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IN PAST & EPISODIC FUTURE THINKING

Effects of Handedness & Saccadic Bilateral Eye Movements

on the Specificity of Past Autobiographical Memory & Episodic Future Thinking.

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Abstract

The present research investigated the effects of personal handedness and saccadic eye movements on the specificity of past autobiographical memory and episodic future thinking. Handedness and saccadic eye movements have been hypothesised to share a common functional basis in that both influence cognition through hemispheric interaction. The technique used to elicit autobiographical memory and episodic future thought involved a cued sentence completion procedure that allowed for the production of memories spanning the highly specific to the very general. Experiment 1 found that mixed-handed (vs. right handed) individuals generated more specific past autobiographical memories, but equivalent numbers of specific future predictions. Experiment 2 demonstrated that following 30 seconds of bilateral (horizontal) saccades, more specific cognitions about both the past and future were generated. These findings extend previous research by showing that more distinct and episodic-like information pertaining to the self can be elicited by either mixed-handedness or eye movements. The results are discussed in relation to hemispheric interaction and top-down influences in the control of memory retrieval.

Keywords

Handedness
Bilateral eye movements
Autobiographical memory
Episodic Future Thinking
Specificity

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1. Introduction

1.1. General overview of the current experiments

The research presented here is concerned with the influence of handedness and saccadic eye-movements, on the production of specific personal cognitions about the past (episodic autobiographical memory) and the future (episodic future thinking). Previous research has typically found superior episodic memory in mixed-handed persons and also following a brief period of saccadic eye-movements prior to retrieval. A common basis for the effect of both handedness and eye-movements has been hypothesised to be related to hemispheric interaction; with these interactions being greater in mixed-handed individuals and momentarily enhanced by saccadic eye-movements. As interhemispheric communication is considered to be important for episodic memory (Habib, Nyberg & Tulving, 2003), variables that influence such interactions should affect episodic memory (Christman & Propper, 2010).

Existing research links together past and future personal cognition to the extent that future thinking about the self is, in part, reliant on the retrieval of past episodic memory. Thus, prospective thinking about the self in imagined future scenarios depends on the ability to recall relevant autobiographical information. To date, no research has considered jointly handedness and saccadic eye movements on both past and future thinking. Consequently, the principal objective of the current work was to assess whether handedness and saccadic eye-movements influence the generation of more specific cognitions about the past and the future.

1.2. Autobiographical memory & the specificity of personal thought

Autobiographical memory is personal memory and refers to both episodic and semantic information about the self (Conway, 2005; Conway, & Pleydell-Pearce, 2000; Levine, 2004). The episodic component denotes memory for event-related experiences involving conscious awareness of the self located in time and place (Tulving, 1985; 2002). Consequently, an additional defining feature of this form of memory is the unique and specific character of the remembered personal experience (Piolino, Desgranges, & Eustache, 2009). During recall, this involves the retrieval of the sensory, emotional & contextual information, which in turn provides a basis for reliving the event and the feeling of mental time-travel. The semantic component of autobiographical memory relates to personal memories that are more generalised and less specific in character. Such memories could include personal autobiographical self-knowledge (e.g., beliefs about ones personality traits or opinions and attitudes), or generalised knowledge about periods within one's life (e.g., period at secondary school or the years spent in a particular relationship).

The distinction between general and specific memories has been conceptualised in the theoretical model of Conway (2005; 2009). This model posits a hierarchically organised autobiographical knowledge base in which personal information is represented in a structured manner ranging from the very general to the most specific. General autobiographical knowledge takes the form of lifetime periods that represent thematic and temporal information typically covering large periods in one's life (Conway, 2005). These periods pertain to relatively abstract or generalised knowledge about persons, activities, plans and goals that are identifiable within particular lifetime phases. Subsumed under this level of representation are general events. The latter comprise single, repeated and extended events. Although, more specific than lifetime periods, such representations are in the order of days to weeks or months. Both general events and lifetime periods can be conceptualised as forms of personal semantic knowledge (Conway, & Pleydell-Pearce, 2000; Coste, Navarro, Vallat-Azouvi, Brami, Azouvi, & Piolino, 2015).

The most specific form of personal knowledge is event-specific knowledge (ESK) and constitutes a form of episodic memory specific to events and possessing direct reference to place and time. Represented at this level are features of events that include sensory, emotional and contextual details. This is the most detailed form of autobiographical remembering in which the temporal extent can range from seconds and hours to a full day.

1.3. Episodic future thinking; functions & processes

Although personal episodic memory is about the past, the function of this form of memory is not simply to enable the individual to recollect past events and people; rather it has been argued that recalling episodic information can serve as a basis for planning the future and in decision-making (e.g., Atance & O'Neill, 2001; Klein, 2013; Schacter, 2012). One manner in which this can be achieved is through *episodic future thinking* (EFT) (Schacter, Addis & Buckner, 2008). Episodic future thinking refers to the retrieval, construction and use of episodic knowledge in order to prospect the future by constructing possible scenarios that the individual may encounter. This type of future oriented cognition is distinct from generalised thought about the future to the extent that the contents of thought are constrained by their autobiographical and personalised nature (Schacter, Benoit, Brigard, & Szpunar, 2015).

In terms of the *constructive episodic simulation* hypothesis, (Schacter & Addis, 2007; Addis & Schacter, 2012), individuals are able to envisage future scenarios by retrieving personal episodic information, flexibly reassembling the products of this into a coherent “simulation” of a possible future, and finally encoding/storing the newly formed simulation. The fact that EFT is deemed to be reliant on episodic memory (at least initially) suggests that the retrieval of the personal past and cognising the future share key similarities. In this context, many studies have shown both structural and functional resemblances between the two. For example, amnesic individuals with damage to the medial temporal lobes (MTLs) have been found to experience difficulties in constructing possible futures (Klein, Loftus, & Kilhstrom, 2002). Neuroimaging work also reveals the importance of the MTLs in EFT (e.g., Addis, Cheng, Roberts, & Schacter, 2011). Moreover, a network of regions has been uncovered that show similarities between autobiographical retrieval and EFT that go beyond the hippocampus/MTLs and include prefrontal regions, the parietal cortex, temporal regions and midline cortical structures (Addis, Wong, & Schacter, 2007; Buckner & Carroll, 2007; Spreng & Grady, 2010; Szpunar, Watson & McDermott, 2007).

