Running Head: EYE MOVEMENTS AND PERCEPTUAL MEMORY

Saccade Induced Retrieval Enhancement & the Recovery of Perceptual Item-Specific Information.

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Abstract

Saccade Induced Retrieval Enhancement (SIRE) effects refer to the finding that memory can be enhanced when a short period of saccadic eye movements takes place prior to retrieval. Previous published work testifies to this eye-movement advantage but no work has yet examined if SIRE effects can be found when retrieval demands are high as a result of testing non-studied memoranda that are identical in name/conceptual codes, similar in perceptual features, but differ in terms of perceptual – item-specific information. The results indicate SIRE effects can be found under such conditions and are independent of encoding orientation (intentional vs. incidental). More particularly, SIRE effects manifested themselves in terms of the retrieval of item-specific detail and recollection (vs familiarity). In terms of the latter, recollection but not familiarity was enhanced by eye-movements. These findings are considered in the context of extant theories of SIRE and related research that has demonstrated post-encoding and pre-retrieval influence on cognition.

Keywords

SIRE effects

Perceptual memory

False memory

Item-specific memory

Recollection

Saccade Induced Retrieval Enhancement & the Recovery of Perceptual Item-Specific Information.

General overview

Episodic memory involves conscious awareness of retrieved information and is a type of memory that retains sensory-perceptual experience in often highly detailed and specific form (Baddeley, 2002; Conway, 2001). Recent work has shown a novel manner to enhance this form of memory. Particularly, research has found that performing a sequence of voluntary saccadic horizontal eye movements to a moving target can improve episodic memory across a range of test-types and materials. Referred to as Saccade Induced Retrieval Enhancement (SIRE) (Lyle & Martin, 2010; Lyle & Edlin, 2014), this was first demonstrated by Christman, Garvey, Propper, and Phaneuf (2003). It was found that 30 seconds of saccadic horizontal eye movements (compared to a range of control conditions) prior to retrieval was sufficient to enhance recognition memory of a list of words by increasing the hit rate and reducing the false alarm rate. The research presented here is concerned with SIRE effects on the retrieval of detailed perceptual information under conditions that require the use of perceptual item-specific information in order to reduce false memories.

The current experiment makes use of a paradigm (described later) that has been designed to elicit high false recognition rates based upon underlying conceptual and perceptual similarities between studied and non-studied items. False recognition can be reduced by recalling distinctive information that allows for accurate discrimination between studied items and related distractors (lures). Before considering the details of this experiment, the influence of saccadic horizontal eye movements is reviewed.

SIRE effects and memory

Research subsequent to the original work of Christman et al., (2003), has developed SIRE effects across a range of test-types and materials. For instance, eye-movement influences have manifested themselves as reductions in false-recall and recognition in experimental tasks that elicit high proportions of associative false memories (Christman, Propper, & Dion, 2004; Parker & Dagnall, 2007). Saccadic eye movements can also improve performance in associative recognition tasks and increase the recovery of detailed information as assessed by remember responses (Lyle, Hanaver-Torrez, Hackländer, & Edlin, 2012; Parker, Relph & Dagnall, 2008). In addition, visuo-spatial recognition memory accuracy is enhanced (Brunyé, Mahoney, Augustyn, & Taylor, 2009), as is the free-recall of neutral and emotional words (Nieuwenhuis, et al., 2013; Phaf, 2017; Samara, Elzinga, Slagter, & Nieuwenhuis, 2011), recognition memory in children (Parker & Dagnall, 2012), face recognition and classification (Lee, et al., 2014; Lyle & Orsborne, 2011), explicit (vs. implicit memory) (Parker, Powell & Dagnall, 2018), free and cued-recall of autobiographical memories (Christman et al., 2003; Christman, Propper & Brown, 2006; Parker & Dagnall, 2010; Parker, Parkin & Dagnall, 2013), and free-recall (Keunsoo, & Hojin, 2017; Lyle, 2018) and recognition of eyewitness information (Lyle & Jacobs, 2010; Parker, Buckley & Dagnall, 2009). Saccade induced enhancement has also been found in some non-memory tasks such as measures of creativity (Shobe, Ross, & Fleck, 2009), convergent thinking, (Fleck & Braun, 2015), and attention (Edlin & Lyle, 2013). However, the principal findings for the current work relate to memory.

Theoretical accounts of SIRE effects

The original explanation for SIRE effects is based upon the Hemispheric Encoding and Retrieval Asymmetry (HERA) account of episodic (vs. semantic) memory. This derived from neuroimaging experiments, and posits episodic memory is influenced by interactions between the right and left prefrontal cortices (Habib, Nyberg & Tulving, 2003). Particularly, successful episodic memory is dependent upon interactions between a combination of left (encoding) and right (retrieval) mechanisms. As horizontal saccades are related to an increase in activation in contralateral hemisphere to the direction of the saccade (e.g., Dean, Crowley, & Platt, 2004; Kastner, et al., 2007), a sequence of saccades is hypothesized to lead to stimulation of both. The result is more efficient interhemispheric communication and improved episodic memory (Christman et al., 2003; Christman & Propper, 2010).

However, direct tests of the HERA account, using measurements of neural activity, have been mixed. One experiment found partial support using EEG coherence measurements as an index of hemispheric communication (Propper, Pierce, Geisler, Christman, & Bellorado, 2007). This experiment found *decreased* coherence in the gamma band in frontal regions after horizontal (vs. no) eye movements. However, in a separate study, Samara et al., (2011) found no coherence changes after horizontal saccades in any EEG band. More recently, Yaggie et al., (2015) did find horizontal saccades to produce a numerical increase in frontal beta coherence, however the magnitude of the effect was small and did not achieve conventional levels of significance.

A more recent explanation of SIRE effects implicates a role for top-down control processes (Edlin & Lyle, 2013; Lyle & Edlin, 2015). The saccadic eye-movement task used in SIRE research is considered to be a minimal attentional control activity in that subjects must exert some degree of top-down influence in order to maintain fixation on the moving target. Once engaged, top-down processing has the potential to affect subsequent task performance by influencing the allocation of attention. This is particularly so for tasks that necessitate top-down activation in order to achieve processing goals. In relation to memory, this is particularly important for controlled retrieval attempts that require more extensive search operations and post-retrieval monitoring.

