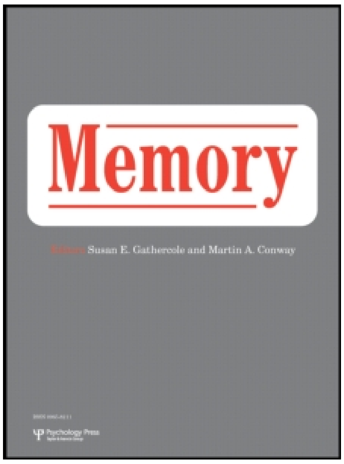

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Is saccade-induced retrieval enhancement a potential means of improving eyewitness evidence?

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Is saccade-induced retrieval enhancement a potential means of improving eyewitness evidence?

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Saccade-induced retrieval enhancement (SIRE) is the effect whereby making bilateral saccades enhances the subsequent retrieval of memories. Two experiments explored SIRE's potential to improve eyewitness evidence. Participants viewed slideshows depicting crimes, and received contradictory and additive misinformation about event details either once (Experiment 1) or three times (Experiment 2). Participants then performed saccades or a fixation control task before being tested on their memory for the slideshows and making confidence judgements. Saccades increased discrimination between seen and unseen event details regardless of whether or what type of misinformation was presented. Because prior studies indicated that SIRE might be more robust for individuals who are strongly right-handed versus not, we examined SIRE as a function of handedness and found that saccades improved memory for event details regardless of participants' handedness. However, participants who were not strongly right-handed had fewer false memories than participants who were strongly right-handed, extending previous findings of superior memory among individuals who are not strongly right-handed. Saccades also increased confidence in true memories (Experiment 1) and decreased confidence in false memories (Experiment 2). The results support SIRE's potential to improve eyewitness evidence.

Keywords: Eyewitness memory; Misinformation; Saccadic eye movements; Memory enhancement; Handedness.

Eyewitness evidence plays a central role in the criminal justice system, and improving its quality is therefore an important goal (Wells, Memon, & Penrod, 2006). The present study is concerned specifically with improving the information garnered from eyewitness interviews. Improvement could consist of increasing retrieval of correct information or decreasing retrieval of incorrect information. Recent studies suggest a surprising possible means of improvement: having witnesses make alternating bilateral (i.e., left–right) saccades immediately before the interview. These studies examined a phenomenon that we (Lyle & Martin, 2010) have elsewhere dubbed saccade-induced retrieval enhancement (SIRE). Most SIRE studies have compared 30 s of saccades to 30 s of central fixation, and found superior retrieval following saccades (e.g., Brunyé, Mahoney, Augustyn, & Taylor, 2009; Christman, Garvey, Propper, & Phaneuf, 2003, Exp. 2; Lyle, Logan, & Roediger, 2008a; Parker & Dagnall, 2007; Parker, Relph, & Dagnall, 2008b). Increased retrieval of correct information and decreased retrieval of incorrect information have both been observed, sometimes in the same study. For example, in Christman et al. (2003, Exp. 2), participants recorded autobiographical events in a diary and, on a test given 2–3 weeks later in the laboratory,

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saccades increased recall of recorded events and decreased false recall of non-recorded events. Of applied importance, saccades enhance retrieval compared not only to the standard fixation control condition, which lacks ecological validity, but to more naturalistic conditions in which eye movements have not been controlled, including when there has been no pre-retrieval activity (Christman et al., 2003, Exp. 1) and when participants were simply told to spend 30 s getting ready for an upcoming test (Lyle et al., 2008a, Exp. 2).

Recently, Parker, Buckley, and Dagnall (2008a) found SIRE for memories that were more forensically relevant than those previously studied. In an eyewitness misinformation experiment (Loftus, Miller, & Burns, 1978; McCloskey & Zaragoza, 1985), participants first viewed a sequence of photographs depicting a plumber stealing cash from a house. Various target objects (e.g., a red toolbox) appeared in the photos. After viewing the photos, participants answered questions about the witnessed event. Some of the questions contained misinformation about the target objects (e.g., the toolbox was described as grey). Other questions contained neutral references to the objects (e.g., the toolbox was referenced without mentioning colour). Finally, participants' memory for how objects had appeared in the photos was tested. On the test, half the target objects were described as they had actually appeared in the photos and half as they had been misleadingly described in the questions. The test also included the names of some new objects that were neither seen in the photographs nor mentioned in the questions. Participants indicated which objects had appeared in the photos exactly as described on the test. Participants who made bilateral saccades before the test, compared to those who fixated a stationary target (or those who made up–down/vertical saccades), were significantly more likely to remember seeing correctly described target objects and significantly less likely to remember seeing either misleadingly described target objects or new objects.

Together, the findings of SIRE for autobiographical events (Christman et al., 2003, Exp. 2) and details of a staged crime (Parker et al., 2008a) raise the intriguing possibility that saccades may be a means of improving eyewitness evidence garnered from interviews. Pursuing novel means of improvement is essential because existing means are scarce. Wells et al. (2006) recently reviewed research on improving eyewitness evidence and identified only a single technique relevant to the interview process—the cognitive interview (Geiselman, Fisher, MacKinnon, & Holland, 1985). The saccade activity is especially attractive as a potential new tool because it is brief and would be relatively easy to administer and for most witnesses to perform.

Before turning to the aims of the present study, we briefly describe two theories of SIRE's cause. One theory is that bilateral saccades increase interaction of the left and right cerebral hemispheres (Christman et al., 2003). Reasons exist to believe that retrieval of episodic memories is influenced by degree of interhemispheric interaction, at least in some cases (for discussions, see Lyle, McCabe, & Roediger, 2008b; Propper, Christman, & Phaneuf, 2005), and therefore it is at least plausible that a manipulation that increased interaction would also enhance retrieval. A second theory (Lyle & Martin, 2010) is that SIRE occurs because making saccades is associated with activation of brain regions involved in the allocation of attention (Corbetta & Shulman, 2002), especially the frontal eye fields and intraparietal sulci (e.g., de Haan, Morgan, & Rorden, 2008; Moon et al., 2007; see also Corbetta, 1998, for a review of earlier research). Activation of these regions may promote or increase their functional contribution to subsequent attentionally demanding cognitive tasks, which would include some types of episodic retrieval tasks. The intraparietal sulcus, in particular, may be involved in retrieving memories when there is high demand for top-down attentional control (Cabeza, 2008; Ciaramelli, Grady, & Moscovitch, 2008).

