



## Effects of saccadic bilateral eye movements on memory in children and adults: An exploratory study

Andrew Parker\*, Neil Dagnall

Manchester Metropolitan University, Department of Psychology, Hathersage Road, Manchester M13 0JA, United Kingdom

### ARTICLE INFO

*Article history:*  
Accepted 6 January 2012

*Keywords:*

Bilateral eye movements  
False memory  
True memory  
Memory development  
Episodic memory  
Hemispheric interaction

### ABSTRACT

The effects of saccadic bilateral (horizontal) eye movements on true and false memory in adults and children were investigated. Both adults and children encoded lists of associated words in the Deese–Roediger–McDermott paradigm followed by a test of recognition memory. Just prior to retrieval, participants were asked to engage in 30 s of bilateral vs. vertical vs. no eye movements. For studied information, the results for adults replicated previous work; bilateral eye movements were demonstrated to increase the accuracy of memory by increasing the hit rate and reducing the false alarm rate for related and unrelated recognition test lures. The results for children also indicated an improvement in memory accuracy, and like adults, was due to both an increase in the hit rate and a reduction in the false alarm rate. In spite of these similarities, the effects of bilateral eye movements differed between adults and children for critical unstudied words; i.e., those associated with the theme of the list. Only in adults did, bilateral eye movements reduce associative false memories; children did not show a reduction in false memory for critical associates. This produced a dissociation between the effects of eye movements on associative false memory as a function of age. The results are discussed from a developmental perspective in terms of potential mechanisms underlying true and false memory.

© 2012 Elsevier Inc. All rights reserved.

### 1. Introduction

Episodic memory is the term used to denote memory for personal experiences involving the retrieval of specific events located in time and place (Tulving, 1985). This form of memory provides the basis for mental time travel that allows the individual to recollect and subjectively relive the past event (Gardiner, 2002; Tulving, 2002). From both a cognitive and neuropsychological perspective it has been given the status of a memory system as distinct from other forms of memory, such as semantic and implicit memory (Gabrieli, 1999; Schacter & Tulving, 1994; Tulving, 2002). In developmental terms, episodic memory abilities have been shown to increase throughout childhood in parallel with the neural circuits that support recollection and self conscious forms of remembering (Johnson, 2001; Perner & Ruffman, 1995; Raj & Bell, 2011; Schneider & Pressley, 1997).

It has been suggested that the interaction between the cerebral hemispheres provides a basis for accurate episodic memory (Christman, Garvey, Propper, & Phaneuf, 2003; Christman & Propper, 2010). Evidence for the importance of interhemispheric processing in episodic memory comes from a range of sources. For example, those with damage to the corpus callosum show

impairments on tests of recognition memory but not implicit memory (Cronin-Golomb, Gabrieli, & Keane, 1996; Phelps, Hirst, & Gazzaniga, 1991). Studies on handedness reveal that mixed-handed individuals outperform strongly right-handed individuals on various tests of episodic memory (Christman & Butler, 2011; Christman & Propper, 2001; Lyle, McCabe, & Roediger, 2008; Propper & Christman, 2004; Propper, Christman, & Phaneuf, 2005). The basis for the latter findings is that mixed-handed subjects have often been shown to have a larger corpus callosum (e.g., Clarke & Zaidel, 1994; Denenberg, Kertesz, & Cowell, 1991; Habib et al., 1991; Witelson, 1985) and show more hemispheric interaction (Christman, 1993, 1995).

From the perspective of the current paper, another source of evidence arises from experimental work on the effects of saccadic bilateral (right to left) eye movements. Repeatedly moving one's eyes, whilst following a dot moving right to left on a screen, has been hypothesised to temporarily enhance hemispheric interaction and improve episodic memory (Christman & Propper, 2010; Christman et al., 2003). To date, a number of research reports have demonstrated memory enhancement following bilateral eye movements across a range of materials and test situations (reviewed below). However, existing work has typically focused on adult participants. The aim of the current paper is to assess eye movement effects in both young adults and children.

\* Corresponding author. Fax: +44 01612476571.

E-mail address: [a.parker@mmu.ac.uk](mailto:a.parker@mmu.ac.uk) (A. Parker).

In the first demonstration of these effects, Christman et al. (2003), assessed episodic recognition memory following 30 s of bilateral eye movements just prior to *retrieval* compared to range of control conditions.<sup>1</sup> The control conditions included vertical saccades, bilateral and vertical smooth pursuit movements and no eye movements. The purpose of these control conditions was to assess the specificity of eye movement effects and rule out any influence due simply to increased oculo-motor activity. The results indicated superior recognition memory only when preceded by bilateral saccades. In addition, eye movements did not influence a non-episodic test of implicit memory. In a second experiment, bilateral eye movements were found to enhance the recall of real life autobiographical memories (Christman et al., 2003). Subsequent research has replicated and extended these findings to: the recall of earliest childhood memories (Christman, Propper, & Brown, 2006), associative recognition and context memory (Parker, Relph, & Dagnall, 2008), visual scenes (Lyle & Jacobs, 2010; Parker, Buckley, & Dagnall, 2009), landmark shape and spatial location information (Brunye, Mahoney, Augustyn, & Taylor, 2009), autobiographical recollection (Parker & Dagnall, 2010) and emotional words (Samara, Elzinga, Slagter, & Nieuwenhuis, 2011).

Interestingly, many studies have found that the effects of eye movements enhance memory accuracy by both increasing the hit rate and reducing the false alarm rate (e.g., Brunye et al., 2009; Lyle, Logan, & Roediger, 2008; Parker et al., 2008). False memory reduction has even been observed using procedures that are constructed to elicit high false alarm rates, such as the Deese–Roediger–McDermott (DRM) paradigm (Christman, Propper, & Dion, 2004; Parker & Dagnall, 2007). This technique was based upon a procedure initially developed by Deese (1959) and recently revived by Roediger and McDermott (1995). The method involves presenting subjects with lists of words, all of which are associated to a critical nonstudied word. For example, for a list comprising of the words: thread, pin, eye, sew and sharp, the critical nonstudied word would be needle. Research has demonstrated that the study of such lists typically leads to false recall and recognition of the critical nonstudied word, often at level approaching true memory (e.g., Gallo, Roediger, & McDermott, 2001; Roediger & McDermott, 1995; Thapar & McDermott, 2001).

In relation to the concerns of the current paper, Christman et al. (2004), exposed subjects to a set of DRM lists followed by a period of 30 s of bilateral eye movements (vs. no eye movements). They found bilateral eye movements to bring about a significant reduction in the false *recall* of nonstudied associates. Subsequently, Parker and Dagnall (2007) found that bilateral eye movements both increased the hit rate for studied words and reduced false *recognition* of nonstudied associates and unrelated words. Bilateral eye movements have also been found to reduce false memory in other false memory paradigms (e.g., Lyle et al., 2008; Parker et al., 2009).

The reason for such false memory effects, and the influence of eye movements, can be found in theoretical accounts of these findings. In relation to false memory, although a number of explanations have been put forward, the most prominent relate to the activation-monitoring framework (Gallo, 2006, 2010; Roediger, Watson, McDermott, & Gallo, 2001), fuzzy-trace theory (Brainerd & Renya, 2005), and the source monitoring framework (e.g., Johnson, 2006). In terms of the activation-monitoring, false

memories arise because it is assumed that presentation of lists of related words brings about the conscious or unconscious activation of the critical nonstudied word. During testing, the critical word is falsely recalled or recognised because of the failure to monitor the fact that the word was not studied during the encoding phase.

In regard to fuzzy-trace theory, it is claimed that two types of memory trace are created during encoding. One is the verbatim trace which represents the specific details of the studied word (item-specific information). The second is the gist trace that represents memory for the general semantic features or theme of the list (gist representation). False memories arise during retrieval when the subject places greater weight to the use of the gist-based representation. This produces false memories for critical words because they match the characteristics of the gist memory trace (Brainerd & Renya, 2005).

The importance of monitoring processes is especially emphasised in cognitive accounts of reality and source monitoring (e.g., Johnson, 2006; Johnson & Raye, 1981; Mitchell & Johnson, 2009). The source monitoring framework claims that mental experiences do not come pre-labeled as to whether they pertain to real (true), or imagined (false) events. Rather, individuals evaluate the contents of retrieved information in terms of perceptual, semantic or contextual details. This is then used as a basis for making an attribution or inference about the information being true or false. False memories can arise because of inaccurate attributions of, say, imagined events to real happenings. This can occur when imagined information possesses a high degree of similarity to what would be expected of real events, or when relatively lax criteria are used in order to make source monitoring decisions (Johnson, 2006). False memories in the DRM task then reflect failures in source monitoring (Mitchell & Johnson, 2009).

Distinct neural regions appear to be related to activation and monitoring processes. With respect to activations, neuroimaging has indicated activations in a number of left inferior prefrontal regions and the temporal lobes during the encoding of DRM lists (McDermott, Petersen, Watson, & Ojemann, 2003). These regions have been shown to be active in other tasks that require the processing of semantic or associative information (e.g., Cabeza, Rao, Wagner, Mayer, & Schacter, 2001; Wagner, Bunge, & Badre, 2004). Consequently, these have been explained as semantic processing arising from the activation of associative networks or the derivation of gist representations during list presentation (Gallo, 2010).