This account is set in the context of neuroimaging research. For example, saccadic eye-movements has been found to activate a frontoparietal system encompassing the frontal eye fields and posterior parietal regions including the intraparietal sulcus (IPS), and superior parietal lobe (SPL) (Corbetta & Shulman, 2002; Konen, Kleiser, Wittsack, Bremmer, & Seitz, 2004). The signals originating in frontal regions represent the top-down control of attention in response to set goals and serves to modulate activity in these parietal regions and enhance attentional performance. Of importance is the finding that similar regions are involved in the top-down control of episodic memory. According to the *attention to memory model* (Cabeza, Ciaramelli, Olson, & Moscovitch, 2008), activity in the dorsal parietal region (that includes the IPS and SPL) reflects the top-down control of attention in accordance with retrieval goals and modulates the retrieval of target information.

Experimental work consistent with this account comes from findings that show larger SIRE effects when top-down control is necessitated to perform the memory task. An example is when target items have been made less accessible through the repeated retrieval of related, but competing items during as in the retrieval practice paradigm (Lyle & Edlin, 2015), or using free (vs. cued) recall (Lyle, 2018). Some additional evidence has recently been found from EEG recordings during a rest period following horizontal eye movements. Fleck et al., (2018), observed that delta-band coherence across frontal-posterior electrode sites was maintained after a period of 30 s of horizontal saccades (vs. fixation). This was interpreted as due to eye-movements engaging a mechanism that enables attentional control to be sustained over time. In addition, alpha-band coherence was reduced over the frontal-posterior midline electrodes after horizontal saccades; explained as an increased readiness to deploy a frontal-parietal attentional network for subsequent tasks.

SIRE and the retrieval of perceptual information

Of importance in the current experiment are findings pertaining to false and true recognition memory for perceptual information. False memories can be easily induced in converging associate procedures in the form of the Deese-Roediger-McDermott (DRM) paradigm (Roediger & McDermott, 1995). In this task, false recall and recognition of non-presented words are found following the study of highly associated word lists. For example, the study of 'thread', 'pin', 'eye', 'sew' and 'sharp' typically leads to false memory for the word 'needle'. False memory effects induced in this paradigm are often at levels similar to true memory (e.g., Roediger & McDermott, 1995; Thapar & McDermott, 2001) and are resistant to procedures that seek to eliminate them (e.g., Anastasi, Rhodes, & Burns, 2000; Gallo, Roberts, & Seamon, 1997; Multhaup & Conner, 2002). It has been found that saccadic eye movements after encoding, but prior to retrieval, can reduce both false recall and recognition (Christman et al., 2004, Parker & Dagnall, 2007). In these experiments, although memory was tested visually, memory was verbal (i.e., the words) and no attempt was made to assess visual memory per-se.

Visual recognition performance, however, was tested by Brunyé, et al., (2009). In these experiments, subjects were exposed to satellite maps of a range of different industrial areas during the encoding phase. Visual recognition memory was tested using seen images and ones that had been digitally manipulated by altering the location of seen objects within the map or introducing new objects. It was found that horizontal saccades just prior to the recognition test increased memory for studied information (hit rate). The false alarm rate was marginally lower following horizontal saccades, but any real effect was potentially obscured by a very low false alarm rate overall (M = .09). Interestingly the effects of eye movements were found only on a yes/no test of recognition and not with an alternative forced-choice test. A reason given for this is that the latter type of test does not demand elaborative recollection (encompassing top-down processing) but can be achieved by use of an overall assessment of relative item familiarity (Aggleton & Shaw, 1996; Bastin & Van der Linden, 2003).

It would seem that the correct rejection of non-studied items in the Brunyé, et al., (2009) experiment was relatively easy given the low proportion of false alarms. Perhaps one reason for this was that studied and non-studied items, although sharing similarity, comprised of a sufficient range of attributes to allow new items to be easily distinguished. As such, it remains to be seen whether saccadic eye movements can improve recognition accuracy for perceptual information when the recognition lures possess many similar perceptual and conceptual features that have been found in previous work to lead to a high proportion of false recognition responses.

Such high false recognition rates can arise in tests of perceptual memory when the lures and studied items have identical name and conceptual codes, possess many similar visual features, but differ in their *fine-grained* perceptual attributes. For instance, a target and a lure that represent two different exemplars of the same type of object (e.g., two different pictures of an acorn). In this case, the name and conceptual codes are identical, they possess many similar visual features, but differ with regard to their *precise* visual details. Previous research has demonstrated that the correct rejection of such (non-presented) related lures is difficult, and the result is a high false recognition rate (Budson, Daffner, Desikan, & Schacter, 2000; Koutstaal, 2003, 2006; Koutstaal & Cavendish, 2006; Slotnick & Schacter, 2004). Consequently, this related picture paradigm represents a means to assess the role of perceptual item-specific information in memory decisions and the extent to which SIRE effects can reduce perceptual memory errors.

Item-specific processing and false memory

Item-specific information is that which distinguishes each item in memory from potential competitors and allows responding to be based upon the retrieval of distinctive representations (Hunt & Einstein, 1981; Hunt & McDaniel, 1993; Schacter & Wiseman, 2006). Thus, item-specific information is that which is unique to a stimulus and not shared across stimuli. This information can be extracted from similar stimuli by encoding tasks that focus attention on differences (vs. similarities) between items (e.g., Hunt 2003; Hunt & McDaniel, 1993). Such information can also be a feature of stimuli by virtue of possessing characteristics that differentiate ostensibly similar items from each other and often this has taken the form of perceptual information (e.g., Arndt & Reder, 2003; Gallo et al., 2001; Dodson & Schacter, 2002; Koutstaal & Cavendish, 2006).

From the perspective of memory, item-specific information is particularly useful in tests of recognition memory (to distinguish studied from non-studied stimuli) and in tasks that require more elaborative retrieval to discriminate between potential targets and false items recovered through a generation process (Guynn, McDaniel, Strosser, Ramirez, Castleberry, & Arnett, 2014; Jacoby & Hollingshead, 1990). The significance of item-specific information is of particular consequence when lures share feature overlap with studied items. In these situations, responding based upon familiarity, rather than the recovery or use of differentiating information, may produce false memories (e.g., Arndt & Reder, 2003; Dodson & Schacter, 2001; McCabe, Presmanes, Robertson, & Smith, 2004; Schacter & Wiseman, 2006). In fact in these situations item-specific information can reduce false memory by a considerable degree, even when false memory effects are particularly high (e.g., Thomas & Sommers, 2005; McCabe et al., 2004).