Both theories described above are compatible with the idea that saccades could improve eyewitness evidence because witnesses are often asked to retrieve specific perceptual and contextual details, and retrieval of such information has been linked to both interhemispheric interaction (Johnson & Raye, 2000) and the top-down control of attention (Ciaramelli et al., 2008).

The present study consisted of two eyewitness misinformation experiments to explore SIRE's potential to improve eyewitness evidence. These experiments, while similar in basic structure to Parker et al.'s (2008a), were designed to be more ecologically valid in certain respects. Parker et al.'s participants were informed before viewing the photos that the study concerned memory for a witnessed event and, while viewing the photos, participants simultaneously heard an audio narrative that referenced and hence drew attention to the target objects. These aspects of the procedure may have promoted intentional encoding of the target objects. Although real eyewitnesses may intentionally encode some details, the specific details that receive intentional processing are likely to be idiosyncratic and witnesses are unlikely to be questioned exclusively about those details. Therefore the present study tested whether SIRE of forensically relevant material occurs following more naturalistic encoding without exogenous attentional cuing of the to-be-remembered information. Furthermore, we examined memory not only for objects, but also for actions.

In addition, the present study included one novel dependent measure and two novel independent variables of applied importance. The novel dependent measure was confidence ratings for memory judgements. Whether saccades affect confidence in retrieved information, as opposed to the information's accuracy, has not previously been examined in any context. Confidence is especially important in relation to eyewitness memory because confidence is an important determinant of eyewitnesses' perceived credibility (e.g., Brewer & Burke, 2002; Whitley & Greenberg, 1986). Ideally, from a forensic perspective, saccades would increase confidence in true memories and decrease confidence in false memories. Cause to expect the first effect comes from Remember/Know/Guess judgements examined in Parker et al. (2008a). Saccades significantly increased the number of true memories receiving Remember responses (indicating recollection of specific details) and decreased the number receiving Guess responses. In so far as Remember and Guess responses are associated with high and low confidence, respectively (Dunn, 2004), saccades should increase mean confidence in true memories. It is less clear from Parker et al.'s Remember/Know/Guess data that saccades should be expected to decrease confidence in false memories. Saccades significantly decreased the number of false memories receiving Guess and Know responses, but not the number receiving Remember responses. Hence, saccades may have reduced the number of false memories associated with low confidence (Know, like Guess, responses being associated with lower confidence than Remember responses; Dunn, 2004), without altering the number associated with high confidence. If saccades consistently have this effect, then one might expect *higher* mean confidence in false memories following saccades. Direct examination of confidence ratings is needed to test for these important possible effects.

The first novel independent variable in the present study was type of misinformation. Misinformation may contradict visual details of previously viewed objects (e.g., a red toolbox is described as grey), or it may suggest the addition of entirely new event details (e.g., a thief is described as looking in some filing cabinets, when in fact he never touched them). These two types of misinformation (called contradictory and additive, respectively) are both possible in forensic settings, but Parker et al. (2008a) examined contradictory misinformation only. The present study tested the effect of saccades on retrieval following exposure to both types.

The second novel independent variable was participants' handedness, which has been found to mediate SIRE effects in memory for word lists (Lyle et al., 2008a) and object–location conjunctions (Brunyé et al., 2009). In those studies (see also Shobe, Ross, & Fleck, 2009), SIRE occurred for individuals who were strongly right-handed (SR) but not for individuals who were not (nSR; i.e., left- or weakly right-handed). In fact, in Lyle et al. (2008a) saccades actually harmed nSR participants in one respect: by increasing recall and recognition of non-studied words. However, saccades do not invariably affect SR and nSR individuals differently: Following saccades, both SR and nSR participants recalled putatively earlier childhood memories (Christman, Propper, & Brown, 2006) and were more accurate in some conditions of a letter-matching task (Lyle & Martin, 2010). Given these limited and complex results, it is unclear whether SIRE of forensically relevant memories will occur for all individuals, or only those who are SR. Obviously, in assessing SIRE's potential as an applied intervention, it is critical to determine whether there is a segment of the population for whom saccades do not enhance retrieval and may even impair it. It bears noting that the percentage of the population that can be considered nSR is considerable. For example, in two random samples of undergraduates in Lyle et al. (2008a), the percentages of participants classified as nSR were 39% and 42%.

To date, explanations for less-reliable SIRE effects for nSR individuals have centred on the idea that the baseline level of either interhemispheric interaction or intrahemispheric attentional processing may be greater in nSR than SR individuals such that the former have a smaller margin for saccade-induced increases than the latter (Brunyé et al., 2009; Lyle & Martin, 2010; Lyle et al., 2008b). The notion that there may be baseline differences between SR and nSR individuals is supported by anatomical and behavioural data. Some anatomical studies (but not all, e.g., Welcome et al., 2009) have found that some regions of the corpus callosum are larger in nSR than SR individuals (e.g., Cowell, Kertesz, & Denenberg, 1993; Witelson, 1985), which could result in greater interhemispheric interaction in the former. Furthermore, given Kinsbourne's (2003) theory that excitatory interhemispheric connections maintain the preparedness of each individual hemisphere to respond to stimuli, Lyle and Martin (2010) proposed that greater interhemispheric connectivity in nSR individuals could lead to greater intrahemispheric processing. Behaviourally, in the absence of saccades, nSR individuals have been found to outperform SR individuals on a variety of memory tests, which may reflect the former's greater baseline interhemispheric interaction (Lyle et al., 2008b; Propper et al., 2005).

