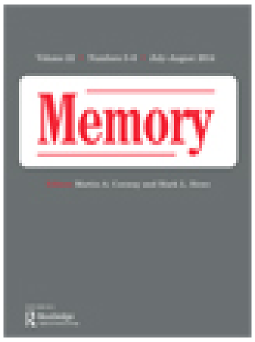

Memory

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pmem20

Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants

Adam Parkin, Andrew Parker & Neil Dagnall

To cite this article: Adam Parkin, Andrew Parker & Neil Dagnall (2022): Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants, Memory, DOI: 10.1080/09658211.2022.2122997

To link to this article: https://doi.org/10.1080/09658211.2022.2122997

Published online: 21 Sep 2022.

MEMORY
https://doi.org/10.1080/09658211.2022.2122997

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants

Adam Parkin, Andrew Parker and Neil Dagnall

Department of Psychology, Manchester Metropolitan University, Manchester, United Kingdom

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.

ARTICLE HISTORY
Received 6 January 2022
Accepted 5 September 2022

KEYWORDS
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

CONTACT Adam Parkin a.parkin@mmu.ac.uk Department of Psychology, Manchester Metropolitan University, Brooks Building, 53 Bonsall Street, Manchester, M15 6GX, United Kingdom

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.

Acknowledgements

The authors would like to thank Lauren Parkin, Aaron Warner, Jack Nightingale, Tara Hensman, Margret Bindeman, Parise Carmichael-Murphy, Manal Almugathwi and Jacinta Meaney for assistance with piloting and the collection of data for the experiments reported here.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Andrew Parker http://orcid.org/0000-0003-4066-7339
Neil Dagnall http://orcid.org/0000-0003-0657-7604

References

Allen, P. A., Madden, D. J., Weber, T. A., & Groth, K. E. (1993). Influence of age and processing stage on visual word recognition. *Psychology and Aging*, *8*(2), 274–282. https://doi.org/10.1037/0882-7974.8.2.274

Amer, T., Campbell, K. L., & Hasher, L. (2016). Cognitive control as a double-edged sword. *Trends in Cognitive Sciences*, *20*(12), 905–915. https://doi.org/10.1016/j.tics.2016.10.002

Armson, M. J., Diamond, N. B., Levesque, L., Ryan, J. D., & Levine, B. (2021). Vividness of recollection is supported by eye movements in individuals with high, but not low trait autobiographical memory. *Cognition*, *206*, 104487. https://doi.org/10.1016/j.cognition.2020.104487

Babiloni, C., Vecchio, F., Cappa, S., Pasqualetti, P., Rossi, S., Miniussi, C., & Rossini, P. M. (2006). Functional frontoparietal connectivity during encoding and retrieval processes follows HERA model: A high-resolution study. *Brain Research Bulletin*, *68*(4), 203–212. https://doi.org/10.1016/j.brainresbull.2005.04.019

Bäckman, L., & Nilsson, L. G. (1996). Semantic memory functioning across the adult life span. *European Psychologist*, *1*(1), 27–33. https://doi.org/10.1027/1016-9040.1.1.27

Balota, D. A., & Ferraro, F. R. (1996). Lexical, sublexical, and implicit memory processes in healthy young and healthy older adults and in individuals with dementia of the Alzheimer type. *Neuropsychology*, *10*(1), 82–95. https://doi.org/10.1037/0894-4105.10.1.82

Beaman, A., Pushkar, D., Etezadi, S., Bye, D., & Conway, M. (2007). Autobiographical memory specificity predicts social problem-solving ability in old and young adults. *The Quarterly Journal of Experimental Psychology*, *60*(9), 1275–1288. https://doi.org/10.1080/17470210600943450

Braver, T. S., & Barch, D. M. (2002). A theory of cognitive control, aging cognition, and neuromodulation. *Neuroscience & Biobehavioral Reviews*, *26*(7), 809–817. https://doi.org/10.1016/S0149-7634(02)00067-2