In line with the above, item-specific processing can be used to reduce false alarms in paradigms assessing perceptual memory, such as that outlined earlier. For instance, use of perceptual item-specific details can reduce memory errors when tested with exemplars visually similar to those that were studied (Koutstaal, 2006; Koutstaal & Cavendish, 2006), or when individuating item-specific features allow for more efficient discrimination or pattern separation between studied and related lures (Kim & Yassa, 2013).

In examples like these, the ability to distinguish studied from *unrelated-unstudied* items can be based on a combination of both item-specific information and more general conceptual information about the objects category. The latter is sometimes referred to as *gist* memory (e.g., Brainerd & Renya, 2005; Koutstaal & Schacter, 1997; Koutstaal & Cavendish, 2006), because discrimination can be achieved by reference to the overall conceptual or meaning based characterization of the items in the test. In contrast, the ability to discriminate between studied and *related* but unstudied exemplars demands the use of perceptual item-specific information (Koutstaal, 2006; Koutstaal & Cavendish, 2006). This is because correctly rejecting a non-studied related item requires the use of perceptual information that allows for effective discrimination, or pattern separation between the two (Kim & Yassa, 2013).

The experiment reported here is concerned with the extent to which pre-retrieval saccades can enhance memory under conditions that necessitate the use of perceptual item-specific information in order to reduce false memories and improve true memory.

The current experiment and hypotheses

In this experiment, participants were exposed to pictures of objects (exemplars) during encoding. Each picture was paired to another that was not encoded and formed the *related* lure on the recognition test. During encoding, participants were allocated to one of two encoding conditions; intentional or incidental. Existing research on SIRE effects has typically made use of intentional encoding instructions. SIRE effects can also be found when participants were given incidental encoding instructions (Lyle & Jacobs, 2010), or when the encoding of information was likely to have been incidental, as in studies of autobiographical memory (Christman et al., 2003; Christman, et al., 2006; Parker & Dagnall, 2010, Parker et al., 2013). However, the authors are not aware of any published work that directly compared intentional with incidental encoding instructions. Accordingly, the experiment reported here assessed SIRE effects following intentional or incidental learning instructions.

Following a 30 second period of horizontal (versus no eye movements), a recognition test was provided. The test comprised of exemplars from the study phase, exemplars that were conceptually similar to those from the study phase, but different in their precise visual attributes (*related-unstudied* items), and exemplars that were both unrelated and unstudied (*unrelated-unstudied* items).

For each exemplar, participants were asked to make old/new recognition judgements and remember-know judgements (e.g., Tulving, 1985; Gardiner & Richardson-Klavehn, 2000). This was used to measure whether both true and false recognition responses were accompanied by memory for recollective details (Remember responses) or item familiarity (Know responses). This procedure has been used in previous work on SIRE effects (e.g., Parker et al., 2008; 2009), and in many false memory experiments using the converging associate paradigm (e.g., Roediger & McDermott, 1995; Dewhurst, Barry & Holmes, 2005). It was of value in the current experiments because of its potential to provide insight into the extent to which the false recognition of related lures is accompanied by memory of item-specific details (Remember/recollection), or more general familiarity.

If horizontal saccades enhance the retrieval of perceptual item-specific information, then measures of item-specific memory (as measured by *d*' and remember/recollection responses) should be increased, and the false alarm rate to conceptually similar exemplars should be decreased compared to the no eye movement condition. To the extent that the effects of eye movements are dependent upon intentional encoding, then an interaction between eye movements and encoding task is predicted.

Method

Design

The experiment was a 2(eye movement; horizontal vs. fixation) by 2(encoding; intentional vs. incidental) completely between-subjects ANOVA. The dependent variables were: (i) signal detection measures of sensitivity and response bias, (ii) process estimates of recollection and familiarity and (iii) proportion measures of the hit and false alarm rates.

Participants

The participants were 96 individuals (24 per-condition) from the Manchester Metropolitan University, who took part on a voluntary basis. All individuals were strongly right-handed scoring +80 or above on the Edinburgh Handedness Inventory.

Materials & Apparatus

Edinburgh Handedness Inventory

A modified version of the Edinburgh Handedness Inventory (EHI) (Oldfield, 1971) was used to select strongly right-handed (sRH) subjects for the experiment[1]. This was similar to earlier reported work (e.g., Edlin, Leppanen, Fain, Hackländer, Hanaver-Torrez, & Lyle, 2015; Lyle et al., 2008) in which some of the items were altered and the response scale was changed from the original format to a Likert scale with a five-point increments ranging from -10 (always left handed) to +10 (always right handed) (See Edlin, et al., 2015 for details). The cut-off point of +80, to classify sRH individuals, has also been used in previous work.

Stimuli

The total pool of stimuli consisted of 240 color pictures of object pairs (e.g., two different pictures of acorns), as used in previous false memory research (e.g., Koutstaal, 2003, 2006)[2]. These 240 picture pairs were divided into two groups. During the study phase, 120 items (one randomly selected from each of 120 pairs) from one of the groups was presented; the group presented was counterbalanced across subjects.

The recognition test consisted of 120 items. This comprised of 40 presented items (studied exemplars), 40 non-studied items that were related to 40 of the studied items (related-unstudied exemplars) and 40 non-studied items that were unrelated to any of the studied items (unrelated-unstudied exemplars). The 40 related exemplars were not taken from the same pairs as the studied exemplars. For example, if a picture of “Acorn 1” was studied and on the recognition test, then “Acorn 2” was not on the test. This produced a studied exemplar for the test. Conversely, if “Acorn 1” was studied and “Acorn 2” was on the test, then “Acorn 1” was not. In this instance, “Acorn 2” produced the related exemplar. The 40 unrelated exemplars were taken from the 120 items not presented at study. The items selected for the test was counterbalanced across subjects by creating 3 sets of items of each exemplar type. For example, the 120 presented items were divided into three sets of 40. Of these 40 were tested as same exemplars and 40 as related exemplars (40 were not used). The 40 selected as same vs. related vs. unused were rotated across subjects. A total of 10 pictures were used as primacy (5) and recency (5) buffers at the beginning and end of the stimulus presentation.

Apparatus

A computer was used to present the stimuli during the encoding phase and to initiate the eye movements. The latter was accomplished via a programme that flashed a black circle against a white background from side to side (horizontal condition), or on and off in the centre of the screen (no eye movement condition). The circle moved once every 500ms and in the eye movement condition and was located approximately 27° of visual angle apart. In the no eye movement condition, the circle flashed from on to off every 500ms.

Procedure

Participants were tested individually and were assigned randomly to one of the experimental conditions. During the encoding phase participants were presented with the appropriate study instructions. For those assigned to the intentional condition, they were informed that were going to view a series of pictures on a computer screen. Their task was to memorise each as best they could for an unspecified test of memory.

