Journal of Cognitive Enhancement
https://doi.org/10.1007/s41465-023-00282-x

ORIGINAL RESEARCH

Saccade Induced Retrieval Enhancement, Handedness & the Retrieval of Central & Peripheral Details in Eyewitness Memory

Andrew Parker[1] · **Adam Parkin**[1] · **Neil Dagnall**[1]

Received: 12 July 2023 / Accepted: 8 December 2023

Abstract

Two experiments are presented that investigated the effects of horizontal saccadic eye movements and handedness on eye-witness memory for central and peripheral information. In both experiments, participants viewed a short video depicting a bank robbery and episodic memory was tested after a short delay. Experiment 1 used recognition memory and found an interaction between eye movement, handedness and type of information recalled. This indicated that eye movements enhanced memory to a greater extent for peripheral information for individuals classified as consistently handed. Experiment 2 used free-recall and found eye movement enhancement effects of similar magnitude for central and peripheral items. A similar pattern of eye movement effects was observed for both consistent and inconsistent-handed individuals. Inconsistent handers also had superior memory overall. The results are discussed in terms of theoretical accounts of eye movement effects and implications for the enhancement of eyewitness memory.

Keywords SIRE effects · Episodic memory · Eye-witness testimony · Handedness · Central vs. peripheral memory

Introduction

General Overview of the Current Experiments

Eyewitness memory typically refers to information recalled by an individual after observing some form of crime. Eye-witnesses are often called upon to retrieve information about the crime event for the purpose of providing evidence. Unfortunately, the reported memory may differ in significant ways from the witnessed event. As memory accuracy is critical, it is important to develop techniques and assess factors that affect the veracity of the eyewitness testimony. Accordingly, this paper assessed the extent to which recognition and free-recall of central and peripheral details of a video-based crime event were enhanced by pre-retrieval saccadic eye-movements and individual differences in personal handedness.

Eye-movements and Episodic Memory Retrieval

Research has shown that executing a series of horizontal saccades to a moving target *prior* to retrieval can improve subsequent performance on tests of episodic memory. This has been labelled Saccade Induced Retrieval Enhancement or SIRE effects (Lyle & Martin, 2010). This effect was first established by Christman et al. (2003), who found that a mere 30 s of saccadic horizontal eye movements (compared to a range of control conditions including vertical up-down movements) prior to testing enhanced verbal recognition. Later work extended these findings to include visual and spatial scene information, (Brunyé et al., 2009; Lyle & Jacobs, 2010), the free recall & recognition of neutral and emotional words (Nieuwenhuis et al., 2013; Phaf, 2017; Phaf et al., Samara et al., 2011), associative recognition and context memory (Lyle et al., 2012; Parker et al., 2008), recognition memory in children (Parker & Dagnall, 2012), and conceptual tests of explicit memory (Parker et al., 2018). For a review and meta-analysis see Christman and Propper (2010) and Qin et al. (2021) respectively.

Importantly, for the current work, SIRE effects can also be found in tests that are closer to everyday remembering such as autobiographical memory (Christman et al., 2003 [Experiment 2]; Christman et al., 2006; Parker & Dagnall,

✉ Andrew Parker
a.parker@mmu.ac.uk

[1] Department of Psychology, Manchester Metropolitan University, 53 Bonsall Street, Manchester M15 6GX, United Kingdom

Published online: 30 December 2023

2010; Parker et al., 2013, 2017, 2018; Parkin et al., 2013). Additionally, work in eyewitness memory has been pursued in some SIRE experiments (e.g., Lyle, 2018; Lyle & Jacobs, 2010; Parker et al., 2009). In some respects, eyewitness memory is similar to episodic autobiographical memory in that both require the retrieval of information more complex than that of word or picture lists. Typically, this involves memory for events, people, and details specific to temporal periods and spatial locations. For eyewitness memory however, there is the additional constraint that the details retrieved need to be as accurate as possible. False autobiographical memory may not have consequences, but false recall of eyewitness information almost certainly does. Inaccurate memory can have far-reaching implications for outcomes in the criminal justice system. In this context, it is noteworthy that eye-movements prior to retrieval can increase true memory for studied event information (Lyle, 2018; Lyle & Jacobs, 2010) and reduce false memory for implied misinformation (Parker et al., 2009). Furthermore, the context in which eyewitness memory takes place can have consequences for processing activity beyond that in many autobiographical memory situations. In particular, source monitoring (distinguishing between actually witnessed events and those that come from the suggestions of others or imagination) is of particular importance (Hollins & Weber, 2016; Lindsay, 1994). Monitoring processes are a critical aspect of eyewitness memory as they help to maintain the reliability and accuracy of the testimony. Because the study of memory in such contexts is of such importance, the applied implications of SIRE effects to eyewitness memory cannot be underestimated. Consequently, the effect of eye movement on eyewitness memory is advanced here with respect to the recognition and recall of central and peripheral details.

Although the primary concern of the present paper is *applied* in nature, some details pertaining to the theoretical explanations of SIRE effects are important as they help to frame the predictions. The earliest account, called the Hemispheric Encoding and Retrieval Asymmetry (HERA) explanation, referred to neuroimaging work that linked successful episodic memory to hemispheric interaction in the prefrontal regions of the brain (Christman & Propper, 2010; Christman et al., 2003). This imaging research found preferential activations in the left (vs. right) prefrontal regions for encoding (vs. retrieval) respectively (e.g., Habib et al., 2003; Kompus et al., 2011; Salami et al., 2012).[1] Additionally, as horizontal eye-movements are associated with increased pre-frontal activations in the contralateral hemisphere to the direction of the movement (e.g., Dean et al., 2004; Kastner et al., 2007), then it was claimed that sequential right-left (vs. up-down vertical) eye-movements lead to stimulation of both frontal regions. This is asserted to result in more efficient interhemispheric communication and thus enhanced episodic retrieval (Christman & Propper, 2010; Christman et al., 2003).

Although plausible, the line of reasoning outlined above, has received little evidence in its favor using EEG and ERP measurements of interhemispheric interaction (e.g., Fleck et al., 2018, 2019; Propper et al., 2007; Samara et al., 2011).

More recently, an alternative explanation has been developed based on top-down processing (Edlin & Lyle, 2013; Lyle & Edlin, 2015). Top-down processing is important to cognitive activities that demand on-going control to achieve processing goals such as memory updating, searching, task-switching, capacity sharing and inhibition (e.g., Hirsch et al., 2018; Miyake et al., 2000) With regard to long-term memory retrieval, this is important in situations that demand extensive search operations, conflict resolution and post-retrieval monitoring (Dudukovic & Kuhl, 2017).

Applied to SIRE effects, the pre-retrieval eye-movement (both horizontal and vertical) represents a *minimal attentional control* activity (Edlin & Lyle, 2013; Lyle & Edlin, 2015). This is because participants need to utilise top-down influences to keep the eyes fixated on the moving target. It is claimed that once top-down processing has been engaged, it can have consequences for performance on subsequent tasks that also require a degree of cognitive control such as searches of memory. Like the HERA explanation, neuroimaging work has investigated the neuroanatomical regions that might underpin these effects. For instance, saccadic eye-movements activate frontoparietal regions that encompass the frontal eye fields and the intraparietal sulcus (IPS), and superior parietal lobe (SPL) (Corbetta & Shulman, 2002; Konen et al., 2005). Functionally, these frontal signals characterise top-down attentional control and regulate activity in posterior parietal regions that can improve performance in attentionally demanding tasks including episodic memory (Cabeza et al., 2008). Consequently, mnemonic performance is deemed to be enhanced by eye-movements when retrieval necessitates cognitive control (Edlin & Lyle, 2013; Lyle & Edlin, 2015).

Behavioural work consistent with this comes from findings in which rivalry between retrieval competitors to the same cue exist during testing (Lyle & Edlin, 2015; Parker et al., 2009). For example, when, "plum" interferes with the recall of "lemon" from the cue "fruit". Additionally, memory tasks that require more extensive search and monitoring operations, such as free recall, sometimes show larger SIRE

[1] Not all findings are equally supportive of the HERA model with some arguing for a material-specific basis for hemispheric specialisation (e.g., Miller et al. 2002; Wagner et al., 1998) (but see Habib et al., 2003 for counterarguments) or differences in hemispheric engagement depending on task complexity (e.g., Nolde et al., 1998). Despite this, the HERA model has proven to be useful for explaining handedness differences in memory.

effects (e.g., Lyle, 2018). In addition, findings from EEG and ERP work have been interpreted within this account. For example, Fleck et al. (2018), explained the maintenance of EEG delta-band coherence across frontal-posterior electrode sites after horizontal saccades (vs. fixation), as due to attentional control being sustained after the eye-movement period. Some fMRI eye-movement results can be explained in the context of top-down control. Harricharan et al. (2019) observed horizontal eye-movements to increase functional connectivity between the frontal eye fields (initiated by movements) and the executive control region of the dorsolateral prefrontal cortex, albeit in an experiment limited to emotional memories. Finally, it has been found that horizontal saccades not only enhance recall, but blood oxygenation in the pre-frontal cortex (PFC) (Loprinzi et al., 2022). Additionally, it was found that increases in oxygenation in the left PFC were positively associated with memory. These findings were interpreted as showing eye-movement induced increases in executive control via pathways from the PFC to the hippocampus.

In this context, research has shown that the prefrontal cortex and hippocampus/medial temporal lobes are interconnected by both direct and indirect pathways and that functional interactions between these are important for episodic memory (Eichenbaum, 2017; Simons & Spiers, 2003). This work indicates that episodic memory retrieval is achieved by multiple processes that can be initiated by activations in the frontal regions. Particularly, controlled retrieval starts by the assembly of a retrieval plan and is associated with activation in the ventrolateral prefrontal cortex (Cabeza & St Jacques, 2007; Wais et al., 2012). This plan is then used to cue memories that can be accessed via the medial temporal lobes or other more posterior regions (Ciaramelli et al., 2008; Eichenbaum, 2017). This cascade of activations would be similar for both horizontal and vertical eye movements and hence the top-down account does not differentiate between eye movement directionality in terms of SIRE effects (Lyle & Edlin, 2015; Lyle et al., 2008).

