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Cognitive Consequences of Asymmetrical Visual Distraction

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ABSTRACT. The authors explored whether manipulating the location of distraction in the participants' visual field influences the degree of competition between visual and other cognitive processes. If a cognitive task is lateralized to a particular hemisphere, visual distraction directed toward that same hemisphere should impair performance on that task more than should visual distraction directed toward the other hemisphere. Consistent with this hypothesis, the authors found in Experiments 1 and 2 that participants better recalled words of high imageability in a verbal memory task when the examiner was in the participant's left visual field (right hemisphere) than when the examiner was in the participant's right visual field (left hemisphere). In Experiment 3, the authors found that this effect reversed for performance on a right-hemisphere spatial task.

Keywords: imagery, interference, lateral eye movements, laterality

EYE MOVEMENTS DETERMINE WHAT individuals can see. Whether a flash of light, a shape, an emoting face, or any other object demands attention, eye movements provide controlled access to objects in the visual world. Eye movements also play an important role in aspects of social communication and information processing (e.g., Argyle & Cook, 1976; Baron-Cohen, 1995; Rayner, 1998), enabling, for example, the use of gaze to determine turn-taking during conversation, the elucidation of other people's intentions and desires, and the efficient extraction of information during reading. However, in some circumstances, eye movements also provide the important ability to remove access to objects

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in the visual world. If performance on a cognitive task is impaired by having to simultaneously attend to irrelevant visual stimuli, the ability to remove those stimuli should afford better performance on the task. Furthermore, to the extent that a cognitive task relies on neural resources residing primarily in a particular hemisphere of the brain, it seems that it would be most beneficial to prevent the irrelevant stimuli from being processed in that particular hemisphere.

Beginning in the late 1960s, researchers in a controversial area sought to explain the direction of lateral eye movements as the consequence of lateralized neural activity. Bakan (1969) argued that individual differences in looking behavior reflect differences in asymmetrical neural activation. Individuals with a dominant or more consistently activated left hemisphere (LH) tend to look to the right, whereas individuals with a dominant right hemisphere (RH) tend to look to the left. Although this line of research has continued, researchers in a separate but related line of research have explored the relation between lateral eye movements and active cognitive processes. In the hemispheric activation model, Kinsbourne (1972) argued that looking direction is indicative of the hemisphere that a particular cognitive task engaged. According to Kinsbourne, an overflow of neurological activity into the orientation control system of a hemisphere provokes a shift in attention and eye movements toward the contralateral visual field. Verbal questions entailing LH language processing induce eye movements to the right, and spatial questions entailing RH processing induce eye movements to the left.

The ability to use eye movements as an index of hemispheric activity could have supplied psychologists with a valuable tool for studying hemispheric function. However, later experiments did not overwhelmingly support Kinsbourne's (1972) model. Of 19 studies reviewed by Ehrlichman and Weinberger (1978), only 9 showed a significant relation between cognitive task and the direction of eye movements. Later studies continued this trend, with many researchers demonstrating the predicted association (e.g., Galluscio & Paradzinski, 1995; Griffiths & Woodman, 1985; Gur, Gur, & Harris, 1975; Hugdahl & Carlgren, 1981; Katz & Salt, 1981; Kinsbourne; Kocel, Galin, Ornstein, & Merrin, 1972; Lenhart, 1985; O'Gorman & Siddle, 1981; Raine, Christie, & Gale, 1988; Schwartz, Davidson, & Maer, 1975) and equally many researchers failing to demonstrate the predicted association (e.g., Crouch, 1976; Ehrlichman, 1977; Ehrlichman, Weiner, & Baker, 1974; Gumm, Walker, & Day, 1982; Hatta, 1984; Hiscock, 1977; MacDonald & Hiscock, 1992; Previc & Murphy, 1997; Reynolds & Kaufman, 1980; Rodin & Singer, 1976; Takeda & Yoshimura, 1979). Because of the bias for only positive outcomes to be published, it is possible that researchers had observed a substantially larger number of failures and had not reported them. By the 1990s, researchers had largely abandoned the phenomenon. If lateral eye movements are automatic byproducts of lateralized hemispheric activity, researchers should have reliably shown that. However, it is possible that lateral eye movements are more than the inconsequential byproducts of neural activation, or that by controlling what cannot be seen, lateral eye movements may provide visual displays that interfere less with other cognitive processes.