Independent of the possibility that handedness might mediate SIRE, the nSR memory advantages just mentioned are interesting in their own right from a forensic perspective, because they raise the possibility that nSR individuals may provide superior eyewitnesses evidence. However, another handedness effect might be taken to suggest the opposite—that nSR eyewitnesses might give poorer evidence than SR ones, at least when exposed to misinformation. Christman, Henning, Geers, Propper, and Niebauer (2008) exposed participants to a persuasive message and found that nSR participants exhibited greater pro-message attitude change than did SR participants. Christman et al. proposed that this finding reflects that nSR individuals are more likely than SR to update their beliefs in the face of new information. Therefore, in so far as incorporating misinformation constitutes updating one's beliefs about a past event in response to a message received after the event, we thought it possible that nSR individuals might be more likely to incorporate misinformation into their memories of witnessed events. We included handedness in the present study to examine whether it mediates SIRE for forensically relevant material, and whether there is any difference between SR and nSR individuals in memory for such material.

Lastly, an important consideration is whether SIRE occurs even after multiple presentations of misinformation. In laboratory studies, repeatedly presenting misinformation increases the incidence of false memories (e.g., Zaragoza & Mitchell, 1996) and real eyewitnesses may be repeatedly exposed to misinformation, given that they may repeatedly read, talk, or be interviewed about a crime. In Experiment 1 of the present study each piece of misinformation was presented only once, as in Parker et al. (2008a), while in Experiment 2 misinformation was presented three times, a condition not previously investigated.

As just stated, the two experiments constituting the present study differed in the number of times each piece of misinformation was presented, but they were otherwise methodologically identical. Therefore, the method of the two experiments is described jointly, followed by separate results sections.

METHOD

Participants

Participants were undergraduates aged 18–30 who received credit in psychology courses for participating. Scores on a modified version of Oldfield's (1971) Edinburgh Handedness Inventory (see Materials) were used to classify participants as SR or nSR. In two previous experiments (Lyle et al., 2008a), the median score on the inventory in undergraduate samples was +80 and participants who scored +80 or higher were affected differently by saccades compared to participants who scored lower. Here, therefore, participants were classified a priori as SR if they scored +80 or higher and nSR if they scored lower. In Experiment 1 there were 72 SR (58 females) and 56 nSR (42 females, 1 unknown) participants. In Experiment 2 there were 64 SR (54 females) and 40 nSR (35 females). No participants in Experiment 2 had participated in Experiment 1. In each handedness group, equal numbers of participants were randomly assigned to the saccades and fixation conditions.

Materials

Modified Edinburgh Handedness Inventory. The inventory consisted of 10 objects or activities (writing, drawing, spoon, open jars, toothbrush, throwing, comb hair, scissors, knife without fork, striking a match) with five mutually exclusive response options describing hand preference when using the object or performing the action (always left, usually left, no preference, usually right, always right). For the purpose of scoring, the five responses had point values of -10, -5, 0, $+5$, and $+10$, respectively. Therefore total scores could range from -100 (exclusive left-handedness) to $+100$ (exclusive right-handedness) in 5-point increments.

Slideshows. To increase generalisability and number of observations, two slideshows depicting different staged criminal events were used (for a similar approach, see Roediger & Geraci, 2007). One depicted a repairman stealing cash from an office (McCloskey & Zaragoza, 1985) and the other depicted a man shoplifting from a campus bookstore (Loftus, 1991). There were 79 slides in the office slideshow and 64 slides in the bookstore slideshow.

Event descriptions. Three descriptions of each of the two events depicted in the slideshows were adapted from Roediger and Geraci (2007). Descriptions were worded differently as though written by different people. In Experiment 1 each description included one piece of contradictory misinformation about an object and one piece of additive misinformation about an action involving either actual or suggested objects. Therefore, across the three descriptions for each slideshow, there were three pieces of contradictory and three pieces of additive misinformation, embedded among numerous accurate descriptions of other event details. Mean description length was 434 ($SD = 96$) words for the office event and 401 ($SD = 118$) words for the bookstore event. In Experiment 2 the descriptions were the same as in Experiment 1 except that each description included all three contradictory and all three additive pieces. Mean description length was 487 ($SD = 103$) words for the office event and 466 ($SD = 140$) words for the bookstore event. Thus, in Experiment 1 each piece of misinformation was presented only once (in one of three descriptions) while in Experiment 2 each piece was presented three times (once per description). Two versions of the descriptions were used in the experiments, each containing a different, non-overlapping set of contradictory and additive misinformation. Assignment of versions was counterbalanced.

Memory tests. There were two memory tests corresponding to the two slideshows. Each test consisted of 24 statements describing five different types of event detail. In addition to contradictory ($n = 3$) and additive ($n = 3$) details, there were slides-only details ($n = 6$), which had been seen in the slides but not mentioned in any of the descriptions, and new details ($n = 6$) not previously seen or mentioned. For a given participant who received a particular version of the event descriptions, new details were those that served as contradictory and additive details in the other version. Finally, there were filler items ($n = 6$) that referenced details that were both seen in the slides and mentioned in the descriptions.

Saccades and fixation stimuli. The stimulus for the saccades task was a computerised sequence showing a black circle on a white background. At a viewing distance of 24 inches, the circle alternated between 13.5 degrees of visual angle left and 13.5 degrees of visual angle right of the vertical midline every 500 ms for 30 s. For the fixation task, the circle flashed in the centre of the screen (500 ms on, 500 ms off) for 30 s. All prior SIRE studies also used saccades and fixation tasks lasting 30 s.

Procedure

Participants first filled out the handedness inventory. Next, participants were informed they would be participating in a study of people's interpretations of complex events. Participants were told they would watch two slideshows and try to figure out what was happening in them. No mention was made of memory. Participants watched both slideshows and viewing order was counter balanced. Rate of presentation was 3 s per slide.

Immediately after viewing the second slideshow, participants were given 15 minutes to read descriptions of the events supposedly written from memory by previous participants. Descriptions of the slideshow viewed first were presented first, followed by descriptions of the slideshow viewed second. Participants read the descriptions at their own pace. All participants finished in the allotted time.

