2. Can you describe one specific moment or event that the word Mountain reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q3. Can you describe one specific moment or event that the word obedience reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q4. Can you describe one specific moment or event that the word Butterfly reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q5. Can you describe one specific moment or event that the word boredom reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree 1 2 3 4 5 6 7 Agree

I travel back to the time when it happened.

Disagree 1 2 3 4 5 6 7 Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree 1 2 3 4 5 6 7 Agree

I can recall the setting where it occurred.

Disagree 1 2 3 4 5 6 7 Agree

It comes to me as a coherent story.

Disagree 1 2 3 4 5 6 7 Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree 1 2 3 4 5 6 7 Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q6. Can you describe one specific moment or event that the word Fire reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q7. Can you describe one specific moment or event that the word attitude reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q8. Can you describe one specific moment or event that the word house reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q9. Can you describe one specific moment or event that the word Moral reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

Q10. Can you describe one specific moment or event that the word cloud reminds you of?

Recollection

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

Component Processes

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

Reported Properties of Events or Memories

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (day/month/year).

Day: Month: Year:

For use of the experimenter only.

Please delete as appropriate.

Eye movement condition	Bilateral / Fixation
Eye Closure condition	Open / Closed
Handedness score	
Age group	1 / 2 / 3

Section 4C – Analysis of phenomenological follow up questions for experiment 2 using only specificity scores of four.

The following section as outlined on page 105 (Results section of experiment two) outlines the results and provides a brief summary of the findings for experiment two if the only data included was that which scored the maximum level of specificity & episodic detail.

Descriptive statistics

Table 4C.1 – Means and Standard deviations (SD) for Time.

	handedness group	eye movement condition	Eye closure condition	N	Mean	SD
concrete time	Mixed	fixation	open	9	5.41	1.579
			closed	13	6.40	0.922
		movement	open	16	5.65	1.382
			closed	14	5.96	1.599
	Strong	fixation	open	26	5.32	1.679
			closed	17	5.81	1.109
		movement	open	23	5.42	1.592
			closed	25	5.87	1.136
abstract time	Mixed	fixation	open	6	6.42	0.492
			closed	11	6.00	1.025
		movement	open	12	5.07	1.542
			closed	9	6.38	1.223
	Strong	fixation	open	18	5.39	1.549
			closed	11	5.08	1.553
		movement	open	13	4.29	2.094
			closed	26	5.43	1.452

Table 4C.2 – Means and Standard deviations (SD) for See & Hear.

	handedness group	eye movement condition	Eye closure condition	N	Mean	SD
concrete see & hear	Mixed	fixation	open	9	5.96	1.296
			closed	13	6.50	0.791
		movement	open	16	6.06	1.320
			closed	14	6.33	1.184
	Strong	fixation	open	26	5.76	1.084
			closed	17	6.35	0.707
		movement	open	23	5.52	1.745
			closed	25	6.27	0.820
abstract see & hear	Mixed	fixation	open	6	5.08	2.154
			closed	11	6.64	0.505
		movement	open	12	5.65	1.554
			closed	9	6.36	1.645
	Strong	fixation	open	18	5.74	1.443
			closed	11	5.73	0.984
		movement	open	13	5.24	1.696
			closed	26	6.00	1.170

Table 4C.3 – Means and Standard deviations (SD) for Setting.

	handedness group	eye movement condition	Eye closure condition	N	Mean	SD
concrete setting	Mixed	fixation	open	9	6.11	1.269
			closed	13	6.71	0.455
		movement	open	16	6.53	1.045
			closed	14	6.74	0.587
	Strong	fixation	open	26	6.65	0.596
			closed	17	6.76	0.472
		movement	open	23	6.64	0.852
			closed	25	6.75	0.433
abstract setting	Mixed	fixation	open	6	6.33	0.816
			closed	11	6.59	0.664
		movement	open	12	6.08	1.298
			closed	9	6.74	0.501
	Strong	fixation	open	18	6.50	1.029
			closed	11	6.27	1.330
		movement	open	13	6.71	0.431
			closed	26	6.72	0.529

Table 4C.4 – Means and Standard deviations (SD) for Story.

	handedness group	eye movement condition	Eye closure condition	N	Mean	SD
concrete story	Mixed	fixation	open	9	5.81	1.281
			closed	13	5.91	1.423
		movement	open	16	5.96	1.232
			closed	14	5.99	1.245
	Strong	fixation	open	26	5.98	1.092
			closed	17	6.06	1.443
		movement	open	23	5.82	1.096
			closed	25	6.16	0.906
abstract story	Mixed	fixation	open	6	6.50	0.548
			closed	11	6.05	1.422
		movement	open	12	5.47	1.266
			closed	9	5.38	2.444
	Strong	fixation	open	18	6.17	0.955
			closed	11	5.69	1.046
		movement	open	13	5.57	1.674
			closed	26	6.02	1.524

Table 4C.5 – Means and Standard deviations (SD) for Relive

	handedness group	Eye closure condition	eye movement condition	N	Mean	SD
concrete relive	Mixed	open	fixation	9	5.26	1.222
			movement	16	5.51	1.462
		closed	fixation	13	6.15	1.135
			movement	14	6.17	0.981
	Strong	open	fixation	26	5.71	1.151
			movement	23	5.30	1.519
		closed	fixation	17	5.90	1.166
			movement	25	6.02	1.020
abstract relive	Mixed	open	fixation	6	6.75	0.418
			movement	12	5.19	1.407
		closed	fixation	11	5.80	1.444
			movement	9	5.75	1.225
	Strong	open	fixation	18	5.56	1.286
			movement	13	5.01	1.742
		closed	fixation	11	5.13	1.525
			movement	26	5.79	1.288

Inferential statistics

A 2 (Cue type, Concrete vs. abstract) by 2 (Eye Closure; Open Vs. Closed) by 2 (Eye movement; Fixation vs. Bilateral) between subjects Between subject ANOVA upon the outlined phenomenological responses with only level 4 specificity rating.

Table 4C.6. ANOVA Results Table for Phenomenology Ratings Using Only Memories with a Specificity Score of Four.

	df	*F*	*p*	η_p^2
Reliving the event				
Main Effects				
Eye Movement	1, 88	2.02	.378	.009
Handedness	1, 88	4.49	.037	.049
Cue-Type	1, 88	.445	.506	.005
Eye closure	1, 88	1.26	.220	.017
Two-Way Interactions				
Cue type X Handedness	1,88	.619	.433	.007
Cue type X Eye Movement	1,88	.402	.528	.005
Cue type X Eye closure	1,88	3.554	.063	.039
Handedness X Eye Movement	1,88	.619	.433	.007
Handedness X Eye Closure	1,88	.000	.987	.000
Eye Movement X Eye Closure	1,88	4.490	.037	.049
Three-Way Interaction				
Cue type X Handedness X Eye Movement	1,88	1.612	.208	.018
Cue type X Handedness X Eye Closure	1,88	.029	.865	.000
Cue type X Eye Movement X Eye closure	1,88	1.241	.268	.014
Hand's X Eye Movement X Eye closure	1,88	.232	.631	.003
Four-Way Interaction				
EM X EC X Hand's X Cue type	1,88	.656	.420	.007
Time				
Main Effects				
Eye Movement	1, 88	1.71	.194	.019
Handedness	1, 88	8.94	.004	.092
Cue-Type	1, 88	3.08	.082	.034
Eye closure	1, 88	1.53	.218	.017
Two-Way Interactions				
Cue type X Handedness	1,88	.647	.423	.007
Cue type X Eye Movement	1,88	.408	.525	.005
Cue type X Eye closure	1,88	.180	.672	.002
Handedness X Eye Movement	1,88	.751	.388	.008
Handedness X Eye Closure	1,88	.029	.865	.000
Eye Movement X Eye Closure	1,88	3.139	.080	.034
Three-Way Interaction				
Cue type X Handedness X Eye Movement	1,88	.323	.571	.004
Cue type X Handedness X Eye Closure	1,88	.357	.552	.004
Cue type X Eye Movement X Eye closure	1,88	3.951	.050	.043
Hand's X Eye Movement X Eye closure	1,88	.011	.919	.000
Four-Way Interaction				
EM X EC X Hand's X Cue type	2,88	.200	.655	.002
See / Hear				
Main Effects				
Eye Movement	1, 88	.486	.488	.005
Handedness	1, 88	7.559	.007	.079
Cue-Type	1, 88	.930	.337	.010
Eye closure	1, 88	8.423	.005	.087