Monitoring processes are associated with a number of neural regions, many of which occur in the prefrontal regions. In particular, during tasks that require the active monitoring of information, it has been suggested that activations observed in the right prefrontal cortex plays an important role in the checking and verification of retrieved information, whilst the left prefrontal cortex is important for production and generation of information (Cabeza, Locantore, & Anderson, 2003). Others propose a role for bilateral activity during monitoring with the left and right prefrontal regions responsible for systematic (vs. heuristic) monitoring (Nolde, Johnson, & D'Esposito, 1998). It is, however, likely that different sub-regions of both the right and left hemispheres, such as the dorsolateral, ventrolateral and anterior regions play different roles depending upon the nature of the retrieval task (Mitchell & Johnson, 2009).

In relation to eye movements, the precise neural and cognitive explanation remains to be fully explored however, the original account proposed by Christman et al. (2003) has provided a framework for understanding these effects. This account is, in part, related to findings from neuroimaging research, which indicates a relative functional specialisation between the left and right prefrontal regions in episodic memory processing. Initial observations from early positron emission tomography studies showed that left

<sup>1</sup> The test of memory is typically taken immediately following eye movements. As yet no research has yet directly investigated the effects of delay between eye movements and retrieval, although the effects are likely to be short lived (Brunye et al., 2009). When eye movements have been manipulated as a within-subjects variable, ten minutes have been found to be sufficient to ensure no carry over effects between conditions (Brunye et al., 2009). Furthermore, Shobe, Ross, and Fleck (2009) found that the influence of eye movements on creativity was reduced after about seven minutes. Reduced effects were also found on a test of memory after a short delay (Lyle & Jacobs, 2010).

prefrontal regions were preferentially activated during semantic and episodic encoding, whilst right prefrontal regions were more activated during episodic memory retrieval (Nyberg, Cabeza, & Tulving, 1996; Tulving, Kapur, Craik, Markowitsch, & Houle, 1994). Subsequent research has extended these findings with the use of other methods, such as: functional magnetic resonance imaging, high resolution EEG, and repetitive transcranial magnetic stimulation (e.g., Babiloni et al., 2006; Gagnon, Blanchet, Grondin, & Schneider, 2010; Habib, Nyberg, & Tulving, 2003; Rossi et al., 2006, 2011).

Results such as these, led to the proposal of the HERA model (Hemispheric Encoding and Retrieval Asymmetry) as they show a degree of asymmetry between the roles of the cerebral hemispheres in mnemonic processing (Tulving et al., 1994). Thus, in relation to episodic memory, the importance of bihemispheric activity is emphasised in which retrieval mechanisms operating in the right prefrontal regions interact with left hemisphere based encoding mechanisms (Christman et al., 2006). Consequently, hemispheric interaction in the HERA model indicates a functional coupling between the right and left prefrontal regions to bring about the recovery of the experienced event.

Using this as a basis, Christman et al. claim that, bilateral saccades enhance episodic memory by increasing hemispheric interaction via the corpus callosum. This is premised upon a number of ideas. In particular, research has indicated that eye movements to the right (vs. left) are associated with increased activity in the contralateral hemisphere (Baken & Svorad, 1969; Hayakawa, Nakajima, Takagi, Fukuhara, & Abe, 2002; Neubauer, Schulte, & Pfurtscheller, 1988). Consequently, repeated bilateral saccades would be expected to bring about the simultaneous and equalised activation of both hemispheres. The resulting equalised activation then provides a basis for more effective functional coupling between the hemispheres. As a result, right hemisphere based retrieval mechanisms are more effective in operating upon memory traces encoded by the left hemisphere (Christman et al., 2006).

The saccadic and bilateral nature of the eye movements are also important as neither smooth pursuit bilateral movements, nor vertical movements enhance memory (e.g., Brunye et al., 2009; Christman et al., 2003; Parker & Dagnall, 2007). According to Christman et al. (2003) this is because bilateral saccadic eye movements produce greater prefrontal lobe activity compared to other forms of eye movement. Indeed, research has shown that both saccadic (vs. pursuit) and bilateral (vs. vertical) components of eye movements can differ in their effects and dissociate in terms of underlying neural circuitry (Bense et al., 2006; Konen, Kleiser, Seltz, & Bremner, 2005; O'Driscoll et al., 1998; Petit, Clark, Ingelholm, & Haxby, 1997). In addition, bilateral saccades have been shown to alter prefrontal EEG coherence in the Gamma frequency range (Propper, Pierce, Bellowado, Geisler, & Christman, 2007). Consequently, the hypothesised increase in interhemispheric interaction from bilateral saccades should increase performance in episodic memory tasks because episodic memory is dependent upon such interactions.<sup>2</sup> In particular, this provides a basis for, (i) the increase in true memory via the enhanced recovery of studied information and, (ii) the decrease in false memory via improved monitoring processes (Christman et al., 2004).

To date, the effects of bilateral eye movements on true and false memory have been studied using adult participants, thus the question arises as to whether such effects can be found in children. The study of false memory using the DRM paradigm has been extended to children. The typical finding is that younger children (e.g., 4–6 year olds) show smaller false memory for nonstudied associates compared to older children and adults (e.g., Anastasi & Rhodes, 2008; Brainerd, Renya, & Forrest, 2002; Howe, Gagnon, & Thouas, 2008; Howe, Wimmer, Gagnon, & Plumpton, 2009). Hence, false memory for the critical item increases with age. The reasons for this are likely due to a number of factors including increases in the speed and strength of processing in conceptual networks (Howe et al., 2009), or enhanced attention to the processing of gist and interconnections amongst list words (Odegard, Holliday, Brainerd, & Renya, 2008).

False memory effects in older (vs. younger children) children can be reduced by manipulations similar to those used with adults (Carneiro & Fernandez, 2010). In adults, false memories can be reduced by explicit warnings about the nature of the false memory illusion (e.g., Westergerg & Marsolek, 2006) and by reducing the presentation rate during encoding (e.g., Gallo & Roediger, 2002; McDermott & Watson, 2001). Both of these manipulations could work by providing a basis for enhanced post retrieval monitoring processes, or increasing item-specific processing during encoding. It has been suggested that false memory reduction may work with older, as opposed to younger children, because younger children are not able to effectively make use of rather complex strategic processes that are necessary to edit false memories as produced in the DRM paradigm.

The primary concern of the current experiment is to examine whether bilateral eye movements can reduce false memory and enhance true memory in a group of 'older' children in comparison to adults. Younger children (e.g., 4–6 year olds) were not used in the current experiment because false memory effects in this age group are typically quite small. The aim was to assess whether false memory reduction could be achieved in children in an age group closer to those in which previous work has demonstrated both reliable false memory effects, and in which prior work has indicated an ability to utilise strategies to reduce false memory (e.g., Carneiro & Fernandez, 2010; Ghetti & Alexander, 2004; Ghetti & Castelli, 2006).

From a developmental viewpoint, some of the neural and cognitive changes that take place during childhood are interesting and possibly relevant to assessing the impact of eye movements on memory from the perspective of Christman et al.'s (2003) original explanation. Although widespread neural and cognitive changes take place throughout childhood, many of these are not of direct bearing here. Consequently, we limit our discussion to some of the developmental changes in the corpus callosum and prefrontal cortex as these structures underpin the basis of Christman et al.'s (2003) framework for the effects of eye movements on memory. With regard to the corpus callosum, this continues to develop throughout childhood into adolescence and adulthood (Hasan et al., 2008; Keshavan et al., 2002). The corpus callosum is involved in integrating cortico-cortical interaction (Wahl et al., 2007; Zaidel & Iacoboni, 2003) and plays a role in both sensori-motor and cognitive functioning, as demonstrated by studies of split-brain patients and those with abnormalities of this structure (e.g., Gazzaniga, 2000; Just, Cherkassky, Keller, Kana, & Minshew, 2006; Yamauchi, Fukuyama, & Shio, 2000). The corpus callosum itself is composed of a number of distinct sub-regions with each specialising in the transfer of specific types of information (Aboitiz, Scheibel, Fisher, & Zaidel, 1992; de Lacoste, Kirkpatrick, & Ross, 1985). The anterior regions are the most important for the transfer of semantic information and for enabling communication between the prefrontal regions (Gazzaniga, 2000; Hasan et al., 2008). In this

<sup>2</sup> These ideas help to explain why such effects are found prior to retrieval (vs. encoding). When bilateral eye movements have been performed prior to encoding, either no effects (Brunye et al., 2009), or impairments have been found (Christman & Butler, 2005). Accordingly, these results implicate eye movement effects to be important with regard to the retrieval stage of processing because it is at retrieval when both hemispheres are required to cooperate with regard to the recovery of the memory trace.

sense, the anterior regions are important for the implementation of top-down and executive control mechanisms (Hasegawa, Fukushima, Ihara, & Miyashita, 1998).

The prefrontal cortex also continues to develop throughout childhood and into adolescence (Kanemura, Aihara, Aoki, Araki, & Nakazawa, 2003) and is one of the last regions to reach full structural maturity (Fuster, 1997; Sowell et al., 2003). Like the corpus callosum, the prefrontal cortex is also composed of a number of sub-regions (Ongur, Ferry, & Price, 2003; Petrides & Pandya, 1994). These make different contributions to cognitive processing and possess different developmental trajectories (Bunge & Crone, 2009; Rajah & D'Esposito, 2005). Although, Christman et al. (2003) do not specify the sub-regions involved, presumably those known to be important in episodic memory are of importance. In particular, the ventrolateral and dorsolateral prefrontal regions have been shown to be of significance in relation to encoding, organisational and control processes important for successful memory (e.g., Blumenfeld & Ranganath, 2007; Fletcher, Shallice, & Dolan, 1998; Prince, Tsukiura, & Cabeza, 2007), retrieval search (e.g., Rugg & Wilding, 2000) and monitoring processes (e.g., Achim & Lepage, 2005; Dobbins & Han, 2006). It has been argued that differences in the development of these sub-regions partly explain the differences in the development of distinct executive cognitive processes over childhood (Bunge & Zelazo, 2006). More specifically, the changes that occur in the prefrontal cortex are, to some extent, considered to underlie the developmental improvements across a range of memory related tasks including episodic memory (Bunge & Wright, 2007; Shing et al., 2010).