Brunyé, T. T., Mahoney, C. R., Augustyn, J. S., & Taylor, H. A. (2009). Horizontal saccadic eye movements enhance the retrieval of landmark shape and location information. *Brain & Cognition*, *70*(3), 279–288. https://doi.org/10.1016/j.bandc.2009.03.003

Cabeza, R. (2008). Role of parietal regions in episodic memory retrieval: The dual attentional processes hypothesis. *Neuropsychologia*, *46*(7), 1813–1827. https://doi.org/10.1016/j.neuropsychologia.2008.03.019

Cabeza, R., Daselaar, S. M., Dolcos, F., Prince, S. E., Budde, M., & Nyberg, L. (2004). Task-independent and task-specific age effects on brain activity during working memory, visual attention and episodic retrieval. *Cerebral Cortex*, *14*(4), 364–375. https://doi.org/10.1093/cercor/bhg133

Campbell, J. I., & Thompson, V. A. (2012). Morepower 6.0 for ANOVA with relational confidence intervals and Bayesian analysis. *Behavior Research Methods*, *44*(4), 1255–1265. https://doi.org/10.3758/s13428-012-0186-0

Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T., & Pashler, H. (2008). Spacing effects in learning: A temporal ridgeline of optimal retention. *Psychological Science*, *19*(11), 1095–1102. https://doi.org/10.1111/j.1467-9280.2008.02209.x

Christman, S. D., Garvey, K. J., Propper, R. E., & Phaneuf, K. A. (2003). Bilateral eye movements enhance the retrieval of episodic memories. *Neuropsychology*, *17*(2), 221–229. https://doi.org/10.1037/0894-4105.17.2.221

Christman, S. D., & Propper, R. E. (2010). Episodic memory and interhemispheric interaction: Handedness and eye movements. In G. M. Davies, & D. B. Wright (Eds.), *Current issues in applied memory research* (pp. 185–205). Psychology Press.

Christman, S. D., Propper, R. E., & Brown, T. J. (2006). Increased interhemispheric interaction is associated with earlier offset of childhood amnesia. *Neuropsychology*, *20*(3), 336–345. https://doi.org/10.1037/0894-4105.20.3.336

Ciaramelli, E., Grady, C. L., & Moscovitch, M. (2008). Top-down and bottom-up attention to memory: A hypothesis (AtoM) on the role of the posterior parietal cortex in memory retrieval. *Neuropsychologia*, *46*(7), 1828–1851. https://doi.org/10.1016/j.neuropsychologia.2008.03.022

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language*, *53*(4), 594–628. https://doi.org/10.1016/j.jml.2005.08.005

Conway, M. A. (2009). Episodic memories. *Neuropsychologia*, *47*(11), 2305–2313. https://doi.org/10.1016/j.neuropsychologia.2009.02.003

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review*, *107*(2), 261–288. https://doi.org/10.1037/0033-295X.107.2.261

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201–215. https://doi.org/10.1038/nrn755

Coste, C., Agar, N., Petitfour, E., Quinette, P., Guillery-Girard, B., Azouvi, P., & Piolino, P. (2011). Exploring the roles of the executive and short-term feature-binding functions in retrieval of retrograde autobiographical memories in severe traumatic brain injury. *Cortex*, *47*(7), 771–786. https://doi.org/10.1016/j.cortex.2010.07.004

Coste, C., Navarro, B., Vallat-Azouvi, C., Brami, M., Azouvi, P., & Piolino, P. (2015). Disruption of temporally extended self-memory system following traumatic brain injury. *Neuropsychologia*, *71*, 133–145. https://doi.org/10.1016/j.neuropsychologia.2015.03.014

Cowell, P. E., Allen, L. S., Zalatimo, N. S., & Denenberg, V. H. (1992). A developmental study of sex and age interactions in the human corpus callosum. *Developmental Brain Research*, *66*(2), 187–192. https://doi.org/10.1016/0165-3806(92)90079-C