Two-Way Interactions				
Cue type X Handedness	1,88	.155	.695	.002
Cue type X Eye Movement	1,88	.664	.417	.007
Cue type X Eye closure	1,88	.035	.852	.000
Handedness X Eye Movement	1,88	.076	.784	.001
Handedness X Eye Closure	1,88	.203	.654	.002
Eye Movement X Eye Closure	1,88	2.295	.133	.025
Three-Way Interaction				
Cue type X Handedness X Eye Movement	1,88	.017	.898	.000
Cue type X Handedness X Eye Closure	1,88	1.319	.254	.015
Cue type X Eye Movement X Eye closure	1,88	.110	.741	.001
Hand's X Eye Movement X Eye closure	1,88	.010	.919	.000
Four-Way Interaction				
EM X EC X Hand's X Cue type	2,88	.067	.796	.001
Setting				
Main Effects				
Eye Movement	1, 88	.044	.835	.000
Handedness	1, 88	.662	.418	.007
Cue-Type	1, 88	7.556	.007	.079
Eye closure	1, 88	1.816	.181	.020
Two-Way Interactions				
Cue type X Handedness	1,88	1.704	.195	.019
Cue type X Eye Movement	1,88	4.229	.043	.046
Cue type X Eye closure	1,88	.43	.835	.000
Handedness X Eye Movement	1,88	.246	.621	.003
Handedness X Eye Closure	1,88	1.795	.184	.020
Eye Movement X Eye Closure	1,88	.748	.389	.008
Three-Way Interaction				
Cue type X Handedness X Eye Movement	1,88	.024	.876	.000
Cue type X Handedness X Eye Closure	1,88	4.757	.032	.051
Cue type X Eye Movement X Eye closure	1,88	.005	.945	.000
Hand's X Eye Movement X Eye closure	1,88	.032	.859	.000
Four-Way Interaction				
EM X EC X Hand's X Cue type	1,88	.732	.394	.008
Story				
Main Effects				
Eye Movement	1, 88	.462	.499	.005
Handedness	1, 88	.000	.999	.000
Cue-Type	1, 88	.663	.418	.007
Eye closure	1, 88	.001	.974	.000
Two-Way Interactions				
Cue type X Handedness	1,88	.209	.649	.002
Cue type X Eye Movement	1,88	.178	.674	.002
Cue type X Eye closure	1,88	.003	.960	.000
Handedness X Eye Movement	1,88	.658	.419	.007
Handedness X Eye Closure	1,88	.006	.936	.000
Eye Movement X Eye Closure	1,88	2.693	.104	.030
Three-Way Interaction				
Cue type X Handedness X Eye Movement	1,88	.813	.370	.009
Cue type X Handedness X Eye Closure	1,88	.524	.471	.006
Cue type X Eye Movement X Eye closure	1,88	2.649	.107	.029
Hand's X Eye Movement X Eye closure	1,88	.329	.568	.004

Four-Way Interaction				
EM X EC X Hand's X Cue type	1,88	.201	.655	.002

Post-hoc analysis

Cue type & eye movement upon setting.

The interaction was assessed by simple main effects analysis by using within-subject t-tests comparing the effects of eye closure for fixation and bilateral separately. This indicated no significant difference between concrete (*M* = 6.64, *SD* = 8.09) and abstract (*M* = 6.58, *SD* = 6.64) condition for the eye movement group, *t*(54) = .639, *p* = .263. However, concrete cues in the fixation condition (*M* = 6.75, *SD* = .52) recalled significantly more words than those in the abstract (M = 6.45, SD = .96) condition, *t*(40) = 2.094 *p* = .021.

Cue type, Handedness & eye closure upon setting.

The interaction between cue type, eye movement and eye closure was significant *F*(1,88) = 4.757, *p* = .032, η_{p2} = .051. This was assessed further by simple interaction effects at each level of cue type. A two way between-subjects ANOVA was completed for eye closure and handedness upon high imaginability cues and low imaginability cues.

For the high imaginability cue there was a close to significant main effect of eye closure *F*(1,139) = 3.412, *p* = .067, η_{p2} = .024. With the eye closed group (mean = 6.74, SD = .088) scoring slightly higher than the eye open group (mean = 6.55, SD = .087). The main effect of handedness was non-significant *F*(1,139) = 1.460, *p* = .229, η_{p2} = .010. The interaction was also non-significant *F*(1,139) = .954, *p* = .331, η_{p2} = .007.

For the low imaginability group there was no main effect of eye closure *F*(1,102) = 2.041, *p* = .156, η_{p2} = .020. There was also no main effect of handedness (1,102) = 1.030, *p* = .313, η_{p2} = .010 and no significant interaction between eye movement and eye closure (1,102) = 1.968, *p* = .164, η_{p2} = .019.

Section 5 – Experimental booklet for Experiment Three.

Demographical Information

How old are you?

How would you describe your gender?

- Male
- Female
- Non-Binary
- Prefer to self-describe (please enter below):

- Prefer not to say

How many years of formal education have you completed?

Have you any of the following:

- A learning disability (i.e., childhood diagnosis or failure of a grade),
- A history of neurological disorders,
- Any significant psychiatric disorders
- A history of abusing illicit substances
- Any medical disorders known to affect cognitive functioning.
- Any none-corrected visual impairments

Please delete the appropriate option.

Yes

No

<u>**Sweet 16 Instrument**</u>

- What is the year?
- What is the date?
- What is the day of the week?
- What is the month?
- Can you tell me where we are? The name of the place?
- What city are we in?
- What County are we in?
- What room of the building are we in?
- am going to name 3 objects. After I have said them, I want you to repeat them. Remember what they are because I am going to ask you to name them again in a few minutes.

The three items are: "Apple" …." Table" …." Penny".

[PRESENT WORDS CLEARLY AND SLOWLY. WORDS MAY BE PRESENTED UP TO 4 TIMES, BUT SCORE ONLY ITEMS REPORTED AFTER FIRST PRESENTATION]

Table ________________

Apple________________

Penny________________

- Now I am going to say some numbers. Please repeat them back to me:

2 – 4 – 9

8 – 5 – 2 – 7

Now I am going to say some more numbers but this time, when I stop, I want you to say them backwards. For example, if I say 7-1-9, what would you say?

4-1-5

3-2-7-9

Now, remember the 3 objects I asked you to remember?

- Apple
- Table
- Penny

Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by circling the appropriate option. Please answer all of the questions, and only leave a blank if you have no experience at all with the object or task.

Writing

Always Left -10	Usually Left -5	No Preference 0	Usually Right +5	Always Right +10

Drawing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Throwing

Always Left	Usually Left	No Preference	Usually Right	Always Right

Using Scissors

Always Left	Usually Left	No Preference	Usually Right	Always Right

Brushing Teeth

Always Left	Usually Left	No Preference	Usually Right	Always Right

Knife (without fork)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Spoon

Always Left	Usually Left	No Preference	Usually Right	Always Right

Continued Overleaf

Combing Hair

Always Left	Usually Left	No Preference	Usually Right	Always Right

Striking a Match

Always Left	Usually Left	No Preference	Usually Right	Always Right

Opening box/jar (lid)

Always Left	Usually Left	No Preference	Usually Right	Always Right

Now wait for instructions from the experimenter

Autobiographical Memory Test (AMT)

In the next section of the experiment, you will be presented with a key word and asked to provide a personal memory. The retrieved memory can be something what has happened recently or a long time ago but must be at least a week old. It does not matter if the memory recalled is something trivial or important if the memory is autobiographical and about your individual past.

There are two ways that people can retrieve memories, when asked to recall personal events in response to cues: The first is when the cue directly triggers a memory, and no additional information needs to be thought about. The second is when the cue does not directly trigger a memory so additional information from one's life is thought about in order to arrive at a specific memory. When thinking of the memory to be recalled try to note of how the retrieval occurs.

Block 1

Can you describe one specific moment or event that the word Frog reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Wisdom reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct	Generative

Can you describe one specific moment or event that the word Mountain reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct	Generative

Can you describe one specific moment or event that the word obedience reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct	Generative

Can you describe one specific moment or event that the word Butterfly reminds you of?

I feel that I am reliving the original event.

Disagree 1 2 3 4 5 6 7 Agree

I travel back to the time when it happened.

Disagree 1 2 3 4 5 6 7 Agree

I can see and/or hearing it in my mind.

Disagree 1 2 3 4 5 6 7 Agree

I can recall the setting where it occurred.