After the 15-minute reading phase, participants performed either the saccades or fixation task. In the saccades task participants were instructed to move their eyes, without moving their heads, to follow the circle that alternated between the left and right sides of the screen. In the fixation task participants were instructed to stare at the stationary flashing circle without moving their eyes. During both tasks participants were positioned approximately 24 inches from the computer monitor. The experimenter observed the participants to ensure compliance with task instructions.

Immediately after the saccades or fixation task, participants were given the memory tests. Participants pressed the "f" key if a statement described a detail they remembered seeing in the slideshow, and the "j" key if it did not. Participants were explicitly instructed that, even if they remembered reading about a detail in the descriptions, they should not press the "f" key unless they also remembered seeing it in the slideshow. Participants rated their confidence in each response on a scale from 1 (guessing) to 7 (as sure as they could be). Participants were tested on both slideshows in the same order in which they had viewed them. The tests were self-paced. Note that the interval between the saccades or fixation task and the first test was necessarily shorter than the interval between the task and the second test because, in the latter case, the first test intervened.

EXPERIMENT 1: RESULTS AND DISCUSSION

Discrimination

The quality of eyewitness evidence depends in large part on witnesses' ability to discriminate between what was seen and what was not. In these experiments memory for seen details was probed by slides-only test items, while memory for three types of unseen detail was probed by contradictory, additive, and new items. Therefore, to analyse discrimination, three d' scores were calculated for each participant by separately comparing the proportion of slides-only items attributed to the slides (hits) to the proportion of contradictory, additive, and new items attributed to the slides (false alarms). Scores were submitted to a 2 (handedness: SR or nSR) $\times$ 2 (pre-test activity: saccades or fixation) $\times$ 2 (test: first or second) $\times$ 3 (unseen item type: contradictory, additive, or new) mixed-design ANOVA in which the first two factors were between-participants and the second two were within-participants.[1]

[1] We analysed response bias in the same manner as d' in both Experiments 1 and 2. There were no significant main effects of pre-test activity or significant interactions involving pre-test activity in either experiment.

d' was largest for new items ($M = .52$), intermediate for additive items ($M = .27$), and smallest for contradictory items ($M = -.03$). The main effect of item type was significant, $F(2, 248) = 100.94$, $MSE = .19$, $p < .001$, $\eta_p^2 = .45$, as were all pairwise comparisons, smallest $t(127) = 7.02$, $p < .001$. Hence we obtained a significant misinformation effect: Participants were less able to discriminate between seen and unseen details (i.e., d' was smaller) when unseen details had been the subject of misinformation. Of greater interest, there was a significant interaction between pre-test activity and test (see the left half of Figure 1), $F(1, 124) = 4.55$, $MSE = .87$, $p = .035$, $\eta_p^2 = .035$. On the first test, as expected, d' was significantly larger following saccades ($M = .35$) than fixation ($M = .13$), although the size of the SIRE effect was small by conventional standards, $t(126) = 1.72$, one-tailed $p = .044$, Cohen's $d = 0.34$. In contrast, on the second test, there was no evidence of SIRE: d' was actually slightly smaller following saccades ($M = .23$) than fixation ($M = .30$). Neither handedness nor item type entered significantly into this interaction (Fs < 1), indicating that, at least on the first test, saccades increased both SR and nSR participants' ability to discriminate between seen details and unseen ones, and equally so regardless of whether the unseen details were contradictory, additive, or new.

SR and nSR participants generally exhibited similar discrimination, but there was a significant handedness $\times$ test $\times$ item type interaction, $F(2, 248) = 3.64$, $MSE = .20$, $p = .028$, $\eta_p^2 = .029$. The interaction arose because nSR participants discriminated between slides-only and new details better on the second test ($M = .68$) than on the first ($M = .41$), $t(55) = 2.91$, $p = .005$, while SR participants discriminated between those two detail types about equally well on the first ($M = .52$) and second ($M = .46$) tests, $t(71) = 0.50$, $p = .62$. More important, though, was that d' scores did not differ significantly between SR and nSR participants for any item type on either test, largest $t(126) = 1.68$, $p = .096$.

Hits and false alarms

To explore the dynamics by which saccades increased discrimination on the first test, hit and false alarm rates were analysed separately. Hit rates were submitted to a 2 (handedness: SR or nSR) $\times$ 2 (pre-test activity: saccades or fixation) $\times$ 2 (test: first or second) ANOVA.

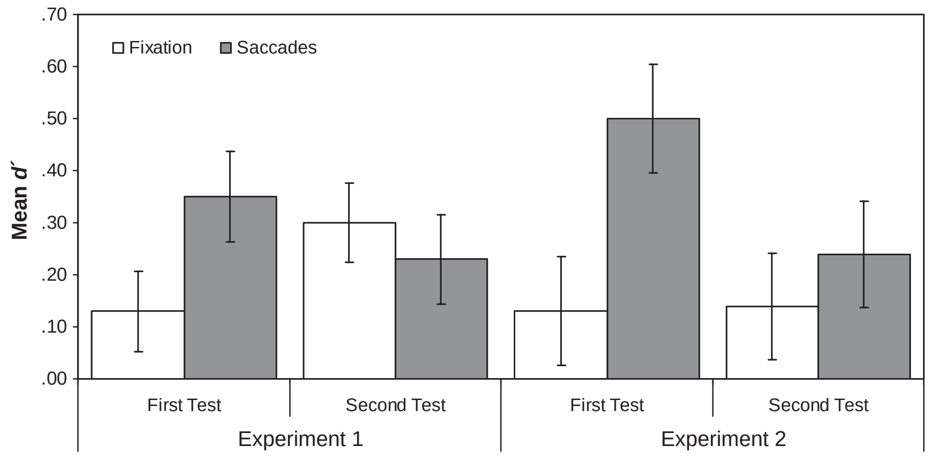

Figure 1. Mean d' as a function of pre-test activity and test in Experiments 1 and 2. Error bars indicate $\pm$1 SEM.