Craik, F. I., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, *104*(3), 268–294. https://doi.org/10.1037/0096-3445.104.3.268

Crane, L., & Goddard, L. (2008). Episodic and semantic autobiographical memory in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *38*(3), 498–506. https://doi.org/10.1007/s10803-007-0420-2

Delvenne, J. F., & Castronovo, J. (2018). Reduced inter-hemispheric interference in ageing: Evidence from a divided field Stroop paradigm. *Brain and Cognition*, *122*, 26–33. https://doi.org/10.1016/j.bandc.2018.01.008

Dritschel, B. H., Williams, J. M. G., Baddeley, A. D., & Nimmo-Smith, I. (1992). Autobiographical fluency: A method for the study of personal memory. *Memory & Cognition*, *20*(2), 133–140. https://doi.org/10.3758/BF03197162

Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in Psychology*, *5*, 781. https://doi.org/10.3389/fpsyg.2014.00781

Dijkstra, K., & Janssen, S. M. (2016). Differential effects of aging on autobiographical memory tasks. *SAGE Open*, *6*(2), 2158244016646412. https://doi.org/10.1177/2158244016646412

Duffy, F. H., Mcanulty, G. B., & Albert, M. S. (1996). Effects of age upon interhemispheric EEG coherence in normal adults. *Neurobiology of Aging*, *17*(4), 587–599. https://doi.org/10.1016/0197-4580(96)00007-3

Edlin, J. M., Leppanen, M. L., Fain, R. J., Hackländer, R. P., Hanaver-Torrez, S. D., & Lyle, K. B. (2015). On the use (and misuse?) of the Edinburgh handedness inventory. *Brain and Cognition*, *94*, 44–51. https://doi.org/10.1016/j.bandc.2015.01.003

Edlin, J. M., & Lyle, K. B. (2013). The effect of repetitive saccade execution on the attention network test: Enhancing executive function with a flick of the eyes. *Brain and Cognition*, *81*(3), 345–351. https://doi.org/10.1016/j.bandc.2012.12.006

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, *14*(3), 340–347. https://doi.org/10.1162/089892902317361886

Fleck, J. I., Olsen, R., Tumminia, M., DePalma, F., Berroa, J., Vrabel, A., & Miller, S. (2018). Changes in brain connectivity following exposure to bilateral eye movements. *Brain & Cognition*, *123*, 142–153. https://doi.org/10.1016/j.bandc.2018.03.009

Fleck, J. I., Payne, L., Halko, C., & Purcell, M. (2019). Should we pay attention to eye movements? The impact of bilateral eye movements on behavioral and neural responses during the attention network test. *Brain and Cognition*, *132*, 56–71. https://doi.org/10.1016/j.bandc.2019.03.001

Frankenberg, C., Knebel, M., Degen, C., Siebert, J. S., Wahl, H. W., & Schröder, J. (2022). Autobiographical memory in healthy aging: A decade-long longitudinal study. *Aging, Neuropsychology, and Cognition*, *29*(1), 158–179. https://doi.org/10.1080/13825585.2020.1859082

Gagnon, G., Blanchet, S., Grondin, S., & Schneider, C. (2010). Paired-pulse transcranial magnetic stimulation over the dorsolateral prefrontal cortex interferes with episodic encoding and retrieval for both verbal and non-verbal materials. *Brain Research*, *1344*, 148–158. https://doi.org/10.1016/j.brainres.2010.04.041

Geraci, L. (2006). A test of the frontal lobe functioning hypothesis of age deficits in production priming. *Neuropsychology*, *20*(5), 539–548. https://doi.org/10.1037/0894-4105.20.5.539

Gonçalves, D. C., Albuquerque, P. B., & Paul, C. (2009). Life review with older women: An intervention to reduce depression and improve autobiographical memory. *Aging Clinical and Experimental Research*, *21*(4-5), 369–371. https://doi.org/10.1007/BF03324931