In terms of these cognitive changes, a number of developmental trends in episodic memory take have been observed and include; a parallel increase in the ability to process item-specific information and form gist-based representations (Brainerd & Renya, 2005), enhanced metacognitive monitoring processes (e.g., Lindsey, Johnson, & Kwon, 1991), increased recollection (Ghetti & Angelini, 2008), and an increase in the use of strategic processing (e.g., Shing et al., 2010). More generally, evidence exists that shows an association between prefrontal development and episodic memory performance in tasks that require the retrieval of specific details of an event (Cycowicz, Friedman, & Duff, 2003; Czernochowski, Mecklinger, Johansson, & Brinkmann, 2005; Ofen et al., 2007).

In the current experiment we assessed whether bilateral eye movement effects on both true and false memory extend to children by assessing memory performance using the DRM paradigm. Based upon previous work (e.g., Parker & Dagnall, 2007), it was predicted that bilateral eye movements would enhance memory accuracy for adults both by increasing the hit rate and reducing the false alarm rate. For children, it was expected that the hit rate and false alarm rate to critical nonstudied words would be lower compared to adults. Nevertheless, false memory for the critical words was still predicted to be larger compared to words that were not associated with the studied lists. It was also predicted that bilateral eye movements would enhance memory accuracy for children. However, the precise magnitude of the enhancement effect is difficult to predict. One prediction could be that the relative size of the effect will be smaller in children compared to adults. This is possible because the corpus callosum and prefrontal cortex (both of which are hypothesised to be involved in the effects of eye movements on memory) are underdeveloped in children. Consequently, the degree of saccade induced interaction and potential for the use of frontally mediated strategic processes will be lower. An alternative possibility, although perhaps more tenuous, is that children may have more to *gain* from the effects of eye movements. To the extent that children are able to make use of more effective retrieval and monitoring strategies when prompted (e.g., Carneiro & Fernandez, 2010) then, bilateral saccades may act to initiate the

use of these strategies that would otherwise not be deployed in a spontaneous manner.

## 2. Method

### 2.1. Design

The experiment had two between participant independent variables. The first was the age of the participant and had two levels: young adult and child. The second was the eye movement condition with three levels: bilateral eye movement, vertical eye movement and central fixation (no eye movement).

The dependent variables were: the hit rate, the false alarm rate to critical lures, the false alarm rate to words from nonstudied lists, and the false alarm rate to critical lures from nonstudied lists. Finally signal detection measures of true (verbatim) memory, false (gist) memory and response bias ( $\beta$ ) were included.

### 2.2. Participants

A total of 138 individuals took part in the experiment. Of these 69 were young adults between the ages of 19 and 22 ( $M = 20.40$ ) recruited from Manchester Metropolitan University, who participated on a voluntary basis. Sixty-nine children between the ages of 8 and 10 ( $M = 9.18$ ) took part in the experiment and were recruited from schools in the North West of England. Participation of the children was dependent upon permission of the head teacher of the schools and parental consent. Assignment to the eye movement conditions was on a random basis.

### 2.3. Materials

Twenty lists were selected from the published norms of Stadler, Roediger, and McDermott (1999). These were divided into two sets of 10 lists for the purposes of counterbalancing. Only one set served as study stimuli, whilst the alternative set was used to create distractors in the recognition test. The lists were reviewed by a teacher in order to eliminate words that were considered to be potentially outside the vocabulary range of the children studied.<sup>3</sup> Additional words were removed so that all lists were of equal length (12 words per list). The same modified lists were used for both the children and adults. The recognition test consisted of a total of 80 words. Of these 30 were from the studied set and taken from serial positions 2, 6 and 10. Ten words were the critical lures associated with the studied lists. The other 40 words comprised of 30 taken from the lists of the nonstudied sets (again from serial positions 2, 6 and 10) and the 10 critical lures from the nonstudied lists. The words were arranged in a random order into a test booklet.

<sup>3</sup> The word lists used in the present experiment were those developed using adults. These lists were similar to those used in previous studies using children (e.g., Brainerd et al., 2002; Carnerio & Fernandez, 2010) and in previous studies of bilateral eye movements (Christman et al., 2004; Parker & Dagnall, 2007). Consequently, the use of adult normed lists allows the current findings to make contact with research in both these domains. An alternative would be to use word lists normed specifically on children (Anastasi & Rhodes, 2008). A reason for this would be to take into account difference in the vocabulary range of children compared to adults. Although the vocabulary of children may indeed differ compared to adults, it is important to recognise that robust false memory effect were obtained in both children and adults; that is, false memory for the critical lure was greater than false memory for unassociated words. Indeed the magnitude of false memories to critical lures was similar in both age groups. Consequently, the use of adult normed lists did not prove to be problematic in the context of the current findings. Furthermore, when both adult and child-normed lists have been directly compared, they have been found to produce similar results as a function of age (Anastasi & Rhodes, 2008). However, it would prove interesting to assess the comparative effects of eye movements in both children and adults across a wider variety of stimulus types and this awaits further exploration.

Words were printed down the left side of the page with boxes labelled 'yes' and 'no' to the right of each word to indicate recognition responses.

A computer programme was used to initiate eye movements. This was done by flashing a black circle against a white background from side to side (bilateral condition), up and down (vertical condition), or on and off in the centre of the screen (fixation condition). The circle moved (flashed) once every 500 ms and in the eye movement conditions was located approximately 27° of visual angle apart.

#### 2.4. Procedure

Participants were tested individually in controlled settings (children), or in an experimental cubicle at University (young adults). Participants were informed that they were about to take part in a study on memory for words. The lists were recorded onto a tape with each word from each presented list spoken by a female voice at the rate of one word every 1 s. Lists were presented in descending order of association to the critical lure. A pause of 5 s was placed between each of the studied lists.

Following the presentation of the final study list, participants were asked to sit in front of a computer screen and randomly assigned to one of the three eye movement conditions. Those in the bilateral condition were asked to follow the dot as it moved back and forth on the right and left of the screen. In the vertical eye movement condition participants were asked to follow the dot as it appears top and bottom of the screen. In both these conditions it was emphasised that following the dot should be done by moving their eyes, whilst keeping their heads stationary. The instructions in the central fixation condition were to stare at the dot as it flashes on and off in the centre of the screen. Compliance with these instructions was monitored by the experimenter.

Following 30 s of eye movements (or central fixation), participants were provided with the recognition test booklet together with instructions for performing the test. The instructions asked participants to read through the booklet and indicate which words they believed to have been spoken during the study phase (by ticking 'yes') and which were new or unstudied (by ticking 'no'). No time limit was placed on the test and completion was followed by a debriefing about the nature of the study.

### 3. Results

Following previous research, analyses were performed upon both proportion hit and false alarms for each item type and signal detection measures. Unless otherwise stated, all results were analysed by 2 (age group; child vs. adult)  $\times$  3 (eye movement condition: bilateral vs. vertical vs. central fixation) between-subjects ANOVAs. Effect sizes are reported as partial Eta squared from the ANOVAs. Descriptive statistics can be seen in Table 1.

#### 3.1. Recognition hit rate and false alarm rate

In terms of the hit rate, (yes responses to studied words), there was no main effect for age group,  $F(1, 132) = 1.24, p = .27, \eta_p^2 = .01$ , a significant effect of eye movement,  $F(2, 132) = 6.14, p = .003, \eta_p^2 = .08$ , and no interaction  $F(2, 132) = 1.37, p = .26, \eta_p^2 = .02$ . Although there was no effect of age group, the mean hit rate for adults was numerically larger compared to children. The effect of eye movements was due to a significant difference between bilateral and vertical condition,  $t(90) = 3.18, p = .001$ , and between the bilateral and the no eye movement condition,  $t(90) = 2.98, p = .002$ . The difference between the vertical and no eye movement condition was not significant,  $t(90) = -0.06, p = .47$ . The absence of

**Table 1**

Mean (SD) proportion of responses to items as a function of group and eye movement condition.