Disagree 1 2 3 4 5 6 7 Agree

It comes to me as a coherent story.

Disagree 1 2 3 4 5 6 7 Agree

It occurred at one specific time.

Disagree 1 2 3 4 5 6 7 Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word boredom reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct	Generative

Block 2

Can you describe one specific moment or event that the word Fire reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word attitude reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word house reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Morality reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Apple reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word philosophy reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Block 3

Can you describe one specific moment or event that the word Ambulance reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct	Generative

Can you describe one specific moment or event that the word virtue reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Cake reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Inspiration reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Boat reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

Can you describe one specific moment or event that the word Irony reminds you of?

I feel that I am reliving the original event.

Disagree	1	2	3	4	5	6	7	Agree

I travel back to the time when it happened.

Disagree	1	2	3	4	5	6	7	Agree

I can see and/or hearing it in my mind.

Disagree	1	2	3	4	5	6	7	Agree

I can recall the setting where it occurred.

Disagree	1	2	3	4	5	6	7	Agree

It comes to me as a coherent story.

Disagree	1	2	3	4	5	6	7	Agree

It occurred at one specific time.

Disagree	1	2	3	4	5	6	7	Agree

Please date the memory (rough year of memory).

Type of memory recalled

Direct Generative

For use of the experimenter only.

Please delete as appropriate.

Indicate between-subject condition below	
Eye movement condition	Bilateral / Fixation
Within-subject conditions below	**Indicate block in which each within-subject condition was ordered**
DVN	B1 / B2 / B3
Blank/White screen	B1 / B2 / B3
Eyes closed	B1 / B2 / B3
Indicate handedness score below	
Handedness score	

Section 5A – SPSS output showing no significant differences in age in experiment 3.

Between-Subjects Factors

		Value Label	N
hand_group	1.00	Strong	64
	2.00	Inconsistent	51
EMcondition	1.00	EM	58
	2.00	Control	57

Descriptive Statistics

Dependent Variable: Age

hand_group	EMcondition	Mean	Std. Deviation	N
Strong	EM	24.0000	7.90965	33
	Control	23.3226	7.40445	31
	Total	23.6719	7.61589	64
Inconsistent	EM	26.7600	11.52996	25
	Control	25.6154	11.12143	26
	Total	26.1765	11.22445	51
Total	EM	25.1897	9.64357	58
	Control	24.3684	9.26906	57
	Total	24.7826	9.42727	115

Tests of Between-Subjects Effects

Dependent Variable: Age

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	202.077[a]	3	67.359	.753	.523	.020
Intercept	70482.901	1	70482.901	787.916	<.001	.877
hand_group	181.041	1	181.041	2.024	.158	.018
EMcondition	23.541	1	23.541	.263	.609	.002
hand_group * EMcondition	1.548	1	1.548	.017	.896	.000
Error	9929.488	111	89.455			
Total	80762.000	115				
Corrected Total	10131.565	114				

a. R Squared = .020 (Adjusted R Squared = -.007)

Section 5B – Analysis of phenomenological follow up questions for experiment 3 using only specificity scores of four.

The following section as outlined on page 149 (Results section of experiment three) outlines the results and provides a summary of the findings for experiment two if the only data included was that which scored the maximum level of specificity & episodic detail.

Descriptives

Table 5B.1 – Means and Standard deviations (SD) for Reliving the event.

	hand group	Eye Movement	N	Mean	SD
DVN Relive	Strong	EM	24	6.24	0.771
		Control	22	5.95	0.942
	Inconsistent	EM	11	6.59	0.491
		Control	9	6.30	0.519
Control Relive	Strong	EM	22	6.33	0.930
		Control	26	6.01	0.961
	Inconsistent	EM	14	6.61	0.816
		Control	11	6.14	0.809
Eye Closure Relive	Strong	EM	28	6.05	0.906
		Control	28	6.01	0.925
	Inconsistent	EM	18	6.17	0.762
		Control	22	5.89	0.684

Table 5B.2 – Means and Standard deviations (SD) for Time.

Descriptives

	hand group	Eye Movement	N	Mean	SD
DVN Time	Strong	EM	24	6.20	0.828
		Control	22	6.22	0.689
	Inconsistent	EM	13	6.50	0.645
		Control	9	6.39	0.601
Control Time	Strong	EM	24	6.19	1.074
		Control	25	6.26	0.648
	Inconsistent	EM	13	6.64	0.596
		Control	12	6.46	0.450
Eye Closure Time	Strong	EM	28	6.11	0.875
		Control	29	6.34	0.741
	Inconsistent	EM	18	6.17	0.887
		Control	22	5.95	0.677

Table 5B.3 – Means and Standard deviations (SD) for See & Hear.

Descriptives

	hand group	Eye Movement	N	Mean	SD
Eye Closure see & hear	Strong	EM	28	6.41	0.624
		Control	29	6.53	0.659
	Inconsistent	EM	18	6.47	0.752
		Control	22	6.20	0.793
Control See & Hear	Strong	EM	24	6.44	0.826
		Control	25	6.56	0.450
	Inconsistent	EM	13	6.78	0.381
		Control	12	6.58	0.417
DVN See & Hear	Strong	EM	24	6.65	0.599
		Control	22	6.58	0.541
	Inconsistent	EM	13	6.62	0.650
		Control	9	6.67	0.500

Table 5B.4 – Means and Standard deviations (SD) for Setting.

Descriptives

	hand group	Eye Movement	N	Mean	SD
DVN Setting	Strong	EM	24	6.75	0.397
		Control	22	6.75	0.650
	Inconsistent	EM	13	7.00	0.000
		Control	9	6.94	0.167
Control Setting	Strong	EM	24	6.69	0.857
		Control	25	6.87	0.415
	Inconsistent	EM	13	6.92	0.277
		Control	12	6.83	0.326
Eye Closure Setting	Strong	EM	28	6.63	0.647
		Control	29	6.73	0.597
	Inconsistent	EM	18	6.53	0.742
		Control	22	6.28	0.932

Table 5B.5 – Means and Standard deviations (SD) for Setting.

Descriptives

	hand group	Eye Movement	N	Mean	SD
DVN Story	Strong	EM	24	6.39	0.691
		Control	22	6.13	0.787
	Inconsistent	EM	13	6.52	1.053
		Control	9	6.72	0.441
Control Story	Strong	EM	24	6.26	1.034
		Control	25	6.05	0.840
	Inconsistent	EM	13	6.04	1.558
		Control	12	6.58	0.417
Eye Closure Story	Strong	EM	28	5.86	1.061
		Control	29	6.28	0.798
	Inconsistent	EM	18	5.88	1.270
		Control	22	5.95	0.792

Inferential statistics

The phenomenological scores were entered into a 2(eye movement: horizontal vs. fixation) between-subjects by 3(distraction: eye closed vs. control vs. DVN) within-subjects by 2(handedness:

consistent vs. inconsistent) between-subjects mixed-ANOVA. Based upon the recommendations of Field (2013) the statistics presented here have again been corrected of violations of sphericity (see page 149 for more information).

Experiment 3 ANOVA – Using only fully episodic memory recollection scores.

	df	*F*	*p*	η_p^2
Reliving the event				
Main Effects				
Eye Movement	1, 42	.465	.499	.011
Handedness	1, 42	2.65	.111	.059
Distraction	2, 88	.481	.620	.011
Two-Way Interactions				
Handedness X Eye Movement	1,42	.127	.724	.003
Handedness X Distraction	2,84	.244	.784	.006
Eye Movement X Distraction	2,84	.231	.794	.005
Three-Way Interaction				
Hand's X Eye Movement X Distraction	2,84	.198	.821	.005
Time				
Main Effects				
Eye Movement	1, 47	.049	.825	.001
Handedness	1, 47	3.33	.074	.066
Distraction	2, 94	.349	.706	.007
Two-Way Interactions				
Handedness X Eye Movement	1,47	.340	.563	.007
Handedness X Distraction	2,94	.319	.727	.007
Eye Movement X Distraction	2,94	.281	.756	.006
Three-Way Interaction				
Hand's X Eye Movement X Distraction	2,94	.695	.501	.015
See / Hear				
Main Effects				
Eye Movement	1, 47	.031	.861	.001
Handedness	1, 47	1.45	.289	.024
Distraction	2, 94	.393	.676	.008
Two-Way Interactions				
Handedness X Eye Movement	1,47	.026	.871	.001
Handedness X Distraction	2,94	1.404	.251	.029
Eye Movement X Distraction	2,94	.386	.681	.008
Three-Way Interaction				
Hand's X Eye Movement X Distraction	2,94	1.642	.199	.034
Setting*				
Main Effects				
Eye Movement	1, 47	.282	.598	.023
Handedness	1, 47	1.13	.293	.023
Distraction	1.72, 88.99	1.07	.347	.022
Two-Way Interactions				
Handedness X Eye Movement	1,47	1.027	.317	.021
Handedness X Distraction	1.72,88.99	.939	.383	.020
Eye Movement X Distraction	1.72,88.99	.459	.604	.010