Greene, J. D., Hodges, J. R., & Baddeley, A. D. (1995). Autobiographical memory and executive function in early dementia of Alzheimer type. *Neuropsychologia*, *33*(12), 1647–1670. https://doi.org/10.1016/0028-3932(95)00046-1

Holland, C., Boukouvalas, A., Wallis, S., Clarkesmith, D., Cooke, R., Liddell, L., & Kay, A. (2017). Transition from community dwelling to retirement village in older adults: Cognitive functioning and psychological health outcomes. *Ageing & Society*, *37*(7), 1499–1526. https://doi.org/10.1017/S0144686X16000477

Holland, C. A., Ridout, N., Walford, E., & Geraghty, J. (2012). Executive function and emotional focus in autobiographical memory specificity in older adults. *Memory (Hove, England)*, *20*(8), 779–793. https://doi.org/10.1080/09658211.2012.703210

Hitchcock, C., Mueller, V., Hammond, E., Rees, C., Werner-Seidler, A., & Dalgleish, T. (2016). The effects of autobiographical memory flexibility (MemFlex) training: An uncontrolled trial in individuals in remission from depression. *Journal of Behavior Therapy and Experimental Psychiatry*, *52*, 92–98. https://doi.org/10.1016/j.jbtep.2016.03.012

Johansson, J., Salami, A., Lundquist, A., Wåhlin, A., Andersson, M., & Nyberg, L. (2020). Longitudinal evidence that reduced hemispheric encoding/retrieval asymmetry predicts episodic-memory impairment in aging. *Neuropsychologia*, *137*, 107329. https://doi.org/10.1016/j.neuropsychologia.2019.107329

Johansson, R., Holsanova, J., Dewhurst, R., & Holmqvist, K. (2012). Eye movements during scene recollection have a functional role, but they are not reinstatements of those produced during encoding. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(5), 1289–1314. https://doi.org/10.1037/a0026585

Karpicke, J. D., & Roediger, III H. L. (2007). Repeated retrieval during learning is the key to long-term retention. *Journal of Memory and Language*, *57*(2), 151–162. https://doi.org/10.1016/j.jml.2006.09.004

Kelley, A. M., & Lyle, K. B. (2021). Repetitive saccadic eye movements enhance eyewitness recall in specific-open questioning. *Journal of Cognitive Enhancement*, *5*(4), 420–433. https://doi.org/10.1007/s41465-020-00199-9

Keunsoo, H., & Hojin, J. (2017). The effect of horizontal saccadic eye movement on eyewitness memory recall. *The Korean Journal of Forensic Psychology*, *8*(3), 195–211. https://doi.org/10.53302/kjfp.2017.11.8.3.195

Laver, G. D., & Burke, D. M. (1993). Why do semantic priming effects increase in old age? A meta-analysis. *Psychology and Aging*, *8*(1), 34–43. https://doi.org/10.1037/0882-7974.8.1.34

Leahy, F., Ridout, N., Mushtaq, F., & Holland, C. (2018). Improving specific autobiographical memory in older adults: Impacts on mood, social problem solving, and functional limitations. *Aging, Neuropsychology, and Cognition*, *25*(5), 695–723. https://doi.org/10.1080/13825585.2017.1365815

Lee, N., Kim, S., Kim, J., Im, W., Kwon, H., Kim, K., Kim, M., & Lim, S. (2014). The effect of bilateral Eye movements on emotional face recognition memory task. *Journal of the Korean Neuropsychiatric Association*, *53*(5), 293–298. https://doi.org/10.4306/jknpa.2014.53.5.293

Lee, T., Crawford, J. D., Henry, J. D., Trollor, J. N., Kochan, N. A., Wright, M. J., Ames, D., Brodaty, H., & Sachdev, P. S. (2012). Mediating effects of processing speed and executive functions in age-related differences in episodic memory performance: A cross-validation study. *Neuropsychology*, *26*(6), 776–784. https://doi.org/10.1037/a0030053

Lee, M. D., & Wagenmakers, E. J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge university press.