For those in the incidental condition, they were told also that they were going to view a series of pictures but told to decide if the real-life referent of each picture was larger or smaller than a box of about 30 cm x 30 cm x 30 cm. No mention was made of a memory test.

Following the instructions, participants were asked to turn their attention to the computer screen and focus on a fixation cross in the centre of the screen. The presentation of the stimulus set and the start of the encoding phase was initiated by the experimenter. This consisted of each stimulus appearing for 2 s with an interstimulus interval of 1 s. Stimuli were presented in colour in the centre of the screen and occupied a space of about 5 cm by 5 cm. A fixation cross occupied the centre of the screen during the interstimulus interval. The target stimuli were buffered by 5 pictures at the start and end of the viewing session with the same presentation timings. Participants were not informed of any transition between the target and buffer items.

Following the encoding phase, participants were given a short break of 3 minutes in which they were asked to write down the names of towns and cities in the UK. Following this, they were placed in one of the eye movement conditions (determined earlier) and given the appropriate instructions. Those in the saccade condition they were asked to follow the dot as it appeared back and forth on the left and right of the screen. It was emphasised that following the dot should be done by moving their eyes, whilst keeping their head stationary. Those in the fixation (no eye movement condition), were asked to stare at the dot as it flashed on and off in the centre of the screen. Both the eye-movement and fixation task lasted for 30 seconds in accordance with previous work. Compliance with these instructions was monitored by the experimenter.

After the eye-movement phase, participants were given the instructions for the memory test. They were informed that they would see a series of pictures of which some were presented earlier in the experiment and some of which were not. They were also informed that some pictures were similar to those seen earlier but were not actually viewed. The instructions indicated that they should respond yes-recognised only if the same picture appeared during the study phase. They were also told that if they recognised a picture they were to indicate if they recalled the details of the picture (Remember response), were sure that the picture was seen but unable to recollect the details (Know response), or if they felt that they were guessing (Guess response). The pictures were presented in a randomised order for each person. Following the test phase, participants were debriefed and thanked for their participation.

Results

Overview of results

Descriptive statistics for all analyses can be found in Tables 1, 2 and 3. The analyses focussed on using signal detection measures of accuracy and response bias, proportion yes responses to each stimulus type and process estimates of recollection and familiarity as derived from the proportion remember and know responses. Details pertaining to each of these are presented in the subsections below.

Signal detection analyses

Recognition sensitivity *d*’ and response bias (β) were calculated in three ways as described by Koustaal and Cavendish (2006). Firstly, SDT measures were computed in the traditional manner by using the hit rate to studied items and false alarm rate to unrelated-unstudied items. According to Koutstaal and Cavendish, this provides a measure of the extent to which recognition depends on a combination of item-specific information and gist information derived from object category membership. Secondly, *d*' and β were calculated using the hit rate to studied items and the false alarm rate to related-unstudied items. This provides a 'purer' measure of item-specific processing as correct responding demands finer discrimination between presented and similar lures from the *same* category (Koutstaal & Cavendish, 2006). Finally, SDT measures were computed from the false alarm rate to related lures and the false alarm rate to unrelated lures. This provides a measure of gist-based responding as subjects may false alarm to related items (vs. unrelated-unstudied items) purely on the basis of category membership or gist.

d prime scores

Using the first set of SDT analyses (studied vs. unrelated-unstudied items) the *d'* scores for this and subsequent analyses were entered into a 2(eye movement condition; horizontal vs. stationary) between-subjects by 2(encoding task; intentional vs. incidental) between-subjects ANOVA. This produced a significant effect of eye movement, $F(1, 92) = 35.15$, $p < .001$, $\eta_p^2 = .28$, showing a higher mean score for the horizontal condition. The effect of encoding condition was also significant, $F(1, 92) = 10.88$, $p = .001$, $\eta_p^2 = .11$, showing higher scores under intentional learning. The interaction was not significant, $F(1, 92) = 0.39$, $p = .53$, $\eta_p^2 = .004$. Thus, both eye movements and intentional learning increased discrimination accuracy (true memory) between studied and unstudied items.

Using the second set of SDT analyses (studied vs. related-unstudied) produced a significant effect of eye movement, $F(1, 92) = 49.61$, $p < .001$, $\eta_p^2 = .35$, showing a higher mean score for the horizontal condition. The effect of encoding condition was also significant, $F(1, 92) = 14.41$, $p < .001$, $\eta_p^2 = .13$, showing higher scores under intentional learning. The interaction approached significance, $F(1, 92) = 3.61$, $p = .06$,

$\eta_p^2 = .04$. However, Bayesian analyses (see below) show evidence for this interaction to be equivocal and thus no definitive conclusions can be drawn from this finding.

Using the third set of SDT analyses (related-unstudied vs. unrelated-unstudied items) produced no effect of eye movement, $F(1, 92) = 0.49$, $p = .48$, $\eta_p^2 = .005$, no effect of encoding task, $F(1, 92) = 0.06$, $p = .80$, $\eta_p^2 = .001$, and no interaction, $F(1, 92) = 1.86$, $p = .18$, $\eta_p^2 = .02$.

Response bias (beta) results

Measures of response bias were skewed and analyses were performed on Log-transformed scores. Similar to previous research (e.g., Koustaal & Cavendish, 2006) there were no effects of any variables on any measures of response bias (all *p*'s > .05), with the exception of a main effect of encoding task on the response bias for true memory, $F(1, 92) = 3.23$, $p = .03$, $\eta_p^2 = .04$. This indicated a more liberal response tendency following incidental encoding.

Proportion analyses for each item-type

As the SDT measures constitute indices derived from the combined hit and false alarm rates, it is informative to assess the effect of the experimental conditions on each of these rates separately. This is because, differences in overall scores could arise because of changes to the hit rate, false alarm rate or both. In previous SIRE experiments, various outcomes have resulted (e.g., Christman et al., 2003; Lyle, Logan & Roediger, 2008; Parker & Dagnall, 2007). Each of these proportion measures were placed into a 2(eye movement condition; horizontal vs. stationary) between-subjects by 2(encoding task; intentional vs. incidental) between-subjects ANOVA.