There was a main effect of test, $F(1, 124) = 4.93$, $MSE = .028$, $p = .028$, $\eta_p^2 = .038$, but, more important, the pre-test activity × test interaction approached significance, $F(1, 124) = 3.65$, $MSE = .028$, $p = .058$, $\eta_p^2 = .029$. As the same interaction was significant in the d' analysis, we focus on this effect. On the first test the hit rate was higher following saccades ($M = .35$) than fixation ($M = .31$). This difference was expected based on Parker et al.'s (2008a) study and means, as in that previous study, that a saccade-induced increase in hits contributed to a significant increase in discrimination. However, the difference in the present study, unlike in Parker et al., was not significant, $t(126) = 1.31$, one-tailed $p = .097$. On the second test the hit rate was higher following fixation ($M = .40$) than saccades ($M = .36$), which helps explain why saccades did not increase discrimination on that test.

False alarm rates for the three unseen item types were submitted to a 2 (handedness) × 2 (pre-test activity) × 2 (test) × 3 (unseen item type) ANOVA. There was a significant main effect of item type, $F(2, 248) = 41.93$, $MSE = .044$, $p < .001$, $\eta_p^2 = .25$, whereby the false alarm rate for contradictory items ($M = .31$) was significantly higher than for either additive ($M = .16$) or new ($M = .17$) items, smallest $t(127) = 7.25$, $p < .001$. The false alarm rates for additive and new items did not differ significantly, $t(127) = 1.15$, $p = .254$. Of greater relevance, neither the main effect of pre-test activity nor the pre-test activity × test interaction was significant (Fs < 1). However, it is the case that, on the first test, the false alarm rate was numerically lower following saccades ($M = .19$) than fixation ($M = .21$). As with hits, this difference was expected based on Parker et al.'s (2008a) results and contributed to the saccade-induced increase in discrimination, but was not significant, $t(127) = 0.94$, one-tailed $p = .175$.

Also regarding false alarms, there was a marginally significant handedness × test × item type interaction, $F(2, 248) = 2.89$, $MSE = .044$, $p = .057$, $\eta_p^2 = .023$, which we examined further because the same three factors interacted significantly in the d' analysis. The interaction in false alarms reflects the fact that the false alarm rate for new items on the second test was significantly lower for nSR participants ($M = .13$) than SR participants ($M = .22$), $t(126) = 2.80$, $p = .006$, Cohen's $d = 0.56$, but false alarm rates otherwise did not differ significantly as a function of handedness. This difference was the only evidence in Experiment 1 of an nSR memory advantage. Although limited to a single item type and test, the advantage is reminiscent of previous findings of lower false recall from word lists among nSR individuals (Christman, Propper, & Dion, 2004, Exp. 1; Lyle et al., 2008a; Propper et al., 2005).

Confidence in true memories

We restricted analysis of confidence to hits/true memories because many participants did not have any false alarms/false memories, even for those items (contradictory) that elicited the most false alarms. Analysis was further restricted to the first test because we were primarily interested in whether memories retrieved under SIRE are held with differential confidence than those retrieved following fixation, and there was significant SIRE on the first test only. For each participant we calculated the mean confidence response given to that participant's hits. Participants who had no hits on the first test were excluded.[2] In this conditional analysis, unequal numbers of participants had been tested on the office and bookstore slideshows, therefore slideshow was included as a between-participants factor. Mean confidence ratings were submitted to a 2 (handedness) × 2 (pre-test activity) × 2 (slideshow) ANOVA. The only significant effect was the pre-test activity × slideshow interaction, $F(1,\ 113) = 5.30$, $MSE =$ 1.09, $p = .023$, $\eta_p^2 = .045$. Confidence in memories of the office event was not significantly different following saccades ($M = 5.9$) versus fixation ($M =$ 6.2), $t(58) = 1.22$, $p = .23$. In contrast, confidence in memories of the bookstore event was, as predicted based on Parker et al.'s (2008a) Remember/Know/Guess results, significantly higher following saccades ($M = 6.0$) than fixation ($M = 5.5$), $t(59) = 2.17$, one-tailed $p = .017$. It is possible that our ability to detect a significant effect of saccades on confidence in office memories was limited by a ceiling effect, given that confidence in those memories was very high following fixation (the upper end of the scale was 7).

Experiment 1 results summary

In Experiment 1 saccades increased discrimination between seen and unseen details, regardless of whether or what type of misinformation was provided about the latter, and for SR and nSR participants equally. Critically, however, SIRE occurred only on the first test administered following saccades. On the second test, saccades did not significantly affect discrimination in any way. On the first test, participants who performed saccades had numerically, but not significantly, more hits and fewer false alarms, which together produced the significant increase in discrimination. SIRE on the first test was accompanied by increased confidence in true memories for seen items but, for reasons that are unclear, only for one of the two witnessed events. The only significant handedness difference favoured nSR participants in that they had fewer false alarms for new unseen items, but this effect was weak in that it occurred only on the second test.

[2] The numbers of participants excluded from each condition were 0 nSR-fixation, 2 nSR-saccades, 3 SR-fixation, and 2 SR-saccades.

EXPERIMENT 2: RESULTS AND DISCUSSION

Discrimination

d' scores were submitted to an ANOVA with the same design as in Experiment 1 and, as in that experiment, there was a significant main effect of item type, $F(2,\ 200) = 108.62$, $MSE =$ .25, $p < .001$, $\eta_p^2 = .52$, such that discrimination between seen and unseen details was greatest for new details ($M = .63$), intermediate for additive details ($M = .23$), and poorest for contradictory details ($M = -.11$). All pairwise comparisons were significant, smallest $t(103) = 7.12$, $p < .001$. More important, d' scores were significantly higher following saccades ($M = .37$) than fixation ($M = .13$) and the effect was of medium size, $F(1,\ 100) = 5.66$, $MSE = 1.52$, $p =$ .019, $\eta_p^2 = .054$. The pre-test activity × handedness and pre-test activity × item type interactions were not significant (Fs < 1), indicating that the SIRE effect was of approximately equal magnitude for both SR and nSR participants and in the face of contradictory, additive, or no misinformation. The pre-test activity × test interaction was also non-significant, $F(1,\ 100) = 1.67$, $MSE = 1.60$, $p = .20$, but because it was significant in Experiment 1, we nevertheless tested the statistical significance of SIRE on each test separately. On the first test, d' scores were significantly higher following saccades ($M =$ .50) than fixation ($M = .13$), $t(102) = 2.49$, $p =$ .007, Cohen's $d = 0.49$. This difference was in the same direction on the second test (Ms = .24 and .14, respectively), but was smaller and not individually significant, $t(102) = 0.79$, $p = .435$. This pattern is shown in the right half of Figure 1.