Eye Movement X Distraction	1.72,88.99	.459	.604	.010
Three-Way Interaction				
Hand's X Eye Movement X Distraction	1.72,88.99	.247	.749	.005
Story				
Main Effects				
Eye Movement	1, 47	.087	.770	.002
Handedness	1, 47	1.674	.202	.034
Distraction	2, 94	.841	.435	.018
Two-Way Interactions				
Handedness X Eye Movement	1,47	.778	.382	.016
Handedness X Distraction	2,94	.998	.372	.021
Eye Movement X Distraction	2,94	.116	.891	.002
Three-Way Interaction				
Hand's X Eye Movement X Distraction	2,94	.1.934	.150	.040

* Indicates the Huynh-Feldt correction was implemented due to breaches of sphericity.

Section 6 – pre-published works associated with this thesis - Parkin, A., Parker, A., & Dagnall, N. (2022). Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants. Memory, 1-13.

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Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants

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ABSTRACT

Research has demonstrated that performing a sequence of saccadic horizontal eye movements prior to retrieval facilitates performance on tests of episodic memory. This has been observed in both laboratory tasks of retention and autobiographical memory. To date, the work has centred on performance in younger individuals. This paper extends previous investigations by examining the effects of saccadic eye movements in older persons. Autobiographical episodic and semantic memory fluency was assessed in younger (age range 18–35, mean = 22.50), and older (age range 55–87, mean = 70.35) participants following saccadic (vs. fixation control) manipulations. The main effects of eye movements and age were found for episodic autobiographical memory (greater fluency after eye movements and in younger participants). Semantic autobiographical memory showed a main effect of age (greater fluency in younger participants), whereas general semantic memory showed no effect of age or eye movement. These findings indicate that saccadic horizontal eye movements can enhance episodic personal memory in older individuals. This has implications as a technique to improve autobiographical recollection in the elderly and as an adjunct in reminiscence therapy.

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SIRE effects; age; autobiographical memory; episodic memory; memory fluency

Overview of current work

Memory enhancement has been the focus of much psychological research and encompasses a range of procedures known to improve performance, such as depth of processing (Craik & Tulving, 1975), spacing (Cepeda et al., 2008) or expanding retrieval (Karpicke & Roediger, 2007). Other techniques have involved training regimes to improve working memory (Von Bastian & Oberauer, 2014) or memory specificity (Hitchcock et al., 2016). With the advent of modern technology, non-invasive stimulation methods have become available that appear to show promise by the direct modulation of neural circuits (Mancuso et al., 2016).

The experiment presented here is concerned with a relatively novel memory-enhancing technique involving saccadic eye movements prior to the recall of autobiographical memory in younger and older individuals. Correspondingly, the nature of autobiographical memory is outlined followed by a consideration of past work on the influence of eye movements on memory.

Autobiographical memory and its decline in aging

Autobiographical memories are those acquired across the lifespan and encompass both episodic and semantic information about the self (Conway, 2005, 2009). Episodic personal memories contain event-specific detail and are typically rich in perceptual and emotional elements. Semantic personal memories are devoid of this type of specificity and pertain to context-free and abstracted information about the self. Age has a differential impact on these two forms of memory with the episodic component subject to greater impairment and decline in the elderly (Meléndez et al., 2018; Piolino et al., 2002). Particularly, ageing is associated with a decrease in specificity and the number of episodic details recalled (Piolino et al., 2010; St. Jacques & Levine, 2007).

This decrease in the accessibility of episodic details can be conceptualised in theoretical models of autobiographical memory that posit personal knowledge to be organised in a hierarchical manner spanning the abstract to the most specific. For instance, Conway (2005, 2009) described the most abstract representations as covering lifetime periods that include temporal and thematic information covering large periods in one's life (Conway, 2005). Below is general event knowledge that depicts single, repeated, and extended events. Both forms of representations are types of personal semantic knowledge (Conway & Pleydell-Pearce, 2000; Coste et al., 2015). The most particular form of autobiographical representation

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is event-specific knowledge (ESK). This is personal episodic memory and represents specific information that possesses direct reference to place, events, people, and time (Conway & Pleydell-Pearce, 2000).

The reduction in the ability to recall specific episodes has several important consequences for older individuals. Particularly, the loss of specific autobiographical memories can lead to a disconnection between current and past selves and the ability to retain a clear appraisal for one's personal identity (Meléndez et al., 2017). Reduced memory specificity is also associated with increased depression in the elderly (Wilson & Gregory, 2018). More practically, impaired social problem solving (Beaman et al., 2007; Leahy et al., 2018), and reduced personal independence (Holland et al., 2017; Leahy et al., 2018) can also result from the inability to retrieve specific autobiographical information.

Consequently, developing techniques to enhance the accessibility of specific memories in older individuals is an important goal. Previously, several procedures have been employed that have shown positive outcomes. These include reminiscence therapy (Meléndez Moral et al., 2015), memory specificity training (Martens et al., 2019) and life review (Gonçalves et al., 2009). The experiment presented here involves the use of pre-retrieval saccadic eye movements to enhance autobiographical memory. Researchers have not previously investigated this in older adults.

Saccade-induced retrieval enhancement of memory

A brief period of horizontal eye movements toward a moving target can enhance memory accuracy (Christman et al., 2003). Subsequently labelled Saccade Induced Retrieval Enhancement (SIRE) effects (Lyle & Martin, 2010), Christman et al., found 30 s of horizonal saccadic eye movements (compared to vertical or no eye movements) prior to retrieval improved performance on an episodic (vs. implicit) test of memory.

Following this demonstration, other research has extended these findings. In laboratory-based memory tasks, SIRE effects have been found to improve: (i) associative recognition memory (Lyle et al., 2012; Parker et al., 2008), (ii) the amount of detail as measured by "remember" responses (Parker et al., 2008; Parker et al., 2009), (iii) perceptual and visuo-spatial recognition (Brunyé et al., 2009; Parker et al., 2020), (iv) free recall of neutral and emotional words (Nieuwenhuis et al., 2013; Phaf, 2017; Samara et al., 2011), (v) faces (Lee et al., 2014; Lyle & Orsborne, 2011), explicit (vs. implicit memory) (Parker et al., 2018), (vi) eyewitness recall and recognition memory (Keunsoo & Hojin, 2017; Lyle, 2018; Lyle & Jacobs, 2010; Parker et al., 2009; Parker & Dagnall, 2007), and (vii) memory in children (Parker & Dagnall, 2012).

SIRE effects have also been observed for autobiographical memory. For example, Christman et al. (2003), asked participants to keep diary records of personal events over the course of six days. Two weeks after completion, free-recall for these events was assessed following horizontal (vs. fixation) eye movement conditions. It was found that the horizontal condition improved recall accuracy without a change in response bias. Christman et al. (2006) found that horizontal saccades can also assist with the recall of putatively earlier memories from childhood. Using the cue-word technique, Parker and Dagnall (2010) found horizontal saccades to increase the recollective characteristics of autobiographical memory including the subjective experience of re-living the recalled situation. To the extent that autobiographical recollection involves the recovery of event-specific details, this implies horizontal eye movements can increase memory specificity, which has been found (Parker et al., 2017).

Theoretical accounts of SIRE effects

Two principal explanations for SIRE effects have been proposed; the original account is based on hemispheric interaction, and a later theory grounded in top-down processing. In the former, Christman et al. (2003) asserted that horizontal saccades increase interhemispheric communication. Consequently, cognitive processes that depend on such communication will be influenced. Episodic (vs. semantic or implicit) memory is deemed to be amongst these. Support for this notion arose from some early Positron Emission Tomographic work that showed functional specialisation between the left and right prefrontal regions in episodic memory encoding and retrieval. Specifically, left (vs. right) prefrontal regional activity was higher during encoding (vs. retrieval) with the opposite during retrieval (vs. encoding) (Nyberg et al., 1996; Tulving et al., 1994). This finding, referred to as Hemispheric Encoding and Retrieval Asymmetry (HERA), has also been observed in later work using a range of imaging techniques (e.g., Babiloni et al., 2006; Gagnon et al., 2010; Rossi et al., 2011).