Researchers have shown advantages to looking away from distracting stimuli. Einstein, Earles, and Collins (2002) found memory improves at the levels of encoding and retrieval when individuals are distracted by simple visual stimuli rather than complicated visual stimuli. Similarly, Glenberg, Schroeder, and Robertson (1998) found that averting the gaze facilitates memory by disengaging the person from the environment and that the frequency of eye movements increases with task difficulty. Further, Doherty-Sneddon and colleagues have repeatedly demonstrated the interfering effects of face monitoring on children's performance on various cognitive tasks (e.g., Doherty-Sneddon, Bonner, & Bruce, 2001; Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle, 2002; Doherty-Sneddon & Phelps, 2005). By relegating two tasks to two separate asymmetrically specialized hemispheres, lateral eye movements may help to obviate the potential trade-off between vision and other cognitive demands (see Rosenberg, 1979). When people look to the right of another person, they place that person in their left visual field (LVF). Because the contralateral hemisphere processes visual space, the RH primarily must now attend that person. Consequently, demand for visual processing in the LH is reduced, perhaps thereby increasing the individual's capacity to perform other cognitive tasks that rely on the LH.

In one of the few lateral eye movement studies to report the functional consequences of looking direction, Walker, Wade, and Waldman (1982) asked participants to fixate to the left, middle, and right while responding to verbal and spatial questions. Participants were significantly faster while looking to the right during verbal questions and to the left during spatial questions. Although those authors interpreted those results in favor of Kinsbourne's (1972) activation model—with eye gaze facilitating performance by priming the contralateral hemisphere—we interpret experimenter location as an alternative explanation. While the participant was looking to the left, the experimenter was in the participant's right visual field (RVF), and the experimenter's image was therefore projected to the participant's LH. While the participant was looking to the right, the experimenter was in the participant's LVF and the experimenter's image was therefore projected to the participant's RH. It is possible that visual distraction in the form of the experimenter interfered with processing in the distracted hemisphere, leading to diminished performance on the task that was primarily dependent on that hemisphere. The participant may have performed better on the verbal task while looking to the right because the experimenter was in the participant's LVF instead of the participant's RVF. Similarly, the participant may have performed better on the spatial task while looking to the left because the experimenter was in the participant's RVF instead of the participant's LVF.

There is evidence of interference between tasks that draw on resources in the same hemisphere. For example, Friedman and Polson's resource theory has claimed that performance is impaired whenever two tasks draw on the same hemisphere’s generalized pool of resources (see, e.g., Friedman, Polson, & Dafoe, 1988; Polson & Friedman, 1988). People are better at remembering nonsense words while tapping their left finger than while tapping their right finger (Friedman et al.). Visual distraction projected toward a particular hemisphere may draw on resources in a similar way, impairing performance on other cognitive tasks that rely on that hemisphere. However, as Boles and Law (1998) argued, tasks that rely on the same hemisphere should interfere with each other only if they rely on the same processes in that hemisphere. One potential process-based explanation may be that visual distraction impairs the ability to generate or take advantage of visual imagery. Researchers have argued that (a) mental imagery relies on neural regions that are also involved in visual perception (for reviews, see, e.g., Farah, 1995; Kosslyn, 2005; Kosslyn & Thompson, 2003) and (b) to the extent that the LH plays a special role in the generation of imagery (e.g., D’Esposito et al., 1997; Farah, 1984; Farah, Levine, & Calvanio, 1988; Farah, Peronnet, Weisberg, & Monheit, 1989), engaging in one process may impair one’s ability to engage in the other.

Although some researchers have examined the effects of visual imagery on visual perception (e.g., Craver-Lemley & Reeves, 1992; Ishai & Sagi, 1997), few researchers have examined the effects of visual perception on visual imagery (however, see, e.g., Lloyd-Jones & Vernon, 2003). However, if the processes of mental imagery and visual perception rely on the same neural and cognitive resources, looking to the right of a distracting stimulus may reduce demand for visual processing in the LH, thus facilitating the ability to use mental imagery. Increasing the capacity to process words in terms of their imagery should enhance the later recall of those words (Paivio, 1971, 1995).