In contrast to the above findings, some other work has revealed null effects of eye movements (Matzke et al., 2015; Polden & Crawford, 2022; Roberts et al., 2020). Some criticism has been levelled against the methods employed by Matzke et al. (2015). For instance, Phaf (2016) claimed that the experimental procedures used in this non-replication were biased against finding SIRE effects in the first place (see also Phaf, 2023 and Phaf et al., 2021 for an elaboration of these ideas). Regarding Roberts et al. (2020) SIRE effects on the free-recall of unrelated words were found in Experiment 1, but not Experiment 2. Finally, Polden and Crawford (2022), found a numerical advantage in recall for the eye-movements (bilateral and antisaccade) for younger subjects compared to a fixation control. This amounted to a reasonable 7% difference favouring the eye movement conditions. However, this did not achieve standard levels of statistical significance.

Despite these contrary findings, a recent meta-analysis found a broad consensus for SIRE effects (Qin et al., 2021). This analysis assessed 22 papers and found a pooled effect size (Cohen's *d*) of 0.45. The effect size was highest for more complex tasks involving the retrieval of event episodes and details in the form of autobiographical memory. Additionally, the moderating factors of eye movement direction and handedness were found. The effect size was lower for vertical (vs. horizontal) eye-movements. However, the number of experiments in which vertical eye-movements have been included was lower and may have influenced the outcome. As for handedness, SIRE effects were greatest for individuals who were strongly right-handed.

Handedness and Episodic Memory Retrieval

Personal handedness refers to hand preference when performing manual tasks (Annett, 1985; McManus, 1985). Some research has revealed neuroanatomical differences in the size of the corpus callosum between individuals with different hand dominances. Particularly, individuals characterised as mixed (or inconsistent) handers have been shown to possess a larger corpus callosum in certain subregions compared to strongly right-handed (consistent) individuals (e.g., Clarke & Zaidel, 1994; Denenberg et al., 1991; Habib et al., 1991; Luders et al., 2010).[2] This has been claimed to lead to differences in the level of hemispheric interaction such that strongly right-handed (consistent) individuals show a lower level of interhemispheric activity compared to inconsistent handed persons (Lyle et al., 2008; Niebauer et al., 2002; Prichard et al., 2013). This difference has functional consequences for cognitive processes that are hypothesised to be dependent on hemispheric interaction including episodic memory (e.g., Habib et al., 2003). For example, inconsistent handedness is associated with superior free-recall (Christman & Butler, 2011; Propper et al., 2005), recognition memory (Propper & Christman, 2004), associative memory (Chu et al., 2012; Lyle et al., 2012), prose memory (Prichard & Christman, 2017) and memory for motor actions (Edlin et al., 2013).

Like SIRE effects, handedness differences have also been found in tests of memory that relate to retrieval in everyday life. This includes autobiographical memory (e.g., Christman et al., 2003; Parker & Dagnall, 2010), and eye-witness memory (Lyle 2018; Lyle & Jacobs, 2010). Accordingly, it is important to assess further the implications of individual

[2] Although such differences are not always found and may appear only in particular sub-regions of the corpus callosum (Jäncke & Steinmetz, 2003; Nowicka & Tacikowski, 2011).

differences to memory performance in more ecologically relevant contexts and possible interactions between handedness and eye-movements (see below).

Synergies between SIRE Effects and Handedness

Existing work has compared the SIRE effects between strongly right-handed and mixed-handed individuals (e.g., Brunyé et al., 2009; Lyle et al., 2008), or consistent and inconsistent handers (e.g., Lyle, 2018; Lyle & Jacobs, 2010). One finding to arise (albeit somewhat inconsistently) is that SIRE effects are more likely to be found in strongly-right or consistent handed individuals.[3] One explanation for this is that the baseline level of hemispheric interaction is *lower* in strongly right-handed (consistent) compared to mixed handed (inconsistent) individuals and thus have more opportunity to benefit from momentary increases in hemispheric interaction brought about via eye-movements (Lyle et al., 2008; Prunier et al., 2018). This explanation is framed within the HERA account of SIRE effects, but handedness differences in SIRE effects can also be derived from the top-down account. For example, Lyle (2018) argued that neural populations that support saccadic eye-movements and encompass the dorsal frontoparietal (top-down) network, differ depending on handedness (see Petit et al., 2015). Lyle's argument is that handedness may influence SIRE effects because of differences in top-down functioning related to manual preference. Consequently, hemispheric interaction is not a prerequisite for explaining SIRE-handedness interactions.

Eye-witness Memory and the Retrieval of Central and Peripheral Details

The precise contents of eyewitness memory vary depending on the nature of the witnessed event and the observer. These contents vary and have been subject to experimental investigation in several ways. For instance, the type of information retrieved and whether it pertains to people (vs. action-event information) (e.g., Odinot et al., 2009) or emotional (vs. neutral) material (e.g., Christianson, 1992). A broader classification scheme distinguishes contents in terms of whether the information retrieved is central or peripheral (Heath & Erickson, 1998; Luna & Migueles, 2009).

According to one definition, central information is that which contains the details or gist of the event episode and materials that are visually central to the event (Burke et al., 1992). In this context, peripheral information denotes information in the background context. Other classification schemes identify central (vs. peripheral) information as that which falls within (vs. outside) the focus of attention of the observer (as opposed to the narrative relevance of the event) (Christianson & Loftus, 1991). Arguably however, details that comprise the narrative of the event are more likely to fall within the focus of attention simply because the observer is attempting to comprehend the nature of the unfolding plotline.

Irrespective of these differences, experimental work has revealed differences between these types of information as a function of important psychological variables such as emotion (Burke et al., 1992), misinformation (Luna & Migueles, 2009), and social suggestibility (Dalton & Daneman, 2006). To date, no research has systematically investigated the impact of eye-movements and handedness on eyewitness memory for central and peripheral details. Hence, the current experiments assessed the extent to which these factors affected recognition and free-recall of information derived from a crime scene video.

Experiment 1. SIRE, Handedness & Recognition of Central and Peripheral Eyewitness Details

Experiment 1 exposed participants to a crime scene video of a bank robbery. Following a short delay, participants were assigned to one of three pre-retrieval conditions: horizontal vs vertical vs, no eye-movements. In previous work, vertical eye-movements has been used as an additional condition to control for eye-activity and any arousal induced by horizontal movements that is not theoretically relevant (Christman et al., 2003). Theoretical relevance in this context derives from the HERA model as it was hypothesised that only horizontal eye-movements should increase hemispheric interaction necessary to produce SIRE effects. Some work is consistent with this prediction (e.g., Brunyé et al., 2009; Parker et al., 2008), however other research has found SIRE effects with vertical eye-movements (e.g., Lyle et al., 2008; Lyle & Edlin, 2015).

Following the assigned eye-movement condition, participants were asked to recognise whether verbal statements pertained to the crime scene. Some of these related to studied central (vs. peripheral) details, while others were non-studied.

In terms of predictions, the theorising by Lyle (2018) is useful. Lyle specified that when item-specific cues (i.e., the recognition test items) are presented at retrieval, then SIRE effects are less likely. This is because item-specific cues direct attention in a bottom-up manner to mnemonic representations and obviate the need for top-down control. Thus, eye-movements would be predicted to have little or no influence. However, if the cues do not direct attention

[3] One exception to this was Lyle, et al. (2012) who compared consistently left, inconsistently left, inconsistently right and consistently right group. That experiment found SIRE effects for both consistent-handed groups regardless of handedness direction.

to the mnemonic representations, then top-down control is required. Consequently, eye-movement effects should occur.

As recognition memory involves providing item-specific cues, it might be supposed that recognition memory for the crime scene details will not show significant SIRE effects (unless, additional interfering information has been studied in between the original encoding and retrieval, Parker et al. (2009)). However, top-down control can even be required for recognition decisions in contexts where memory retrieval is difficult or details are recognised with relatively low confidence (Burianová et al., 2012). Because peripheral (vs. central) information is less well encoded (To et al., 2011; Yeari et al., 2015), it is likely less accessible. Accordingly, mnemonic representations rendered less accessible will be more likely to benefit from top-down retrieval support (Lyle & Edlin, 2015). Thus, larger SIRE effects are predicted for peripheral (vs. central) details because even though cues are provided, access to relevant representations is not achievable via direct retrieval. That is, by relatively automatic processing in the absence of elaborative or effortful searches of memory. Furthermore, this interaction between eye-movement and type of item is potentially dependent on handedness. As noted earlier, SIRE effects have sometimes been found to be moderated by handedness consistency, with larger effects for consistent (or strongly right-handed) participants. If so, the predicted interaction might be observable for only consistently handed individuals.