Lenoble, Q., Janssen, S. M., & El Haj, M. (2019). Don't stare, unless you don't want to remember: Maintaining fixation compromises autobiographical memory retrieval. *Memory (Hove, England)*, *27*(2), 231–238. https://doi.org/10.1080/09658211.2018.1501068

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689. https://doi.org/10.1037/0882-7974.17.4.677

Light, L. L., Prull, M. W., & Kennison, R. F. (2000). Divided attention, aging, and priming in exemplar generation and category verification. *Memory & Cognition*, *28*, 856–872.

Lyle, K. B. (2018). Effects of handedness consistency and saccade execution on eyewitness memory in cued- and free-recall procedures. *Memory (Hove, England)*, *26*(9), 1169–1180. https://doi.org/10.1080/09658211.2017.1420802

Lyle, K. B., & Edlin, J. M. (2015). Why does saccade execution increase episodic memory retrieval? A test of the top-down attentional control hypothesis. *Memory (Hove, England)*, *23*(2), 187–202. https://doi.org/10.1080/09658211.2013.877487

Lyle, K. B., Hanaver-Torrez, S. D., Hackländer, R. P., & Edlin, J. M. (2012). Consistency of handedness regardless of direction predicts baseline memory accuracy and potential for memory enhancement. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *38*(1), 187–193. https://doi.org/10.1037/a0024831

Lyle, K. B., & Jacobs, N. E. (2010). Is saccade-induced retrieval enhancement a potential means of improving eyewitness evidence? *Memory (Hove, England)*, *18*(6), 581–594. https://doi.org/10.1080/09658211.2010.493891

Lyle, K. B., Logan, J. M., & Roediger, H. L. (2008). Eye movements enhance memory for individuals who are strongly right-handed and harm it for individuals who are not. *Psychonomic Bulletin & Review*, *15*(3), 515–520. https://doi.org/10.3758/PBR.15.3.515

Lyle, K. B., & Martin, J. M. (2010). Bilateral saccades increase intrahemispheric processing but not interhemispheric interaction: Implications for saccade-induced retrieval enhancement. *Brain & Cognition*, *73*(2), 128–134. https://doi.org/10.1016/j.bandc.2010.04.004

Lyle, K. B., McCabe, D. P., & Roediger, III H. L. (2008). Handedness is related to memory via hemispheric interaction: Evidence from paired associate recall and source memory tasks. *Neuropsychology*, *22*(4), 523–530. https://doi.org/10.1037/0894-4105.22.4.523

Lyle, K. B., & Orsborne, A. E. (2011). Inconsistent handedness and saccade execution benefit face memory without affecting interhemispheric interaction. *Memory (Hove, England)*, *19*(6), 613–624. https://doi.org/10.1080/09658211.2011.595418

Martens, K., Takano, K., Barry, T. J., Goedleven, J., Van den Meutter, L., & Raes, F. (2019). Remediating reduced autobiographical memory in healthy older adults with computerized memory specificity training (c-MeST): An observational before-after study. *Journal of Medical Internet Research*, *21*(5), e13333. https://doi.org/10.2196/13333

Martinelli, P., Anssens, A., Sperduti, M., & Piolino, P. (2013). The influence of normal aging and Alzheimer's disease in autobiographical memory highly related to the self. *Neuropsychology*, *27*(1), 69–78. https://doi.org/10.1037/a0030453

Mancuso, L. E., Ilieva, I. P., Hamilton, R. H., & Farah, M. J. (2016). Does transcranial direct current stimulation improve healthy working memory?: A meta-analytic review. *Journal of Cognitive Neuroscience*, *28*(8), 1063–1089. https://doi.org/10.1162/jocn_a_00956