The main effect of handedness was also significant, $F(1,\ 100) = 7.39$, $MSE = 1.52$, $p =$ .008, $\eta_p^2 = .069$, such that d' scores were higher for nSR ($M = .39$) than SR participants ($M = .11$). This extends other findings of nSR memory advantages (Christman et al., 2004, Exp. 1; Lyle et al., 2008b; Propper et al., 2005) to more forensically relevant materials and it contradicts the prediction that hypothetically greater belief updating among nSR individuals (Christman et al., 2008) might reduce the quality of the eyewitness evidence they provide following exposure to misinformation. Figure 2 depicts the

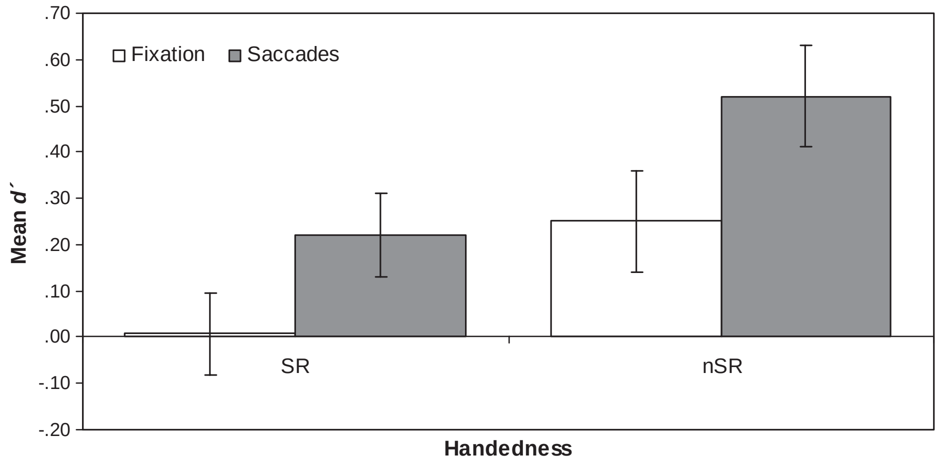

Figure 2. Mean d' as a function of pre-test activity and handedness in Experiment 2. Errors bars indicate ± 1 SEM.

main effects of pre-test activity and handedness and makes clear the absence of an interaction.

Hits and false alarms

To explore the dynamics underlying superior discrimination given saccades or nSR handedness, hits and false alarms were analysed as in Experiment 1. The hit rate was significantly higher following saccades ($M = .43$) than fixation ($M = .36$), $F(1, 100) = 6.23$, $MSE = .045$, $p = .014$, $\eta_p^2 = .059$. The hit rate for nSR participants (.42) was higher than for SR participants (.37), but not significantly so, $F(1, 100) = 2.00$, $MSE = .045$, $p = .16$.

Analysis of false alarms yielded a significant main effect of item type, $F(2, 200) = 51.65$, $MSE = .061$, $p < .001$, $\eta_p^2 = .34$, with the false alarm rate highest for contradictory details ($M = .42$), intermediate for additive details ($M = .23$) and lowest for new details ($M = .17$). All pairwise comparisons were significant, smallest $t(103) = 2.72$, $p = .008$. More important, the false alarm rate was significantly lower for nSR participants ($M = .24$) than SR participants ($M = .31$), $F(1, 100) = 3.94$, $MSE = .19$, $p = .05$, $\eta_p^2 = .038$. Hence, both a somewhat higher hit rate and a significantly lower false alarm rate contributed to nSR participants' significantly better discrimination. The false alarm rate following saccades ($M = .27$) was only slightly and non-significantly lower than following fixation ($M = .28$), $F < 1$, indicating, when combined with the results of the hits analysis, that saccades enhanced discrimination primarily by increasing hits.

Confidence in true and false memories

The analysis of confidence was the same as in Experiment 1 except that, because false alarms for contradictory misinformation items were sufficiently numerous, we calculated the mean confidence response each participant gave to contradictory false alarms, as well as to hits. Response type (hit or false alarm) was included as a within-participants factor in the ANOVA. Participants lacking at least one hit and one false alarm were excluded.[3] As in Experiment 1, analysis was restricted to the first test, on which significant SIRE occurred. Only the pre-test activity × response type interaction was significant, $F(1, 68) = 4.89$, $MSE = .73$, $p = .03$, $\eta_p^2 = .067$. Mean confidence in hits was identical and near ceiling regardless of pre-test activity ($M = 6.0$), but confidence in false alarms was significantly lower following saccades ($M = 5.5$) versus fixation ($M = 6.2$), $t(74) = 2.04$, $p = .045$. Moreover, following fixation, confidence was not diagnostic of accuracy: Participants were actually numerically less confident in true memories than false ones, albeit non-significantly so, $t(37) = 0.86$. In contrast, following saccades, confidence was significantly higher in true than in false memories, $t(37) = 2.25$, $p = .031$. Confidence in true memories of both the office and the bookstore events was near ceiling given fixation (Ms = 6.0 and 6.1, respectively) and this may have limited our ability to detect any saccade-induced increase.

[3] The numbers of participants excluded from each condition were 14 nSR-fixation, 17 nSR-saccades, 12 SR-fixation, and 9 SR-saccades.