Table 1 Experiment 1: Mean (SD) for SDT and proportion measures as a function of eye condition, handedness & item-type

Eye Condition			
Handedness & Item-Type	Horizontal	Vertical	Fixation
Signal Detection Measures – Accuracy			
Consistent			
	($n=22$)	($n=22$)	($n=25$)
d' Central	1.09 (.90)	.81 (.72)	.54 (.89)
d' Peripheral	.96 (.87)	.57 (.50)	-.13 (.87)
Inconsistent			
	($n=17$)	($n=19$)	($n=13$)
d' Central	.83 (.86)	.81 (.72)	.61 (.48)
d' Peripheral	.19 (1.14)	.57 (.50)	.36 (.74)
Signal Detection Measures—Response Bias			
Consistent			
Log β Central	-.12 (.31)	-.06 (.30)	-.10 (.21)
Log β Peripheral	-.02 (.39)	.03 (.37)	-.02 (.29)
Inconsistent			
Log β Central	-.16 (.36)	-.04 (.39)	-.10 (.21)
Log β Peripheral	-.06 (.31)	.048 (.32)	.01 (.14)
Proportion Measures			
Consistent			
Hit Central	.78 (.22)	.68 (.23)	.70 (.24)
Hit Peripheral	.73 (.20)	.59 (.23)	.43 (.26)
Inconsistent			
Hit Central	.78 (.19)	.68 (.22)	.67 (.19)
Hit Peripheral	.53 (.28)	.51 (.23)	.58 (.16)
Consistent			
False Alarm	.36 (.22)	.38 (.21)	.48 (.24)
Inconsistent			
False Alarm	.44 (23)	.37 (.18)	.44 (.17)

Note: (1). There was only one type of false alarm. (2) Numbers in each condition are shown for *d*' only as these are the same for all dependent variables

Method

Design

The design of the study was a 3(Eye-movement: Horizontal vs. Vertical vs. Fixation) between-subjects by 2(Item Type: Central vs. Peripheral) within-subjects by 2(Handedness Group: Consistent vs. Inconsistent) between-subjects mixed factorial. The dependent variables were the signal detection measures of recognition sensitivity (*d*' and *B*), and the proportion hit and false alarm rates.

Participants

In total, 118 individuals were recruited from the Manchester Metropolitan University subject-pool and colleagues.[4] The mean (SD) age was 29.8 (11.6). The gender balance was 47 males and 72 females). All individuals took part on a voluntary basis and those who were not from the subject-pool were enlisted by experimental assistants via opportunity sampling. The participants were divided into consistent and inconsistent handers based on their scores on the Edinburgh Handedness Inventory (EHI) (Oldfield, 1971). Those who scored + 80 and above were classified as consistent handers and those who scored less than + 80 (range -75 to + 75) were classified as inconsistent handers. Consistent handers who expressed a strong manual left preference (-80 to -100) were very few and were not included in the experiment (see Table 1 of the supplementary materials associated with this paper). The classification scheme was similar to that used in previous SIRE research. Although there are several

[4] Sample size was determined by a consideration of both past research (e.g., Lyle & Edlin, 2015; Lyle & Jacobs, 2010; Parker et al., 2009) and calculations using MorePower 6.0 (Campbell & Thompson, 2012). For a medium effect size with $\alpha = .05$, for 80% power, a sample size of 120 was specified to enable the detection of main effects of eye movement and interactions with item-type and handedness. A total of 125 subjects were tested with 118 used in the final analysis due to failure of some individuals to comply with experimental instructions.

handedness inventories and systems of scoring (e.g., Edlin et al., 2015; Gyimesi et al., 2019; Prichard et al., 2020), it was considered that the ones adopted here were the most appropriate. The principal rationale behind this was to maintain consistency both with our own past work and that used by others undertaking similar research (e.g., Lyle et al., 2012; Parkin et al., 2013; Prichard & Christman, 2021). Consequently, this allowed for more systematic comparisons with this work, that would have been precluded should alternate measures or scoring systems have been used. This could have been particularly important if the current outcomes were different. In such instances it would be unclear whether the outcomes were real or produced by differences in measurement.

Materials & Apparatus

The materials comprised the Edinburgh Handedness Inventory (Oldfield, 1971), a video depicting a crime event and a response booklet to collect biographical information and recognition memory responses. The apparatus comprised a PC to present the video clips and to initiate the eye-movements.

Edinburgh Handedness Inventory (EHI)

The EHI is a self-report inventory that asks respondents to specify their handedness preference for a range of ten manual activities (e.g., writing, drawing, & throwing). The response scale and the scoring procedure for the activities were those as described by Lyle et al. (2008). For each activity, the participant indicated the degree of their handedness preference on a Likert scale ranging from -10 to + 10. The scale choices were: always left (-10), usually left (-5), no preference (0), usually right (+ 5) and always right (+ 10). The numbers indicated the scoring scheme for quantifying preference. Values for each item were totalled to produce a score between -100 and + 100 in 5-point increments. This scoring corresponded with previous SIRE work (e.g., Brunyé et al., 2009; Christman & Butler, 2011; Edlin et al., 2013, 2015; Lyle & Jacobs, 2010; Lyle et al., 2008).

The Crime Video

The crime video depicting a bank robbery was provided by Luna and Migueles (2009). Their paper should be consulted for information regarding their original pilot testing and normative study. The video shows a bank robbery in which two security guards bring some money to the vault of a bank that has been under surveillance by the robber. The robber cuts off the electricity supply to the bank and subsequently enters the bank wearing the mask of a clown. The robber makes threats to both customers and staff before obtaining the money and leaving. The clip lasts 2-min and 8-s in total.

The Response Booklet

The first section of the booklet contained pages to provide biographical information followed by the instructions and the items for the EHI. Subsequent pages provided the instructions for the encoding phase, a filler task (writing the names of towns and cities in the UK), and test-items for the recognition phase. The recognition test items were based on those developed by Luna and Migueles (2009). The items consisted of short statements about details within the video clip, or not from the video clip (see supplementary materials associated with this paper).

Four items tested studied information central to the narrative of the video, four items referred to studied information peripheral to the events in the video, and eight non-studied but plausible details. Designation of items as central or peripheral was based on Luna and Migueles (2009). The items were placed on the left side of a response table in the booklet. To right of each item were the response options 'yes' and 'no' to indicate studied or not studied.

Eye-movement Software

Computer software was used to initiate eye movements by flashing a black circle against a white background from side to side (horizontal condition), up and down (vertical condition), or on and off (fixation condition). The circle moved (flashed) once every 500 ms and in the eye movement conditions was located about 27° of visual angle apart for each of these.

Procedure

All participants were tested individually, and they were informed that the experiment would consist of several phases. However, precise details about the experiment were not provided and no one had taken part in any similar work. Participants initially provided biographical information and then completed the EHI. Grouping into handedness categories took place after testing.

In the encoding phase, participants were told that they were about to watch a short video depicting a sequence of events. They were asked to watch the video as later they would be required to answer some questions about what they had seen. They were not told that memory would be tested or provided with any instructions regarding what to look for in the video. The video was displayed on a computer with software to play the mp.4 video file. The start of the clip was initiated by the Experimenter.

After viewing the video, participants were asked to turn to their response booklet that contained instructions to write down the names of towns and cities in the UK for 5-min as a distractor task.

In the final phase, the recognition test was administered. Initially, participants were randomly assigned to one of the eye-movement conditions. The instructions given to those in the horizontal (vertical) eye-movement conditions was to follow the dot as it appears right and left (up and down) on the screen. Participants were informed that this should be accomplished by moving their eyes only while keeping their heads motionless. Those assigned to the no eye-movement condition were asked to fixate on the dot as it flashed in the centre of the screen. Each of the three conditions lasted for 30 s. Distance of the subjects' eyes from the screen was determined by the experimenter to provide an angular separation of 27°. Compliance with instructions was monitored by the experimenter.

Immediately after the assigned eye-movement condition, participants were informed that they would now be asked to recognise a set of verbal statements of which some depicted information in the video while others did not. Their task was described as indicating which of these statements they recognised as coming from the video by answering 'yes' or 'no'.

Following completion of the experiment, participants were debriefed and provided with the opportunity to ask questions about the experiment. Additionally, all participants were reminded of their right to withdraw from the study at any point up to a specified date and were provided with their participant number and contact information for the experimenter in case of this eventuality.

Results

Analysis Plan

The analyses comprise a combination of both traditional frequentist (null hypothesis testing) and Bayesian approaches. Even though frequentist testing has come under scrutiny, especially in recent years (e.g., Keysers et al., 2020), it remains the most dominant approach to assessing significance (Kass, 2011; Ringland et al., 2021). As the majority of the research on SIRE effects has made use of null hypothesis testing (including our own), we felt it important to include here to provide a point of contact and comparison with previous literature. The use of Bayesian analyses was employed to complement this and again to make contact and comparison easier with existing SIRE work (e.g., Parker et al., 2020; Parkin et al., 2013).

The reason for using Bayesian techniques is that non-significant results using traditional frequentist analyses are inconclusive and do not provide evidence for the null hypothesis. As such, the "absence" of main or interaction effects does not mean such effects do not exist, only that such influences were not observed in the data analysed. To overcome this limitation, and to assess the magnitude of support for the null (vs. alternative) hypothesis, the use of Bayesian analyses was adopted (Rouder et al., 2012).

As an alternative, Bayesian hypothesis testing assesses the strength of support for the alternative and null hypotheses. In this context, it has been recommended as a supplement to frequentist testing to assess how much (or little) support is provided by the data for the null hypothesis when frequentist statistics are not significant (e.g., Dienes, 2014; Rouder et al., 2012). Consequently, Bayesian ANOVAs were computed to evaluate the extent to which the null findings reported here actually provide evidence in support of the null hypothesis.

Bayesian analyses were calculated using JASP v 0.16.4.0 (JASP Team, 2022), and BF_{01} (Bayes factor) values reported. The BF_{01} represents the ratio of the probabilities in support of the null vs. alternative hypothesis. Thus, a BF_{01} of 1 indicates equal support for both the null and alternative hypotheses. That is, the findings are inconclusive. A BF_{01} above 1 indicates that the results provide stronger support for the null hypothesis and conversely for values below 1 (Morey et al., 2016). To aid with interpretation, a BF_{01} of 3 and above is deemed to be good evidence for the null hypothesis. Values between 0.3 and 3 are more equivocal and indicate somewhat inconclusive findings and that further work is needed.

Overview of Results

Separate analyses on each of the DVs were performed. These took the form of a 3(Eye-movement: Horizontal vs. Vertical vs. Fixation) between-subjects by 2(Item Type: Central vs. Peripheral) within-subjects by 2(Handedness Group: Consistent vs. Inconsistent) between-subjects mixed factorial. For clarity, the numerical outcomes of the omnibus analyses as well as descriptive statistics are presented in tables with follow-up analyses presented in the text.