1.4. Factors influencing past and future autobiographical cognition

Previous research has examined a range of factors that influence the specificity of autobiographical cognitions about the past and the future (e.g., Lind & Bowler, 2010; Madore, Gaesser, & Schacter, 2014; Race, Keane, & Verfaellie, 2011; Reas, Watkins, Williams & Hermans, 2008). The experiments presented here examined the effects of both handedness and saccadic eye movements on the specificity of autobiographical memory and EFT. Earlier work has demonstrated that both handedness and saccadic eye movements influence performance on tasks of episodic memory. For instance, superior episodic memory has been found in persons who are mixed-handed (vs, strongly right-handed) (Lyle, McCabe & Roediger, 2008) and following bilateral saccades (Christman, Garvey, Propper and Phaneuf, 2003). It has been hypothesised that a common neuroanatomical and functional basis underlies the effects on memory of both handedness and bilateral saccades (Christman & Propper, 2010; Prichard, Propper & Christman, 2013). This basis is related to the connectivity between the two cerebral hemispheres and to hemispheric interaction as proposed within the Hemispheric Encoding and Retrieval Asymmetry (HERA) model.

According to this model, there are functional asymmetries between encoding and retrieval that are implemented in the left and right prefrontal regions respectively. Evidence for this was initially derived from early neuroimaging studies that found preferential activation of the left (vs. right) prefrontal region during encoding (vs. retrieval) of episodic memories (Nyberg, Cabeza & Tulving, 1996; Habib, et al., 2003).

Later work has found similar and broadly consistent results using a range of imaging methods (Babiloni, et al., 2004; Babiloni, et al., 2006; Düzel, et al., 1999; Kompus, Kalpouzos, Westerhausen, 2011; Lui, Liang, Kuncheng, & Reder, 2014; Manenti, Cotelli, & Miniussi, 2011; McDermott, Buckner, Petersen, Kelley, & Sanders, 1999; Sandrini, Cappa, Rossi, & Miniussi, 2003; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) and stimulation techniques such as TMS and tDCS (Gagnon, Blanchet, Grondin, & Schneider, 2010; Manenti, et al., 2011; Manenti, Brambilla, Petesi, Ferrari, & Cotelli, 2013; Rossi, et al., 2004; Rossi, et al., 2006)[1].

Within this context, the degree of personal handedness has been hypothesised to provide a behavioural index for stable or baseline levels of hemispheric interaction and bilateral saccades conjectured to momentarily increase this level (e.g., Christman et al., 2003; Lyle et al., 2008; Prichard et al., 2013). The details pertaining to each of these are outlined in sections 2 and 5 for Experiments 1 and 2 respectively.

2. Experiment 1. Handedness & past & future autobiographical cognition

Experiment 1 developed previous research on the influence of handedness on memory to autobiographical and EFT specificity. Preceding work has examined handedness on a range of performance measures by contrasting strongly right-handed with mixed-handed groups. The rationale for this comparison is based on observations that handedness is related to underlying neuroanatomical differences in the size of the corpus callosum. Indeed a number of studies have found that this structure is larger in mixed (vs. right-handed) individuals (e.g., Clarke & Zaidel, 1994; Denenberg, Kertesz, & Cowell, 1991; Habib, Gayraud, Oliva, Regis, Salamon, & Khalil, 1991; Luders et al., 2010; Witelson, 1985)[2]. This finding has been argued to provide a basis for interpreting performance differences between mixed (vs right-handed persons) in terms of differences in the baseline level of hemispheric interaction between these persons (e.g., Christman, 1993; 1995; Prichard, et al., 2013; Niebauer, Aselage, & Schutte, 2002).

Existing research has found a mixed (inconsistent) handed) advantage across a range of tasks that assess *episodic* (conscious and event-specific) memory. These include: (i) superior free-recall (Christman & Butler, 2011; Propper, Christman, & Phaneuf, 2005), (ii) more accurate associative memory (Chu, Abeare, & Bondy, 2012; Lyle, et al., 2008; Lyle, Hanaver-Torrez, Hackländer, & Edlin, 2011), (iii) improved recognition memory (as assessed by “remember” responses that indicate the retrieval of more particular details of an event), (Propper & Christman, 2004), (iv) enhanced memory for motor actions (Edlin, Carris, & Lyle, 2013), (v) lower false recall and decreased false recognition in a source discrimination recognition task, (Christman & Butler, 2011), and, superior memory for prose-level information (Prichard & Christman, 2016).

Handedness differences have also been found in autobiographical memory. For example, Christman, Propper & Brown, (2003), assessed memory for events from a personal diary kept over a six-day period. One week later it was found that the free recall of experienced diary events (true memory) was higher and false recall was lower in the mixed-handed group. Mixed-handed individuals have also scored higher on scales measuring the qualitative nature of autobiographical memories; showing higher ratings of recollective experience along the dimensions of seeing, hearing and emotions (Parker & Dagnall, 2010).

Cumulatively, the findings suggest that mixed-handed individuals are capable of accessing more detailed and specific episodic information that can be explained in terms of more effective retrieval of ESK. However, although research is suggestive of this hypothesis, no work has been undertaken to examine this in the context of both past and future thinking.

To pursue this aim, the current experiments made use of a recently developed sentence completion procedure to assess both past memories and future thinking. This procedure has advantages over other methods, such as the word-cue procedure; because the latter often produces a limited number of general memories in non-clinical populations such as the ones used here (Reas, Hermans, Williams, & Eelen, 2007).

Ideally, a range of both general and specific memories should be generated, and in this context, Reas et al. developed the Sentence Completion for Events from the Past Test (SCEPT). This comprises of a number of sentence stems (e.g., “The most important thing I have ever . . .” or “When I think back to I . . .”) designed to elicit past autobiographical memories. Participants are required to complete these sentences by continuing them with reference to personal information. Compared to the cue word procedure, participants produce a greater range of both general and specific memories (e.g., Anderson, Boland & Garner, 2016; Anderson & Dewhurst, 2009; Boelen, Huntjens, & van den Hout, 2014; Crane, Lind & Bowler, 2012; Deeber, Raes, Williams, & Hermans, 2013; Eisma, et al., 2015; Reas, et al., 2008, Reas, Williams & Hermans, 2009).

In relation to EFT, a number of procedures have been employed such as using cues for idiosyncratic future plans (e.g., Viard , et al., 2014), generalised single-word cues (e.g., Kleim, Graham, Fihosy, Stott, & Ehlers, 2013), and semi-structured interview-style techniques (e.g., Lind & Bowler, 2010). A more recently developed technique parallels the SCEPT, and is called the Sentence Completion for Events in the Future Test (SCEFT) (Anderson & Dewhurst, 2009). This follows the format of the SCEPT but rephrases the sentence stems to orient towards the future (e.g., “The most important thing that I will ever . . .” and “In the future I imagine how/that I . . .”). As the instructions for this test (and the SCEPT) does not necessitate the production of specific responses, then it can be viewed as measuring an individual’s predominant tendency to access more specific (vs. general) memories from the past or generate more specific (vs. general) cognitions about the future.