Experiment 2 results summary

In Experiment 2 saccades increased discrimination between seen and unseen items, regardless of whether or what type of information was presented about the latter, and for SR and nSR participants equally. The increase was significant only on the first test administered following saccades. Saccades increased discrimination mainly by significantly increasing hits. Saccades decreased the false alarm rate only incrementally, but they decreased confidence in false alarms significantly. There was a robust handedness difference favouring nSR participants, who exhibited significantly greater discrimination between seen and unseen items. nSR participants' superior discrimination was driven by a significantly lower false alarm rate, which held for all unseen item types and on both tests.

GENERAL DISCUSSION

The results of the present study support SIRE's potential to improve eyewitness evidence. In two experiments, participants who performed saccades before answering questions about staged crimes, versus those who did not, exhibited significantly greater discrimination between seen and unseen event details. This occurred regardless of whether the unseen details were contradictory misinformation, additive misinformation, or new, and regardless of whether misinformation was presented once (Experiment 1), as in Parker et al. (2008a), or multiple times (Experiment 2). As in real eyewitness interviews, but unlike in Parker et al. (2008a), the tested details concerned both objects and actions and attention had not been exogenously directed to the details during encoding. Our finding of SIRE following relatively incidental encoding is notable in the larger context of SIRE research because all previous studies with laboratory materials have involved intentional encoding. Apparently, however, SIRE does not depend on intentional encoding, a conclusion suggested previously by findings of SIRE for autobiographical events experienced outside of the laboratory (Christman et al., 2003, Exp. 2, 2006).

Also encouraging, we obtained no evidence that SIRE for forensically relevant memories is limited to SR individuals. Saccades had similar positive effects on SR and nSR individuals (see also Christman et al., 2006; Lyle & Martin, 2010). Given previous findings in other procedures that SIRE does not occur for nSR individuals (Brunyé et al., 2009; Lyle et al., 2008a), it would be injudicious to conclude on the basis of these two experiments that saccades will invariably enhance eyewitness memory for nSR individuals. The results are promising, but future research is needed to increase our understanding of the conditions under which nSR individuals do and do not experience SIRE.

Likewise favourable to SIRE as a means of improving eyewitness evidence is the finding that saccades increased memory accuracy without negative, and possibly with positive, effects on confidence, which is an important feature of memory reports (e.g., Brewer & Burke, 2002; Whitley & Greenberg, 1986) not previously examined in any SIRE study. We obtained suggestive evidence that, following saccades, true memories may be more confidently held (Experiment 1) and false memories less confidently held (Experiment 2). This is encouraging, and the finding regarding true memories is consistent with previous Remember/Know/Guess data (Parker et al., 2008a), but the results must be considered preliminary for reasons described next. First, in Experiment 1, saccades increased confidence in true memories about only one of the two events we studied (the bookstore). Second, the finding in Experiment 2 that saccades decreased confidence in false memories of contradictory details was based on a relatively small sub-sample of participants; namely, those who had at least one true memory for a slide-only detail and one false memory for a contradictory unseen detail. Additional research is needed to firmly establish the relationship between SIRE and confidence but, practically speaking, so long as SIRE is not accompanied by negative effects on confidence, its viability as a means of improving eyewitness evidence is unimpeached. Any positive effects on confidence that may accompany SIRE (and the present results suggest there may indeed be some) come essentially as an added bonus.

A final consideration in evaluating SIRE's applied potential is the size of the effect. A significant increase in discrimination between seen and unseen details occurred on the first test in Experiments 1 and 2 and the effect sizes were, in Cohen's d, .34 and .49, respectively. By conventional standards, these are small to medium effects, similar to the size of SIRE effects in other experiments in our laboratory (Lyle et al., 2008a). Larger effects would obviously be ideal but SIRE may be worth pursuing as an applied intervention even if it produces only small-to-medium effects, given that the saccades activity is fast, free, easy, and apparently without negative consequences.

Although the results of three experiments now bolster the expectation that saccades may increase real eyewitnesses' discrimination between seen and unseen event details, we cannot yet predict more specifically whether saccades would increase retrieval of correct details, decrease retrieval of incorrect details, or both. Both effects were significant in Parker et al.'s (2008a) study. In contrast, while both effects were in the desired direction in the present experiments, neither effect was individually significant in Experiment 1, and only the increase in correct retrieval (i.e., hits) was significant in Experiment 2. Such variability is also present in the larger SIRE literature. Christman et al. (2004) found that saccades significantly reduced incorrect recall of critical non-presented words from associative word lists but only non-significantly increased correct recall of presented words. In contrast, Parker and Dagnall (2007) found that saccades both significantly decreased false recognition of non-presented associates and significantly increased correct recognition of presented words. Also, in experiments on memory for random word lists, Lyle et al. (2008a) found that saccades significantly increased correct recall and significantly decreased incorrect recall but only non-significantly increased correct recognition and non-significantly decreased false recognition (leading to a significant increase in discrimination).

Thus, while it is clear saccades have the potential to significantly increase correct retrieval and decrease incorrect retrieval, and mean differences are often in those directions, it is difficult, at the present time, to predict a priori which effect, if either, will reach conventional significance. It is unknown whether exact outcomes are systematically related to experimental factors or whether they reflect the fact that confidence intervals for p values are large even given real population differences (Cumming, 2008). In either event, the conservative conclusion at present is that SIRE has the potential to improve eyewitness evidence by increasing discrimination between seen and unseen details. More specific claims about SIRE's ability to substantially increase correct retrieval or decrease incorrect retrieval do not seem warranted at this time.