Signal Detection Analyses

Descriptive statistics can be found in Table 1 and omnibus ANOVA findings in Table 2. For the measure of response accuracy, two main effects were found: one for eye-movements and one for item-type. The former showed numerically higher *d*' scores in the horizonal compared to the vertical condition and in the vertical compared to fixation condition. The latter showed a higher *d*'score for central (vs. peripheral) items. The two-way interaction between eye-movements and handedness was marginally significant. Importantly, the three-way interaction was significant. To examine this, separate simple interaction effects were assessed at each level of handedness.

For consistent handers there was a main effect of item-type, $F(1, 66) = 15.39$, $p < 0.001$, $\eta_p^2 = 0.19$, showing a larger

Table 2 Experiment 1. Summary of ANOVA results for SDT and proportion measures

Response Type & Source of Effect	*df*	*F*	*p*	η_p^2
SDT Measure Analyses—Accuracy				
Main Effects				
Eye Condition	2,112	3.357	.038	.057
Handedness	1,112	0.479	.490	.004
Item-Type	1,112	31.772	< .001	.221
Two-Way Interactions				
Eye Condition X Handedness	2,112	2.830	.063	.048
Item Type X Eye Condition	2,112	0.286	.751	.005
Handedness X Item-Type	1,112	0.423	.517	.004
Three-Way Interaction				
Eye Cond'n X Hand's X Item-type	2,112	3.760	.026	.063
SDT Measure Analyses—Response Bias				
Main Effects				
Eye Condition	2,112	0.875	.420	.015
Handedness	1,112	0.006	.938	.000
Item-Type	1,112	10.002	.002	.082
Two-Way Interactions				
Eye Condition X Handedness	2,112	0.124	.884	.002
Item Type X Eye Condition	2,112	0.057	.944	.001
Handedness X Item-Type	1,112	0.054	.817	<.001
Three-Way Interaction				
Eye Cond'n X Hand's X Item-type	2,112	0.076	.927	.001
Proportion Analyses—Hits				
Main Effects				
Eye Condition	2,112	4.28	.016	.071
Handedness	1,112	0.66	.417	.006
Item-Type	1,112	31.05	< .001	.217
Two-Way Interactions				
Eye Condition X Handedness	2,112	2.012	.139	.035
Item Type X Eye Condition	2,112	0.287	.751	.005
Handedness X Item-Type	1,112	0.352	.554	.003
Three-Way Interaction				
Eye Cond'n X Hand's X Item-type	2,112	3.587	.031	.060
Proportion Analyses – False Alarms				
Main Effects				
Eye Condition	2,112	1.692	.189	.029
Handedness	1,112	0.105	.747	.001
Two-Way Interaction				
Eye Condition X Handedness	2,112	0.808	.448	.014

Note: Because there was only one type of false alarm, no three-way interaction was possible

accuracy score for central (vs. peripheral) items (0.81 vs. 0.47) respectively. The main effect of eye-movement was significant, $F(2, 66) = 7.67$, $p = 0.001$, $\eta_p^2 = 0.19$ (1.02, 0.69 and 0.20, for horizontal, vertical and fixation conditions respectively). In addition, the interaction was significant, $F(2, 66) = 3.70$, $p = 0.03$, $\eta_p^2 = 0.10$. The interaction was assessed by simple main effects at each level of item-type. This enabled the examination of whether eye-movements influenced memory for central and peripheral items separately. This produced a significant effect for peripheral items, $F(2, 66) = 12.07$, $p < 0.001$, $\eta_p^2 = 0.27$, 95% CI [0.091, 0.411]. Multiple comparisons with Bonferroni correction indicated that the difference between the horizontal and fixation conditions was significant ($p < 0.001$, mean difference = 1.09, 95% CI [0.533, 1.64]), as was the difference between the vertical and fixation conditions ($p = 0.008$, mean difference = 0.71, 95% CI [0.15, 1.26]). However, the difference between the horizontal and vertical conditions was not significant ($p = 0.32$, mean difference = 0.38, 95% CI [-0.193, 0.954]). For central items the difference between the conditions was not significant, $F(2, 66) = 2.47$, $p = 0.09$, $\eta_p^2 = 0.07$, 95% CI [0.000, 0.190], although there was a numerical trend in in the direction consistent with eye-movements enhancing memory.

For inconsistent handers, there was a main effect of item type, $F(1, 46) = 16.39$, $p < 0.001$, $\eta_p^2 = 0.26$. However, neither the main effect of eye-movement ($F(2, 46) = 1.06$, $p = 0.35$, $\eta_p^2 = 0.04$) or interaction ($F(2, 46) = 1.06$, $p = 0.35$, $\eta_p^2 = 0.04$) was significant.

Analyses of response bias β revealed only one significant effect for item-type, showing a more conservative response tendency (bias to respond new) for peripheral items.

Proportion Hit and False Alarm Rate Analyses

As *d*' is a composite score of both hit and false alarm rates, separate analyses were conducted on these. It is of interest to analyse the influence of the experimental variables on each of these rates independently because differences in the composite scores can arise because of changes to the hit rate, false alarm rate or both. In previous SIRE work, various outcomes have been found with greater effects on false alarms (e.g., Christman et al., 2003; Lyle et al., 2008), hits (e.g., Brunyé et al., 2009) or a combination of both (e.g., Parker & Dagnall, 2007). The descriptive statistics and omnibus ANOVA results can be found in Table 1 and 2. The findings for the hit rate near mirrored those for *d*'. Again, the three-way interaction was significant and thus simple interaction effects were assessed at each level of handedness.

For consistent handers there was a main effect of item-type, $F(1, 66) = 14.24$, $p < 0.001$, $\eta_p^2 = 0.18$, showing a larger hit rate for central (vs. peripheral) items, (0.72 vs. 0.58) respectively. The main effect of eye-movement was significant, $F(2, 66) = 6.94$, $p = 0.002$, $\eta_p^2 = 0.17$ (0.76, 0.64, and 0.57 for horizontal, vertical and fixation respectively). The interaction was also significant, $F(2, 66) = 3.35$, $p = 0.04$, $\eta_p^2 = 0.09$. The interaction was examined by one-way ANOVAs at each level of item-type. This produced a significant effect for peripheral items, $F(2, 66) = 9.49$, $p < 0.001$, $\eta_p^2 = 0.22$, 95% CI [0.059, 0.368]. Multiple comparisons with Bonferroni correction indicated that the difference between the horizontal and fixation conditions was significant ($p < 0.001$, mean difference = 0.30, 95% CI [0.129, 0.465], horizonal higher). The difference between the vertical and fixation conditions was marginal ($p = 0.06$, mean difference = 0.16, 95% CI [-0.007, 0.329], vertical higher). However, the difference between the horizontal and vertical conditions was not significant ($p = 0.17$, mean difference = 0.13, 95% CI [-0.037, 0.309]). For central items the difference between the conditions was not significant, $F(2, 66) = 1.23$, $p = 0.30$, $\eta_p^2 = 0.04$, 95% CI [0.000, 0.138].

For inconsistent handers, there was a main effect of item type, $F(1, 46) = 17.66$, $p < 0.001$, $\eta_p^2 = 0.28$, with a higher hit rate for central items. However, neither the main effect of eye-movement ($F(2, 46) = 0.51$, $p = 0.60$, $\eta_p^2 = 0.02$) or interaction ($F(2, 46) = 1.10$, $p = 0.34$, $\eta_p^2 = 0.04$) was significant. Finally, no significant effects were found for the false alarm rate.

Bayesian Analyses

A Bayesian ANOVA with the same specification of factors and levels as the frequentist ANOVAs was used for signal detection and proportion measures. Default Cauchy priors were used in all analyses. For *d*', the non-significant effect of handedness produced a BF_{01} of 3.87 and thus indicated a lack of support for this variable. Two and three-way interactions were assessed by combining lower order effects into the null model and assessing the unique contributions of the interactions accordingly. Using this approach, the two-way interactions between item-type and eye condition and between handedness and item-type produced BF_{01}'s of 6.45 and 4.15 respectively. This again demonstrated greater support for the null hypothesis and is in-line with the frequentist findings. The frequentist non-significant interaction for eye condition and handedness produced an equivocal BF_{01} of 0.61, suggesting a possible effect and that further work is needed.

For response bias, the frequentist non-significant main effects of eye condition and handedness were backed-up with BF_{01}'s of 4.61 and 4.16 respectively. All frequentist two-way interactions were non-significant and produced BF_{01}'s of 5.06 (eye condition and handedness), 11.74 (item-type and eye condition), and 5.01 (handedness and eye condition). Thus, Bayesian analyses provided no support for any two-way interactions. The non-significant three-way interaction similarly received no support from Bayesian analysis and produced a BF_{01} of 7.59.

Proportion hits produced only one frequentist non-significant main effect for handedness, and this was affirmed by a BF_{01} of 4.81. The frequentist non-significant two-way interactions between item-type and handedness and between item-type and eye-movement were affirmed by BF_{01}'s of 4.34 and 5.97 respectively. The BF_{01} result for eye condition and handedness was equivocal (1.83).

All Bayes factor analyses for proportion false alarms produced BF_{01} values in favor of the null hypotheses, 2.13, for eye conditions, 5.00 for handedness, and 3.51 for the interaction.

Discussion

The most important outcome from Experiment 1 is that eye movements enhanced memory (as measured by *d*' and the hit rate) for peripheral (vs. central) details but only in consistently handed individuals. This was observed without a shift in the response bias or any change in the false alarm rate. This outcome was also observed for vertical eye-movements. In relation to the models specified in the introduction, the latter is more consistent with the top-down account of SIRE effects. This is because eye movement in either horizonal or vertical directions comprises a similar minimal attention orienting task and both should initiate the top-down control of retrieval (Lyle & Edlin, 2015). Memory enhancement effects from vertical eye movements is of course inconsistent with the HERA explanation in which enhancement is due to the posited hemispheric interactions arising from horizontal eye movements. Although the size of the SIRE effect was numerically greater for the horizontal (vs. vertical) condition (and like some other work (Christman et al., 2003) this was not significant.