Group and measure	Eye movement condition		
	Bilateral	Vertical	Central
<i>Hits (presented words)</i>			
Adults	0.74 (0.12)	0.62 (0.12)	0.60 (0.16)
Children	0.66 (0.13)	0.60 (0.16)	0.62 (0.14)
<i>False alarms (words from non-presented list)</i>			
Adults	0.13 (0.09)	0.19 (0.15)	0.23 (0.21)
Children	0.28 (0.19)	0.34 (0.22)	0.35 (0.18)
<i>d' True</i>			
Adults	1.93 (0.42)	1.35 (0.60)	1.20 (0.69)
Children	1.14 (0.55)	0.82 (0.69)	0.77 (0.58)
<i>Log <math>\beta</math> true</i>			
Adults	0.24 (0.35)	0.27 (0.29)	0.25 (0.31)
Children	0.12 (0.28)	0.12 (0.30)	0.03 (0.27)
<i>False alarms (critical words)</i>			
Adults	0.48 (0.29)	0.68 (0.14)	0.71 (0.17)
Children	0.75 (0.17)	0.69 (0.17)	0.70 (0.14)
<i>False alarms (critical words from non-presented lists)</i>			
Adults	0.18 (0.14)	0.26 (0.22)	0.30 (0.28)
Children	0.33 (0.22)	0.34 (0.18)	0.41 (0.26)
<i>d' False</i>			
Adults	0.97 (1.07)	1.31 (0.86)	1.34 (1.08)
Children	1.26 (0.54)	1.04 (0.60)	0.87 (0.75)
<i>Log <math>\beta</math> false</i>			
Adults	0.14 (0.33)	0.27 (0.27)	0.27 (0.44)
Children	0.12 (0.26)	0.08 (0.28)	0.09 (0.26)

an interaction indicates that bilateral eye movements enhance the hit rate for adults and children to an equal extent.

In terms of the false alarm rate, (yes responses to list words from the unstudied lists), this produced an overall effect of age group,  $F(1, 132) = 20.94, p \leq .001, \eta_p^2 = .14$ , (indicating a higher false alarm rate for children), a significant effect of eye movement condition,  $F(2, 132) = 3.02, p = .05, \eta_p^2 = .04$ , and no interaction,  $F(2, 132) = 0.12, p = .89, \eta_p^2 = .002$ . The effect of eye movement was assessed by multiple comparisons. The difference between the bilateral and vertical condition was marginally significant,  $t(90) = -1.53, p = .06$ . The difference between the bilateral and the no eye movement condition was significant,  $t(90) = -2.35, p = .01$ . In both of these comparisons, the mean values for the bilateral group were lower compared to the vertical and no eye movement conditions. There was no significant difference between the vertical and no eye movement condition,  $t(90) = -0.74, p = .23$ . Once again, in the absence of an interaction, this indicates that bilateral eye movements reduce the false alarm rate for unstudied list words in adults and children to an equal extent.

#### 3.2. Signal detection analyses for true memory

The measure  $d'$  was computed from the proportion of yes responses to studied words and yes responses to list words from the unstudied lists. This produced an overall effect of age group,  $F(1, 132) = 32.49, p \leq .001, \eta_p^2 = .20$ , indicating higher memory accuracy for young adults. The effect of eye movement was also significant,  $F(2, 132) = 11.13, p \leq .001, \eta_p^2 = .14$ . There was no interaction between age group and eye movement,  $F(2, 132) = 1.11, p = .33, \eta_p^2 = .02$ . Follow up comparisons revealed a significant difference between the bilateral and vertical condition,  $t(90) = 3.26, p = .001$ , and between the bilateral and the no eye movement condition,  $t(90) = 4.10, p \leq .001$ . In both comparisons,  $d'$  scores were higher following bilateral eye movement. The difference between the vertical and no eye movement condition was not significant,  $t(90) = 0.71, p = .24$ . These results indicate that bilateral eye

movements enhanced memory accuracy to an equal degree for both adults and children.

The signal detection criterion measure,  $\beta$ , was positively skewed and thus log transformed values were used for all analyses. This produced a main effect for age group,  $F(1,132) = 10.67$ ,  $p = .001$ ,  $\eta_p^2 = .07$ . Neither the effects of eye movement or the interaction were significant,  $F(2,132) = 0.41$ ,  $p = .66$ ,  $\eta_p^2 = .006$ , for eye movement and,  $F(2,132) = 0.36$ ,  $p = .69$ ,  $\eta_p^2 = .005$ , for the interaction. This finding demonstrates a more liberal response bias in children compared to adults. That is, they are more likely to say that a test item was from the study phase.

### 3.3. Critical false recognition memory

Associative false memory effects can be assessed by comparing yes responses to critical lures from studied lists to yes responses to critical lures from unstudied lists. If an associative false memory effect is present, then yes responses to the former should be higher compared to the latter (because the critical lure was activated or gist information extracted).

To assess this, a 2 (age group; adult vs. child)  $\times$  3 (eye movement condition; bilateral vs. vertical vs. no eye movement)  $\times$  2 (item type; critical of studied vs. critical of unstudied) ANOVA with repeated measures on the last factor produced a number of effects. Firstly, there was a main effect of item type,  $F(1,132) = 281.30$ ,  $p \leq .001$ ,  $\eta_p^2 = .68$ . This was produced by more yes responses to critical items from studied (vs. unstudied) lists and indicates a strong associative false memory effect. There was a main effect of age group  $F(1,132) = 13.54$ ,  $p \leq .001$ , (indicating greater false memory in children over both item types)  $\eta_p^2 = .09$ , and an effect of eye movement,  $F(2,132) = 4.15$ ,  $p = .02$ ,  $\eta_p^2 = .06$  (with the overall means smaller for the bilateral condition). In addition, the age group  $\times$  eye movement interaction was significant,  $F(2,132) = 3.78$ ,  $p = .02$ ,  $\eta_p^2 = .05$ , but the item type  $\times$  age group interaction was not significant,  $F(1,132) = 0.42$ ,  $p = .52$ ,  $\eta_p^2 = .003$ , and neither was the item type  $\times$  eye movement interaction,  $F(2,132) = 0.21$ ,  $p = .81$ ,  $\eta_p^2 = .003$ . However, the three way interaction approached significance,  $F(2,132) = 2.72$ ,  $p = .07$ ,  $\eta_p^2 = .04$ . By virtue of the potential importance of this higher order interaction, separate analyses were performed for each item type. This has the advantage of assessing the effects of eye movements and age for the item types separately, and thus parallels the analyses for true memory where separate ANOVAs were performed for studied and unstudied items.

Analysis of the responses to the critical lures of studied lists showed a significant effect of age group,  $F(1,132) = 7.27$ ,  $p = .008$ ,  $\eta_p^2 = .052$ , a significant effect of eye movement,  $F(2,132) = 3.07$ ,  $p = .05$ ,  $\eta_p^2 = .044$ , and a significant interaction,  $F(2,132) = 7.68$ ,  $p = .001$ ,  $\eta_p^2 = .104$ . The interaction was assessed in terms of simple main effects by one way ANOVA's at each level of age group. For adults, there was a significant effect of eye movement,  $F(2,66) = 8.11$ ,  $p = .001$ ,  $\eta_p^2 = .19$ . For children, eye movement produced no significant effect,  $F(2,66) = 0.85$ ,  $p = .43$ ,  $\eta_p^2 = .02$ . The significant effect of eye movements for adults was assessed by comparisons between each eye movement group. This revealed a marginally significant difference between the bilateral and vertical group,  $t(46) = -1.44$ ,  $p = .07$ , a significant difference between the bilateral and no eye movement group,  $t(46) = -2.07$ ,  $p = .02$ , and no difference between the vertical and no eye movement group,  $t(46) = -0.86$ ,  $p = .19$ . These findings reveal that only in adults did bilateral eye movements reduce false memory for the critical associated words.

Analysis of the responses to critical lures from unstudied lists indicated a significant effect of age group,  $F(1,132) = 9.21$ ,  $p = .003$ ,  $\eta_p^2 = .065$ , no effect of eye movement,  $F(2,132) = 2.27$ ,

$p = .11$ ,  $\eta_p^2 = .03$ , and no interaction,  $F(2,132) = 0.27$ ,  $p = .76$ ,  $\eta_p^2 = .004$ .

### 3.4. Signal detection analyses for false memory

The measure  $d'$  was also used to assess false memory. Measures like this have sometimes been referred to as a measure of gist based processing (Koutstaal & Schacter, 1997), and represents a way of combining responses to critical lures from studied lists and, responses to critical words from unstudied lists. Higher scores indicate greater discrimination between the types of items. The analysis revealed no significant effect of age,  $F(1,132) = 1.08$ ,  $p = .30$ ,  $\eta_p^2 = .008$ , (although the scores were numerically larger for adults) no effect of eye movement,  $F(2,132) = 0.09$ ,  $p = .92$ ,  $\eta_p^2 = .001$ , and no interaction,  $F(2,132) = 2.49$ ,  $p = .09$ ,  $\eta_p^2 = .036$ . The findings on  $d'$  may appear somewhat surprising given the results from the proportion measure of critical false recognition. However, before moving on, a number of points deserve clarification. Firstly, an absence of significant findings in the overall gist based  $d'$  measure does *not* mean an absence of an associative false memory effect; this was found by comparing yes responses to the critical lures from studied (compared to unstudied lists). Rather these results indicate that discrimination scores between the two item types were roughly equivalent for adults and children (with numerically higher scores for adults). Secondly, the absence of an overall effect of eye movement may be obscured in these analyses by the fact that responses to the critical lures from unstudied lists were not influenced by eye movements in the proportion ANOVAs. Clearly, when the analyses are based upon the critical lures from studied lists, then bilateral eye movements do reduce false recognition in adults at least.

The signal detection criterion measure,  $\beta$ , was also calculated for false memory using responses to critical words from studied and unstudied lists respectively. Like the previous analysis for true memory, these scores were positively skewed, and so a log transformation was performed prior to the ANOVA. This produced a significant main effect of age group,  $F(1,132) = 5.79$ ,  $p = .02$ ,  $\eta_p^2 = .042$ , no effect of eye movement,  $F(2,132) = 0.33$ ,  $p = .72$ ,  $\eta_p^2 = .005$ , and no interaction,  $F(2,132) = 1.02$ ,  $p = .36$ ,  $\eta_p^2 = .015$ . The effect of age group demonstrates once again a more liberal response bias in children compared to adults.