As both the tests follow a similar format, and produce responses on a common metric, then the SCEPT and SCEFT are ideally suited to quantifying both past and future cognition within a single experiment. Consequently, Experiments 1 and 2 employed both of these to assess memory specificity as a function of handedness (Experiment 1) and eye-movements (Experiment 2).

As previous work suggests that mixed-handers possess an advantage for the recall of recollective details in laboratory-based episodic memory and of autobiographical memories, then it is predicted that mixed-handed (vs. right handed) individuals will exhibit greater autobiographical memory specificity. In addition, in line with the similarities often observed between autobiographical memory and EFT, the predictions arising from the constructive episodic simulation hypothesis can be derived. Namely, as access to ESK is important for EFT, then episodic memory should, in-part, underpin performance on tests of EFT. Consequently, it is expected that mixed-handed participants will produce a greater number of specific cognitions about the future.

3. Method

3.1. Design

The design of the study was a 2(Handedness Group; Strong-right Handed vs. Mixed-handed) between-subjects by 2(Time Frame; Past Autobiographical Memory vs. Future Episodic Thought) within-subjects mixed ANOVA. The dependent variables were the number of specific, categorical and extended memories/predictions produced by the participant.

3.2. Participants

The participants were 60 individuals from the Manchester Metropolitan University. One individual was removed from the analyses for failure to produce any responses on either the SCEPT or SCEFT, this left a total of 59 participants in the final analysis. All individuals took part on a voluntary basis and were recruited by a experimental assistants via opportunity sampling. The participants were divided into two groups based on their scores on the Edinburgh Handedness Inventory (EHI) (described in the materials section). Those who scored +80 and above were classified as strongly-right handed and those who scored less than +80 (range -75 to +75) were classified as mixed-handed. Strongly left-handed subjects (-80 to -100) were not included in the study. The classification scheme was chosen as it has been used in previous similar research and thus provides a point of comparison with that work. Consequently, in the reported study, 35 individuals were classified as mixed-handed and 24 as strongly right-handed)

3.3. Materials

The materials comprised the Edinburgh Handedness Inventory and a booklet containing the sentence completion task. The EHI is a self-report scale that asks respondents to indicate their handedness preference. A number of different versions of the original EHI have been used in past research (Edlin et al., 2015). Some of these variations pertain to the items contained within the inventory, the response scale and the scoreing procedure. In the present research, a total of ten activities (e.g.,writing, drawing, & throwing) were used as described by Lyle et al., (2008). For each activity, the participant placed a check at one of the five points of a Likert scale to indicate handedness preference for each of the ten activities. The five points were defined as always left (-10), usually left (-5), no preference (0), usually right (+5) and always right (+10). The figures in parentheses indicate the scoring scheme of the inventory and thus total scores can range between -100 and +100. This scoring scheme (as opposed to the original EHI scoring scheme) was adopted in-line with previous research on this topic (e.g., Brunyé, Mahoney, Augustyn, & Taylor, 2009; Christman & Butler, 201; Edlin, et al., 2013, 2015; Lyle et al., 2008; Lyle & Jacobs, 2010).

The sentence stems for past autobiographical memory (SCEPT) and future episodic thinking (SCEFT) were taken from Reas et al. (2007) and Anderson and Dewhurst (2009) respectively. The past and future sentences were placed in separate sections of a booklet each consisting of 11 sentence stems. The order of the past (vs. future) sections was counterbalanced across participants. The order of presentation of the sentence stems was randomised for each participant.

Following previous work (e.g., Reas et al., 2007; Anderson & Dewhurst, 2009), responses on the SCEPT and SCEFT were categorized as being (i) specific events, (ii) extended events, (iii) categorical events, (iv) semantic associations and (v) omissions (where the stem was left blank). The definitions of each of these categories, used for coding, can be found in the Appendix 1 together with examples of each category.

The procedure for scoring the responses followed previous research by assigning a first rater, blind to the conditions, to score all responses from all participants. Following this, a second rater (blind to the conditions and the scores of the first rater) scored a randomly selected sample of 30% of the participants. The interrater agreement was calculated as a Cohen's Kappa score and like previous research showed very good to excellent agreement. For SCEPT, Kappa was .86 and for SCEFT, Kappa was .88.

3.4. Procedure

Participants were initially tested for handedness in a separate session before taking the memory test. All participants were tested individually, and they were informed that the study was concerned with aspects of personal memory from the past and their ability to see themselves as they might be in the future. Consequently, they were made aware that the experiment was in some way concerned with personal memory and cognition but no information was provided relating to the more specific details of the investigation (e.g., the role of handedness).

In the memory testing session, participants received the test booklet together with the instructions for the section that came first (past or future). The instructions for the tests can be found in Appendix 2. Following each type of recall (past vs. future), the subject was allowed a small break and then completed the next phase.

Following completion of the experiment, participants were debriefed about the aims of the study and given the opportunity to ask any questions. All participants were informed of their right to withdraw from the study at any time up until the point of results analysis, and were provided with their participant number and contact information for the experimenter in case of this eventuality.

4. Results & Discussion

Following previous work, the proportion of response types were analysed by separate univariate statistics. These were, 2(Handedness; Strong Right-Handed vs. Mixed-Handed) between-subjects by 2(Time Frame; Past vs. Future) within-subjects mixed ANOVAs. The descriptive statistics can be seen in Table 1.

INSERT TABLE 1 ABOUT HERE

For specific responses the results produced a significant main effect of handedness, $F(1, 57) = 4.72$, $p = .03$, $\eta_p^2 = .08$, showing more specific cognitions for mixed-handed individuals. The main effect of time frame was also significant, $F(1, 57) = 26.92$, $p < .001$, $\eta_p^2 = .32$ indicating more specific responses for the past. In addition, the interaction was significant, $F(1,57) = 8.67$, $p = .005$, $\eta_p^2 = .13$. Follow up tests comparing the effects of handedness for each time frame revealed a significant difference for past autobiographical memory $t(57) = 3.37$, $p = .001$, Cohens $d = 0.98$, with no effect of handedness on episodic future thought, $t(57) = 0.27$, $p = .78$, Cohens $d = 0.06$. For the past period, more specific memories were generated by mixed-handed individuals.

For extended memories, there was no effect of handedness, $F(1, 57) = 1.48$, $p = .23$, $\eta_p^2 = .02$, no effect of time frame, $F(1, 57) = 0.99$, $p = .32$, $\eta_p^2 = .02$, and no interaction, $F(1,57) = 0.12$, $p = .73$, $\eta_p^2 = .002$.