SIRE effects were also limited to consistently-handed individuals; an outcome that has sometimes been found in previous work (e.g., Brunyé et al., 2009; Lyle & Edlin, 2015, Experiment 1). An explanation of this is that these individuals have a lower baseline level of hemispheric interaction and are thus more likely to benefit from any boost to such interactions (Lyle et al., 2008). This was framed within the context of the HERA account, but more recently it has been argued that handedness might influence eye-movement effects independently of hemispheric interaction. Particularly, Lyle (2018) cites Petit et al., (2015), who found that the activation of the dorsal fronto-parietal network involved in top-down attentional control was influenced by handedness consistency. Thus, reducing the requirement to refer to hemispheric interaction as an explanatory mechanism. Further work is required to determine the actual mechanisms that underpin the moderating effect of handedness on SIRE effects and the variability observed across the literature. Overall, the findings from Experiment 1, could be interpreted as providing greater support for the top-down explanation of SIRE effects.

Experiment 2. SIRE, Handedness & the Free-recall of Central and Peripheral Eyewitness Details

Experiment 1 found evidence consistent with the prediction that SIRE effects were greater in magnitude for peripheral details and thus in accordance with the top-down account. Furthermore, this effect was moderated by consistency of handedness. The test of memory used in the first experiment was recognition. Experiment 2 examined if similar results would be obtained using free-recall. This extension is important as it will allow an assessment of the extent to which SIRE effects obtained in the first experiment encompass other tests of episodic memory. Additionally, free-recall (vs. recognition) is more likely to be important in eyewitness investigations as interviewers typically do not have ready-made tests of recognition of the crime scene. Rather interviewees are prompted to recall in response to questions or freely retrieve any information they can (e.g., Paulo et al., 2021). Thus, in the second experiment, rather than recognise statements, participants were asked to recall and write down as much detail as they could remember from the crime scene video.

In addition to the change in retrieval instructions, the second experiment compared horizontal to fixation conditions only. This was done to increase the number of participants per condition and because the vertical condition produced similar outcomes to the horizontal condition.

The hypotheses are the same as for Experiment 1. Namely, it is predicted that eye movements will increase memory for studied details and will be moderated by the type of detail. This in turn is expected to be moderated by personal handedness.

Method

Design

The design of the study was a 2(Eye-movement: Horizontal vs. Fixation) between-subjects by 2(Item Type: Central vs. Peripheral) within-subjects by 2(Handedness Group: Consistent vs. Inconsistent) between-subjects mixed factorial. The dependent variable was corrected recall (studied minus unstudied).

Participants

A total of 158 individuals were recruited from the Manchester Metropolitan University subject-pool and colleagues.[5] The mean (SD) age was 28.3 (11.2). The gender balance was 81 males, 76 females, and 1 undisclosed. All individuals took part on a voluntary basis. Participants were divided into consistent and inconsistent handers on the same basis as described in Experiment 1 (see Table 2 of the supplementary materials associated with this paper).

Materials & Apparatus

The materials and apparatus were the same as those described in Experiment 1. The difference was the testing and the scoring system. The experimental booklet was adapted so that the response table consisted of separate rows to write down each detail recalled. Since the original test stimuli were for a recognition task, a scoring scheme was developed for free-recall. Initially, five individuals were presented with the bank robbery video clip and provided with definitions of central and peripheral items. They were asked to view the video, multiple times if necessary, and list the information in the clip as either central, peripheral, or uncertain. This was used to create a list in which all responses were combined (repetitions of items were excluded). The combined list was then given to five other individuals who watched the video and for each item indicated if they thought it was central or peripheral. Items that were scored similarly by four or more of the individuals were used as to-be-scored items in the free-recall test. Thus, it was this consensual set of items against which the free-recall protocols of participants were checked (see supplementary materials associated with this paper). None of the individuals who took part in the development of the scoring took part in the experiment.

The free-recall responses for each participant were blind scored using the scheme described above. Reliability of scoring was checked by a random selection of 30% of the recall protocols. Interrater agreement was calculated using Cohen's Kappa and found substantial concurrence with a high Kappa coefficient of 0.91.

Procedure

The details of the procedure are the same as Experiment 1. The only difference was that the vertical eye-movement

[5] Sample size was determined in a similar manner to Experiment 1. It was decided to use a more conservative estimate of the effect size of a three-way interaction from Experiment 1 to ensure an adequate sample size. For an effect size (eta squared) of .055 with $\alpha = .05$, for 80% power, a sample size of 144 was obtained. A total of 158 were tested.

Table 3 Experiment 2: Mean (SD) for corrected recall as a function of eye condition, handedness & item-type

Eye Condition		
Handedness	Horizontal	Fixation
Corrected Recall (Studied – Unstudied)		
Consistent		
	($n=32$)	($n=36$)
Central	9.06 (3.51)	7.28 (3.17)
Peripheral	5.06 (6.21)	2.44 (3.16)
Inconsistent		
	($n=48$)	($n=42$)
Central	11.54 (5.50)	8.33 (3.42)
Peripheral	4.87 (4.11)	3.79 (2.51)

Note: The untransformed scores are shown in the table

Table 4 Experiment 2. Summary of ANOVA results for corrected recall measure as a function of eye condition, handedness and item-type

Response Type & Source of Effect	*df*	*F*	*p*	η_p^2
Main Effects				
Eye Condition	1,154	15.30	<.001	.09
Handedness	1,154	9.94	.002	.06
Item-Type	1,154	151.03	<.001	.50
Two-Way Interactions				
Eye Condition X Handedness	1,154	0.52	.47	.003
Item Type X Eye Condition	1,154	0.003	.96	<.001
Handedness X Item-Type	1,154	0.40	.53	.003
Three-Way Interaction				
Eye Cond'n X Hand's X Item-type	1,154	1.38	.24	.009

condition was not used, and the final memory test was free-recall. The instructions for free recall indicated that they could recall details from the video in any manner they choose and in any order. For each detail recalled they were told to write this down in the booklet.

Results

Analysis Plan

The analysis plan is the same as Experiment 1; frequentist analyses are presented first followed by Bayesian analyses.

Overview of Results

Analyses were performed on corrected recall scores (recall of studied minus recall of unstudied) to account for response bias. The recall scores displayed a positive skew and were subject to a Log10 transformation prior to analysis. The ANOVA was a 2(Eye-movement: Horizontal vs. Fixation) between-subjects by 2(Item Type: Central vs. Peripheral) within-subjects by 2(Handedness Group: Consistent vs. Inconsistent) between-subjects mixed factorial. The numerical outcomes of the analyses as well as non-transformed descriptive statistics are presented in Table 3 and 4 with follow-up analyses presented in the text.

Corrected Recall Analyses

The results revealed main effects for eye-movement (higher after horizontal) and item-type (higher for central items), and handedness (higher for mixed handers). None of the two-way interactions were significant. The three-way interaction also failed to attain significance.

Bayesian Analyses

Like Experiment 1, Bayesian analyses were conducted to assess the degree of support for the non-significant findings. For the two-way interactions, the main effects were added to the null model and the unique contribution of the interactions was assessed. This produced a BF_{01} 3.84, for the eye condition by handedness interaction, a BF_{01} 2.57, for the eye condition by item-type interaction, and a BF_{01} 4.17, for the handedness by item-type interaction. The three-way interaction was assessed by additionally combining the two-way interactions into the null model. This produced a BF_{01} of 2.00. All these largely affirmed the frequentist analyses although the interactions with Bayes factors of 2.57 and 2.00 suggest more caution and that additional work is required.

Discussion

Some of the outcomes of Experiment 2 were different to those of the first experiment and not in-line with the hypotheses. In particular, the expectation that eye-movements would show larger effects for peripheral items was not borne out. However, the results for two of the interactions were somewhat equivocal, although leaning towards non-significant effects. The results do not provide strong support for either of the two models of SIRE effects. Although the "basic" effects were found (more accurate memory following eye movements and inconsistently handed persons), these were not moderated in ways that would be predicted by either of the main explanations. This point is taken up further in the general discussion.

General Discussion

General Overview & Summary

In terms of overall main effects, the current experiments found eye-movements enhanced memory for eye-witness information when tested by both recognition (Experiment 1) and recall (Experiment 2). Inconsistent handedness was associated with superior free recall. Central (vs. peripheral) items were also better recognised and recalled.

The predicted interaction between eye-movements and item-type was found for recognition memory but not recall. Additionally, this pattern of outcomes was observed in consistent handers only. For free-recall, the hypotheses were not fully borne out. Here, eye-movements improved recall and was not moderated by handedness or item-type.

Theoretical Accounts of the Effects of SIRE and Handedness on Memory in Relation to Hemispheric Interaction

Results from the eye-movement manipulation in Experiment 1 are hard to reconcile with the hemispheric interaction account of SIRE effects. According to that explanation, the influence of eye-movement should be limited to the horizontal condition. Past work has been inconsistent in this regard with some experiments showing no effects of vertical eye-movements (e.g., Brunyé et al., 2009) and others finding an influence (e.g., Lyle et al., 2008). Observation of the pattern of the means for *d*' and hits across the eye-movement conditions shows a smaller effect for the vertical compared to the horizontal condition. Although this did not attain statistical significance, the results of the vertical condition were in-between the horizontal and fixation condition and is similar to some past work (e.g., Christman et al., 2003; Parker & Dagnall, 2007).