Yes responses to studied items (hit rate)

This analysis indicated a significant main effect of eye movement, $F(1, 92) = 22.29$, $p < .001$, $\eta_p^2 = .19$, (showing a higher hit rate after horizontal eye movements). Surprisingly, the effect of encoding task was not significant, $F(1, 92) = 1.75$, $p = .20$, $\eta_p^2 = .02$ (although the mean was numerically higher for the intentional condition). The interaction was not significant, $F(1, 92) = 0.32$, $p = .57$, $\eta_p^2 = .003$.

Yes responses to related unstudied items (related false alarm rate)

This analysis produced a significant main effect of eye movement, $F(1, 92) = 29.46$, $p < .001$, $\eta_p^2 = .24$, (showing a lower related false alarm rate after horizontal eye movements). The effect of encoding task was significant, $F(1, 92) = 15.69$, $p < .001$, $\eta_p^2 = .15$, (with a lower related false alarm rate after intentional encoding). The interaction was not significant, $F(1, 92) = 1.14$, $p = .29$, $\eta_p^2 = .01$.

Yes responses to unrelated unstudied items (unrelated false alarm rate)

This analysis indicated a significant main effect of eye movement, $F(1, 92) = 18.28$, $p < .001$, $\eta_p^2 = .16$, (showing a lower unrelated false alarm rate after horizontal eye movements). The effect of encoding task was significant, $F(1, 92) = 7.60$, $p = .007$, $\eta_p^2 = .08$, (with a lower unrelated false alarm rate after intentional encoding). The interaction was not significant, $F(1, 92) = 1.33$, $p = .25$, $\eta_p^2 = .01$.

Recollection vs. familiarity results

The raw ‘Remember’ and ‘Know’ responses were transformed into *process estimates* of *recollection* and *familiarity* respectively. This is because dual-process frameworks of memory conceive the processes of recollection and familiarity to operate *independently* of each other (e.g., Jacoby, 1991, 1998; Jacoby, Begg & Toth, 1997; Slotnick, 2017; Yonelinas, 2002; Yonelinas & Jacoby, 1995; Yonelinas et al., 1998). Consequently, the use of the raw proportion measure is problematic because ‘Remember’ and ‘Know’ responses are themselves mutually exclusive (as subjects only provide one response per item). However, in independence models it is feasible that more than one process can contribute to a particular response. Essentially, raw proportion scores cannot be assumed to map onto underlying processes of recollection and familiarity.

To assess underlying processes, a method of correcting the raw proportion scores was used. With regard to the assumption of independence, the proportion of raw ‘Know’ responses underestimates process familiarity because ‘Know’ responses are only used when recollection fails. Formally, this can be expressed as K = F(1 - R), where K equals the proportion of ‘Know’ responses, F represents familiarity and R equals recollection. By rearranging this expression, it is possible to calculate process familiarity as based on independence (Yonelinas & Jacoby, 1995; Yonelinas, Aly, Wang, & Koen, 2010). This is given as, F = K/(1-R). Process recollection is easier to calculate and can be obtained by subtracting the proportion of remember responses to unrelated-unstudied items from remember responses to studied and related items (Yonelinas et al., 1998). The analyses presented below make use of process estimates of both familiarity and recollection.

Process estimates of familiarity and recollection were placed into separate 2(eye movement condition; horizontal vs. stationary) between-subjects by 2(encoding task; intentional vs. incidental) between-subjects ANOVAs.

Process recollection results

Recollection for studied items (true recollection) revealed a significant main effect for eye movement, $F(1, 92) = 38.42$, $p < .001$, $\eta_p^2 = .29$, showing higher recollection scores after horizontal eye movement. The main effect of encoding task was also significant, $F(1, 92) = 4.68$, $p = .03$, $\eta_p^2 = .05$, indicating higher scores after intentional learning. The interaction was not significant, $F(1, 92) = 0.22$, $p = .64$, $\eta_p^2 = .002$.

Recollection for related items (false recollection) revealed a significant main effect for eye movement, $F(1, 92) = 14.30$, $p < .001$, $\eta_p^2 = .13$, showing lower *false* recollection scores after horizontal eye movement. The main effect of encoding task was also significant, $F(1, 92) = 5.59$, $p = .03$, $\eta_p^2 = .05$, indicating lower *false* recollection after intentional learning. The interaction was not significant, $F(1, 92) = 0.12$, $p = .74$, $\eta_p^2 = .001$.

Process familiarity results

Process familiarity calculated for studied items (true memory), revealed no effect of eye movement, $F(1, 92) = 0.48$, $p = .50$, $\eta_p^2 = .005$, no effect of encoding task, $F(1, 92) = 0.001$, $p = .99$, $\eta_p^2 < .001$, and no interaction, $F(1, 92) = 0.32$, $p = .57$, $\eta_p^2 = .003$.

Estimates of process familiarity for related-unstudied items revealed no effect of eye movement, $F(1, 92) = 2.91$, $p = .09$, $\eta_p^2 = .03$, an effect of encoding task, $F(1, 92) = 7.18$, $p = .009$, $\eta_p^2 = .07$, (showing higher familiarity estimates following incidental encoding) and no interaction, $F(1, 92) = 0.12$, $p = .72$, $\eta_p^2 = .001$.

Estimates of process familiarity for unrelated-unstudied items revealed a significant effect of eye movement, $F(1, 92) = 13.34$, $p < .001$, $\eta_p^2 = .12$, (indicating higher score after no eye movement), an effect of encoding task, $F(1, 92) = 14.65$, $p < .001$, $\eta_p^2 = .14$, (showing higher familiarity estimates following incidental encoding) and a significant interaction, $F(1, 92) = 6.07$, $p = .02$, $\eta_p^2 = .06$. The interaction was assessed by simple main effects at each level of eye-condition. In the horizontal condition, the difference was not significant, $t(46) = 1.74$, $p = .09$. In the no eye movement condition, the mean score was higher following incidental learning, $t(46) = 3.42$, $p = .02$.

Bayesian analyses

In the results reported above, more support was found for the independent (additive) contributions of encoding task and eye movements to recognition memory. The major exception being for process familiarity for unrelated-unstudied items. To assess further the weight of evidence in favour of a main-effects only model compared to one that contained this plus an interaction term, Bayesian analyses were conducted. Use of such analyses in this context, allows for a direct comparison between competing models of the effects (e.g., Dienes , 2011, 2014; Wagenmakers, et al., 2018).