According to the original account, horizontal saccades temporarily facilitate inter-hemispheric communication and enable more effective functional coupling between right hemisphere retrieval processes that operate upon the memory traces created by left hemisphere encoding processes (Christman et al., 2006; Christman & Propper, 2010). As such, the memory of stored episodic information is enhanced because the interaction between the right (retrieval) and left (encoding) hemispheres is more efficient.

In contrast to the hemispheric interaction model, Lyle and Edlin (2015) asserted that SIRE effects arise from enhanced top-down processing. In this, the task of sequentially moving the eyes from left to right to follow an on-screen target actively demands attentional control. This is because participants need to utilise some degree of top-down governance to maintain eye-fixation on the moving target. Once top-down processing has been engaged, this continues for a short time afterward and can then influence subsequent performance by influencing the allocation of attention. Consequently, tasks that require the contribution of top-down control receive a processing boost and performance is enhanced. In relation to memory, this is of importance for controlled retrieval tasks that require effortful search operations and post-retrieval monitoring.

This explanation is set against a background of neuroimaging work in which the functional engagement between the dorsal frontal and dorsal parietal cortex supports the top-down control of attention and memory (Cabeza, 2008; Corbetta & Shulman, 2002). Regarding memory, it is argued that during episodic memory retrieval, top-down signals arising in the pre-frontal regions apportion attentional resources to activate posterior parietal and visual regions (e.g., Ciaramelli et al., 2008; Wagner et al., 2005). Lyle and Edlin (2015), state that SIRE effects result from eye movements increasing top-down control leading to the allocation of attention to stored memories and making them more accessible and thus recallable.

Although support for these accounts has arisen from *behavioural* work (e.g., Brunyé et al., 2009; Christman et al., 2003; Edlin & Lyle, 2013; Lyle & Edlin, 2015) more direct assessment deriving from the measurement of neural activity is somewhat scarce and equivocal. For instance, in relation to the HERA account, horizontal saccades did not lead to an increase in the EEG measure of Gamma band coherence (taken as a measure of interhemispheric communication) across right-left frontal regions; instead, a reduction was observed (Propper et al., 2007). In addition, subsequent work found no alterations in EEG coherence across any frequency band after horizontal saccadic eye movements (Samara et al., 2011).

Subsequent work found horizontal saccades to enhance interhemispheric Beta coherence over prefrontal regions. However, this was only a numerical increase and did not achieve established levels of significance reporting ($p = .061$). Although the authors explain their results as consistent with the HERA account, they state that their findings should be viewed more cautiously and to be taken as *suggestive* of an interhemispheric effect rather than being definite in this regard. Unfortunately, there are no direct tests of the HERA explanation of SIRE effects using techniques such as fMRI and any conclusions await further research.

Regarding the top-down account, Fleck et al. (2018), found that Delta band coherence covering frontal-posterior electrode sites was sustained after a period of 30 s of horizontal saccades (vs. fixation). This was explained as the consequence of eye movements engaging an attentional control mechanism being maintained over time. Further, coherence in the Alpha band decreased over the frontal-posterior midline electrodes after horizontal saccades. This was interpreted as underpinning the increased readiness to deploy a top-down attentional network for tasks after eye movements.

More direct assessment of the role of top-down control processes has been made using the Attentional Network Test (Fan et al., 2002). In an event-related potential study, Fleck et al. (2019) found horizontal saccades were associated with changes in N100 and P200 ERP components (both of which have been related to attention) compared to a fixation condition. This was explained as resulting in a shift in the allocation of attentional processes leading to the prioritisation of ongoing cognitive tasks including memory retrieval. Like the research on the HERA explanation, no work has yet been conducted on the top-down account using fMRI. Consequently, both theories need additional examination using neuroimaging technologies.

The current experiment

The current experiment assessed the effects of eye movements on episodic and semantic personal memory by use of the autobiographical fluency task (Dritschel et al., 1992). This task requires the production of as many examples as possible of personal episodic, semantic, and general semantic memories within 90 s (i.e., fluency). This, and similar fluency techniques, have been used in past work to measure episodic and semantic autobiographical memory (e.g., Coste et al., 2011; Greene et al., 1995; Smith et al., 2010; Unsworth et al., 2012), and have been shown to be sensitive to a range of group differences including autism (Crane & Goddard, 2008), mild cognitive impairment (Tomadesso et al., 2015), and age (Martinelli et al., 2013; Mevel et al., 2013). The task has also been utilised to assess memory performance as a function of saccadic eye movements (Parker et al., 2013). In this, pre-retrieval horizontal saccades enhanced episodic autobiographical, but not semantic autobiographical memory fluency. Principally, horizontal eye movements increased the number of personal memories for episodic events over two lifetime periods of 5–11 and 12–18. Conversely, memory for the names of friends and teachers (personal semantic memory) and of semantic categories (general semantic memory) were uninfluenced by eye movements. However, to date, this fluency task has not been used in conjunction with both eye movements and older (vs. younger) individuals.

In the current experiment, the saccadic eye movement (vs. fixation) task was implemented prior to the recall of personal episodic memory, personal semantic memory, and general semantic memory for both older and younger individuals. The episodic memories recalled were from 5 to 11 and 12–18 to maintain consistency with previous work and to facilitate comparisons with prior results. The implications of selecting these lifetime periods are assessed in the discussion in relation to the age of the actual memories which will naturally be greater for the older participants. Tentative predictions are derived from the SIRE explanations outlined earlier. From perspective of the hemispheric interaction (HERA) account, it is known that ageing is associated with a decrease in the size and structural integrity of the corpus callosum (e.g., Cowell et al., 1992; McLaughlin et al., 2007; Weis et al., 1993). As this is the major pathway by which interhemispheric communication takes place, ageing should bring about a decrease in the degree of interaction (Delvenne & Castronovo, 2018; Duffy et al., 1996; Lyle, McCabe, et al., 2008). Indeed, neuroimaging work has shown a reduced HERA signature to be associated with impaired episodic memory in older individuals (Cabeza et al., 2004; Johansson et al., 2020; Rönnlund et al., 2005). Consequently, a possible enhancement of interhemispheric communication, via horizontal saccades, could serve to increase episodic autobiographical memory performance in both older and younger individuals.

Regarding the top-down explanation, research indicates that top-down processing is impaired in older adults (e.g., Amer et al., 2016; Braver & Barch, 2002; Lee et al., 2012). Furthermore, this impairment has been found to impact performance on tests of episodic and autobiographical episodic memory (e.g., Piolino et al., 2010). In the context of the top-down account, the result of eye movement induced increases in controlled processing would lead to the activation of mnemonic representations and the facilitation of their retrieval (Lyle & Orsborne, 2011). This is hypothesised to take place by the upmodulation of target representations making them more accessible and reducing interference from non-target competitors (Kelley & Lyle, 2021; Lyle & Edlin, 2015).

What is more difficult to predict is whether the magnitude of the SIRE effect will differ across older and younger participants. It could be argued that if hemispheric interaction is reduced in older participants, then eye movements could provide a particularly valuable boost to recall and thus the size of the SIRE effect could be larger. A similar argument could be made from the perspective of the top-down account as top-down processing is deficient in older subjects, eye movements should enhance retrieval.

Method

Design

The experiment had two between-subject variables; eye movement task (horizontal vs. fixation) and age of the individual (older vs. younger).[1] The episodic autobiographical memory condition also contained a within-subject variable which was the age of the recalled memory (ages 5–11 years old vs. 12–18 years old). The dependent variables were the number of examples generated for each of the memory categories. These included: (i) personal episodic memory (episodic events from 5 to 11 years and 12–18 years), (ii) personal semantic memory (names of teachers and names of friends, both from 5 to 18) and (iii) general semantic memory (names of vegetables and animals).

Participants

One-hundred and twenty participants took part in the experiment. Eighty younger adults (age range 18-34, mean = 22.50), and 40 older adults (age range 55–87, mean = 70.35) were recruited using opportunity snowball sampling. Participants were randomly allocated to each eye movement condition (59 in the horizontal condition and 61 in the fixation condition)[2] by the data collection team. The participants in the younger condition were primarily recruited from the university and surrounding facilities and had to be at least 18 years of age. The older participants were all community dwelling and autonomous individuals who were recruited from several community establishments, such as local churches and community centres. The exclusion criteria were: (i) presence of neurological or psychiatric medical history, (ii) current or past memory complaints, (iii) taking any medication known to impair memory.