A recent meta-analysis found a lower effect size for vertical (vs. horizontal) eye-movements, and the authors concluded that these findings were consistent with the HERA explanation (Qin, et al., 2021). However, the number of experiments in which vertical eye-movements have been included was lower and may have influenced the outcome.

Despite the above, consideration of the effects of handedness in some of the findings could be considered partially supportive of the role of hemispheric interaction on memory. Experiment 2 found inconsistent handers to have superior memory for both central and peripheral detail. Though this was not found in the first experiment, perhaps part of the reason for this relates to the type of memory test used. The second experiment made use of free-recall which compared to recognition requires greater use of self-generated retrieval cues and constructive processing (Cleary, 2018). In addition, free-recall places greater emphasis on recollection, (Yonelinas, 2002), a process that has also been associated with inconsistent handedness (Christman & Propper, 2010). Consequently, the handedness effect found in the second experiment could reflect the nature of the test and, more importantly, the cognitive processing activities that support performance on these tests.

Handedness moderated the effects of eye movements in the first but not the second experiment. This is not the first-time handedness moderation effects differ across dependent variables. For example, Kelley and Lyle (2021) found moderation effects for open but not closed form questions. Such findings have different theoretical interpretations. The absence of moderation suggests eye movements and handedness work by different mechanisms whilst their interaction implies a common basis at some level. In terms of HERA, this common basis is of course hemispheric interaction. But this suggestion is negated by the finding of vertical eye movement effects (for Experiment 1). An alternative is that eye movement effects arise due to some other mechanism such as the top-down control of retrieval. This alternative is discussed below.

Theoretical Accounts of the Effects of SIRE and Handedness on Memory in Relation to Top-down Processing

The top-down account of SIRE effects predicted a greater effect for peripheral (vs. central) items. This is because eye-movements are considered to potentiate top-down influences and possibly involve frontal-parietal interactions. As peripheral items are less accessible, they should be more likely to benefit from top-down control and thus produce greater SIRE effects (Lyle & Edlin, 2015). This was observed in Experiment 1 but not in Experiment 2. Finding this in recognition memory is important as recognition performance can be achieved by reliance on familiarity-based processing (Yonelinas, 2002) and the direct matching of the cue to the items memory representation. The latter of which would unlikely demand top-down retrieval assistance (Ciaramelli et al., 2008). However, if items are somewhat inaccessible (e.g., peripheral items), then a degree of top-down support would be advantageous to enhance performance accuracy. This model claims that such support results in the "up modulation" of memory traces by increasing their overall activation and thus accessibility. Theoretically, this should primarily influence the recognition hit rate (rather than reducing false alarms) as was found in Experiment 1. Consequently, outcomes from the first experiment provided support for the top-down hypothesis of SIRE effects.

The second experiment was expected to extend the finding of recognition to free-recall. However, although SIRE and item-type effects were found, the magnitude of the former was similar for central and peripheral items. This does not support the top-down based account of eye-movement effects. The reason for this is not immediately obvious. This is especially so given free-recall was used, which would presumably place greater demands on top-down processing compared to recognition. Perhaps one explanation is that top-down processes were recruited equally for both types of items. Perhaps one reason for this is both central and peripheral details were not encoded as effectively, and both could have been difficult to retrieve. Thus, recall of both types of items were effectively boosted by an increase in top-down control.

Conceivably, there is a continuum of accessibility ranging from the very high to the very low. For *differential* SIRE effects to emerge (greater for peripheral vs. central), then (i) item-accessibility needs to span a broader range along this scale compared to that in the second experiment and, (ii) the weighting of top-down activation needs to be biased towards the lower end of the accessibility range. Of course, this is somewhat speculative but can be argued to arise from the top-down processing account.

Unlike recognition memory, eye movement effects on free-recall were not moderated by handedness. Previously, moderation of this form has been taken as evidence in favour of the HERA model in that both eye movements and handedness work via a common mechanism. However, this effect has been rather inconsistent across research and may be due to the measurement and incorporation of inappropriate moderator variables. More recently it has been argued that eye, rather than hand, dominance and dopamine asymmetries are of greater importance (Phaf, 2023). According to the dopaminergic regulation hypothesis, eye movement effects are greatest when eye dominance and dopamine production are collateralized. This collateralization is related to handedness but not perfectly. Because of this, handedness will not fully capture variations in collateralization. Thus, in some experiments, the relationship may be strong and moderation effects are observed and conversely in other studies. If this hypothesis is correct, then top-down modulation could be moderated by variables only partly related to handedness.

More generally, the top-down account could be claimed to provide a better account of the current findings but only within particular limits as discussed above. This does not rule out the possibility that hemispheric interaction may indeed be shown to have a role in more refined studies or that the accounts should be considered mutually exclusive. For instance, HERA type prefrontal interactions may set the basis for top-down processing or work in tandem with interhemispheric activities (e.g., Babiloni et al., 2006). Essentially, it might be considered that top-down control is optimally enhanced by balanced bilateral activation between frontoparietal regions. Of course, only future work will be able to assess this.

Limitations of the Current Research & Future Considerations

Although SIRE effects were found in both the experiments, other work has reported some inconsistencies (see the introduction for details about some null findings). The reason for these inconsistencies is not yet clear but several possible moderators have been proposed and include memory reactivation *during* eye movements, eye-dominance, and emotionality (Phaf, 2016, 2017, 2023; Phaf et al., 2021).

Emotionality is of particular interest given the current experiments that used a bank robbery video and some past work that has shown larger effects for emotional, especially negative, stimuli, (Phaf, 2017; Phaf et al., 2021; Samara et al., 2011). Though this does not account for the findings of Parker and Dagnall (2010) who found equivalent effects for neutral and emotional autobiographical memories. Although the video clip was not chosen because of its emotional qualities, it is likely that the clip would have been experienced as more emotional and arousing compared to a list of neutral words or pictures. The effects of emotion on eyewitness memory have been the focus of much research and has produced a plethora of outcomes (Głomb, 2022). To the extent that emotion has been proposed as a moderator of SIRE effects, it would be of both theoretical and practical interest to assess its impact on eyewitness memory following eye movements. One way this could be achieved is by using video clips that are closely matched on the main event narrative but differ in specific details such as the appearance or emotional or neutral objects (e.g., a gun vs. a lighter). If emotion is indeed an important moderator of SIRE effects, then memory would be predicted to be higher for emotional objects. This could even further interact with the status of the object (central vs. peripheral) in complex ways depending on the precise details of the experimental design. Of course, there are multiple ways in which these ideas could be tested and represents a fascinating and important objective for future work.

From an applied perspective, two additional limitations are that the participants were informed that they would be asked questions about the video and the delay between encoding and retrieval was short. Regarding the former, while participants were not informed that memory would be tested, it is possible that they were able to infer this given the nature of the instructions. Thus, it is likely that information was intentionally encoded and committed to memory to a greater degree that would be the case as a casual bystander. Although this is an important limitation, previous research has demonstrated SIRE effects even with incidental encoding instructions (Kelley & Lyle, 2021; Lyle, 2018; Lyle & Jacobs, 2010; Parker et al., 2020). Consequently, it is unlikely that any major differences would arise as a function of encoding orientation.

As for the retention interval, the only SIRE work that has been done over extended periods has been that investigating autobiographical memory (Christman et al., 2003, 2006; Parker & Dagnall, 2010; Parker et al., 2013, 2018). This research demonstrated eye-movements can enhance memory across weeks and years and thus once again, there is no reason to expect this would not differ for eye-witness information. However, it is clearly important for future work to examine this more explicitly and in the context of various encoding scenarios, retrieval tests and the type of information recovered.

An additional limitation of the current work is the fact that only a single video was used. Research in psychology needs to concern itself not only with generalizability across subject populations, but stimuli (e.g., Judd et al., 2012). If the effects observed are limited to a single stimulus or class of stimuli, then the potential to apply the research is limited to a greater extent. For instance, it could be that SIRE effects like the ones observed here are restricted to events that elicit emotional arousal. Thus, future work needs to assess how the type of findings obtained here generalize across other stimulus forms. One way to do this would be to use a greater range of video clips that are longer in length and more fully characterize a real eyewitness event. Such manipulations might necessarily have to be between-subjects given the possibility of viewing fatigue and likely interference between the clips. Alternatively, a larger range of shorter clips could be employed to mimic the recall of distinct eyewitness episodes. Although not concerned with eyewitness memory per-se, St-Laurent et al. (2014) made use of multiple short (approximately 20 s each) video clips and measured recall of thematic and perceptual information from these. This could be done in SIRE work with an investigation into whether effects are consistent across such clips.

A final limitation pertains to Experiment 2 which did not include a vertical condition. Partly this was done to increase the number of participants per eye movement condition (given a limited number of possible recruits). Additionally, the vertical condition produced similar outcomes to the horizontal condition in Experiment 1 and thus we felt it to be somewhat redundant. In some respects, this constrains some of the conclusions that can be drawn regarding top-down influences. Future work might want to include the vertical condition as an additional control and assess if such movements produce SIRE effects as claimed by the top-down account.

Overall, it would not be surprising if SIRE effects were sensitive to various experimental parameters and clearly these need to be the object of investigation. In the meantime, SIRE effects have shown to be effective in the retrieval of complex episodes like those in eyewitness testimony (e.g., Kelley & Lyle, 2021; Lyle, 2018; Lyle & Jacobs, 2010; Parker et al., 2009), and should remain a procedural contender for the improvement of such memories.

Summary & Conclusion

Eye-movement effects were found for a complex visual-event narrative for both central and peripheral information. Regarding the latter, less accessible information was shown to particularly benefit from goal-directed saccades in the first experiment when recognition memory was tested. This finding was particularly consistent with the top-down account of SIRE effects. The hemispheric interaction explanation was less well supported as Experiment 1 found eye-movement effects for both horizontal and vertical saccades. A possible role for interhemispheric interaction could be claimed from the main effect of handedness in the second experiment and the interaction between handedness and eye-movements and item-type. However, the nature of the three-way interaction differed between the first and second experiments.