For categorical memories the results produced no effect of handedness, $F(1, 57) = 0.17$, $p = .68$, $\eta_p^2 = .003$, and a main effect of time frame, $F(1,57) = 11.53$, $p = .001$, $\eta_p^2 = .17$, showing more future categorical memories. The interaction was also significant, $F(1, 57) = 7.02$, $p = .01$, $\eta_p^2 = .11$. Subsequent tests indicated a handedness difference for the past but not the future, $t(57) = -2.67$, $p = .01$, Cohens d

= 0.75, and $t(57) = 1.19$, $p = .24$, Cohens d = 0.37, for the past and future respectively. These findings demonstrate more categorical memories from the past for strongly right (vs. mixed) handed) subjects.

The responses classified as omissions or semantic associates were not analysed because the number of such responses was very low (see Table 1). The majority of participants did not produce any memories or future thoughts in these categories.

Experiment 1 found that mixed-handed participants generated more specific cognitions overall (main effect of handedness). However, handedness interacted with time-frame such that more specific cognitions were only generated when the time frame was the past. Handedness did not lead to the generation of more specific cognitions about the future (although the score for mixed-handed subjects was numerically slightly higher). Consequently, mixed-handers produced more particular and detailed past memories that contained episodic qualities pertaining to persons, locations and contexts that define the very nature of ESK.

In relation to overgeneral cognitions (categorical and extended), individuals displaying a strong hand preference were significantly more likely to produce categorical memories for the past (vs future). For extended cognitions, this was numerically higher for strong right-handers but did not achieve significance.

With regard to memory for the past, one explanation is that mixed-handed individuals are more proficient in accessing and recovering ESK compared to strongly right-handed individuals. By this account, mixed-handed participants differ from strongly-right handed participants in terms of their ability to *retrieve* fine-grained knowledge about their past (but presumably do not use this in deriving possible futures). Of course, it is not that mixed-handed individuals do *not* use episodic information to simulate the future, but the extent to which this is done is no greater than those who are strongly right-handed.

This account locates the memory advantage of mixed-handed individuals at the retrieval stage of processing, as suggested by previous work (e.g., Christman & Proper, 2010; Prichard, et al., 2013). However, handedness is trait-variable, and therefore a stable and enduring characteristic of the person (McCrae & Costa, 1997). Consequently, it is difficult to determine if their relative advantage in memory tasks is based purely on retrieval or some other mnemonic function such as encoding or storage. The findings from Experiment 1, do not distinguish between these alternatives. To demonstrate more conclusively the role of retrieval processes, a manipulation is required that takes place after encoding but prior to retrieval. This is assessed in Experiment 2 in which the effects of eye-movements on memory are considered.

5. Experiment 2. Saccadic eye movements & past & future autobiographical cognition

The aim of Experiment 2 was to assess if processes occurring after encoding, but before retrieval, can enhance the specificity of personal episodic cognitions about the past and future. One recent example that has demonstrated retrieval-based effects made use of a so-called *episodic specificity induction* procedure (Madore, et al., 2014). In this experiment, some participants were firstly oriented to recall *specific* information from a short film clip. This *retrieval induction phase* was hypothesised to instantiate a retrieval mode that encouraged the recovery of fine-grained information from memory. The extent to which this occurred was assessed in a second phase in which participants were asked to recall an ABM (past retrieval), imagine a future event (EFT), or describe a picture. Compared to a control condition, it was found that the induction procedure enhanced the amount of episodic detail in both the past and future time frames. No effect was found on the picture description task that did not demand any episodic recall.

Experiment 2, extended this retrieval-based effect with a different manipulation that has been shown previously to enhance episodic memory. This technique, as noted earlier, is theoretically related to handedness effects and involves the subject executing a series of bilateral (horizontal) saccades to a moving target *prior* to retrieval. In previous work, this has been dubbed Saccade Induced Retrieval Enhancement or SIRE effects (Lyle & Martin, 2010).

In one of the earliest experiments, Christman, et al., (2003) demonstrated that 30 s of saccadic horizontal eye movements enhanced recognition memory for a list of words seen earlier. In this experiment, the effect was particular to horizontal saccades and was not found in a range of control conditions that involved either vertical or smooth pursuit eye movements (nor a stationary eye fixation condition). Other research has extended these findings. For example, saccadic horizontal eye movements have been shown to reduce false memory in the converging associates (Christman, Propper, & Dion, 2004; Parker & Dagnall, 2007) and the misinformation paradigm (Parker, Buckley & Dagnall, 2009). Such eye movements can also enhance the retrieval of event-specific associations and remember responses (Lyle, et al., 2011; Parker, Relph & Dagnall, 2008), visual and spatial scene information, (Brunyé, et al., 2009; Lyle & Jacobs, 2010), the free recall of neutral and emotional words

(Nieuwenhuis, et al., 2013; Samara, Elzinga, Slagter, & Nieuwenhuis, 2011) and of faces (Lee, et al., 2014; Lyle & Orsborne, 2011).

SIRE effects have also been observed in autobiographical memory (Christman et al. 2003), and can prompt the recall of putatively earlier childhood memories (Christman, et al., 2006). The *recollective* characteristics of autobiographical recall can also be enhanced as eye movements produce higher ratings of the episodic-like qualities of memories associated with re-living and re-experiencing the event (Parker & Dagnall, 2010). Finally, the fluency with which episodic (vs. semantic) autobiographical information can be retrieved is augmented (Parker, Parkin, & Dagnall, 2013).

The original explanation for SIRE effects is, in part, similar to that for handedness (Christman et al., 2003). According to this account, sideways eye movements are associated with increased activations in the hemisphere contralateral to the direction of movement. (e.g., Dean, Crowley, & Platt, 2004; Kastner, et al., 2007). As a result, performing a *sequence* of horizontal eye movements is hypothesized to result in the alternating activation of both hemispheres. This is considered to lead to equalized activation between the hemispheres and provide a basis for more efficient interhemispheric communication (Christman et al., 2003; Christman & Propper, 2010). As the HERA model proposes that episodic memory is, in part, determined by a combination of left (encoding) and right (retrieval) mechanisms, then greater hemispheric interaction forms the basis for SIRE effects and thus superior episodic memory.

Experiment 2 extended existing research by assessing the effects of saccade execution on the specificity of past and future thinking. The participants selected for study were those who scored +80 and above on the EHI and are thus classed as strongly right-handed. In this context, existing research has sometimes compared the effects of saccadic eye-movements between strongly-right-handed and mixed-handed individuals (e.g., Brunyé, et al., 2009; Lyle et al., 2008)[3]. Other work has selected only strongly right-handed individuals (e.g., Christman et al., 2003; Nieuwenhuis, et al., 2013). Typically, SIRE effects have been found most reliably in strongly right-handed individuals. One reason for this has been related differences in baseline levels of hemispheric interaction; considered to be *lower* in right-handed individuals. As such, right-handers have more scope to benefit from momentary boosts in interaction compared to mixed-handers with their higher baseline levels of interaction (Lyle et al., 2008). Interestingly, the activation of neural networks supporting saccade execution have also been shown to differ as a function of handedness (Petit et al., 2015); supporting the idea that handedness may indeed influence the potential to observe SIRE effects. Consequently, in light of the above, only strongly right-handed individuals were selected for inclusion in the current study.