Using JASP (2018), Bayesian ANOVAs were performed, on each of the DVs using a Cauchy distribution with .5 on the prior (Rouder, Morey, Speckman, & Province, 2012; Wagenmakers et al., 2018). The main interest here is on the direct comparison between the main effects model and that including the interaction. Equal priors (0.5) were used for both models and Table 4, shows the Bayes Factor (BF_{10}) for each of the DVs. A BF_{10} of 1 indicates no evidence either way for the models being compared. In the present analyses, a BF_{10} of less that one indicates more weight or evidence in favour of a main effects model only and a value greater than 1, for a model that incorporates the interaction. Values increasing beyond 1 at either side provide increasingly more evidence in favour of one or other model. As can be seen, most of the evidence is in favour of independent effects of the encoding task and eye movements except for unrelated process familiarity. In this sense, the analyses compared favourably to the traditional frequentist ANOVAs.

Discussion

General summary of findings

The principal finding of the current experiment was that pre-retrieval saccades improved memory accuracy as indicated by higher *d'* scores derived from studied and unrelated-unstudied items. Intentional encoding also improved discrimination accuracy but the two factors did not interact. As noted earlier, discrimination accuracy in this comparison can be influenced by using both item-specific and general category membership (gist) information. Computing discrimination scores from studied and related-unstudied items provides a more stringent assessment of the extent to which item-specific information is used. The *d'* score calculated from these items indicated main effects for both eye condition and encoding task. In these analyses, higher scores signify greater discrimination between studied and related lures; indicating more reliance on the use of item-specific information. Analyses based on related-unstudied and unrelated-unstudied items showed no significant effects; thus, the use of gist information did not appear to differ across the conditions.

Analyses of recollection and familiarity, revealed a dissociation such that eye movements increased recollection but had no appreciable influence on familiarity. True recollection was enhanced by eye movements and by intentional encoding whilst false recollection was reduced by eye movements and intentional encoding.

Overall, the present results indicate that item-specific processing and recollection were enhanced by both eye movements and by intentional encoding but these effects were largely independent of one another apart from *d'* scores for false unrelated familiarity. Although enhancement effects were found, how this was achieved, in terms of cognitive strategies, needs further consideration and is discussed below.

Consideration of the results in relation to theoretical conceptions of SIRE and cognitive processes supporting false memory

Although this experiment was not designed to tease apart the HERA and top-down processing accounts of SIRE effects, the findings can be assessed in terms of the merits of each. Both accounts predict that horizontal saccades would improve memory accuracy. The HERA explanation would explain the present findings by reference to the idea that saccades increase the degree of interhemispheric processing, which in turn provides a basis for accurate episodic memory. By this account, encoding is associated with left-hemisphere (LH) processing, whilst retrieval placed greater demand on the right-hemisphere (RH). Interhemispheric interaction then provides a basis for greater access to LH encoded memory traces by RH retrieval processes Christman et al., 2003; 2006; Christman & Propper 2010). However, a potential problem with this explanation is that the stimuli used in the current experiment were visual and some neuroimaging experiments have shown material-specific lateralisation during word (vs. visual) processing, with the latter showing predominantly right activations (e.g., Lee et al., 2000; Miller et al., 2002). Consequently, both encoding and retrieval would be biased towards RH activations and the importance of interhemispheric communication would be lessened. It could be that the images led to encoding activations in the LH because of their respective verbal codes (as all images were nameable objects). However, the verbal code was identical for both studied and related images and thus would, by itself, not be useful for discriminating between these two classes of stimuli.

An alternative account of improved mnemonic accuracy posits that saccades result in an increase the contribution of top-down attentional signals to retrieval (Edlin & Lyle, 2013; Lyle & Edlin, 2015). This is particularly the case when bottom-up processing is insufficient to meet task demands and thus strategies involving top-down control are required. The outcome of such controlled processing is an enhancement of target accessibility and thus an increase in true memory and a potential reduction of false memory.

The precise strategies that could be employed to reduce false memory in the paradigm used here have not yet been evaluated. In this context, it is worth considering the nature of the stimuli and the decisions required on the test. The stimuli used in this experiment were pairs of objects that shared name/conceptual codes but differed in their precise (fine-grained) visual details. Accurate decisions required rejecting a *related* lure as non-studied. This can be achieved by the retrieval of perceptual item-specific information for studied items using a *recall-to-reject* strategy (e.g., Gallo, 2004; 2010). This entails related lures initiating a recall process that results in a mismatch between the recalled (studied) item and the lure. Such mismatches are taken as a diagnostic indicator that the lure was *not* studied and thus false alarms can be avoided. Recall-to-reject strategies (and subsequent decisions) are more likely due to the retrieval of information that discriminates between items of different study classes; typically, this would be based on recollective information (Gallo, Bell, Beier, & Schacter, 2006) because both studied and non-studied (related) items possess high degrees of familiarity that would be insufficient to distinguish between items of these classes respectively.

Previous work using paradigms like the one employed here have indicated a role for recall-to-reject strategies in reducing false recollection of related items (Curran & Cleary, 2003; Goldman et al., 2003; Rotello, Macmillan, & Van Tassel, 2000). Interestingly, results from Event Related Potential studies show enhanced positivity across parietal regions for both true and accurately rejected lures; a finding that has been taken to indicate the retrieval of studied item information prior to making a response (Curran & Cleary, 2003). In addition, other findings show that false recognition of highly related lures are more readily obtainable on yes/no compared to forced-choice recognition tasks (Guerin, Robbins, Gilmore, & Schacter, 2012; Migo, Montaldi, Norman, Quamme, & Mayes, 2009). This, together with other results that show a relationship between executive functioning and accuracy on yes/no tasks with related lures implicate a role for strategic, top-down processing (Trelle, Henson, Green,& Simons, 2017).

Recent neuroimaging work has demonstrated a functional network supporting recall-to-reject processes (Bowman & Dennis, 2016). This constituted a frontoparietal network that was more active for the rejection of related items and in addition showed increased coupling between the prefrontal and hippocampal regions. In other words, regions and networks important for exercising top-down control and recollection.

Based on the foregoing, it is proposed that the current findings are congruent with the top-down account advanced by Lyle and Edlin, (2015). In particular, accurate performance in the memory task used in this experiment is likely to benefit from the deployment of top-down processing in order to recall studied targets and reject related lures.

However, despite the assertion above, it is important to exercise some caution regarding this interpretation for several reasons. Firstly, no direct measurements of neural mechanisms were taken. Secondly, although the mechanisms of SIRE effects differ between the two accounts, this does not mean that these explanations are mutually exclusive. For example, the HERA account specifies a role for frontal (and possible top-down) activations originating in the frontal eye fields. Bilateral frontal activation in turn is hypothesized to enhance interhemispheric communication (e.g., Christman et al., 2006).