More generally, the current findings extend past work and illustrate the practical value of SIRE effects in enhancing memory in an applied context given the effect sizes found here and in similar research (e.g., Kelley & Lyle, 2021). Of course, further investigation is required across multiple eyewitness type contexts and in more precisely determining the extent to which less accessible information might receive a preferential boost in accessibility.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41465-023-00282-x.

Acknowledgements The authors would like to thank Joseph Lee, Peter Walsh, Alex George Nesbitt, Martha Miles, Emma Wright, Callie Mcconville, & Aroosa Khan for assistance with the piloting of the experiments and the collection of data for the research reported here.

Author Contributions Parker & Parkin designed the experiments, collected parts of the data sets, and analyzed the data. All authors contributed to writing and checking the manuscript in proportion to the authorship order.

Funding Research was conducted in the absence of any funding.

Data Availability The data that support the findings of these experiments are available from the corresponding author upon reasonable request.

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was granted by independent scrutineers from the Department of Psychology at the Manchester Metropolitan University.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare that they have no conflict of interest.

References

Annett, M. (1985). Left*, right, hand and brain: The right-shift theory*. Hove, UK: Lawrence Erlbaum Associates Ltd.

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

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

Burianová, H., Ciaramelli, E., Grady, C. L., & Moscovitch, M. (2012). Top-down and bottom-up attention-to-memory: Mapping functional connectivity in two distinct networks that underlie cued and uncued recognition memory. *NeuroImage, 63*(3), 1343–1352. https://doi.org/10.1016/j.neuroimage.2012.07.057

Burke, A., Heuer, F., & Reisberg, D. (1992). Remembering emotional events. *Memory & Cognition, 20*(3), 277–290. https://doi.org/10.3758/BF03199665

Cabeza, R., & St Jacques, P. (2007). Functional neuroimaging of autobiographical memory. *Trends in Cognitive Sciences, 11*(5), 219–227. https://doi.org/10.1016/j.tics.2007.02.005

Cabeza, R., Ciaramelli, E., Olson, I. R., & Moscovitch, M. (2008). The parietal cortex and episodic memory: An attentional account. *Nature Reviews Neuroscience, 9*(8), 613–625. https://doi.org/10.1038/nrn2459

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

Christianson, S. Å. (1992). Emotional stress and eyewitness memory: A critical review. *Psychological Bulletin, 112*(2), 284. https://doi.org/10.1037/0033-2909.112.2.284

Christianson, S. Å., & Loftus, E. F. (1991). Remembering emotional events: The fate of detailed information. *Cognition & Emotion, 5*(2), 81–108. https://doi.org/10.1080/02699939108411027

Christman, S. D., & Butler, M. (2011). Mixed-handedness advantages in episodic memory obtained under conditions of intentional learning extend to incidental learning. *Brain & Cognition, 7*(1), 717–722. https://doi.org/10.1016/j.bandc.2011.07.003

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., 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., & 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

Chu, O., Abeare, C. A., & Bondy, M. A. (2012). Inconsistent vs consistent right-handers' performance on an episodic memory task: Evidence from the California Verbal learning Test. *Laterality, 17*(3), 306–317. https://doi.org/10.1080/1357650X.2011.568490

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. *Neuropsychologica, 46*(7), 1828–1851. https://doi.org/10.1016/j.neuropsychologia.2008.03.022

Clarke, J. M., & Zaidel, E. (1994). Anatomical-behavioral relationships: Corpus callosum morphometry and hemispheric specialization. *Behavioural Brain Research, 64*(1–2), 185–202. https://doi.org/10.1016/0166-4328(94)90131-7

Cleary, A. M. (2018). Dependent measures in memory research: From free recall to recognition. In *Handbook of research methods in human memory* (pp. 19–35). Routledge. https://doi.org/10.4324/9780429439957-2

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

Dalton, A. L., & Daneman, M. (2006). Social suggestibility to central and peripheral misinformation. *Memory, 14*(4), 486–501. https://doi.org/10.1080/09658210500495073

Dean, H. L., Crowley, J. C., & Platt, M. L. (2004). Visual and saccade-related activity in macaque posterior cingulate cortex. *Journal of Neurophysiology, 92*(5), 3056–3068. https://doi.org/10.1152/jn.00691.2003

Denenberg, V. H., Kertesz, A., & Cowell, P. E. (1991). A factor analysis of the human's corpus callosum. *Brain Research, 548*(1–2), 1260–2132. https://doi.org/10.1016/0006-8993(91)91113-F

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

Dudukovic, N. M., & Kuhl, B. A. (2017). Encoding and Retrieval. The Wiley handbook of cognitive control, 357. https://doi.org/10.1002/9781118920497.ch20

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 & Cognition, 81*(3), 345–351. https://doi.org/10.1016/j.bandc.2012.12.006

Edlin, J. M., Carris, E. K., & Lyle, K. B. (2013). Memory for hand-use depends on consistency of handedness. *Frontiers in Human Neuroscience, 7*, 555. https://doi.org/10.3389/fnhum.2013.00555

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 & Cognition, 94*, 44–51. https://doi.org/10.1016/j.bandc.2015.01.003

Eichenbaum, H. (2017). Prefrontal–hippocampal interactions in episodic memory. *Nature Reviews Neuroscience, 18*(9), 547–558. https://doi.org/10.1038/nrn.2017.74

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 & Cognition, 132*, 56–71. https://doi.org/10.1016/j.bandc.2019.03.001

Głomb, K. (2022). How to improve eyewitness testimony research: Theoretical and methodological concerns about experiments on the impact of emotions on memory performance. *Psychological Research Psychologische Forschung, 86*(1), 1–11. https://doi.org/10.1007/s00426-021-01488-4

Gyimesi, M. L., Vilsmeier, J. K., Voracek, M., & Tran, U. S. (2019). No evidence that lateral preferences predict individual differences in the tendency to update mental representations: A replication-extension study. *Collabra: Psychology*, *5*(1), 38. https://doi.org/10.1525/collabra.227

Habib, B., Gayraud, D., Oliva, A., Regis, J., Salamon, G., & Khalil, R. (1991). Effects of handedness and sex on the morphology of the corpus callosum: A study with brain magnetic resonance imaging. *Brain & Cognition, 16*(1), 41–61. https://doi.org/10.1016/0278-2626(91)90084-L

Habib, R., Nyberg, L., & Tulving, E. (2003). Hemispheric asymmetries of memory: The HERA model revisited. *Trends in Cognitive Sciences, 7*(6), 241–245. https://doi.org/10.1016/S1364-6613(03)00110-4

Harricharan, S., McKinnon, M. C., Tursich, M., Densmore, M., Frewen, P., Théberge, J., ... & Lanius, R. A. (2019). Overlapping frontoparietal networks in response to oculomotion and traumatic autobiographical memory retrieval: implications for eye movement desensitization and reprocessing. *European Journal of Psychotraumatology*, *10*(1), 1586265. https://doi.org/10.1080/20008198.2019.1586265

Heath, W. P., & Erickson, J. R. (1998). Memory for central and peripheral actions and props after varied post-event presentation. *Legal and Criminological Psychology, 3*(2), 321–346. https://doi.org/10.1111/j.2044-8333.1998.tb00369.x

Hirsch, P., Nolden, S., Declerck, M., & Koch, I. (2018). Common cognitive control processes underlying performance in task-switching and dual-task contexts. *Advances in Cognitive Psychology, 14*(3), 62. https://doi.org/10.5709/acp-0239-y

Hollins, T. J., & Weber, N. (2016). Monitoring and regulation of accuracy in eyewitness memory: Time to get some control. *The Oxford handbook of metamemory*, (pp. 171–195). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199336746.001.0001

Jancke, L., & Steinmetz, H. (2003). Anatomical brain asymmetries and their relevance for functional asymmetries. In K. Hugdahl & R. J. Davidson (Eds.), *The Asymmetrical Brain* (pp. 187–230). The MIT Press.

JASP Team (2022). JASP (Version 0.16.4.0) [Computer software].

Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality & Social Psychology, 103*(1), 54. https://doi.org/10.1037/a0028347

Kass, R. E. (2011). Statistical inference: The big picture. *Statistical Science: A Review Journal of the Institute of Mathematical Statistics, 26*(1), 1. https://doi.org/10.1214/10-STS337

Kastner, S., DeSimone, K., Konen, C. S., Szczepanski, S., Weiner, K. S., & Schneider, K. A. (2007). Topographic maps in human frontal cortex revealed in delayed saccade and spatial working memory tasks. *Journal of Neurophysiology, 97*(5), 3494–3507. https://doi.org/10.1152/jn.00010.2007

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

Keysers, C., Gazzola, V., & Wagenmakers, E. J. (2020). Using Bayes factor hypothesis testing in neuroscience to establish evidence of absence. *Nature Neuroscience, 23*(7), 788–799. https://doi.org/10.1038/s41593-020-0660-4

Kompus, K., Kalpouzos, G., & Westerhausen, R. (2011). The size of the anterior corpus callosum correlates with the strength of hemispheric encoding-retrieval asymmetry in the ventrolateral prefrontal cortex. *Brain Research, 1419*, 61–67. https://doi.org/10.1016/j.brainres.2011.08.052

Konen, C. S., Kleiser, R., Seltz, R. J., & Bremmer, F. (2005). An fMRI study of optokinetic nystagmus and smooth pursuit movements in humans. *Experimental Brain Research., 165*, 20–216. https://doi.org/10.1007/s00221-005-2289-7

Lindsay, D. S. (1994). Memory source monitoring and eyewitness testimony. In D. F. Ross, J. D. Read, & M. P. Toglia (Eds.), *Adult eyewitness testimony: Current trends and developments* (pp. 27–55). Cambridge University Press. https://doi.org/10.1017/CBO9780511759192.003