McLaughlin, N. C. R., Paul, R. H., Grieve, S. M., Williams, L. M., Laidlaw, D., DiCarlo, M., Clark, C. R., Whelihan, W., Cohen, R. A., Whitford, T. J., & Gordon, E. (2007). Diffusion tensor imaging of the corpus callosum: A cross-sectional study across the lifespan. *International Journal of Developmental Neuroscience*, *25*(4), 215–221. https://doi.org/10.1016/j.ijdevneu.2007.03.008

Meléndez Moral, J. C., Fortuna Terrero, F. B., Sales Galan, A., & Mayordomo Rodríguez, T. (2015). Effect of integrative reminiscence therapy on depression, well-being, integrity, self-esteem, and life satisfaction in older adults. *The Journal of Positive Psychology*, *10*(3), 240–247. https://doi.org/10.1080/17439760.2014.936968

Meléndez, J. C., Agusti, A. I., Satorres, E., & Pitarque, A. (2018). Are semantic and episodic autobiographical memories influenced by the life period remembered? Comparison of young and older adults. *European Journal of Ageing*, *15*(4), 417–424. https://doi.org/10.1007/s10433-018-0457-4

Melendez, J. C., Torres, M., Redondo, R., Mayordomo, T., & Sales, A. (2017). Effectiveness of follow-up reminiscence therapy on autobiographical memory in pathological ageing. *International Journal of Psychology*, *52*(4), 283–290.

Mevel, K., Landeau, B., Fouquet, M., La Joie, R., Villain, N., Mézenge, F., Perrotin, A., Eustache, F., Desgranges, B., & Chételat, G. (2013). Age effect on the default mode network, inner thoughts, and cognitive abilities. *Neurobiology of Aging*, *34*(4), 1292–1301. https://doi.org/10.1016/j.neurobiolaging.2012.08.018

Mitchell, D. B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(1), 31–49. https://doi.org/10.1037/0278-7393.15.1.31

Morey, R. D., Romeijn, J. W., & Rouder, J. N. (2016). The philosophy of Bayes factors and the quantification of statistical evidence. *Journal of Mathematical Psychology*, *72*, 6–18. https://doi.org/10.1016/j.jmp.2015.11.001

Nieuwenhuis, S., Elzinga, B. M., Ras, P., Berends, F., Duijs, P., Samara, Z., & Slagter, H. A. (2013). Bilateral saccadic eye movements and tactile stimulation, but not auditory stimulation, enhance memory retrieval. *Brain and Cognition*, *81*(1), 52–56. https://doi.org/10.1016/j.bandc.2012.10.003

Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin & Review*, *3* (2), 135–148. https://doi.org/10.3758/BF03212412

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Parker, A., Buckley, S., & Dagnall, N. (2009). Reduced misinformation effects following saccadic bilateral eye movements. *Brain & Cognition*, *69*(1), 89–97. https://doi.org/10.1016/j.bandc.2008.05.009

Parker, A., & Dagnall, N. (2007). Effects of bilateral eye movements on gist based false recognition in the DRM paradigm. *Brain and Cognition*, *63*(3), 221–225. https://doi.org/10.1016/j.bandc.2006.08.005

Parker, A., & Dagnall, N. (2010). Effects of handedness and saccadic bilateral eye movements on components of autobiographical recollection. *Brain & Cognition*, *73*(2), 93–101. https://doi.org/10.1016/j.bandc.2010.03.005

Parker, A., & Dagnall, N. (2012). Effects of saccadic bilateral eye movements on memory in children and adults: An exploratory study. *Brain & Cognition*, *78*(3), 238–247. https://doi.org/10.1016/j.bandc.2012.01.007

Parker, A., Parkin, A., & Dagnall, N. (2013). Effects of saccadic bilateral eye movements on episodic and semantic autobiographical memory fluency. *Frontiers in Human Neuroscience*, *7*, 630. https://doi.org/10.3389/fnhum.2013.00630