In Experiment 2, participants partook in a pre-test eye movement task for 30 s prior to completing the SCEPT and SCEFT. Given past research, it is predicted that SIRE effects will manifest themselves by a greater number of specific responses for both the past and future timeframes.

6. Method

6.1. Design

The design of the experiment was a 3(Eye-movement Condition; Bilateral vs. Vertical vs. No-eye movement) between-subjects by 2(Time Frame; Past Autobiographical Memory vs. Future Episodic Thought) within-subjects mixed

ANOVA. The dependent variables were the number of specific, categorical and extended memories/predictions produced by the participant.

6.2. Participants

The participants were 84 individuals from the Manchester Metropolitan University, all of whom scored +80 on the Edinburgh Handedness Inventory (described in the method for Experiment 1). All took part on a voluntary basis and were recruited by experimental assistants via opportunity sampling. Four subjects were excluded from the analyses for failure to follow the eye-task instructions. This resulted in a total of 80 subjects; 26 in each of the eye-movement conditions and 28 in the no movement condition.

6.3. Materials & Apparatus

The materials were the same as those described in Experiment 1. The categorisation and scoring scheme were also the same. Interrater agreement (Cohen's Kappa) was 0.91 for the SCEPT and 0.90 for SCEFT, again indicating very-good to excellent agreement.

Computer software was used to direct the eye movements by flashing a black circle against a white background from side to side (bilateral condition), up and down (vertical condition), or on and off in the centre of the screen (no-eye movement condition). The circle moved (flashed) once every 500ms and in the eye movement conditions was located approximately 27° of visual angle apart. The size of the computer monitor was approx 55 cm (diagonal) and the viewing distance was adjusted to maintain 27° of visual angle.

6.4. Procedure

Participants were assessed initially for handedness preference in a separate session before taking the memory test. All participants were tested individually and they were informed that the study was concerned with aspects of personal memory from the past and their ability to consider themselves as they might be in the future. As in Experiment 1, no information was provided relating to the more particular details of the investigation.

Initially, participants were randomly allocated to one of the eye-movement conditions. The instructions given to those in the eye-movement conditions was to follow the dot as it appears right and left or up and down on the screen. The instructions indicated that this should be done by moving their eyes and keeping their heads motionless. Those assigned to the no eye-movement condition were required to look at the dot as it flashed in the centre of the screen. Compliance with these instructions was observed by the experimenter. The eye manipulation took place twice; once prior to each test (i.e., SCEPT and SCEFT) and was the same for both versions of the tests.

Following the eye-manipulation, participants received the test booklet together with the instructions for the section that came first (past or future). The instructions and information provided were the same as in Experiment 1. Following each type of recall (past vs. future), the subject was allowed a break before undertaking the second set of eye movements (or no eye movements) and then the test not taken initially.

Following completion of the experiment, participants were debriefed on the full nature of the study, and once again given the opportunity to ask any questions they may have regarding the study and their individual results. All participants were informed of their right to withdraw from the study at any time up until the point of results analysis, and were provided with their participant number and contact information for the experimenter in case of this eventuality.

7. Results & Discussion

The proportion of response types were analysed by the use of a 3(Eye Movement Condition; Horizontal vs. Vertical vs. Central Fixation) between-subjects by 2(Time Frame; Past vs. Future) within-subjects mixed ANOVA. The descriptive statistics can be seen in Table 2.

INSERT TABLE 2 ABOUT HERE

For specific responses the results produced a significant main effect of eye movement, $F(2, 77) = 32.06$, $p < .001$, $\eta_p^2 = 0.45$. The effect of time frame was significant, $F(1, 77) = 38.13$, $p < .001$, $\eta_p^2 = 0.33$, showing more specific responses for the past (vs. future) time frame (M = 0.43 vs. 0.32) respectively. The interaction was not significant, $F(2, 77) = 0.20$, $p = .81$, $\eta_p^2 = 0.005$. The main effect of eye movement was examined further and showed significant differences between the bilateral and vertical condition, $t(50) = 7.01$, $p < .001$, Cohens d = 1.95, showing a greater proportion of specific memories in the bilateral condition (M = .52) compared to the vertical condition (M = .30). The difference between the vertical and no-eye movement condition did not reach significance, $t(52) = 0.13$, $p = .90$, Cohens d = .08. Finally, the difference between the bilateral and no-eye movement condition was significant, $t(52) = 7.61$, $p < .001$, Cohens d = 2.14, showing a greater proportion of specific memories in the bilateral condition.

For extended memories the results produced a significant main effect of eye movement, $F(2, 77) = 52.99$, $p < .001$, $\eta_p^2 = 0.58$. The effect of time frame was significant, $F(1, 77) = 26.10$, $p < .001$, $\eta_p^2 = 0.25$, showing fewer extended memories from the past (M = 0.34) compared to the future (M = 0.43). The interaction was not significant, $F(2, 77) = 1.99$, $p = .14$, $\eta_p^2 = 0.05$. The main effect of eye movement was examined and showed significant differences between the bilateral and vertical condition, $t(50) = -9.66$, $p < .001$, Cohens d = 2.62, showing fewer extended memories in the bilateral condition (M = .20) compared to the vertical condition (M = .48). The difference between the vertical and no-eye movement condition did not reach significance, $t(52) = 0.13$, $p = .89$, Cohens d = .07. Finally, the difference between the bilateral and no-eye movement condition was significant, $t(52) = 10.27$, $p < .001$, Cohens d = 2.70, showing fewer extended memories in the bilateral condition.

For categorical memories, the main effect of eye movement approached significance, $F(2, 77) = 2.81$, $p = .07$, $\eta_p^2 = 0.07$. The effect of time frame was not significant, $F(1, 77) = 0.85$, $p < .36$, $\eta_p^2 = 0.01$. The interaction approached significance, $F(2, 77) = 2.71$, $p = .07$, $\eta_p^2 = 0.06$. Although not significant by conventional standards, examination of the means indicated that the effect time-frame was largest in the horizontal condition, with numerically more categorical memories for the future (vs. the past). Of course, due to their marginal nature, caution must be exercised with interpreting these values and little explanatory emphasis is derived from these in the discussions that follow.