In addition, complex cognitive operations that underpin performance on tests such as the one used here are dependent on multiple cognitive operations (Bowman & Dennis, 2016; Dennis, Bowman, & Vandekar, 2012), with detailed episodic memory reliant on both frontal/top-down and interhemispheric influences (e.g., Botzung, Denkova, Ciuciu, Scheiber, & Manning, 2008; Conway, Pleydell-Pearce, & Whitecross, 2001; Kubota, Toichi, Shimizu, Mason, Findling, Yamamoto, & Calabrese, 2006; Wang, Negreira, LaViolette, Bakkour, Sperling, & Dickerson, 2010).

In this context, work using similar stimuli to those employed here has revealed the contributions of hemispheric processing/specialization and top-down activity. Previous findings have indicated separate neural subsystems for the representation of abstract-category and exemplar-specific information (McMenamin, Deason, Steele, Koutstaal, & Marsolek, 2015). Furthermore, these are localised to the left and right hemisphere respectively. The abstract-category subsystem is responsible for the recognition of the category to which a specific-exemplar belongs. In contrast, the exemplar-specific subsystem, recognises objects from within a category class based on individuating features. In this respect the subsystems can be considered together to represent, bilaterally, gist and exemplar information accordingly. Later work has also demonstrated a role for top-down processing involving a frontoparietal network that operates under conditions of competition between these subsystems, particularly when retrieval goals necessitate responding based on gist or exemplar-specific information (McMenamin, Marsolek, Morseth, Speer, Burton, & Burgund, 2016). However, this work has largely involved repetition priming and working memory tasks as opposed to tests of episodic memory. Some work has considered the role of hemispheric specialisation in gist (vs. exemplar-specific) recognition and has found different event-related potential profiles for these types of memory (Küper, & Zimmer, 2015). However, the fuller implications for SIRE research is somewhat speculative and requires further consideration.

The contributions of recollection & familiarity

Of interest is the finding that the relative contribution of recollection to related items was higher than familiarity. This may seem at odds with the idea that associative false memories are driven by gist-based representations (e.g., Brainerd & Renya, 2005; Gallo, 2006; Koutstaal & Cavendish, 2006; Norman & Schacter, 1997). If this is the case, then such false memories would be expected to produce a preponderance of know/familiarity-based responses (Gallo, 2006; Pierce, et al., 2005). This is because gist representations lack the necessary episodic or item-specific detail that would drive a remember/recollection response. However, this finding is not unique; recently, Kim and Yassa (2013) found also that false memories for highly similar picture-items were largely accompanied by remember responses. One explanation for this comes from the complimentary notions of pattern separation and pattern completion. Pattern separation refers to the processes that maintain the episodic integrity of encoded items by the creation of orthogonal representations for those items. This allows the distinct and unique features of those items to be preserved and later recalled. Pattern completion occurs when a partially matching input leads to the recall of the whole episodic event. However, under some circumstances, the mechanisms that usually provide a basis for efficient pattern separation break down. One of these is under conditions of high stimulus similarity, where feature overlap between individual items is considerable (Norman, 2010; Yonelinas, et al., 2010). When such conditions prevail, the feature overlap between stimuli reduces the diagnosticity of the memory signal, which would otherwise be useful as a basis for the determination of study status. In this instance, both studied and related items generate a strong recall signal resulting in false recollection to related, but non-studied items.

In relation to SIRE effects, the enhancement of memory cannot be due to changes in pattern separation (as determined during encoding), but must relate to other processes prior to or during retrieval. The top-down account could explain this as arising from the increased accessibility of item-specific encoded information. In other words, the encoded information was stored (available) but just not accessible. Other work has shown that accessibility of item details can be problematic and drive false recognition in paradigms like the one used here (e.g., Guerin, et al., 2012; Koutstaal, 2003). When alternative measures of memory are used (e.g., perceptual identification or forced-choice tests), the availability of encoded information is demonstrated and false recognition reduced.

SIRE effects and encoding goals

SIRE effects were found under both intentional and incidental encoding conditions. This is consistent with previous work that has found such effects under intentional (e.g., Christman, et al., 2003; Parker, et al., 2009) and incidental (Lyle & Jacobs, 2010) conditions. However, these studies did not compare directly encoding tasks within one experiment. Consequently, the present work indicates that SIRE effects can be found under both intentional and incidental orienting tasks, although it would be beneficial for the field if future work were to examine this under different experimental conditions.

Potential limitations and future considerations

The current work made use of stimuli that were identical in their name/conceptual codes but differed perceptually. Further evidence relevant for hypothesis that SIRE effects can increase the retrieval of perceptual item-specific information could be derived from research in which items have no pre-existing conceptual codes and differ only regarding perceptual attributes (e.g., abstract shapes that vary in perceptual similarity to each other).

In this experiment, horizontal eye-movements were compared to that of a central fixation (no-eye movement) control condition only. This differs from other work that has made use of an additional control condition involving vertical eye-movements. The reason for this is that the HERA account specifies that only horizontal saccades should enhance memory. However, the findings have been rather mixed with some work finding no effect for vertical eye movements (Brunyé et al., 2009) some finding an effect (Lyle, et al., 2008, Lyle & Edlin, 2014) and others numerically in-between bilateral and vertical (Christman et al., 2003). Consequently, the use of a vertical condition is less diagnostic with respect to the mechanisms underpinning SIRE than was originally proposed (Lyle & Edlin, 2015). Perhaps for this reason, most existing SIRE work has simply compared a horizontal to a fixation condition and the work here followed that trend. However, there is of course a need to explore further the more precise mechanisms that more directly addresses the precise mechanisms that underpin SIRE effects (e.g., Fleck et al., 2018; Fleck, Payne, Halko, Purcell, 2019; Propper et al., 2007; Samara et al., 2011)

Although the present results found SIRE effects for both incidental and intentional encoding conditions, as noted earlier, this does not rule out the possibility that this will always be the case. Use of more varied stimulus types and a wider range of encoding tasks will be required to examine this more thoroughly.

As is typical of many experiments using the remember-know procedure, subjects make these responses for items identified as old. Other work has also requested that remember and know responses are made to new items as a means of indicating how new responses are *rejected* (Matzen, Taylor, & Benjamin, 2011). This has allowed the assessment of whether correct rejections are based on recollection or familiarity. If, as suggested here, SIRE influences the use of a recall-to-reject strategy, then eye-movements should increase the proportion of correct rejections associated with remember responses.