Materials and apparatus

Materials included an experimental booklet that consisted of three main sections. The first contained the participant information sheet, consent form, and spaces to record demographic information such as the participant age. The second section contained a modified version of the "Edinburgh Handedness Inventory" (Oldfield, 1971).[3] Several different versions of the scale have been used in the past (Edlin et al., 2015). In the present work, a total of ten activities (e.g., writing, drawing and throwing) were used as described by Lyle, McCabe et al. (2008). For each activity, the participant placed a check at one of the five points of a Likert scale to indicate handedness preference for each of the ten activities. The five points were defined as always left (−10), usually left (−5), no preference (0), usually right (+5) and always right (+10). An example question from the scale asks, "What hand do you write with?" or "When brushing your teeth, what hand do you use?"

The third section contained the experimental instructions pertaining to the recall of episodic autobiographical memory, semantic autobiographical memory, and general semantic memory. Each sub-section of the test contained explicit instructions and examples for the experimenters to follow.

A digital timer was used to time the 90 s given for each memory recall trial and an audio programme on a portable PC was used to record all responses provided by the participants. Finally, computer programme was used to initiate eye movements. This was done by flashing a black circle against a white background from side to side (horizontal condition), or on and off in the centre of the screen (fixation condition). The circle moved once every 500 ms and in the eye movement conditions was located approximately 27° of visual angle apart.

Procedure

Participants were tested individually. Each participant was assigned randomly to one of the eye movement conditions. The participants were then asked to read the participant information sheet and if they had no questions complete the provided consent forms and participant codes.

Next, the participants were asked to complete the Edinburgh Handedness Inventory. Once this was completed, the participants gave back the booklet to the experimenter and was asked to relax and face the computer monitor. At this point, all the instructions were presented verbally, and responses were recorded by the audio recording software. The participants were then told the experiment would consist of several phases. In each phase, they were asked to view a moving or stationary dot on the screen for 30 s. Participants were in the same eye movement condition for all the phases of the experiment. Compliance with the eye movement instructions was monitored by the experimenter as in previous studies. After the eye movement (vs. fixation) task, standardised instructions were read to the participants based on those described by Dritschel et al. (1992).

For the test of episodic autobiographical memory, the instructions were "For this test, I would like you to recall as many personal memories as possible of events from two periods in your life. The first period is between 5–11 years old, and the second period is between 12 and 18 years old. For each of these periods, I would like you to recall as many memories as you can within 90 s. Please try to name specific memories of events that relate to particular and single occurrences such as 'the time I beat my best friend in the school swimming competition' rather than general memories, such as 'having a paper round'. Please do not go into detail about each memory, just state each one as it comes to mind and then move onto the next." Participants were provided with additional examples where required and were told that they did not have to reveal any memories they were not comfortable with disclosing. The task progressed only when the instructions were understood.

For the test of semantic autobiographical memory, the instructions were:

> For this test, I would like you to recall as many autobiographical facts as you can from two periods in your life. The first period is between 5 and 11 years old, and the second period is between 12 and 18 years old. For each of these periods, I would like you to recall as many autobiographical facts as you can within 90 seconds. By autobiographical facts, in this case, I mean names of school friends (vs. teachers). You do not need to tell me each memory in detail, just try to recall as many facts as you can about your life.

The task progressed only when the instructions were understood.

For the test of general semantic memory, the instructions were:

> For this test, I would like you to generate as many examples from two semantic categories as you can. I will give you 90 seconds to generate from each semantic category. By generating examples from semantic categories what I mean is this, if I were to say "transport" then I would like you to say as many examples of transport that you can such as cars, trains, boats, ships etc. Just state out loud the examples that come to mind. You do not need to tell me about each example in detail, just try to generate as many examples as you can.

Following the presentation of these instructions, either animals or vegetables were read aloud in a randomised order and the recall period commenced. Once the recall period for one category had elapsed, the next category was presented, and the second recall period commenced.

After presenting the appropriate instructions, the timer was set to 90 s and the recall trial began. Following Dritschel et al. (1992), the recall of episodic memory always started with earlier autobiographical period. After each recall trial, there was a short pause of a few minutes before the next set of eye movements (vs. fixation) and recall trial. The order in which episodic autobiographical, semantic autobiographical (friends and teachers names) and general semantic memories were tested was counterbalanced.

Once the study was complete the participants were debriefed and reminded of their ethical rights.

Results

The number of memories recalled (minus repetitions or irrelevant/incorrect information) for each memory type were scored separately.[4] These were then entered into separate univariate ANOVAs for each DV. The descriptive statistics for all tests can be found in Table 1.

Episodic autobiographical memory

The cumulative number of specific autobiographical memories were placed in a 2 (Eye Movements: Horizontal vs. Fixation) between-subjects by 2 (Age Group: Young vs. Old) between-subjects by 2 (Lifetime Period: 5–11 vs. 12–18) within-subject mixed factorial ANOVA.[5] This revealed a significant main effect of participant age group, $F(1,116) = 16.53$, $p < .001$, $\eta_p^2 = .125$, indicating more episodic memories recalled for the younger group ($M = 11.67$) compared to the older participants ($M = 9.20$). The main effect of eye movement was significant, $F(1,116) = 14.88$, $p < .001$, $\eta_p^2 = .114$, indicating that participants in the horizontal group ($M = 11.62$) scored significantly higher than the fixation group ($M = 9.67$). The main effect of lifetime period was also significant, $F(1,116) = 5.50$, $p = .021$, $\eta_p^2 = .045$, showing more memories for 12–18 ($M = 11.05$) compared to 5–11 ($M = 10.25$).

The interaction between eye movement and lifetime period was not significant, $F(1,116) = 0.87$, $p = .35$, $\eta_p^2 = .008$. The interaction between age and lifetime period was not significant, $F(1,116) = 1.03$, $p = .31$, $\eta_p^2 = .009$. The interaction between eye movement and age was not significant, $F(1,116) = 0.039$, $p = .84$, $\eta_p^2 < .001$. Finally, the

Table 1. Mean (SD) Number of memories recalled for each memory type as a function of eye movement condition and age group.

	Eye movement condition								
	Horizontal $n = 59$			Fixation $n = 61$			Total $n = 120$		
Age group	*N*	*M*	*(SD)*	*N*	*M*	*(SD)*	*N*	*M*	*(SD)*
Episodic ABM 5–11									
Younger	37	11.68	(3.53)	43	10.53	(2.87)	80	11.62	(3.22)
Older	22	10.45	(2.18)	18	8.33	(3.40)	40	9.50	(2.95)
Total	59	11.22	(3.13)	61	9.89	(3.17)	120	10.54	(3.21)
Episodic ABM 12–18									
Younger	37	13.73	(3.72)	43	10.77	(2.87)	80	12.14	(3.72)
Older	22	10.64	(2.17)	18	9.06	(3.19)	40	9.93	(2.79)
Total	59	12.58	(3.55)	61	10.26	(3.23)	120	11.40	(3.57)
Personal semantic memory									
Younger	37	19.81	(5.84)	43	18.99	(6.45)	80	19.37	(6.15)
Older	22	10.32	(3.15)	18	9.67	(5.89)	40	10.03	(5.54)
Total	59	16.27	(6.80)	61	16.24	(7.57)	120	16.25	(7.17)
General semantic memory									
Younger	37	23.88	(5.37)	43	23.02	(5.87)	80	23.41	(5.63)
Older	22	18.05	(3.44)	18	17.86	(4.51)	40	17.96	(3.90)
Total	59	21.70	(5.50)	61	21.50	(5.96)	120	21.60	(5.72)

three way interaction was not significant, $F(1,116) = 3.01$, $p = .09$, $\eta_p^2 = .025$.

The absence of an interaction is inconclusive regarding support for the null hypothesis. However, the use of Bayesian analyses can be used to assess the relative degree of support for the null (vs. alternative) (Rouder et al., 2012). Bayesian hypothesis testing has been proposed as a replacement to traditional frequentist hypothesis testing (e.g., Wagenmakers, 2007). It has also been suggested as a supplement to such analyses to evaluate the relative evidence in support of the null hypothesis when the outcome of frequentist statistics is not significant (e.g., Dienes, 2014; Rouder et al., 2012).