Parker, A., Parkin, A., & Dagnall, N. (2017). Effects of handedness & saccadic bilateral eye movements on the specificity of past autobiographical memory & episodic future thinking. *Brain and Cognition*, *114*, 40–51. https://doi.org/10.1016/j.bandc.2017.03.006

Parker, A., Poole, J., & Dagnall, N. (2020). Saccade-induced retrieval enhancement and the recovery of perceptual item-specific information. *Cognitive Processing*, *21*(2), 223–237. https://doi.org/10.1007/s10339-019-00943-w

Parker, A., Powell, D., & Dagnall, N. (2018). Effects of saccade induced retrieval enhancement on conceptual and perceptual tests of explicit & implicit memory. *Brain & Cognition*, *121*, 1–10. https://doi.org/10.1016/j.bandc.2017.12.002

Parker, A., Relph, S., & Dagnall, N. (2008). Effects of bilateral eye movements on the retrieval of item, associative and contextual information. *Neuropsychology*, *22*(1), 136–145. https://doi.org/10.1037/0894-4105.22.1.136

Phaf, R. H. (2017). Eye movements enhance recollection of re-imagined negative words: A link between EMDR and SIRE? *Journal of Experimental Psychopathology*, *8*(4), 364–375. https://doi.org/10.5127/jep.059916

Piolino, P., Coste, C., Martinelli, P., Macé, A. L., Quinette, P., Guillery-Girard, B., & Belleville, S. (2010). Reduced specificity of autobiographical memory and aging: Do the executive and feature binding functions of working memory have a role? *Neuropsychologia*, *48* (2), 429–440. https://doi.org/10.1016/j.neuropsychologia.2009.09.035

Piolino, P., Desgranges, B., Benali, K., & Eustache, F. (2002). Episodic and semantic remote autobiographical memory in ageing. *Memory (Hove, England)*, *10*(4), 239–257. https://doi.org/10.1080/09658210143000353

Piolino, P., Desgranges, B., Clarys, D., Guillery-Girard, B., Taconnat, L., Isingrini, M., & Eustache, F. (2006). Autobiographical memory, autonoetic consciousness, and self-perspective in aging. *Psychology and Aging*, *21*(3), 510–525. https://doi.org/10.1037/0882-7974.21.3.510

Propper, R. E., Pierce, J., Bellorado, N., Geisler, M. W., & Christman, S. D. (2007). Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy. *Journal of Nervous and Mental Disease*, *195*(9), 785–788. https://doi.org/10.1097/NMD.0b013e318142cf73

Rönnlund, M., Nyberg, L., Bäckman, L., & Nilsson, L. G. (2005). Stability, growth, and decline in adult life span development of declarative memory: Cross-sectional and longitudinal data from a population-based study. *Psychology and Aging*, *20*(1), 3–18. https://doi.org/10.1037/0882-7974.20.1.3

Rouder, J. N., Morey, R. D., Speckman, P. L., & Province, J. M. (2012). Default Bayes factors for ANOVA designs. *Journal of Mathematical Psychology*, *56*(5), 356–374. https://doi.org/10.1016/j.jmp.2012.08.001

Rossi, S., Innocenti, I., Polizzotto, N. R., Feurra, M., De Capua, A., Ulivelli, M., Bartalini, S., & Cappa, S. F. (2011). Temporal dynamics of memory trace formation in the human prefrontal cortex. *Cerebral Cortex*, *21*(2), 368–373. https://doi.org/10.1093/cercor/bhq103

Samara, Z., Elzinga, B. M., Slagter, H. A., & Nieuwenhuis, S. (2011). Do horizontal saccadic eye movements increase interhemispheric coherence? Investigation of a hypothesized neural mechanism underlying EMDR. *Frontiers in Psychiatry*, *2*, 4. https://doi.org/10.3389/fpsyt.2011.00004