Although removing visual distraction from the LH may enhance performance on verbal tasks that benefit from the use of mental imagery, removing visual distraction from the RH may enhance performance on certain spatial tasks. Researchers have shown spatial tasks to rely on the RH, particularly when those tasks involve the specification of coordinate spatial representations that identify the exact locations of objects in the visual field (e.g., Jager & Postma, 2003; Kosslyn, Maljkovic, Hamilton, Horwitz, & Thompson, 1995). Therefore, it would not be surprising to find that visual distraction directed toward the RH interferes with this type of spatial processing to a greater extent than otherwise identical visual distraction directed toward the LH.

In the present experiments, we explored the consequences of unilateral visual distraction on both verbal and spatial cognitive tasks. The extent to which visual distraction interferes with a specific task should depend on the location of that distraction in the visual field. Visually distracting the hemisphere that contains resources specialized for a task should impair performance more than visually distracting the hemisphere that does not contain resources specialized for that task. Therefore, we hypothesized that although performance on a verbal memory task would be most impaired by visual distraction to the LH (RVF), performance on a coordinate spatial task would be most impaired by visual distraction to the RH (LVF).

EXPERIMENT 1

We asked each participant to look 15° to the left, straight ahead, or 15° to the right while the examiner was 15° to the left or right of where the participant was looking. In each condition, the examiner read a list of 15 words and, after a brief delay, asked the participant to recall as many of the words from the list as possible. Regardless of actual looking direction, we predicted that participants would recall more words and with greater accuracy when the examiner was in the participant's LVF (RH distraction) than when the examiner was in the participant's RVF (LH distraction).

Method

Participants

Participants were 40 right-handed undergraduates (19 women, 21 men; *M* age = 18.9 years, *SD* = 1.3 years) from the University of California, Santa Barbara, who had no immediate left-handed family members. For their participation in Experiment 1, participants received credit in an introductory psychology course.

Materials

The experimental setting consisted of (a) a table separating the examiner and participant and (b) a uniform white wall directly behind the examiner. The distance between the examiner and the participant was 1.5 m. We placed three *X*s horizontally on the wall and spaced them 0.4 m apart. At the participant's sitting position, an eye movement from one *X* to another crossed 15°. We randomly distributed 90 six-letter words into six lists of 15 words. All words were nouns of relatively high use frequency and imageability (e.g., *castle*, *hammer*, *forest*, *rabbit*).

Procedure

Experiment 1 consisted of the participants listening to and recalling words from six lists while we manipulated the looking direction and the location of distraction in a 2 × 3 within-subject design. We manipulated the looking direction so that the participant looked 15° to the left, straight ahead, or 15° to the right. In Experiment 1 and all subsequent experiments, we seated each participant so that the head and body faced in precisely the same direction. Recent researchers have indicated that asymmetrical body orientation can influence the direction of attention and eye movements (e.g., Baker & Ledner, 2004; Grubb & Reed, 2002).

We manipulated distraction location by placing the examiner in the participant's LVF or RVF (15° from where the participant was looking). We refer to having the examiner in the participant's RVF as *having the LH distracted* and to having the examiner in the participant's LVF as *having the RH distracted*. Across participants, the order in which (a) a particular participant went through the six conditions and (b) the particular list paired with each experimental condition was randomly determined.

Each trial involved a verbal free-recall task. The examiner presented 15 words orally at a rate of 1 word per s. After the examiner presented the last word, the participant sat silently for a 10-s delay and then had 1 min to free-recall as many words from the list as possible. We recorded responses for later analysis. The examiner looked directly at the participant during the entirety of each trial to ensure that the participant maintained proper eye gaze fixation, which they consistently were able to do. We operationalized the dependent variable as the number of words the participant correctly recalled minus the number of intruding errors (*performance score*). Errors consisted mostly of words from previous lists and words semantically or phonologically similar to target words. We did not reward or penalize participants for repeating words. By measuring performance scores (correct recall – errors), we hoped to approximate the participant's performance efficiency. If the participant were more likely to say more words in one condition, we would expect increase in not only the recall but also the number of errors. Last, we debriefed participants and concluded the experiment.