In summary, the results support the hypothesis that bilateral eye movements can enhance memory accuracy in both adults and children. However, the effects of bilateral eye movements on false memory for critical associated words differed across adults and children. Only in adults, did bilateral eye movements lead to a significant reduction in false memories.

## 4. Discussion

In terms of true memory, the main findings from the current experiment are that bilateral eye movements enhanced memory accuracy in both adults and children. This was due to both an increase in the hit rate and a decrease in the false alarm rate. With regard to false memory, bilateral eye movements reduced false memory for the critical lures in adults but not in children.

The effect of eye movements on true memory in adults was expected and based upon previous findings. The novel result here is a parallel effect upon children's memory accuracy. This effect was not due to children simply adopting a more liberal response bias (i.e., a general response tendency to say "yes" that items on the test had been studied earlier), because eye movements did not influence the signal detection measure of bias. Rather, bilateral eye movements increased the ability to discriminate between studied and non-studied items by a decrease in the false alarm rate and

an increase in the hit rate. Consequently, this produced higher  $d'$  values (enhanced true memory) in both adults and children.

In adults, false memory for the critical lure was reduced by eye movements. Once more this finding was expected and replicates previous work. However, eye movements did not reduce false memory for critical lures in children. Thus the age of the participant appears to dissociate the effect of eye movements on associative false memory. A degree of caution must be exercised when interpreting these findings. This is due to the fact that the effects of eye movements were found in the analyses of the critical lures from studied lists, but not in the  $d'$  gist based measure. In a previous study, the effects of eye movements were found on both proportion scores and the gist based measure (Parker & Dagnall, 2007). It is possible that the effects of eye movements on false  $d'$  were obscured because the proportion scores showed only a significant effect with regard to the critical lures from studied lists. If larger effects were found on the critical lure scores from unstudied lists then this would likely have translated into larger scores in the overall false  $d'$  measure, presumably bringing about a significant effect of eye movements for adults. As of yet, the precise reason why eye movement effects were not found on the gist based measure is unclear but, numerically at least, the scores were in the predicted direction.

How can the current findings be explained? The original explanation, as outlined in the introduction, hypothesises that bilateral eye movements increase interhemispheric interaction via the corpus callosum. As the corpus callosum continues to undergo development throughout childhood and into adulthood, then one prediction is that the effects of bilateral eye movements would be smaller in children compared to adults. In terms of the hit rate and  $d'$  measure for true memory, this was not found and eye movements enhanced memory to an equal degree in both groups. However, as expected, children's overall accuracy scores were lower compared to those of adults because of a higher false alarm rate to items from unstudied lists.

Another, but not necessarily mutually exclusive, explanation of eye movement effects suggests such eye movements may enhance anterior–posterior interactions (Parker & Dagnall, 2007). These interactions are important for episodic memory retrieval (Simons & Spiers, 2003; Summerfield & Mangels, 2005), and are considered to reflect the coupling of frontal control processes with more posterior regions, where the memory trace is stored. More recently, Lyle and Martin (2010) propose that eye movement effects may arise due to bilateral saccades activating neural regions that are involved in the allocation of attention and top-down control mechanisms. This may occur *within* (vs. across) each hemisphere. In support of this idea, bilateral saccades were found to increase the accuracy of detection in a letter matching task, but only for within hemisphere trials.

In relation to the current findings, bilateral saccades may enhance the coupling of anterior–posterior regions or frontally mediated control processes that guide retrieval. Cognitively, these influences may manifest themselves as more effective retrieval strategies that enhance the recovery of stored information. However, to the extent that these processes are still somewhat underdeveloped in children (Shing et al., 2010), it is not clear why the magnitude of eye movement effects were comparable across adults and children. Perhaps one reason is that memory was assessed with a yes/no recognition test. Performance on tests of recognition memory can be conceptualised as being driven by dual retrieval processes called recollection and familiarity that can be measured separately (e.g., Diana, Reder, Arndt, & Park, 2006; Yonelinas, 2002). Recollection provides that basis of detailed remembering of a study episode that involves the retrieval of elaborative and associative information. Familiarity represents a form of memory in which such details are lacking and recognition instead depends

upon an overall global awareness of the studied item. These two processes have different developmental trajectories and neural underpinnings (e.g., Ghetti & Angelini, 2008; Yonelinas, Otten, Shaw, & Rugg, 2005). In addition, hemispheric interaction has been shown to be more important for recollection (Parker et al., 2008; Propper & Christman, 2004).

Consequently, although the eye movement effects were of an overall similar magnitude in the present results, if recollection and familiarity had been measured, then differences may have been found between children and adults. In particular, recollection would have been likely to be higher in adults and perhaps showing a greater influence of eye movements. In addition, it is known that some forms of memory test demand greater reliance upon self-generated retrieval cues and more strategic processing (e.g., Long, Öztekin, & Badre, 2010; Mangels, 1997; Shing et al., 2010). Tests like these also show developmental trends (Schneider & Pressley, 1997) and are dependent upon frontal processes (e.g., Achim & Lepage, 2005; Wheeler & Buckner, 2003). Accordingly, memory differences between children and adults as a function of eye movements, may also be more likely to be apparent in such tests. Thus the finding of no differences between children and adults here does not mitigate against such difference being found in future work; careful experimentation is needed and comparisons across a range of memory tests.

Associative false memory effects occurred for both adults and children. In fact, the size of the false memory effect was equivalent for both groups. This was unexpected given that previous findings have shown a developmental increase in false memory in the DRM paradigm (Anastasi & Rhodes, 2008; Brainerd et al., 2002; Howe et al., 2008). In terms of the activation-monitoring and fuzzy-trace frameworks, this could be taken to indicate equivalent activation of the critical lure or gist representation in adults and children. However, children showed a higher false alarm rate to critical lures from *unstudied* lists and a more liberal response criterion. Consequently, children found it more difficult to distinguish between the different types of items on the recognition test. As words from unstudied lists would have received little or no activation, yes responses to these words are unlikely to reflect activation processes. Instead, in theoretical terms, they are more likely to reflect monitoring failures. Additionally, it can be noted that although the size of the false memory effect was equivalent for both age groups, it was numerically larger in adults compared to children.

Considering adults, a significant effect of bilateral eye movements on critical lure recognition was found. In children, eye movements had no effect on false memory for critical lures. As the critical lures were clearly activated (because associative false memories were produced), and the eye movement manipulation took place *after* encoding, then reduced false memory in adults could be due an influence on monitoring processes (Christman et al., 2004). The source monitoring framework, outlined in the introduction, provides a basis for understanding these processes. Basically, memories that are formed on the basis of actual experience (vs. imagination) with an object have associated with them more perceptual details (Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2003; Johnson, Foley, Suengas, & Raye, 1988). As the critical lures were not actually presented then they should contain less perceptual detail compared to presented words (Hicks & Starns, 2005). Alternatively, in terms of fuzzy-trace theory, adults could be relying less upon gist-based representations during retrieval. This would have the effect of reducing the false recognition rate to critical lures as gist-based representations form the basis of illusory memory in the DRM paradigm (Brainerd & Renya, 2005).

These two accounts need not be mutually exclusive as the correct rejection of critical lures could take place via increased attention to the qualitative and item-specific characteristics of the retrieved information. Effective source monitoring can then

reduce the incidence of false memories (Johnson, 2006). Following retrieval, the relative absence of perceptual information and distinctive recollection can serve as an indicator that the item was likely not studied and therefore can be rejected; this is referred to as diagnostic monitoring (Gallo, 2004). Young children in particular are less able to monitor the source or item-specific characteristics of their memories especially when distinctions are required between actual and imagined events (Foley & Johnson, 1985; Lindsay, 2002). Recent work in neuroimaging has also revealed the importance of monitoring processes in the DRM task. In particular, enhanced activations in the right anterior prefrontal cortex were explained as being associated with the source monitoring of critical lures. (Paz-Alonso, Ghetti, Donohue, Goodman, & Bunge, 2008). These activations were smaller in children and increased with age. In addition, behavioural evidence shows correlated changes in tests of executive/prefrontal functioning with age and the ability to monitor differences between studied and nonstudied information, and thus reduce false memories (Drumme & Newcombe, 2002; Ruffman, Rustin, Garnham, & Parkin, 2001).

If this is so, then it may not be age per se that is the important factor in reducing false memory but the associated changes or prefrontal functioning and more specifically, the development of enhanced metacognitive monitoring and executive functioning. For example, research using elderly subjects has demonstrated that age related changes in performance on the DRM task were mediated by frontal-executive functioning (Butler, McDaniel, Dornburg, Price, & Roediger, 2004). In particular, older adults who scored high on tests of frontal-executive functioning showed similar memory performance to younger adults. As yet, no research has examined how individual differences in monitoring and executive functioning may impact or moderate the effects of eye movements on memory in either adults or children. Consequently, this represents an important avenue for future research in both these age groups as this offers a potential explanation of the differences observed here in cognitive terms.