The principal finding of Experiment 2 was that 30 seconds of horizontal saccades increased the specificity of both past autobiographical memories and future cognitions. In relation to past autobiographical memories, it is not possible to explain these findings by reference encoding or consolidation factors (as could be the case with handedness). Instead, a retrieval-based explanation is more appropriate. In relation to hierarchical models of autobiographical memory, (e.g., Belli, 1998; Cabeza & St Jacques, 2007; Conway, 2005; Conway, & Pleydell-Pearce, 2005), saccadic eye-movements appear to facilitate access to ESK at the expense of extended or categorical knowledge. One process by which this could arise is by the subjects more efficiently traversing the autobiographical knowledge base from higher to lower levels. In contrast to Experiment 1, eye-movements influenced the generation of more specific cognitions in *both* the past and future time periods. The reason for this is not clear and may reflect a number of factors related to the mechanisms underpinning handedness and eye-movement effects. This point receives comment in the general discussion.

Similar to Experiment 1 and previous work, specificity scores were higher for the past (vs. future time-frame). There was also a reduction in extended and categorical memories for the past (significant for the former and numerical for the latter). One account of the difference between past and future cognition is that future cognition depends upon processing activities beyond those associated with mere access to episodic representations of the past and is embedded in the constructive episodic simulation hypotheses outlined in the introduction (Schacter & Addis, 2007; Addis & Schacter, 2012).

Comparable to Experiment 1, the number of semantic associates and omissions was extremely low and numerically lower than previous studies (e.g., Anderson & Dewhurst, 2009; Crane, et al., 2012). Although it is not clear why this was found it could be due to a number of factors. For example, the lower number of omissions might simply mean that our subjects were more motivated to produce responses to the sentence stems. Alternatively, it could be the result of the instructions given to the participants; in both experiments they were informed that the study was concerned with personal autobiographical memory from the past and their ability to envisage themselves as they might be in the future. This differs marginally from some previous work in which such information was not provided. Thus our participants were *oriented* to the fact that the study was concerned with aspects of memory and participants may have adopted a more focussed set of retrieval strategies compared to past studies.

8. General Discussion

8.1. General overview & summary

The current experiments assessed the effects of handedness and saccadic eye-movements on the specificity of past and future episodic thought. The principal findings for Experiments 1 and 2 were that mixed-handed individuals and bilateral saccades increased the specificity of past autobiographical memories and future episodic thinking (Experiment 2). These findings broaden the scope of previous research by demonstrating that both variables influence the retrieval of fine-grained episodic detail from the past and, to a more limited extent, future prospection.

To be more particular, mixed-handed individuals produced more specific cognitions about the past, and were less likely to produce generalised cognitions of a categorical or extended nature. As noted previously, enhanced production of more specific memories could be due to retrieval, or to encoding and consolidation mechanisms. As similar effects were found with a retrieval-based manipulation

(Experiment 2), a more parsimonious account is that *both* outcomes are explicable as a result of retrieval. The retrieval of more specific details from the past should, in turn, provide a basis for more episodic-like future cognitions. However, this latter expectation was found only for bilateral saccades.

Some interesting differences in the effects of handedness and bilateral saccades were also found. One of these was that handedness did not influence future prospection. Another was that mixed handedness reduced the production of categorical memories whereas bilateral saccades reduced the number of extended memories. Although such differences were not anticipated, it could be that they were, in part, driven by the overall magnitude of the effects; Experiment 2, found a much larger proportion of specific cognitions compared to Experiment 1. In this instance, perhaps *recent* momentary activations produced by bilateral saccades (compared to the tonic baseline levels of activation in mixed-handers) are more influential in "driving" the search for more specific information.

8.2. Theoretical accounts of the effects of handedness and SIRE on personal cognitions in relation to hemispheric interaction and top-down processing.

In the context of neuro-cognitive models of autobiographical memory (e.g., Cabeza and St Jacques, 2007; Conway, 2005; 2009), overgeneral or semanticised memories provide a gateway for the recovery of ESK. This occurs through a process of *generative* retrieval in which *executive* processes derive retrieval plans that are then used to initiate an iterative search process of the autobiographical knowledge base. Retrieved information is subsequently evaluated with respect to retrieval goals and, if necessary, a second iteration process occurs until the retrieval goal is met. In contrast to this, *direct* retrieval progresses via cues that provide access to ESK without mediating goal hierarchies and executive control.

Generative retrieval is especially likely when minimal retrieval support is provided such as with single cue words or phrases (e.g., Addis, Knapp , Roberts, & Schacter, 2012; Addis et al., 2007; Conway, 2005; Haque & Conway, 2001; Moscovitch, 1992). In the current experiments, the stimuli were short sentence stems that provided minimal retrieval support. Consequently, it could be argued that handedness and horizontal saccades influenced generative rather than direct retrieval.

The question of why handedness and saccade execution increase memory specificity has been noted earlier and is based on the role of hemispheric interaction and the HERA model. By this explanation, the left prefrontal region is primarily responsible for episodic encoding (and semantic processing), whilst the right prefrontal region in mainly responsible for episodic retrieval by accessing memories stored in the left hemisphere. Consequently, the interaction between the hemispheres is important for successful episodic memory.

With respect to handedness, this is facilitated in mixed-handed individuals whom are hypothesised to have a larger corpus callosum. The larger cross-sectional area of the callosum provides a basis for a greater baseline level of hemispheric interaction. Therefore, cognitive activity dependent on these interactions will be enhanced (Christman & Propper, 2013; Prichard, 2013).

With regard to SIRE effects, hemispheric interaction is predicted to be facilitated momentarily by saccadic horizontal eye-movements. The outcome is enhanced episodic memory and more detailed recollection. Particular support for the role of hemispheric interaction comes from findings where SIRE effects, are limited to the horizontal saccades as only horizontal saccades are hypothesised to enhance hemispheric interaction (Christman et al., 2003). However, previous research has not always been consistent, with some results showing effects only following horizontal eye movements (e.g., Brunyé, et al., 2009; Parker & Dagnall, 2007), and others showing equal effects for vertical saccades (Lyle, et al., 2008). In addition, direct tests of this idea have not proven to be conclusive. For example, using EEG, Propper, Pierce, Geisler, Christman and Bellorado (2007) found *decreased* Gamma coherence in frontal regions after horizontal (vs. no) eye movements whilst Samara et al., (2011) found no coherence changes across any EEG bands following similar eye movements. More recently, Yaggie et al., (2015) found an increase in frontal Beta coherence after horizontal saccades but the effects were rather small.

In spite of these shortcomings, the role of bilateral activation patterns has been demonstrated to be of importance across a range of neuroimaging studies of autobiographical memory (e.g., Greenberg, et al., 2005; Vandekerckhove, Markowitsch, Mertens, & Woermann, 2005; Söderlund, Moscovitch, Kumar, Mandic, Levine, 2012; Viard, et al., 2010), especially during the recall of specific episodic memories that entail re-experiencing the event (Viard, Desgranges, Eustache, & Piolino, 2012). Hence, research indicates that interhemispheric cooperation of some form is of significance when retrieving specific episodic memories, and is congruent with Christman's hypotheses regarding the role of hemispheric interaction for episodic memory. Similar bilateral activations have also been found for EFT with many commonalities observed between past and future thought (Addis et al., 2007; Okuda et al., 2003).