Results and Discussion

Table 1 shows the mean number of words each participant correctly recalled minus the mean number of errors made (performance score) for the word lists as a function of the direction in which the participant was looking and the location of the experimenter in the participant's visual field. We analyzed the data by conducting a 2 (LH distraction vs. RH distraction) × 3 (left looking direction vs. middle looking direction vs. right looking direction) repeated-measures analysis of variance (ANOVA).

Mean performance scores were significantly worse when the RVF (LH) was distracted ($M = 4.79$, $SE = 0.24$, $CI_{.95} = 4.30, 5.29$) than when the LVF (RH) was distracted ($M = 5.43$, $SE = 0.22$, $CI_{.95} = 5.00, 5.87$), $F(1, 39) = 9.56$, $p < .01$, $\eta^2 = .20$. However, looking direction did not significantly affect performance, $F(2, 38) < 1$, because performance scores were roughly equivalent while participants looked to the left, to the right, and straight ahead. There was no significant interaction between looking direction and examiner location, $F(2, 38) < 1$.

We used two additional ANOVAs to separately explore recall performance and errors made. We found the predicted effect of distraction location for both measures. Participants correctly recalled more words, $F(1, 39) = 5.28$, $p < .05$, $\eta^2 = .12$, and made fewer errors, $F(1, 39) = 4.57$, $p < .05$, $\eta^2 = .11$, when the RH

TABLE 1. Mean Performance Scores (Words Recalled – Errors Made) and Standard Errors as a Function of Looking Direction and Distraction Location in Experiment 1

Looking direction and measurement	Distraction location: Left hemisphere *M*	Left hemisphere *SE*	Right hemisphere *M*	Right hemisphere *SE*
Left				
Recall	5.15	0.21	5.70	0.29
Errors	0.60	0.16	0.33	0.09
Performance score	4.55	0.29	5.38	0.31
Straight ahead				
Recall	5.63	0.31	6.08	0.29
Errors	0.68	0.16	0.38	0.11
Performance score	4.95	0.38	5.70	0.30
Right				
Recall	5.48	0.26	5.60	0.28
Errors	0.60	0.12	0.38	0.11
Performance score	4.88	0.31	5.23	0.31

was distracted than when the LH was distracted. Once again, we did not find significant differences in relation to participants' direction of looking.

These results support the hypothesis that the extent to which visual distraction (in the form of the examiner) affects the participant's performance on a verbal memory task depends on the side of the visual field that is distracted. Regardless of looking direction, participants recalled more words and made fewer errors when the examiner was in the participant's LVF (RH) than when the examiner was in the participant's RVF (LH).

EXPERIMENT 2A

Results from Experiment 1 suggest that RVF distraction can impair performance on a verbal memory task to a greater extent than can otherwise-identical LVF distraction. Because of the visual nature of the distraction, one explanation may be that the examiner's presence in the participant's RVF impaired the participant's ability to generate or use mental imagery associated with the to-be-learned words. To test this hypothesis, we manipulated the imageability of the to-be-learned words in Experiments 2A and 2B. Because of a lack of associated visual features, the processing of low-imageable words should not benefit from an increased ability to use mental imagery, and so distracting the LH and RH should not lead to different levels of performance on the memory task. However, because the participant's processing of high-imageable words should benefit from an increased ability to use mental imagery, we expected recall performance for high-imageable words to be most impaired by distraction to the LH. We also manipulated task instructions so that we instructed participants to use either visual imagery or verbal rehearsal while encoding and recalling the words. We included this manipulation to explore whether the benefits of removing LH distraction would be most pronounced when participants explicitly use a mental-imagery strategy.

Method

Participants

Participants were 33 right-handed male undergraduate students at the University of California, Santa Barbara (*M* age = 19.1 years, *SD* = 1.3 years), who had no immediate left-handed family members. For participation, each participant received credit in an introductory psychology course at the university.