In spite of these findings, some recent work indicates that children of similar ages to the ones used in this experiment are able, under some circumstances, to make use of monitoring processes in order to reduce false memory. For example, when specifically instructed to do so or when the conditions enable the use of monitoring (Carneiro & Fernandez, 2010). Overall however, monitoring processes are still relatively underdeveloped and continue to improve with age (Ghetti & Alexander, 2004; Ghetti & Castelli, 2006). Clearly the children in the current experiment did not simply lack monitoring abilities altogether as they were able to reject words from *non-studied* lists effectively and indeed bilateral eye movements enhanced these abilities. Perhaps therefore, the children were simply less skilled or proficient at using source monitoring strategies towards the critical lures because of the failure to appreciate the difference between the qualitative characteristics of actually presented (vs. self generated/imagined) information.

Although the current experiment focussed upon episodic memory, the influence of bilateral eye movements have also been observed in certain non-memory tasks that are hypothesised to involve interhemispheric processing or frontal activity. For example, Christman and Garvey (2001) found that bilateral eye movements reduced the magnitude of perceptual asymmetries in a chimeric faces task. In a different experiment, Christman and Garvey (2003) found increased Stroop interference effects after a period of bilateral eye movements. This was predicted on the basis that such interference effects are partly related to hemispheric interaction (Christman, 2001).

In addition to this, performance in a letter matching task was demonstrated to be influenced by bilateral eye movements (Lyle & Martin, 2010), although this appeared primarily on within-hemisphere trials. Shobe et al. (2009) argue for a role of

interhemispheric processing in creativity and established bilateral eye movement effects on a test of divergent thinking. In addition, non-cognitive influences of eye movements have sometimes been observed. For example, based upon the notion that the right and left frontal lobes are differentially involved in distinct motivational and affective states (Davidson, 1992, 1995, 2004), bilateral eye movements were shown to bring about the neutralisation of positive and negative moods (Christman & Stieber, 2005). Consequently, the influence of bilateral eye movements appears to extend and generalise beyond those of episodic memory to other cognitive and non-cognitive domains. As yet, research within these fields is relatively limited and deserves further consideration in both adults and children.

Overall, the results of the current experiment demonstrate that the effects of saccadic bilateral eye movements can enhance memory accuracy in children as well as adults. Of course, this demonstration pertains to one experimental paradigm with one age group of children. A more complete developmental picture would arise from the study of a broader range of age groups across multiple tests of memory that previous research has already shown to be sensitive to the influence of bilateral eye movements. This should be considered an important objective for future study.

## Acknowledgments

The authors would like to thank Megan Harvey for assistance with the collection of data for this experiment, and three anonymous reviewers for constructive comments on an earlier version of this paper.

## References

- Aboitiz, F., Scheibel, A. B., Fisher, R. S., & Zaidel, E. (1992). Fiber composition of the human corpus callosum. *Brain Research*, 598, 143–153.
- Achim, A. M., & Lepage, M. (2005). Dorsolateral prefrontal cortex involvement in memory post-retrieval monitoring revealed in both item and associative recognition tests. *Neuroimage*, 24, 1113–1121.
- Anastasi, J. S., & Rhodes, M. G. (2008). Examining differences in the levels of false memory in children and adults using child-normed lists. *Developmental Psychology*, 44, 889–894.
- Babiloni, C., Vecchio, F., Cappa, S., Pasqualetti, P., Rossi, S., Miniussi, C., et al. (2006). Functional frontoparietal connectivity during encoding and retrieval processes follows the HERA model: A high-resolution study. *Brain Research Bulletin*, 68, 203–212.
- Baken, P., & Svorad, D. (1969). Resting EEG alpha asymmetry of reflective lateral eye movements. *Nature*, 223, 975–976.
- Bense, S., Janusch, B., Vucurevic, G., Bauermann, T., Schindwein, P., Brandt, T., et al. (2006). Brainstem & cerebellar fMRI activation during horizontal and vertical optokinetic stimulation. *Experimental Brain Research*, 174, 312–323.
- Blumenfeld, R. S., & Ranganath, C. (2007). Prefrontal cortex and long term memory encoding: An integrative review of findings from neuropsychology and neuroimaging. *The Neuroscientist*, 13, 280–291.
- Brainerd, C. J., & Renya, V. F. (2005). *The science of false memory*. New York: Oxford University Press.
- Brainerd, C. J., Renya, V. F., & Forrest, T. J. (2002). Are young children susceptible to the false memory illusion? *Child Development*, 73, 1363–1377.
- Brunye, T. T., Mahoney, C. R., Augustyn, J. S., & Taylor, H. A. (2009). Horizontal saccadic eye movements enhance the retrieval of landmark shape and location information. *Brain & Cognition*, 70, 279–288.
- Bunge, S., & Crone, E. A. (2009). Neural correlates of the development of cognitive control. In J. M. Rumsey & M. Ernst (Eds.), *Neuroimaging in developmental clinical neuroscience* (pp. 22–37). Cambridge: Cambridge University Press.
- Bunge, S. A., & Wright, S. B. (2007). Neurodevelopmental changes in working memory and cognitive control. *Current Opinion in Neurobiology*, 17, 243–250.
- Bunge, S. A., & Zelazo, P. D. (2006). A brain-based account of the development of rule use in childhood. *Current Directions in Psychological Science*, 15, 118–121.
- Butler, K. M., McDaniel, M. A., Dornburg, C. C., Price, A. L., & Roediger, H. L. (2004). Age differences in veridical and false recall are not inevitable: The role of frontal lobe function. *Psychonomic Bulletin & Review*, 11, 921–925.
- Cabeza, R., Locantore, J. K., & Anderson, N. D. (2003). Lateralization of prefrontal activity during episodic memory retrieval: Evidence for the production-monitoring hypothesis. *Journal of Cognitive Neuroscience*, 15, 249–259.
- Cabeza, R., Rao, S. M., Wagner, A. D., Mayer, A. R., & Schacter, D. L. (2001). Can medial temporal lobe regions distinguish true from false? An event-related functional MRI study of veridical and illusory recognition memory. *Proceedings of the National Academy of Sciences*, 98, 4805–4810.