Smith, S. J., Souchay, C., & Conway, M. A. (2010). Overgeneral autobiographical memory in Parkinson's disease. *Cortex*, *46*(6), 787–793. https://doi.org/10.1016/j.cortex.2009.08.006

St. Jacques, P. L., & Levine, B. (2007). Ageing and autobiographical memory for emotional and neutral events. *Memory (Hove, England)*, *15*(2), 129–144. https://doi.org/10.1080/09658210601119762

JASP Team. (2018). JASP (Version 0.9). *Computer software*. https://jasp-stats. org

Tomadesso, C., Perrotin, A., Mutlu, J., Mézenge, F., Landeau, B., Egret, S., de la Sayette, V., Jonin, P.-Y., Eustache, F., Desgranges, B., & Chételat, G. (2015). Brain structural, functional, and cognitive correlates of recent versus remote autobiographical memories in amnestic mild cognitive impairment. *NeuroImage: Clinical*, *8*, 473–482. https://doi.org/10.1016/j.nicl.2015.05.010

Tulving, E., Kapur, S., Markowitsch, H. J., Craik, F. I., Habib, R., & Houle, S. (1994). Neuroanatomical correlates of retrieval in episodic memory: Auditory sentence recognition. *Proceedings of the National Academy of Sciences*, *91*(6), 2012–2015. https://doi.org/10.1073/pnas.91.6.2012

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2012). The role of working memory capacity in autobiographical retrieval: Individual differences in strategic search. *Memory (Hove, England)*, *20*(2), 167–176. https://doi.org/10.1080/09658211.2011.651087

Verhaegen, P., Borchelt, M., & Smith, J. (2003). Relation between cardiovascular and metabolic disease and cognition in very old age: Cross-sectional and longitudinal findings from the Berlin aging study. *Health Psychology*, *22*(6), 559–569. https://doi.org/10.1037/0278-6133.22.6.559

Von Bastian, C. C., & Oberauer, K. (2014). Effects and mechanisms of working memory training: A review. *Psychological Research*, *78*(6), 803–820. https://doi.org/10.1007/s00426-013-0524-6

Wagenmakers, E. J. (2007). A practical solution to the pervasive problems of *p* values. *Psychonomic Bulletin & Review*, *14*(5), 779–804. https://doi.org/10.3758/BF03194105

Wagenmakers, E.-J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Selker, R., Gronau, Q. F., Dropmann, D., Boutin, B., Meerhoff, F., Knight, P., Raj, A., van Kesteren, E.-J., van Doorn, J., Šmíra, M., Epskamp, S., Etz, A., Matzke, D., … Morey, R. D. (2018). Bayesian inference for psychology, part II: Example applications with JASP. *Psychonomic Bulletin and Review*, *25*(1), 58–76. https://doi.org/10.3758/s13423-017-1323-7

Wagner, A. D., Shannon, B. J., Kahn, I., & Buckner, R. L. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences*, *9*(9), 445–453. https://doi.org/10.1016/j.tics.2005.07.001

Weis, S., Kimbacher, M., Wenger, E., & Neuhold, A. (1993). Morphometric analysis of the corpus callosum using MR: Correlation of measurements with aging in healthy individuals. *American Journal of Neuroradiology*, *14*(3), 637–645.

Wilson, F. C. L., & Gregory, J. D. (2018). Overgeneral autobiographical memory and depression in older adults: A systematic review. *Aging & Mental Health*, *22*(5), 575–586. https://doi.org/10.1080/13607863.2017.1326461

Wolf, T., & Zimprich, D. (2016). The distribution and the functions of autobiographical memories: Why do older adults remember autobiographical memories from their youth? *European Journal of Ageing*, *13*(3), 241–250. https://doi.org/10.1007/s10433-016-0372-5

Wrzus, C., Hänel, M., Wagner, J., & Neyer, F. J. (2013). Social network changes and life events across the life span: A meta-analysis. *Psychological Bulletin*, *139*(1), 53–80. https://doi.org/10.1037/a0028601

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)