Materials

We used the same experimental setting as in Experiment 1. We selected 120 single-syllable words from the *MRC Psycholinguistic Database* (Coltheart, 1981). We selected 60 words, such as *joke*, *wealth*, *itch*, and *lard* (each having an imagery rating of between 483 and 502; *M* = 491), as having low imageability. We selected the other 60 words, such as *queen*, *jail*, *jeep*, and *cat* (each having a rating between 607 and 659; *M* = 618), as having high-imageability. We matched the subsets for frequency, with all words ranging between 1 and 44 occurrences per million on the Kucera and Francis (1967) written frequency database. High-imageable words had a mean frequency rating of 16.2, and low-imageable words had a mean frequency rating of 15.0. We divided each subset of 60 words into four lists of 15 words each. Each participant received two high-imageable word lists and two low-imageable word lists. As in Experiment 1, we randomly assigned for each participant the particular experimental condition and ordering associated with each list.

Procedure

Each participant took part in all four experimental conditions that we describe in this section. Unlike in Experiment 1, in Experiment 2A the direction of looking was not manipulated. The examiner asked participants to look straight ahead while the examiner was either 15° to the left or 15° right of the participant's fixation. Once the examiner gave instructions, the examiner read aloud 15 words at a rate of 1 word per 3 s. We used the slower presentation rate to allow participants more time to use the designated task instructions (mental imagery or verbal rehearsal). After a 10-s delay, each participant had 1 min to free-recall as many words from the original list as possible. We calculated performance as the number of words that the participant correctly recalled minus the number of intruding errors.

We asked 16 participants to use only visual imagery and to refrain from using any verbal or auditory technique, such as silently repeating words in their head. Once participants understood these instructions, we administered four randomly ordered conditions consisting of two within-subject variables (examiner location and word imageability). For each condition, participants tried to recall words of either high or low imageability while the examiner was 15° either to the right or the left of the participant's looking direction.

We instructed the other 17 participants to use only verbal rehearsal when trying to learn and remember the words. We gave them an example of repeating a list of words in their head and told them to refrain from using other techniques such as visual imagery. Once we gave the instructions, each participant participated in the same four aforementioned randomly ordered conditions.

Results and Discussion

Table 2 shows recall performance for the word lists as a function of rehearsal strategy, imageability, and the location of the experimenter in the participant's visual field. We conducted a 2 (verbal rehearsal vs. mental imagery) × 2 (low imageability vs. high imageability) × 2 (LH distraction vs. RH distraction) mixed-design ANOVA on the performance scores, with task instructions being the only between-subjects variable.

As in Experiment 1, in Experiment 2A mean performance scores were significantly worse when the LH was distracted ($M = 5.98$, $SE = 0.34$, $CI_{.95} = 5.29, 6.67$) than when the RH was distracted ($M = 6.71$, $SE = 0.29$, $CI_{.95} = 6.13, 7.29$), $F(1, 31) = 5.79$, $p < .05$, $\eta^2 = .16$. Furthermore, mean performance scores were significantly better for lists containing high-imageable words than for lists containing low imageable words, $F(1, 31) = 22.50$, $p < .001$, $\eta^2 = .42$. Most important, a significant interaction emerged between imageability and distraction location, $F(1, 31) = 9.72$, $p < .01$, $\eta^2 = .24$. Although recall performances for low imageable words were equivalent when the LH ($M = 5.53$, $SE = 0.36$, $CI_{.95} = 4.79, 6.27$) and RH ($M = 5.41$, $SE = 0.35$, $CI_{.95} = 4.71, 6.12$) were distracted, recall performance for high-imageable words was substantially worse when the LH ($M = 6.44$, $SE = 0.46$, $CI_{.95} = 5.50, 7.38$) was distracted than when the RH ($M = 8.01$, $SE = 0.37$, $CI_{.95} = 7.25, 8.76$) was distracted.