Bayesian analyses were performed using JASP software (JASP Team, 2018) using a Cauchy distribution with .5 on the prior (Rouder et al., 2012; Wagenmakers et al., 2018) and BF_{01} (Bayes factor) values reported.

This Bayes factor represents the ratio of the probabilities in the data set to support the null vs. alternative hypothesis. A Bayes factor of 1 indicates equal support for the null and the alternative hypothesis. A Bayes factor of 1 and above indicates more support for the null hypothesis (Morey et al., 2016). However, although Bayesian evidence is continuous, standard thresholds are sometimes reported and provide a more categorical interpretation of the findings. For these, values of between 3 and 0.33 are taken to indicate the results are indeterminate (Lee & Wagenmakers, 2014). These reporting thresholds are included below.

Consequently, Bayesian ANOVAs were performed in which the significant main effects were combined into the null model and the unique contribution of the two-way and the three-way outcomes were assessed. The interaction between eye movement and lifetime period produced a BF_{01} of 1.93, indicating this finding is somewhat inconclusive and more work needs to be done to assess the likelihood of an interaction between eye movements and lifetime period. The Bayes factor for the interaction between eye movement and age was BF_{01} of 3.24, showing moderate evidence in favour of the absence of an interaction. The interaction between age and lifetime period produced a BF_{01} of 3.25, also showing evidence of the absence of an interaction. The three-way interaction resulted in a BF_{01} of 1.18, showing somewhat inconclusive evidence for the absence of an interaction between all factors.

Personal semantic memory

The cumulative number of personal semantic memory indicated a significant main effect of participant age group, $F(1,116) = 71.90$, $p < .001$, $\eta_p^2 = .383$, showing more personal semantic memories recalled for the younger group ($M = 19.37$) compared to the older participants ($M = 10.03$). The main effect of eye movement was not significant, $F(1,116) = .441$, $p = .508$, $\eta_p^2 = .004$. The interaction between the two variables was also not significant, $F(1,116) = .006$, $p = .939$, $\eta_p^2 < .001$. Bayes factors were computed for the null effects eye movement and the interaction. For the main effect of eye movement, the BF_{01} was 5.26, showing moderate evidence in favour of the null hypothesis for an absence of a SIRE effect. For the interaction, the BF_{01} was 3.70, showing moderate evidence for the absence of an interaction between eye movements and age. Thus, support was found for only the main effect of age.

General semantic memory

The cumulative number of general semantic memories produced a significant main effect of participant age group, $F(1,116) = 30.10$, $p < .001$, $\eta_p^2 = .206$, indicating more general semantic memories recalled for the younger group ($M = 23.41$) compared to the older participants ($M = 17.96$). The main effect of eye movement was not significant, $F(1,116) = .269$, $p = .605$, $\eta_p^2 = .002$. The interaction between the two variables was not significant, $F(1,116) = .112$, $p = .738$, $\eta_p^2 = .001$. Bayes factors were computed for the null effects eye movement and the interaction. For the main effect of eye movement, the BF_{01} was 5.00, showing moderate evidence for the absence of a SIRE effect. For the interaction, the BF_{01} was 3.57, showing moderate evidence for the absence of an interaction between eye movements and age. Consequently, support was found for only the main effect of age.

General summary

Horizontal saccades enhanced autobiographical memory fluency but only when this required the recollection of episodic information. Age had a significant main effect in all three of the dependent variables showing that the older participants recalled significantly less information in the provided 90 s time windows.

Discussion

The current experiment demonstrated that SIRE effects for autobiographical episodic memory can be found in both younger and older participants. The effect for younger participants replicates the findings from Parker et al. (2013). The novel finding is that similar SIRE effects can be found for older individuals. Additionally, the fact that no interaction occurred showed the magnitude of the SIRE effect was similar for both age groups (although the absolute number of memories produced was lower for older participants).

The current findings in the context of theory and related work

The current experiment was not designed to tease apart theoretical accounts of SIRE effects. Consequently, both the HERA and top-down descriptions can explain the current outcomes. Regarding the HERA account, horizontal saccades enhance hemispheric interaction and allow right-hemisphere retrieval processes to more effectively access left-hemisphere encoded representations (Christman et al., 2003; Christman & Propper, 2010). This is only for episodic (vs. semantic) memories only as these are considered to be dependent on hemispheric interaction. Consequently, the finding that only episodic fluency was enhanced by eye movements is consistent with this account.

Another explanation claims that eye movements potentiate top-down processes that are then more readily employed to perform subsequent tasks that also require such processes. This includes episodic memory retrieval and attentional tasks (e.g., Edlin & Lyle, 2013). Within this framework, it has been proposed that SIRE effects are more likely to be found for less accessible information, as this requires more top-down support for successful recall (Lyle & Edlin, 2015). One possible prediction arising form this is that less accessible older memories (5–11) would benefit more from eye movements compared to more accessible recent memories (12–18). However, this conjecture was not supported and deserves further consideration in future work.

In this experiment, eye movements did not interact with age. Although this should not yet be taken as a general expectation, the lack of an interaction indicates that episodic autobiographical fluency can be enhanced to a similar degree in older as well as younger participants (see the limitations below in relation to the choice of lifetime periods). This is a good pragmatic outcome if eye movements are to be considered useful as a means of memory improvement in older people and used alongside other techniques for enhancing memory in the elderly such as reminiscence therapy, memory specificity training, and life review (Gonçalves et al., 2009; Martens et al., 2019; Meléndez Moral et al., 2015). Although the practical significance is clear, the theoretical importance of the lack of an interaction is more difficult to assess. It was earlier conjectured that SIRE effects could be larger in older participants if hemispheric interaction or top-down processing were less than optimal (but still available for implementation). Of course, too much remains unknown about the precise mechanisms of SIRE and exploration of this issue remains for future work.

In this paper, the effects of eye movements have been depicted in terms of memory facilitation. An alternative explanation is the fixation condition *reduced* memory performance. For example, prior research has shown that instructed eye fixation on an area of a screen can impair the recall of visual and auditory scene descriptions (Johansson et al., 2012), the vividness of a staged visual tour (Armson et al., 2021), and detailed episodic autobiographical memories (Lenoble et al., 2019). However, in these and similar studies, the fixation task is implemented *during* retrieval and thus disrupts spontaneous eye movements that may have a functional role during accessing memory. In contrast to SIRE work, the manipulation takes place *prior* to retrieval and thus eye movements are unconstrained during the recall period itself. In addition, Lyle, Logan, et al. (2008) directly compared horizontal, fixation and free eye movements prior to retrieval and found only pre-task saccades to increase memory. The fixation condition produced equivalent performance to spontaneous free eye movements. Thus, it is reasonable to conclude that the SIRE effects found here are due to eye movement enhancement as opposed to fixation-induced impairment.

The outcomes of the current work can also be examined in a broader context on the episodic-semantic distinction and ageing. Aging has a greater impact on episodic (vs. semantic) memory in both traditional laboratory measures of these concepts (e.g., Bäckman & Nilsson, 1996; Verhaegen et al., 2003) and in autobiographical memory (e.g., Meléndez et al., 2018; Piolino et al., 2002). In relation to general semantic memory, the current results showed fewer items recalled in older (vs. younger) individuals. However, previous work has revealed older individuals to perform to equivalent standards on tests that require the use of semantic memory such as naming, lexical decisions or semantic priming (e.g., Allen et al., 1993; Balota & Ferraro, 1996; Laver & Burke, 1993; Mitchell, 1989).

Conclusive reasons for differences between the past and current work are beyond the scope of the present paper but one explanation could relate to differences in task demands. Often, tasks that require verification of responses as opposed to overt production show smaller age differences because of reduced response competition or the involvement of frontal-executive processes (Geraci, 2006; Light et al., 2000). As the semantic fluency task used here required response production, this could have exaggerated or produced age differences that relate less to semantic knowledge and more to task demands.

Differences in personal semantic (vs. episodic) memory are eliminated or much reduced in older individuals using autobiographical interview techniques (e.g., Frankenberg et al., 2022; Levine et al., 2002). In the present experiment, a main effect of age was found for personal semantic memory as measured by the recall of names of teachers and friends. As autobiographical interview techniques likely require production demands greater than that in the current experiment, the production differences are unlikely to explain the age reduction found here. However, one reason for the disparity might relate to younger individuals possessing larger social networks compared to older persons (e.g., Wrzus et al., 2013). If so, then the age difference might be more apparent than real and simply represent a larger memory set size for younger persons.