- Carneiro, P., & Fernandez, A. (2010). Age differences in the rejection of false memories: The effects of giving warning instructions and slowing the presentation rate. *Journal of Experimental Child Psychology*, 105, 81–97.
- Christman, S. D. (2001). Individual differences in Stroop and local-global processing: A possible role of interhemispheric interaction. *Brain and Cognition*, 45, 97–118.
- Christman, S. D. (1993). Handedness in musicians: Bimanual constraints on performance. *Brain & Cognition*, 22, 266–272.
- Christman, S. D. (1995). Independence versus intergration of right and left hemisphere processing: Effects of handedness. In F. Kitterle (Ed.), *Hemispheric communication: Mechanisms & models* (pp. 231–253). Hillsdale, NJ: Erlbaum.
- Christman, S. D., & Butler, M. (2005). Bilateral eye movements impair the encoding and enhance the retrieval of episodic memories. *Paper presented at the 46<sup>th</sup> annual meeting of the Psychonomic Society*, Toronto, Ontario.
- Christman, S. D., & Butler, M. (2011). Mixed-handedness advantages in episodic memory obtained under conditions of intentional learning extend to incidental learning. *Brain & Cognition*, 77, 17–22.
- Christman, S. D., & Garvey, K. (2001). Bilateral eye movements reduce asymmetries in hemispheric activation. *Paper presented at the 2001 EMDR international association conference*, Austin, TX.
- Christman, S. D., & Garvey, K. (2003). Bilateral eye movements increase Stroop interference: A role of interhemispheric interaction. *Paper presented at the 31st annual meeting of the international neuropsychological society*.
- Christman, S. D., & Stieber, P. (2005). Bilateral eye movements lead to a neutralisation of affective state. *Paper presented at the 33rd annual meeting of the international neuropsychological society*, St. Louis, MO.
- Christman, S. D., Garvey, K. J., Propper, R. E., & Phaneuf, K. A. (2003). Bilateral eye movements enhance the retrieval of episodic memories. *Neuropsychology*, 17, 221–229.
- Christman, S. D., & Propper, R. E. (2001). Superior episodic memory is associated with interhemispheric processing. *Neuropsychology*, 15, 607–616.
- Christman, S. D., & Propper, R. E. (2010). Episodic memory and hemispheric interaction: Handedness and eye movements. In G. M. Davies & D. B. Wright (Eds.), *Current issues in applied memory research* (pp. 185–205). Hove: Psychology Press.
- Christman, S. D., Propper, R. E., & Brown, T. J. (2006). Increased interhemispheric interaction is associated with earlier onset of childhood amnesia. *Neuropsychology*, 20, 336–345.
- Christman, S. D., Propper, R. E., & Dion, A. (2004). Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm. *Brain & Cognition*, 56, 313–319.
- Clarke, J. M., & Zaidel, E. (1994). Anatomical-behavioral relationships: Corpus callosum morphometry and hemispheric specialization. *Behavioural Brain Research*, 64, 185–202.
- Conway, M. A., Pleydell-Pearce, C. W., Whitecross, S. E., & Sharpe, H. (2003). Neurophysiological correlates of memory for experienced and imagined events. *Neuropsychologia*, 41, 334–340.
- Cronin-Golomb, A., Gabrieli, J. D. E., & Keane, M. M. (1996). Implicit & explicit memory retrieval within and across the disconnected cerebral hemispheres. *Neuropsychology*, 10, 254–262.
- Cycowicz, Y. M., Friedman, D., & Duff, M. (2003). Pictures and their colors: What do children remember. *Journal of Cognitive Neuroscience*, 15, 759–768.
- Czernochowski, D., Mecklinger, A., Johansson, M., & Brinkmann, M. (2005). Age-related differences in familiarity and recollection: ERP evidence from a recognition memory study in children and young adults. *Cognitive, Affective and Behavioral Neuroscience*, 5, 417–433.
- Davidson, R. J. (1992). Anterior cerebral asymmetry & the nature of emotion. *Brain & Cognition*, 20, 125–151.
- Davidson, R. J. (1995). Cerebral asymmetry, emotion, & affective style. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 361–387). Cambridge, MA: MIT Press.
- Davidson, R. J. (2004). Well-being and affective style: Neural substrates and biobehavioural correlates. *Philosophical Transactions of the Royal Society (London)*, 359, 1395–1411.
- de Lacoste, M. C., Kirkpatrick, J. B., & Ross, E. D. (1985). Topography of the human corpus callosum. *Journal of Neuropathology & Experimental Neurology*, 44, 578–591.
- Deese, J. (1959). Influence of inter-item associative strength upon immediate free recall. *Psychological Reports*, 5, 305–312.
- Denenberg, V. H., Kertesz, A., & Cowell, P. E. (1991). A factor analysis of the human's corpus callosum. *Brain Research*, 548, 126–132.
- Diana, R. A., Reder, L. M., Arndt, J., & Park, H. (2006). Models of recognition: A review of arguments in favour of a dual-process account. *Psychonomic Bulletin & Review*, 13, 1–21.
- Dobbins, I. G., & Han, S. (2006). Cue- versus probe-dependent prefrontal cortex activity during contextual remembering. *Journal of Cognitive Neuroscience*, 18, 1439–1452.
- Drumme, A. B., & Newcombe, N. S. (2002). Developmental changes in source memory. *Developmental Science*, 5, 502–513.
- Fletcher, P. C., Shallice, T., & Dolan, R. J. (1998). The functional role of prefrontal cortex in episodic memory: I. Encoding. *Brain*, 121, 1239–1248.
- Foley, M. A., & Johnson, M. K. (1985). Confusions between memories for performed & imagined actions: A developmental comparison. *Child Development*, 56, 1145–1155.
- Fuster, J. M. (1997). *The prefrontal cortex: Anatomy, physiology and neuropsychology of the frontal lobe*. Philadelphia, PA: Lippincott-Raven.
- Gabrieli, J. D. E. (1999). The architecture of human memory. In J. K. Foster & M. Jelicic (Eds.), *Memory: Systems, process or function?* (pp. 205–231). Oxford: Oxford University Press.
- Gagnon, G., Blanchet, S., Grondin, S., & Schneider, C. (2010). Paired-pulse transcranial magnetic stimulation over the dorsolateral prefrontal cortex interferes with episodic encoding and retrieval for both verbal and non-verbal materials. *Brain Research*, 1344, 148–158.
- Gallo, D. A. (2004). Using recall to reduce false recognition: Diagnostic and disqualifying monitoring. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 30, 120–128.
- Gallo, D. A. (2006). *Associative illusions of memory: False memory research in DRM and related tasks*. New York & Hove: Psychology Press.
- Gallo, D. A. (2010). False memories & fantastic beliefs: 15 years of the DRM illusion. *Memory & Cognition*, 38, 833–848.
- Gallo, D. A., & Roediger, H. L. (2002). Variability among word lists in eliciting memory illusions: Evidence for associative activation & monitoring. *Journal of Memory & Language*, 47, 469–497.
- Gallo, D. A., Roediger, H. L., & McDermott, K. B. (2001). Associative false recognition occurs without strategic criterion shifts. *Psychonomic Bulletin & Review*, 8, 579–586.
- Gardiner, J. M. (2002). Episodic memory and autoegetic consciousness: A first person approach. In A. Baddeley, M. Conway, & J. Aggleton (Eds.), *Episodic memory: New directions in research* (pp. 11–30). Oxford: Oxford University Press.
- Gazzaniga, M. S. (2000). Cerebral specialization and interhemispheric communication: Does the corpus callosum enable the human condition? *Brain*, 123, 1293–1326.
- Ghetti, S., & Alexander, K. W. (2004). "If it happened I would remember it": Strategic use of event memorability in the rejection of false autobiographical events. *Child Development*, 75, 542–561.
- Ghetti, S., & Angelini, L. (2008). The development of recollection and familiarity in childhood and adolescence: Evidence from the dual-process signal detection model. *Child Development*, 79, 339–358.
- Ghetti, S., & Castelli, P. (2006). Developmental differences in false-event rejection: Effects of memorability-based warnings. *Memory*, 14, 762–776.
- Habib, R., Gayraud, D., Oliva, A., Regis, J., Salamon, G., & Khalil, R. (1991). Effects of handedness and sex on the morphology of the corpus callosum: A study with brain magnetic resonance imaging. *Brain & Cognition*, 16, 41–61.
- Habib, R., Nyberg, L., & Tulving, E. (2003). Hemispheric asymmetries of memory: The HERA model revisited. *Trends in Cognitive Sciences*, 7, 241–245.
- Hasan, K. M., Kamali, A., Kramer, L. A., Papnicolaou, A. C., Fletcher, J. M., & Ewing-Cobbs, L. (2008). Diffusion tensor quantification of the human midsagittal corpus callosum subdivisions across the lifespan. *Brain Research*, 1227, 52–67.
- Hasegawa, I., Fukushima, T., Ihara, T., & Miyashita, Y. (1998). Callosal window between prefrontal cortices: Cognitive interaction to retrieve long-term memory. *Science*, 281, 814–818.
- Hayakawa, Y., Nakajima, T., Takagi, M., Fukuhara, N., & Abe, H. (2002). Human cerebellar activation in relation to saccadic eye movements: A functional magnetic resonance study. *Ophthalmologica*, 216, 399–405.
- Hicks, J. L., & Starns, J. J. (2005). False memories lack perceptual detail: Evidence from implicit word-stem completion and perceptual identification tests. *Journal of Memory & Language*, 52, 309–321.
- Howe, M. L., Gagnon, N., & Thouas, L. (2008). Development of false memories in bilingual children and adults. *Journal of Memory & Language*, 58, 669–681.
- Howe, M. L., Wimmer, M. C., Gagnon, N., & Plumptre, S. (2009). An associative-activation theory of children's and adults' memory illusions. *Journal of Memory & Language*, 60, 229–251.
- Johnson, M. H. (2001). Functional brain development in humans. *Nature Reviews Neuroscience*, 2, 475–483.
- Johnson, M. K. (2006). Memory and reality. *American Psychologist*, 61, 760–771.
- Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journal of Experimental Psychology: General*, 117, 371–376.
- Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review*, 88, 67–85.
- Just, M. A., Cherkassky, V. L., Keller, T. A., Kana, R. K., & Minshew, M. J. (2006). Functional and anatomical cortical underconnectivity in autism: Evidence from an fMRI study of an executive function task and corpus callosum morphometry. *Cerebral Cortex*, 17, 951–961.
- Kanemura, H., Aihara, M., Aoki, S., Araki, T., & Nakazawa, S. (2003). Development of the prefrontal lobe in infants and children: A three dimensional magnetic resonance volumetric study. *Brain & Development*, 25, 195–199.
- Keshavan, M. S., Diwadkar, V. A., DeBellis, M., Dick, E., Kotwal, R., Rosenberg, D. R., et al. (2002). Development of the corpus callosum in childhood adolescence and early adulthood. *Life Sciences*, 70, 1909–1922.
- Konen, C. S., Kleiser, R., Seltz, R. J., & Bremner, F. (2005). An fMRI study of optokinetic nystagmus and smooth pursuit movements in humans. *Experimental Brain Research*, 165, 20–216.
- Koutstaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory & Language*, 37, 555–583.
- Lindsay, D. S. (2002). Children's source monitoring. In H. L. Westcott, G. M. Davies, & R. H. C. Bull (Eds.), *Children's testimony: Psychological research and forensic practice* (pp. 83–98). Chichester, UK: John Wiley.
- Lindsey, D. S., Johnson, M. K., & Kwon, P. (1991). Developmental changes in memory source monitoring. *Journal of Experimental Child Psychology*, 52, 297–318.
- Long, N. M., Öztekin, I., & Badre, D. (2010). Separable prefrontal cortex contributions to free recall. *The Journal of Neuroscience*, 30, 10967–10976.
- Lyle, K. B., & Jacobs, N. (2010). Is saccade-induced retrieval enhancement a potential means of improving eyewitness evidence? *Memory*, 18, 581–594.