We used two additional ANOVAs to analyze separately recall performance and errors made. Participants recalled significantly fewer words when the LH was distracted than when the RH was distracted, $F(1, 31) = 5.14$, $p < .05$, $\eta^2 = .14$, and we observed a similar pattern of results in terms of errors made, such

TABLE 2. Mean Performance Scores (Words Recalled – Errors Made) and Standard Errors as a Function of the Participant's Rehearsal Strategy, Word List Imageability, and Distraction Location in Experiment 2A

Imageability of words and measurement	Distraction location			
	Left hemisphere		Right hemisphere	
	M	*SE*	*M*	*SE*
Visual imagery				
Low				
Recall	6.19	0.44	6.50	0.45
Errors	0.25	0.17	0.44	0.20
Performance score	5.94	0.52	6.06	0.50
High				
Recall	7.50	0.54	8.38	0.49
Errors	0.56	0.21	0.19	0.11
Performance score	6.94	0.66	8.19	0.53
Visual rehearsal				
Low				
Recall	6.06	0.43	5.65	0.44
Errors	0.94	0.16	0.88	0.19
Performance score	5.12	0.51	4.77	0.48
High				
Recall	6.71	0.52	8.06	0.48
Errors	0.77	0.20	0.24	0.10
Performance score	5.94	0.64	7.82	0.52

that participants made more errors when the LH was distracted than when the RH was distracted, $F(1, 31) = 3.30$, $p = .08$, $\eta^2 = .10$. Thus, the predicted interaction between imageability and distraction location was significant in terms of both recall performance, $F(1, 31) = 6.15$, $p < .05$, $\eta^2 = .17$, and errors made, $F(1, 31) = 9.68$, $p < .05$, $\eta^2 = .24$.

Although the main effect for rehearsal strategy was not significant, $F(1, 30) = 2.50$, $p = .12$, participants who used visual imagery tended to outperform participants who used verbal rehearsal. Furthermore, rehearsal strategy did not significantly interact with any other variable in Experiment 2A. However, the predicted interaction between distraction location and imageability was quantitatively stronger for participants in the verbal rehearsal condition than for those in the visual imagery condition. This observation suggests that participants did not need to explicitly use a mental imagery strategy to incur the benefits of reduced LH visual distraction.

In sum, although the recall of low-imageable words did not vary as a function of which hemisphere was distracted, the recall of high-imageable words did.

These results suggest that mental imagery may be the particular cognitive process that is impaired by visual distraction to the RVF (LH). In Experiment 2B, we sought to replicate this finding with examiners who were naive to the purpose of the experiment and with participants whom we did not explicitly tell to use any type of rehearsal strategy.

EXPERIMENT 2B

Method

Participants

Participants were 48 right-handed male undergraduate students (*M* age = 19.7 years, *SD* = 1.8 years) from the University of California, Los Angeles, who had no immediate left-handed family members.

Materials and Procedure

We trained three male examiners to administer the same procedures that we used in Experiment 2A, but we did not inform them of the purpose of Experiment 2B. Unlike in Experiment 2A, in Experiment 2B we did not instruct the participants explicitly to use any type of rehearsal strategy. Although set in a room that was different from that of Experiments 1 and 2A, the spacing and dimensions of the room used in Experiment 2B were almost identical to those of the other experiments. Each participant learned and was asked to recall words from two lists consisting of high-imageable words and two lists consisting of low-imageable words. The participant learned one of the high-imageable lists and one of the low-imageable lists while the examiner was in the participant's LVF (RH), and the participant learned the other high-imageable list and the other low-imageable list while the examiner was in the participant's RVF (LH). We counterbalanced equally across participants the order placement and particular list with which an experimental condition paired.

Results and Discussion

Table 3 shows Experiment 2B's recall performance as a function of word imageability and distraction location. A 2 (low imageability vs. high imageability) × 2 (LH distraction vs. RH distraction) repeated-measures ANOVA indicated that low-imageable words were remembered somewhat better when the LH was distracted than when the RH was distracted, whereas high-imageable words were remembered better when the RH was distracted than when the LH was distracted. As in Experiment 2A, this interaction between imageability and distraction location was significant, $F(1, 47) = 4.10$, $p < .05$, $\eta^2 = .08$. When we analyzed recall and errors independently, the interaction neared significance in

TABLE 3. Mean Performance Score (Words Recalled – Errors Made) and Standard Errors as a Function of Word List Imageability and Distraction Location in Experiment 2B

	Distraction location			
	Left hemisphere		Right hemisphere	
Imageability of words and measurement	*M*	*SE*	*M*	*SE*
Low				
Recall	7.46	0.30	7.04	0.31
Errors	0.40	0.10	0.44	0.11
Performance score	7.06	0.33	6.60	0.37
High				
Recall	8.08	0.32	8.38	0.34
Errors	0.56	0.11	0.15	0.05
Performance score	7.52	0.35	8.23	0.35

terms of recall, $F(1, 47) = 2.14$, $p = .15$, $\eta^2 = .04$, and was statistically significant in terms of errors made, $F(1, 47) = 6.41$, $p < .05$, $\eta^2 = .12$. These results replicate those of Experiment 2A in a new experimental setting, without explicit rehearsal instruction, and with three naive examiners who were blind to the purpose of Experiment 2B.