Another explanation for SIRE effects relies upon the notion of top-down control processes (Edlin & Lyle, 2013; Lyle & Edlin, 2015). This is based on the proposal that interactions between the dorsal pre-frontal (PFC) and dorsal parietal regions implement top-down control in both attention (Corbetta & Shulman, 2002) and memory (Cabeza, 2008). With regard to memory, Cabeza (2008) claims that the dorsal parietal cortex is important during episodic memory retrieval, and that its role is to allocate attentional resources in accordance with top-down signals originating in the dorsal PFC. The parietal cortex has been shown to be activated in a range of episodic memory tasks (e.g., Ciaramelli, Grady, & Moscovitch, 2008; Wagner, Shannon, Kahn, & Buckner, 2005), including autobiographical memory. Here it is thought to mediate selfness, first-person perspective and detailed recollection (Freton, et al., 2014; Summerfield, Hassabis, & Maguire, 2009). For example, patients with parietal damage, although not amnesic in the classical sense, have relatively impoverished personal memories that lack specificity, especially when retrieval support is not provided (Berryhill, Phuong, Picasso, Cabeza, & Olson, 2007).

In the Corbetta & Shulman model, the top-down signal originates in the frontal eye-fields (FEFs) and activates parietal and eventually visual regions in a system they refer to as the dorsal frontoparietal network. Lyle & Edlin (2015) contend that performing eye movements prior to episodic retrieval potentiates fronto-parietal interactions and makes mnemonic representations more accessible and thus recallable.

Given the importance of executive control in autobiographical retrieval (e.g., Addis et al., 2012; Cabeza, & St Jacques, 2007; Conway, 2005, 2009; Conway, Pleydell-Pearce, & Whitecross, 2001; Haddad, Harmer, Williams, 2014), eye movements may influence frontal-control processes that in turn operate to extract more specific information from the autobiographical knowledge base. This is particularly likely under conditions of impoverished retrieval support (as in the current experiments), as executive processes are required to develop retrieval plans or reduce the impact of retrieval competition (Lyle & Edlin, 2015).

The top-down control theory can also account for increased specificity in EFT as prospective thinking is also reliant on executive processes and episodic memory (Addis et al., 2007; Cole, Morrison, & Conway, 2013; deVito, et al., 2012). If executive processes can make episodic information more accessible (e.g., by eye-movements), then more specific future simulations are possible.

One potential problem with the top-down account in explaining the findings for Experiment 2, is that only horizontal saccades influenced the specificity of ABM and EFT. To the extent that vertical saccades are associated with frontal activations, then memory enhancement should be expected under this condition also. As noted some previous work has indeed demonstrated this, (e.g., Lyle, et al., 2008) and the reason for the lack of effect in this and some other experiments is not clear. Although somewhat conjectural, it could be that different types of eye-movements have different effects as research has found that both saccadic (vs. pursuit) and bilateral (vs. vertical) components of eye movements can dissociate in their underlying neural circuitry (Bense, et al., 2006; Konen, Kleiser, Seltz, & Bremmer, 2005; O'Driscoll et al., 1998; Petit, Clark, Ingeholm, & Haxby, 1997).

While the two theories outlined above have been discussed separately, they need not be mutually exclusive. It is reasonable that a combination of both top-down and interhemispheric processes account for SIRE effects. For example, covert shifts of attention that precede saccade execution have been found not only to activate the FEFs (Gitelman et al., 1999), but the top-down activation of the *contralateral* parietal and occipital cortices; an effect that was reduced by transcranial magnetic stimulation of the FEFs (Marshall, O'Shea, Jensen, & Bergmann, 2016). These findings were taken to indicate the importance of hemispheric interactions in implementing top-down control processes in attentional networks. Such conclusions would be congruent with results from imaging studies of autobiographical memory that show the operation of both top-down and interhemispheric processes during retrieval (Botzung, Denkova, Ciuciu, Scheiber, & Manning, 2008; Conway, Pleydell-Pearce, & Whitecross, 2001).

8.3. Potential problems & limitations of the current research

The argument proposed here is that handedness and saccadic eye-movements can enhance the specificity of personal cognitions about the past and future. It is argued further that this results from improved access to ESK. Prior to accepting this argument, some potential problems need to be considered.

As specified by the constructive simulation hypothesis, prospective thinking involves more than just accessing ESK; involved also are processes related to *scene construction.* This involves generating relevant episodic, semantic and sensory information from long-term memory, followed by the organisation and maintenance of this information into a coherent representation. For example, if an individual is asked to imagine themselves at some future point with a friend, this will require the identification and retrieval of relevant elements (e.g., people or objects), and placing these into some imagined spatial scene or extended narrative (Hassabis, & Maguire, 2007; Summerfield et al., 2009). On the basis of the methods employed here, it is not possible to assess whether handedness or horizontal saccades influenced only episodic memory or scene construction. Current findings on both the effects of handedness and eye-movements have not examined the additional processes probably involved in scene construction. However, given the evidence for their influence on episodic memory, even if such influences were to be demonstrated, they would likely be in addition to those related to episodic memory.

Other strands of research have found that both mixed-handed individuals and horizontal saccades can increase divergent thinking and creativity (Shobe, Ross, & Fleck, 2009). Divergent thinking is related also to the amount of detail in EFT (Addis, Pan, Musicaro, & Schacter, 2016). As such, a case could be made that the current findings reflect non-episodic processes as opposed to enhanced access to ESK as argued here. However, although such non-episodic processes may indeed have had some role to play, it seems unlikely that they can account fully for the findings. This is so because, firstly, the SCEPT and SCEFT tasks were *not* framed as requiring creative or divergent thinking. Secondly, previous research has demonstrated that handedness and horizontal saccades improve the retrieval of studied information and this has been observed in “remember” responses and associative details (Parker, et al., 2008; Lyle, et al., 2012; Propper, et al., 2005). Accordingly, we contend that enhanced specificity does indeed reflect the outcome of episodic processes and access to ESK.

The current method relied upon self-reports of both past and future thinking and as such it could be argued that it is not possible to examine the veracity of the reported memories. This is a problem encountered in much work of this kind and is thus not limited to the studies reported here. In spite of this, we assert that the findings are not unduly contaminated by biased or false reports of their memories. For example, participants were informed that they did not have to disclose any information that made them feel uncomfortable and that all data would be anonymous. Therefore, participants had no reason to bias or fabricate their reports. This, together with the fact that very few omissions were observed, indicated that the participants were at ease with following the task instructions and produced truthful memories. In addition, previous work has shown that horizontal saccades and mixed-handedness *de*crease false memory (e.g., Christman, et al., 2004; Parker & Dagnall, 2007). Together, these points argue against the possibility that the reports were biased or fictitious.