- Lyle, K. B., Logan, J. M., & Roediger, H. L. (2008a). Eye movements enhance memory for individuals who are strongly right-handed and harm it for individuals who are not. *Psychonomic Bulletin & Review*, 15, 515–520.
- Lyle, K. B., & Martin, J. M. (2010). Bilateral saccades increase intrahemispheric processing but not interhemispheric interaction: Implications for saccade-induced retrieval enhancement. *Brain & Cognition*, 73, 128–134.
- Lyle, K. B., McCabe, D. P., & Roediger, H. L. (2008). Handedness is related to memory via hemispheric interaction: Evidence from paired associate recall and source memory tests. *Neuropsychology*, 22, 523–530.
- Mangels, J. A. (1997). Strategic processing and memory for temporal order in patients with frontal lobe lesions. *Neuropsychology*, 11, 207–221.
- McDermott, K. B., Petersen, S. E., Watson, J. M., & Ojemann, J. G. (2003). A procedure for identifying regions preferentially activated by attention to semantic and phonological relations using functional magnetic resonance imaging. *Neuropsychologia*, 41, 293–303.
- McDermott, K. B., & Watson, J. M. (2001). The rise and fall of false recall: The impact of presentation duration. *Journal of Memory & Language*, 45, 160–176.
- Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychological Bulletin*, 135, 638–677.
- Neubauer, A., Schuller, G., & Pfurtscheller, G. (1988). Lateral eye movements as a function of hemispheric preference: An EEG validation study. *International Journal of Psychophysiology*, 6, 177–184.
- Nolde, S. F., Johnson, M. K., & D'Esposito, M. (1998). Left prefrontal activation during episodic remembering: An event-related fMRI study. *NeuroReport*, 9, 3509–3514.
- Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin & Review*, 3, 135–148.
- Odegard, T. N., Holliday, R. E., Brainerd, C. J., & Renya, V. F. (2008). Attention to global gist processing eliminates age effects in false memories. *Journal of Experimental Child Psychology*, 99, 96–113.
- O'Driscoll, G. A., Strakowski, S. M., Alpert, N. M., Matthisse, S. W., Rauch, S. L., Levy, D. L., et al. (1998). Differences in cerebral activation during smooth pursuit and saccadic eye movements using positron-emission tomography. *Biological Psychiatry*, 44, 685–689.
- Ofen, N., Kao, Y., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2007). Development of the declarative memory system in the human brain. *Nature Neuroscience*, 10, 1198–1205.
- Ongur, D., Ferry, A. T., & Price, J. L. (2003). Architectonic subdivision of the human orbital and medial prefrontal cortex. *Journal of Comparative Neurology*, 460, 425–449.
- Parker, A., Buckley, S., & Dagnall, N. (2009). Reduced misinformation effects following saccadic bilateral eye movements. *Brain & Cognition*, 69, 89–97.
- Parker, A., & Dagnall, N. (2007). Effects of bilateral eye movements on gist based false recognition in the DRM paradigm. *Brain & Cognition*, 63, 221–225.
- Parker, A., & Dagnall, N. (2010). Effects of handedness and saccadic bilateral eye movements on components of autobiographical recollection. *Brain & Cognition*, 73, 93–101.
- Parker, A., Relph, S., & Dagnall, N. (2008). Effects of bilateral eye movements on the retrieval of item, associative and contextual information. *Neuropsychology*, 22, 136–145.
- Paz-Alonso, P. M., Ghetti, S., Donohue, S. E., Goodman, G. S., & Bunge, S. A. (2008). Neurodevelopmental correlates of true and false recognition. *Cerebral Cortex*, 18, 2208–2216.
- Perner, J., & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and a theory of childhood amnesia. *Journal of Experimental Child Psychology*, 59, 516–548.
- Petit, L., Clark, V. P., Ingeholm, J., & Haxby, J. V. (1997). Dissociation of saccade-related and pursuit-related activation in human frontal eye fields as revealed by fMRI. *Journal of Neurophysiology*, 77, 3386–3390.
- Petrides, M., & Pandya, D. N. (1994). Comparative architectonic analysis of the human and the macaque frontal cortex. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (pp. 17–57). Amsterdam: Elsevier.
- Phelps, E. A., Hirst, W., & Gazzaniga, M. S. (1991). Deficits in recall following partial and complete commissurotomy. *Cerebral Cortex*, 1, 492–498.
- Prince, S. E., Tsukiura, T., & Cabeza, R. (2007). Distinguishing the neural correlates of episodic memory encoding & semantic memory retrieval. *Psychological Science*, 18, 144–151.
- Propper, R. E., & Christman, S. D. (2004). Mixed-versus strong right-handedness is associated with biases towards “remember” versus “know” judgements in recognition memory: Role of interhemispheric interaction. *Memory*, 12, 707–714.
- Propper, R. E., Christman, S. D., & Phaneuf, K. A. (2005). A mixed-handed advantage in episodic memory: A possible role of interhemispheric interaction. *Memory & Cognition*, 33, 751–757.
- Propper, R. E., Pierce, J., Bellowado, N., Geisler, M. W., & Christman, S. D. (2007). Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy. *Journal of Nervous and Mental Disease*, 195, 785–788.
- Raj, V., & Bell, M. A. (2011). Cognitive processes supporting episodic memory formation in childhood: The role of source memory, binding & executive functioning. *Developmental Review*, 30, 384–402.
- Rajah, M. N., & D'Esposito, M. D. (2005). Region-specific changes in prefrontal function with age: A review of PET and fMRI studies on working and episodic memory. *Brain*, 128, 1964–1983.
- Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented on lists. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 21, 803–814.
- Roediger, H. L., Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: A multiple regression analysis. *Psychonomic Bulletin & Review*, 8, 385–407.
- Rossi, S., Innocenti, L., Polizzotto, N. R., Feurra, M., De Capua, A., Olivelli, M., et al. (2011). Temporal dynamics of memory trace formation in the human prefrontal cortex. *Cerebral Cortex*, 21, 368–373.
- Rossi, S., Pasqualetti, P., Zito, G., Vecchio, F., Cappa, S. F., Miniussi, C., et al. (2006). Prefrontal and parietal cortex in human episodic memory: An interference study by repetitive transcranial magnetic stimulation. *European Journal of Neuroscience*, 23, 793–800.
- Ruffman, T., Rustin, C., Garnham, W., & Parkin, A. J. (2001). Source monitoring & false memories in children: Relation to certainty & executive functioning. *Journal of Experimental Child Psychology*, 80, 95–111.
- Rugg, M. D., & Wilding, E. L. (2000). Retrieval processing and episodic memory. *Trends in Cognitive Sciences*, 4, 108–115.
- Samara, Z., Elzinga, B. M., Slagter, H. A., & Nieuwenhuis, S. (2011). Do horizontal saccadic eye movements increase interhemispheric coherence? Investigation of a hypothesized neural mechanism underlying EMDR. *Frontiers in Psychiatry*, 2, 4. doi:10.3389/fpsy.2011.00004.
- Schacter, D. L., & Tulving, E. (1994). What are the memory systems of 1994? In D. L. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 1–38). Cambridge, MA: MIT Press.
- Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty*. Mahwah, NJ: Erlbaum.
- Shing, Y. L., Werkle-Bergner, M., Brehmer, Y., Müller, V., Li, S., & Lindenberger, U. (2010). Episodic memory across the lifespan: The contributions of associative and strategic components. *Neuroscience & Biobehavioral Reviews*, 34, 1080–1091.
- Shobe, E. R., Ross, N. M., & Fleck, J. I. (2009). Influence of handedness and bilateral eye movements on creativity. *Brain & Cognition*, 71, 204–214.
- Simons, J. S., & Spiers, H. J. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews: Neuroscience*, 4, 637–648.
- Sowell, E. R., Peterson, B. S., Thompson, P. M., Welcome, S. E., Henkenius, A. L., & Toga, A. W. (2003). Mapping cortical change across the human lifespan. *Nature Neuroscience*, 6, 309–315.
- Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for word lists that create false memories. *Memory & Cognition*, 27, 494–500.
- Summerfield, C., & Mangels, J. A. (2005). Functional coupling between frontal and parietal lobes during recognition memory. *NeuroReport*, 16, 117–122.
- Thapar, A., & McDermott, K. B. (2001). False recall and false recognition induced by presentation of associated words: Effects of retention interval and level of processing. *Memory & Cognition*, 29, 424–432.
- Tulving, E. (1985). Memory & consciousness. *Canadian Psychologist*, 26, 1–12.
- Tulving, E. (2002). Episodic memory and common sense: How far apart? In A. Baddeley, M. Conway, & J. Aggleton (Eds.), *Episodic memory: New directions in research* (pp. 269–287). Oxford: Oxford University Press.
- Tulving, E., Kapur, S., Craik, F. I. M., Markowitsch, H. J., & Houle, S. (1994). Hemispheric encoding and retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Sciences, USA*, 91, 2016–2020.
- Wagner, A. D., Bunge, A. A., & Badre, D. (2004). Cognitive control, semantic memory & priming: Contributions from prefrontal cortex. In M. S. Gazzaniga (Ed.), *The cognitive neuroscience* (pp. 709–726). Cambridge: MIT Press.
- Wahl, M., Lauterbach-Soon, B., Hattingen, E., Jung, P., Singer, O., Volz, S., et al. (2007). Human motor corpus callosum: Topography, somatotopy, and link between microstructure and function. *Journal of Neuroscience*, 27, 12132–12138.
- Westergerg, C. E., & Marsolek, C. J. (2006). Do instructional warnings reduce false recognition? *Applied Cognitive Psychology*, 20, 97–114.
- Wheeler, M. R., & Buckner, R. L. (2003). Functional dissociation among components of remembering: control, perceived oldness, and content. *Journal of Neuroscience*, 23, 3869–3880.
- Witelson, S. (1985). The brain connection: The corpus callosum is larger in left-handers. *Science*, 229, 655–668.
- Yamauchi, H., Fukuyama, H., & Shio, H. (2000). Corpus callosum atrophy in patients with leukoaraiosis may indicate global cognitive impairment. *Stroke*, 31, 1515–1520.
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory & Language*, 46, 441–517.
- Yonelinas, A. P., Otten, L. J., Shaw, K. N., & Rugg, M. D. (2005). Separating brain regions involved in recollection and familiarity in recognition memory. *The Journal of Neuroscience*, 25, 3002–3008.
- Zaidel, E., & Iacoboni, M. (2003). *The parallel brain: The cognitive neuroscience of the corpus callosum*. Cambridge: MIT press.