An unexpected finding with potentially important forensic implications is that, in both experiments, significant SIRE occurred on the first test participants took following saccades, but not on the second test. The finding was unexpected because no previous SIRE study had a design in which multiple tests were administered following a single performance of the saccades activity. At least two explanations of the finding are possible. One explanation builds on the observation that the first test covered the slideshow participants viewed first, and, hence, memory for that slideshow potentially suffered from retroactive interference from the second slideshow. It could be hypothesised that SIRE occurred on the first test only because saccades enhance retrieval primarily by reducing retroactive interference. However, by this explanation, SIRE should not have occurred in Parker et al.'s (2008a) study, in which participants viewed and were tested on only a single event. A second explanation, which we favour, is that SIRE is greatest immediately following saccades and diminishes over time. Two results support this explanation. One, in the saccade conditions of the present experiments, performance was poorer on the second test than the first, as would be expected if saccade effects wore off. Specifically, d' fell from the first to the second test by 34% and 52% in Experiments 1 and 2 respectively. By this account, no declines would be expected in the fixation condition, and, indeed, none occurred: Following fixation, mean d' was numerically higher on the second than the first test in both experiments.

Two, Shobe et al. (2009) examined the effect of the same bilateral saccade activity as in the present research on a measure of creativity, rather than memory retrieval, and found that saccade-induced enhancements lasted no more than 9 minutes and possibly as little as 3 minutes. Although comparisons between SIRE and saccade-induced changes in other forms of cognition must be made with caution, this result adds weight to our suggestion that SIRE may have diminished during the several minutes it took participants in the present experiments to complete the first test. Of course, at some level, it is obvious that retrieval enhancement cannot endure indefinitely following saccades, but more research is needed to determine its duration and also whether it can be reinstated by repeating saccades. Resolving these issues will tell would-be investigators how much time they have to question eyewitnesses under SIRE.

A final novel finding of potential forensic significance is that nSR participants made fewer false alarms than SR ones, especially in Experiment 2. In Experiment 2 this effect of handedness was not mediated by unseen item type, meaning that nSR participants made fewer false alarms regardless of whether unseen items were mentioned for the first time on the test (new items) or had previously been mentioned in the event descriptions (contradictory and additive items). This suggests that nSR individuals may be more reliable eyewitnesses, because their memories may be less vulnerable to distortion from leading questions or post-event misinformation. More generally, the present finding joins prior ones in indicating that nSR handedness is a marker for superior episodic memory (Christman et al., 2003, Exp. 2, 2004, Exp. 1; Lyle et al., 2008a, 2008b).

Despite prior evidence of nSR memory advantages, we also considered, in the Introduction, the possibility that nSR individuals might be more likely than SR individuals to incorporate contradictory and additive misinformation into their memories for witnessed events. We raised this possibility because Christman et al. (2008) found that nSR participants exhibited greater attitude change than did SR participants in response to a persuasive message, and, from this, Christman et al. argued that nSR individuals are more likely to update their beliefs in response to new information. Incorporating misinformation may be seen as an instance of updating beliefs in response to new information, so greater receptivity to misinformation among nSR participants seemed possible. However, this was not found in either of the present experiments, and in fact nSR participants were actually more resistant to misinformation in Experiment 2. Hence, if nSR individuals do more readily update their beliefs, this tendency apparently does not necessarily extend from the attitudinal domain Christman et al. examined to the memory domain. Indeed, it may be that, when it comes to memories, nSR individuals are less likely to update their beliefs about past events in the face of misinformation. There is evidence that nSR individuals' memories are more vividly detailed, in addition to more accurate, than those of SR individuals (Parker & Dagnall, 2010; Propper & Christman, 2004), so perhaps nSR individuals are less likely to accept misinformation because they do not remember sufficient detail about it, compared to the standard set by their memories of actual events.

Three earlier studies found superior free recall among nSR versus SR individuals (Christman et al., 2003, Exp. 2, 2004, Exp. 1; Lyle et al., 2008a, Exp. 1), but two studies of recognition memory did not find significant handedness differences (Lyle et al., 2008a, Exp. 2; Propper & Christman, 2004). Based on the theory that interhemispheric interaction is greater in nSR than SR individuals, Lyle et al. (2008b) argued that nSR advantages are more to be expected in recall than in recognition because recall may be influenced by interhemispheric interaction more than is recognition. Recall tasks typically recruit prefrontal cortex bilaterally—and hence presumably require some degree of interhemispheric interaction—while recognition tasks often recruit right prefrontal cortex only, especially when recognition responses can be based largely on item familiarity (Nolde, Johnson, & Raye, 1998b). Yet a clear nSR advantage did occur on the recognition tests in Experiment 2 of the present study.

Why did a robust nSR memory advantage occur on the recognition tests in Experiment 2 but not Experiment 1? Accounts of cross-experimental differences must be offered with caution, but a theoretically sensible explanation is that, in Experiment 1 more so than in Experiment 2, event details could be attributed to the slides based on familiarity only, with more familiar details being attributed to the slides and less familiar ones not being so. Such a familiarity-based attribution strategy might be about equally effective regardless of baseline differences in interhemispheric interaction between nSR and SR individuals. The strategy may have been less viable in Experiment 2, in which unseen contradictory and additive details were highly familiar following multiple presentations of misinformation. Therefore, participants in Experiment 2 more so than in Experiment 1 may have attempted to recall additional source information (Johnson, Hashtroudi, & Lindsay, 1993) to help determine whether the details were in the slides or only in the event descriptions. To the extent that the self-initiated retrieval and evaluation of source information recruits prefrontal cortex bilaterally (e.g., Nolde, Johnson, & D'Esposito, 1998a; Nolde et al., 1998b; Ranganath, & Knight, 2003), and hence depends on interhemispheric interaction (Johnson & Raye, 2000), nSR participants may have had an advantage, even on these nominal recognition tests, as they did on more explicit source memory tests in Lyle et al. (2008b). Additional research manipulating frequency of misinformation, or otherwise manipulating the use of source information, within a single experiment would help assess the validity of this account and clarify the conditions under which nSR individuals may be expected to provide more reliable eyewitness evidence.

In closing, we reiterate that the present results, obtained under laboratory conditions, support SIRE as a means of improving eyewitness evidence, and we suggest that additional research is warranted to examine SIRE under conditions that more closely approximate those of the real world (e.g., more realistic stimuli, longer retention intervals, open-ended test questions).

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