Previous research has shown that eye movements can *decrease* autobiographical memory vividness (van den Hout, Muris, Salemink, & Kindt, 2001) and *disrupt* EFT (de Vito, Buonocore, Bonnefon, & Della Salla, 2015). However, in these experiments, eye movements were implemented *during* retrieval in contrast to the current research (and other SIRE experiments) that used eye movements *prior* to retrieval. The execution of eye-movements during retrieval is akin to creating a dual-task situation (e.g., Gunter & Bodner, 2008), and thus eye-movements and retrieval compete for limited attentional resources and produce performance decrements. Consequently, the phase in which eye movements are manipulated is potentially of significance and is likely to indicate the operation of different mechanisms (Jeffries & Davies, 2013).

Although Experiment 2 found evidence for SIRE effects, a recently published paper did not find such evidence (Matzke, et al., 2015). The experiment took the form of an adversarial collaboration between a group of proponents and a rival group that challenged the idea of SIRE effects. In that experiment, no effects of eye movements were found on the free recall of words. Both the proponents and challengers provided separate discussions about the findings. Considered in the context of the current results, and the numerous other replications across different laboratories, Matzke, et al.'s (2015) findings are surprising and difficult to understand. Explanations for the lack of replication were offered by the challengers and include, chance effects (false negative), overestimation of the size and magnitude of the effect in the published research and experimenter effects. The single lack of replication did *not* change the conviction of the proponents concerning the validity of SIRE effects; a conviction that was bolstered by a *p*-curve analysis that supported the claim that SIRE effects on episodic memory are real. The most general outcome is that SIRE effects may not be ubiquitous, but are dependent of a range of moderator variables and particular experimental constraints that remain to be fully established. This is something that represents an important priority for future research.

8.4. Future research considerations

From a theoretical perspective, it was earlier suggested that generative (vs. direct) retrieval is a likely candidate mechanism for explaining the results found in both experiments. This is because generative retrieval is more likely with the use of generic cues as used here. However, the contributions of generative and direct retrieval were not assessed and remain to be explored in future work. If correct, then either more effective or numerous iterations would be predicted for mixed-handed subjects or following horizontal saccades.

The practical implications for the findings reported here should not be overlooked. For example, in reminiscence therapy, individuals with memory impairments engage in the retrieval and discussion of life narratives and experiences to bring about improvements in psychological well being (Subramaniam & Woods, 2012). Usual cues for memory included familiar artefacts from the individuals own life. Facilitating this could be the use of techniques as reported here to increase the specificity and recollective details of those memories.

9. Conclusion

Together, the two experiments described here demonstrate that access to the past and future projection can be influenced by individual difference factors and by experimental manipulations. Theoretically, in both instances, both the past and the future can become more specific under conditions that enable hemispheric interaction or top-down control.

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Footnotes

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, Kingstone, & Gazzaniga, 2002; Wagner, et al., 1998) (but see Habib et al, 2003 for counter-arguments) or differences in hemispheric engagement depending on task complexity (e.g., Nolde, Johnson, and Raye, 1998). In spite of this, the HERA model has proven to be useful for explaining handedness differences in memory.

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).

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

Appendix 1

The definitions of each of the categories used to code the responses from the SCEPT and SCEFT tests are outlined below followed by an example pertaining to that category.

Specific events. These were responses that recounted a particular event at a specific point in time that can include additional contextual information.

Past example. “I will never forget the day I . . . got my first bike and went exploring in the country with it.”

Future example. “Next week I . . . have to complete my revision for my first multiple choice test on the 14^{th}.”

Extended events. These were responses that referred to more extended periods in an individual’s life such that the details being described occurred over more than one particular event or day.

Past example. “I still remember well how . . . I spent my first weeks at university and how new and different everything seemed to be.”

Future example. “Next year I . . . plan to spend some time looking for voluntary work to help with my job prospects.”

Categorical events. These were responses that described categories or classes of activities that typically recur and have little reference to particular/single episodes.

Past example. "In the past I . . . have done loads of things that I wish I hadn't done."

Future example. "In the future I . . . plan to save money on a regular basis."

Semantic associations. These responses pertained to overgeneral descriptions and information that cannot always be counted as memories or personal reflections.

Past example. "Last year I . . . felt generally good about things."

Future example. "In the future I can picture how . . . my life might change and I will too."

Appendix 2

In the memory testing session, participants received the test booklet together with the instructions for the section that came first (past or future). The instructions for the past read:

> "This part of the study is concerned with your personal past and what you can remember about yourself. Below you will find eleven sentences. Actually these are only parts of sentences, because only the beginning of each of the sentences is provided. The purpose of this task is for you to complete each of the sentences. You can complete the sentences any way you want just as long as what you write corresponds to the provided stems. Also make sure that each of the sentences is on a different topic."

The instructions for the future task were adapted from the past instructions and read as follows:

> "This part of the study is concerned with your personal future and what you might believe or think about yourself in the future. Below you will find eleven sentences. Actually these are only parts of sentences, because only the beginning of each of the sentences is provided. The purpose of this task is for you to complete each of the sentences. You can complete the sentences any way you want just as long as what you write corresponds to the provided stems. Also make sure that each of the sentences is on a different topic."

Prior to completing the sentence stems the participants were told that they did not have to think about or disclose any information that they were not comfortable with sharing. Following each type of recall (past vs. future), the subject was allowed a small break and then completed the next section.

Table 1. Mean Proportion (SE) of Response Type as a Function of Handedness and Time Frame.

	Handedness	
	Strong RH	Mixed
Response Type & Time Frame		
Specific		
Past	.16 (.03)	.31 (.03)
Future	.10 (.03)	.11 (.03)
Extended		
Past	.46 (.03)	.42 (.03)
Future	.50 (.04)	.43 (.04)
Categorical		
Past	.34 (.03)	.25 (.02)
Future	.37 (.04)	.43 (.04)
Omissions & Semantic Associations		
Past	.04 (.03)	.01 (.01)
Future	.03 (.01)	.02 (.01)

Table 2. Mean Proportion (SE) of Response Type as a Function of Eye Movement Condition and Time Frame.

	Eye Movement Condition		
	Horizontal	Vertical	Central Fixation
Response Type & Time Frame			
Specific			
Past	.58 (.03)	.37 (.03)	.34 (.03)
Future	.46 (.03)	.24 (.03)	.25 (.02)
Extended			
Past	.18 (.03)	.42 (.03)	.42 (.03)
Future	.22 (.03)	.54 (.02)	.54 (.02)
Categorical			
Past	.24 (.03)	.22 (.03)	.24 (.02)
Future	.32 (.03)	.21 (.02)	.22 (.02)