Loprinzi, P. D., Crawford, L., Moore, D., Blough, J., Burnett, G., Chism, M., & Robinson, G. (2022). Motor behavior-induced prefrontal cortex activation and episodic memory function. *International Journal of Neuroscience, 132*(2), 133–153. https://doi.org/10.1080/00207454.2020.1803307

Luders, E., Cherbuin, N., Thompson, P. M., Gutman, B., Anstey, K. J., Sachdev, P., & Toga, A. W. (2010). When more is less: Associations between corpus callosum size and handedness lateralization. *NeuroImage, 52*(1), 43–49. https://doi.org/10.1016/j.neuroimage.2010.04.016

Luna, K., & Migueles, M. (2009). Acceptance and confidence of central and peripheral misinformation. *The Spanish Journal of Psychology, 12*(2), 405–413. https://doi.org/10.1017/S1138741600001797

Lyle, K. B. (2018). Effects of handedness consistency and saccade execution on eyewitness memory in cued-and free-recall procedures. *Memory, 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, 23*(2), 187–202. https://doi.org/10.1080/09658211.2013.877487

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

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, 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., 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

Matzke, D., Nieuwenhuis, S., van Rijn, H., Slagter, H. A., van der Molen, M. W., & Wagenmakers, E. J. (2015). The effect of horizontal eye movements on free recall: a preregistered adversarial collaboration. *Journal of Experimental Psychology: General*, 144(1), e1. https://psycnet.apa.org/doi/10.1037/xge0000038

McManus, I. C. (1985). Handedness, language dominance and aphasia: A genetic model. *Psychological Medicine Monograph Supplement, 8*, 3–40. https://doi.org/10.1017/S0264180100001879

Miller, M. B., Kingstone, A., & Gazzaniga, M. S. (2002). Hemispheric encoding asymmetry is more apparent than real. *Journal of Cognitive Neuroscience, 14*(5), 702–708. https://doi.org/10.1162/08989290260138609

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

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

Niebauer, C. L., Aselage, J., & Schutte, C. (2002). Interhemispheric interaction and consciousness: Degree of handedness predicts the intensity of a sensory illusion. *Laterality, 7*(1), 85–96. https://doi.org/10.1080/13576500143000159

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 & Cognition, 81*(1), 52–56. https://doi.org/10.1016/j.bandc.2012.10.003

Nolde, S. F., Johnson, M. K., & Raye, C. L. (1998). The role of the prefrontal cortex during tests of episodic memory. *Trends in Cognitive Sciences, 2*(10), 399–406. https://doi.org/10.1016/S1364-6613(98)01233-9

Nowicka, A., & Tacikowski, P. (2011). Transcallosal transfer of information and functional asymmetry of the human brain. *Laterality, 16*(1), 35–74. https://doi.org/10.1080/13576500903154231

Odinot, G., Wolters, G., & van Koppen, P. J. (2009). Eyewitness memory of a supermarket robbery: A case study of accuracy and confidence after 3 months. *Law and Human Behavior, 33*(6), 506. https://doi.org/10.1007/s10979-008-9152-x

Oldfield, R. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*(1), 19–34. https://doi.org/10.1016/0028-3932(71)90067-4

Parker, A., & Dagnall, N. (2007). Effects of bilateral eye movements on gist based false recognition in the DRM paradigm. *Brain & 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., 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

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., 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 & Cognition, 114*, 40–51. https://doi.org/10.1016/j.bandc.2017.03.006

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., 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

Parkin, A., Parker, A., & Dagnall, N. (2013). Effects of saccadic eye movements on episodic & semantic memory fluency in older and younger participants. *Memory, 31*(1), 34–46. https://doi.org/10.1080/09658211.2022.2122997

Paulo, R. M., Jones, E., & Mendes, R. (2021). Testing two retrieval strategies to enhance eyewitness memory: Category and location clustering recall. *Psychology, Public Policy, and Law, 27*(1), 140. https://doi.org/10.1037/law0000281

Petit, L., Zago, L., Mellet, E., Jobard, G., Crivello, F., Joliot, M., Mazoyer, B., & Tzourio-Mazoyer. (2015). Strong rightward lateralization of the dorsal attentional network in left-handers with right sighting-eye: an evolutionary advantage. *Human Brain Mapping, 36*(3), 1151–1164. https://doi.org/10.1002/hbm.22693

Phaf, R. H. (2016). Replication requires psychological rather than statistical hypotheses: The case of eye movements enhancing word recollection. *Frontiers in Psychology, 7*, 2023. https://doi.org/10.3389/fpsyg.2016.02023

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

Phaf, R. H. (2023). Merging and modifying hypotheses on the emotional and cognitive effects of eye movements: The dopaminergic regulation hypothesis. *New Ideas in Psychology, 70*, 101026. https://doi.org/10.1016/j.newideapsych.2023.101026

Phaf, R. H., Hermans, M. E., Krepel, A., Lieuw-On, R. L., Mulder, C. B., & Weijland, S. (2021). Horizontal eye movements foster approach to negative pictures but do not change emotional valence: A dopaminergic regulation hypothesis. *New Ideas in Psychology, 62*, 100872. https://doi.org/10.1016/j.newideapsych.2021.100872

Polden, M., & Crawford, T. J. (2022). On the Effect of Bilateral Eye Movements on Memory Retrieval in Ageing and Dementia. *Brain Sciences, 12*(10), 1299. https://doi.org/10.3390/brainsci12101299

Prichard, E. C., & Christman, S. D. (2017). Inconsistent-handed advantage in episodic memory extends to paragraph-level materials. *Memory, 25*(8), 1063–1071. https://doi.org/10.1080/09658211.2016.1257725

Prichard, E. C., & Christman, S. D. (2021). Memory effects of manipulating text column width: Eye-movement induced attentional processes interfere with prose encoding among consistent handers. *Perceptual and Motor Skills, 128*(1), 560–577. https://doi.org/10.1177/0031512520962591

Prichard, E., Propper, R. E., & Christman, S. D. (2013). Degree of handedness, but not direction, is a systematic predictor of cognitive performance. *Frontiers in Psychology, 4*, 3–6. https://doi.org/10.3389/fpsyg.2013.00009

Prichard, E. C., Christman, S. D., & Walters, J. (2020). The pen is not always mightier: Different ways of measuring handedness with the Edinburgh handedness inventory yield different handedness conclusions. *Perceptual and Motor Skills, 127*(5), 789–802. https://doi.org/10.1177/0031512520927562

Propper, R. E., & Christman, S. D. (2004). Mixed-versus strong right-handedness is associated with biases towards "remember" versus "know" judgements in recognition memory: Role of interhemispheric interaction. *Memory, 12*(6), 707–714. https://doi.org/10.1080/09658210344000503

Propper, R. E., Christman, S. D., & Phaneuf, K. A. (2005). A mixed-handed advantage in episodic memory: A possible role of interhemispheric interaction. *Memory & Cognition, 33*, 751–757. https://doi.org/10.3758/BF03195341

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

Prunier, S., Christman, S., & Jasper, J. (2018). The effects of varying levels of hemispheric activation on episodic memory. *Laterality, 23*(4), 409–421. https://doi.org/10.1080/1357650X.2017.1369985

Qin, X. J., Yang, H. X., Cui, J. F., Ye, J. Y., & Wang, Y. (2021). Horizontal but not vertical saccades enhance memory retrieval: A meta-analysis and systematic review. *Quarterly Journal of Experimental Psychology, 74*(5), 801–811. https://doi.org/10.1177/1747021821992276

Ringland, V., Lewis, M. A., & Dunleavy, D. (2021). Beyond the p-value: Bayesian statistics and causation. *Journal of Evidence-Based Social Work, 18*(3), 284–307. https://doi.org/10.1080/26408066.2020.1832011

Roberts, B. R., Fernandes, M. A., & MacLeod, C. M. (2020). Re-evaluating whether bilateral eye movements influence memory retrieval. *PLoS ONE, 15*(1), e0227790. https://doi.org/10.1371/journal.pone.0227790

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

Salami, A., Eriksson, J., & Nyberg, L. (2012). Opposing effects of aging on large-scale brain systems for memory encoding and cognitive control. *Journal of Neuroscience, 32*(31), 10749–10757. https://doi.org/10.1523/JNEUROSCI.0278-12.2012

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

Simons, J. S., & Spiers, H. J. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews Neuroscience, 4*(8), 637–648. https://doi.org/10.1038/nrn1178

St-Laurent, M., Moscovitch, M., Jadd, R., & McAndrews, M. P. (2014). The perceptual richness of complex memory episodes is compromised by medial temporal lobe damage. *Hippocampus, 24*(5), 560–576. https://doi.org/10.1002/hipo.22249

To, M. P. S., Gilchrist, I. D., Troscianko, T., & Tolhurst, D. J. (2011). Discrimination of natural scenes in central and peripheral vision. *Vision Research, 51*(14), 1686–1698. https://doi.org/10.1016/j.visres.2011.05.010

Wagner, A. D., Poldrack, R. A., Eldridge, L. L., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1998). Material-specific lateralization of prefrontal activation during episodic encoding and retrieval. *NeuroReport, 9*(16), 3711–3717. https://doi.org/10.1097/00001756-199811160-00026

Wais, P. E., Kim, O. Y., & Gazzaley, A. (2012). Distractibility during episodic retrieval is exacerbated by perturbation of left ventrolateral prefrontal cortex. *Cerebral Cortex, 22*(3), 717–724. https://doi.org/10.1093/cercor/bhr160

Yeari, M., van den Broek, P., & Oudega, M. (2015). Processing and memory of central versus peripheral information as a function of reading goals: Evidence from eye-movements. *Reading and Writing, 28*(8), 1071–1097. https://doi.org/10.1007/s11145-015-9561-4

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*(3), 441–517. https://doi.org/10.1006/jmla.2002.2864