More generally, the instructions for the remember-know procedure were adapted from previous research and emphasised the use of particular details in responding with the former and the latter in its absence (e.g., Dudukovic & Knowlton, 2006; Gardiner & Parkin, 1990; Rajaram, 1996). When used with visual object stimuli, ‘remembering’ is deemed to be dependent on the recall of distinctive item-specific pictorial information that allows for effective discrimination between studied and unstudied information (e.g., Bowman, & Dennis, 2015). It is assumed that “know” responses reflect acknowledgement that the picture has been studied, and thus familiar within the context of the experiment. In this context, “knowing” without the retrieval of specific information may seem unusual to the extent that recognition of the picture must surely entail the retrieval of some pictorial detail to make a recognition response in the first place. However, “knowing” or familiarity-based responses can be used by subjects to indicate recognition based on category-class or perhaps verbal information encoded at the same time as visual detail during the study phase. In such instances, retrieval of distinctive pictorial information is not used or required.

In the present experiment, it was not possible to draw any conclusions about the information that might have been used as a basis for responding because only final recognition and 'remember-know' judgements were recorded. However, one method to assess what information might be used to make such responses is the *justified response procedure* (e.g., Migo, Mayes, & Montaldi, 2012). In this, subjects are required to provide more information about each remember-know decision such as what details about the test-item are currently within conscious awareness. These details are recorded and allow for an evaluation of how particular memory decisions are made. For example, it could be that subjects are able to articulate item-specific information on some trials but not others. This could be used to assess the mnemonic foundation for 'remember-know' decisions. Of course, this would only apply to details that can be verbalised but would at least provide a foundation for future work and a basis for establishing the contents of awareness that might contribute to 'remember-know" responses.

Summary & Conclusions

The research presented here demonstrates that SIRE effects can be observed under experimental conditions that demand access to precise, perceptual characteristics of the encoded stimuli. These SIRE effects were manifested in terms of enhanced item-specific retrieval and measured indices indicating recollection as opposed to global familiarity.

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Compliance with ethical standards

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

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

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

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Footnotes

1. The reason for this selection was that some past experiments have shown stronger eye-movement effects in those who are sRH (vs. mixed-handed) (e.g., Lyle et al., 2008). However, findings have been varied (e.g., Lyle & Jacobs, 2010). Rather than assess if mixed-handers would show eye-movement effects, the current experiment was primarily concerned with whether SIRE would enhance the retrieval of perceptual item-specific information in subject groups in which such effects have been most robust in the first place.
2. Examples of the stimuli can be found in ‘Koutstaal, W. (2006). Flexible remembering. *Psychonomic Bulletin & Review*, *13*, 84-91’. The hyperlink to the paper is https://link.springer.com/content/pdf/10.3758%2FBF03193817.pdf

TABLE 1
Mean (SE) SDT scores as a function of eye condition, response measure and encoding condition.

Response Type & Encoding Condition	Eye Condition: Fixation	Eye Condition: Horizontal
	SDT Analyses Sensitivity	
d’ studied / unrelated-unstudied (gist + item-specific)		
Incidental	1.66 (0.12)	2.32 (0.08)
Intentional	2.00 (0.13)	2.81 (0.15)
d’ studied / related-unstudied (item-specific)		
Incidental	0.56 (0.10)	1.17 (0.10)
Intentional	0.80 (0.07)	1.83 (0.17)
d’ related-unstudied / unrelated-unstudied (gist)		
Incidental	1.08 (0.09)	1.15 (0.11)
Intentional	1.20 (0.12)	0.98 (0.09)
	SDT Analyses Response Bias	
Log β studied / unrelated-unstudied (gist + item-specific)		
Incidental	0.71 (0.17)	1.10 (0.15)
Intentional	1.21 (0.17)	1.34 (0.18)
Log β studied / related-unstudied (item-specific)		
Incidental	-0.13 (0.07)	-0.10 (0.06)
Intentional	-0.02 (0.03)	-0.05 (0.08)
Log β related-unstudied / unrelated-unstudied (gist)		
Incidental	0.85 (0.14)	1.20 (0.13)
Intentional	1.23 (0.17)	1.39 (0.13)

TABLE 2
Mean (SE) yes responses to stimuli as a function of eye condition, item type and encoding condition

Item Type & Encoding Condition	Eye Condition: Fixation	Eye Condition: Horizontal
Studied		
Incidental	0.64 (0.03)	0.75 (0.02)
Intentional	0.66 (0.02)	0.79 (0.03)
Related-unstudied		
Incidental	0.44 (0.02)	0.33 (0.03)
Intentional	0.37 (0.02)	0.20 (0.02)
Unrelated-unstudied		
Incidental	0.13 (0.02)	0.06 (0.01)
Intentional	0.08 (0.01)	0.04 (0.01)

TABLE 3
Mean (SE) process estimates as a function of eye condition, response measure and encoding condition.

	Eye Condition	
Response Type & Encoding Condition	Fixation	Horizontal
Familiarity – True		
Incidental	0.25 (0.03)	0.25 (0.02)
Intentional	0.22 (0.31)	0.27 (0.05)
Familiarity – False Related		
Incidental	0.16 (0.02)	0.13 (0.03)
Intentional	0.11 (0.02)	0.07 (0.01)
Familiarity – False Unrelated		
Incidental	0.07 (0.01)	0.02 (0.01)
Intentional	0.02 (0.01)	0.01 (0.01)
Recollection - True		
Incidental	0.43 (.01)	0.61 (.01)
Intentional	0.48 (.01)	0.70 (.01)
Recollection – False		
Incidental	0.26 (.02)	0.18 (.02)
Intentional	0.21 (.02)	0.12 (.02)

TABLE 4
Bayes Factors for inclusion for each interaction term (eye-movements X encoding task) compared to a model comprising the null plus the main effects model

Response Type	BF_{10} for Inclusion
SDT Measures	
d’ studied / unrelated-unstudied (gist + item-specific)	0.34
d’ studied / related-unstudied (item-specific)	1.21
d’ related-unstudied / unrelated-unstudied (gist)	0.58
Log β studied / unrelated-unstudied (gist + item-specific)	0.36
Log β studied / related-unstudied (item-specific)	0.32
Log β related-unstudied / unrelated-unstudied (gist)	0.35
Proportion ‘yes’ Measures	
Studied items	0.35
Related-unstudied items	0.48
Unrelated-unstudied	0.50
Process Estimates	
Familiarity – True	0.33
Familiarity – False Related	0.31
Familiarity – False Unrelated	3.38
Recollection – True	0.32
Recollection – False	0.31