Limitations

There are several limitations to the current work that could be addressed in subsequent research. Firstly, although handedness data was collected, the number of subjects per cell was too low to allow for this to be incorporated as a variable. As some previous work has shown SIRE effects are more robust for consistently-handed (mainly strongly right-handed) persons (e.g., Lyle, Logan et al., 2008), it would have been ideal to incorporate handedness as a factor. Past work on autobiographical cognition has also considered eye movements and handedness in separate studies (Parker et al., 2017; Parker & Dagnall, 2010). Consequently, there is a need to assess the joint influence of both eye movements and consistency of hand usage in one experiment. Despite this, the current work has at least shown the existence of SIRE effects even when consistent and inconsistently-handed persons are combined into one group.

The lifetime periods assessed in the present experiment covered childhood and adolescence. The reason for this was to maintain consistency with prior experiments (e.g., Parker et al., 2013). However, one drawback is that the age of the memory was not matched between the groups and such memories were necessarily older for the elder group. Older memories are presumably less accessible (indicated by a main effect of age) and thus could be more likely to benefit from eye movements according to the top-down account. Although the absence of an interaction would seem to go against this idea, it would be clearly advantageous to have a within-subject comparison of the remoteness of the memory. Thus, to achieve this, future work could attempt to match the age range of memories by the inclusion of a more recent lifetime period. For example, recall of personal episodic and semantic memories over the past 10 years. It is possible that a different pattern of findings might result compared to the ones observed here.

The present experiment made use of a fluency task to assess autobiographical retrieval and the episodic-semantic distinction. This could be extended to include other important measures of these concepts. For example, the autobiographical interview, as noted above, assesses the episodic and semantic components of personal memory *within* a recall protocol as opposed to separate recall trials as done here (Levine et al., 2002). This technique makes use of a scoring system that quantifies the internal (episodic or event-specific) and external (including semantic) qualities of memory across several lifetime periods.

An advantage of this technique is that is allows for the objective assessment of personal memory elements as they are freely recalled in a natural manner without the need for artificially distinguishing between components of personal memory with separate testing trials. Findings using the autobiographical interview show age to be positively associated with a decline in internal and event-specific detail and a preservation or even increase in semantic recall (Levine et al., 2002; St. Jacques & Levine, 2007). Use of the autobiographical interview would be particularly valuable in the context of age and SIRE effects for several reasons. Firstly, it would ensure that the current results are not limited to one particular method. Secondly, it would allow an appraisal of how eye movements influence components of *narrative* recall. This is an important consideration especially in an applied context if eye movements were to be used to improve memory in the elderly or other populations.

In this context, the current research needs to be extended to include participants who are in older age groups and to clinical populations who experience episodic memory difficulties. Although of course, we are not claiming that eye movements can in any way remediate such impairments. Rather, our view is more modest, and it would be of interest and value to at least examine if any form of mnemonic improvement could be achieved in such populations.

Conclusion

Eye movements were shown to improve episodic autobiographical memory fluency whilst having no effect on semantic or general autobiographical memory. This is a novel finding and the first demonstration of episodic memory enhancement in elderly individuals initiated by eye movements. This finding holds promise for future work aiming to enhance memory in older individuals where personal recollection can be important for either maintaining or improving the quality of life of those individuals.

Notes

1. The youngers participants were aged 18–34 years old (Levine et al., 2002; Piolino et al., 2006) and older participants were aged 55–87 years old (Holland et al., 2012; Wolf & Zimprich, 2016).
2. Sample size was based on similar previous work (e.g., Dijkstra & Janssen, 2016; Holland et al., 2012; Parker et al., 2013) and a sample size analysis performed in MorePower 6.0 (Campbell & Thompson, 2012). For a main effect and interaction effect size of $\eta_p^2 = 063$, with $\alpha = .05$, and for 80% power, the estimated total sample size was 120.
3. The handedness scores were not used in the analyses as this produced too few participants in each of the conditions. For completeness, the number of consistent (vs. inconsistent handed) individuals in each condition can be found in the appendix together with the relevant descriptive statistics. This of course represents a limitation of the current experiment and is dealt with in the discussion. However, to provide some assessment of the possible contribution of handedness we performed an ANCOVA with the handedness scores as a covariate using the same factors and fluency scores as described in the results section. This did not alter the pattern of findings of main effects and handedness was found not to relate to any of the fluency scores. The conclusion we draw from this is that in this sample at least, handedness does not moderate the effects of eye movements.
4. All data collectors undertook a training period in which the procedure and experimental instructions were worked thorough and performed prior to any contact with subjects. They were provided with examples of "acceptable" responses (i.e., within the definitions for each of the tasks). These were also used during data collection to provide greater clarity around the wording of the task instructions. Personal episodic memories were examined directly after the experiment with the participant to clarify any ambiguous responses and were very few. Later, a random sample of 35% was checked by two individuals to assess if these were congruent with the criteria as defined in the instructions (i.e., specific experiences). Over 98% were within the definition and agreed upon by the coders. Personal semantic memory responses were also examined with the participant directly after the experiment to check if any repetition of a name pertained to different people with the same name or genuine repeats. Any repetitions were removed. Semantic responses were checked for accuracy and were virtually 100%. Any errors were removed from the tally prior to analysis.
5. The analyses were also completed using adjusted sample age brackets with a total of 114 participants. For this, the younger group remained the same, but the older group was changed to a minimum of 60 years and resulted in an older sample of 32 with an age range of 60–87 and mean of 72.92. The same main effects were found in these age brackets as the ones reported in the results section.

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Appendix

Number of participants in each condition as a function of eye movement condition, age group & handedness.

	Eye movement condition								
Age group & handedness	Horizontal *n* = 59			Fixation *n* = 61			Total *n* = 120		
Episodic ABM 5–11									
Younger									
Consistent	23	11.52	(3.36)	32	10.69	(2.67)	55	11.04	(2.97)
Inconsistent	14	11.93	(3.91)	11	10.09	(3.51)	25	11.12	(3.78)
Older									
Consistent	15	11.52	(3.36)	14	8.36	(3.56)	46	9.07	(2.87)
Inconsistent	7	12.00	(2.00)	4	8.25	(3.20)	15	10.64	(3.00)
Total									
Consistent	38	10.82	(2.98)	46	9.98	(3.12)	84	10.36	(3.07)
Inconsistent	21	11.95	(3.34)	15	9.60	(3.41)	36	10.97	(3.53)
Episodic ABM 12–18									
Younger									
Consistent	23	14.17	(4.30)	32	11.10	(3.78)	55	12.13	(3.96)
Inconsistent	14	13.00	(2.48)	11	10.66	(2.97)	25	12.16	(3.20)
Older									
Consistent	15	10.27	(3.15)	14	9.21	(3.53)	46	9.76	(2.69)
Inconsistent	7	11.43	(2.17)	4	8.50	(1.73)	15	10.36	(3.00)
Total									
Consistent	38	12.63	(3.96)	46	10.22	(3.19)	84	11.31	(3.73)
Inconsistent	21	12.48	(2.75)	15	10.40	(3.50)	36	11.61	(3.21)
Personal semantic memory									
Younger									
Consistent	23	19.76	(6.60)	32	18.39	(5.97)	55	18.96	(6.22)
Inconsistent	14	19.89	(4.56)	11	20.73	(7.72)	25	20.26	(6.02)
Older									
Consistent	15	9.47	(2.58)	14	9.43	(6.71)	46	9.45	(4.92)
Inconsistent	7	12.14	(3.67)	4	10.50	(0.70)	15	11.55	(2.99)
Total									
Consistent	38	15.69	(7.38)	46	15.66	(7.38)	84	15.68	(7.35)
Inconsistent	21	17.31	(5.62)	15	18.00	(5.62)	36	17.60	(6.63)
General semantic memory									
Younger									
Consistent	23	23.17	(5.52)	32	22.97	(6.02)	55	23.05	(5.77)
Inconsistent	14	25.04	(5.09)	11	23.18	(5.68)	25	24.22	(5.33)
Older									
Consistent	15	17.83	(3.38)	14	17.57	(4.51)	46	21.33	(6.05)
Inconsistent	7	18.50	(3.79)	4	18.88	(6.05)	15	22.03	(5.86)
Total									
Consistent	38	21.07	(5.43)	46	21.33	(6.05)	84	21.21	(5.74)
Inconsistent	21	22.86	(5.58)	15	22.03	(5.86)	36	22.51	(5.63)