EXPERIMENT 3

Experiments 1, 2A, and 2B demonstrated that performance on a verbal memory task for high-imageable words can be impaired when visual distraction is directed toward the RVF (LH). In Experiment 3, we examined a potential negative consequence of visual distraction to the LVF (RH). Specifically, we predicted that visually distracting the LVF would impair performance on a RH spatial task to a greater extent than would visually distracting the RVF. To test this prediction, we engaged the participant in an RH coordinate spatial task while manipulating the location of distraction in the participant's visual field.

We modeled the procedure after a spatial task on which Kosslyn et al. (1995) showed that participants performed most effectively when they processed the stimuli in the LVF. Kosslyn et al. created a 4 × 5 box grid with boundaries denoted by right-angle brackets at each corner of the grid, and asked participants to memorize the configuration of eight uppercase block letters that were presented one at a time on the grid. Afterwards, the researchers showed the participants a series of probe stimuli (an *X* placed in one cell of the grid) and asked them to decide whether a specified block letter would have eclipsed the cell with the *X* if it were transposed onto the grid. Participants were more accurate when probes were projected to the LVF, indicating that the task relies more heavily on RH processing.

We modified Kossyln et al.'s (1995) procedure for Experiment 3. Rather than presenting the probe stimuli in either the RVF or the LVF, we placed the stimuli directly in front of the participants, and, as in Experiments 1, 2A, and 2B, varied the location of visual distraction. Again, a naive examiner served as the source of visual distraction by appearing in the participants' RVF or LVF next to the computer screen. To make the task more comparable to the those of Experiments 1, 2A, and 2B, rather than asking the participants to determine whether a single letter would have eclipsed the probe, we instructed the participants to name as many of the uppercase block letters—whose configurations they had memorized—that would have eclipsed the probe. We predicted that performance on the RH spatial task would be better when the examiner was in the participant's RVF (LH distraction) than when the examiner was in the participant's LVF (RH distraction).

Method

Participants

Participants were 32 right-handed male undergraduates (*M* age = 20.4 years, *SD* = 6.6 years) from the University of California, Los Angeles. For their participation, they received partial fulfillment of course requirements. A subset of the participants had participated in Experiment 2B. However, we selected these participants before observing their performance in Experiment 2B.

Materials

We modeled the experiment after a coordinate spatial task that Kosslyn et al. (1995) showed to demonstrate a RH advantage. We created a blank 4 × 5 box grid with boundaries denoted by brackets, and we created 12 uppercase block letters (i.e., *A*, *B*, *C*, *F*, *G*, *H*, *J*, *L*, *O*, *P*, *S*, and *U*) so that their configurations fit within this grid (see left panel of the Appendix). We also created two sets of four probe stimuli, each consisting of an *X* in a single cell (see right panel of the Appendix). A computer monitor, which we centered in the participant's line of sight, presented instructions, the letters, a fixation marker, and the probe stimuli. One of two naive examiners, who was serving as the distractor, appeared half the time in the LVF and half the time in the RVF in conjunction with presentation of the probe stimuli.

Procedure

During the initial learning phase (which was repeated), we presented the block letters on the grid for 4 s each in alphabetical order for participants to memorize their spatial configuration. In the testing phase, we instructed participants to fixate on a marker that was in the center of the screen and wait for a probe to appear within the bracket boundaries. Once the probe appeared, participants had 5 s to name as many block letters that would have covered that probe as possible. The probe appeared for 1 s and then disappeared for an additional 4 s while the participants continued to respond. A naive male examiner, who was sitting either to the left (RH distraction) or to the right (LH distraction) of the computer screen, recorded participant responses until 5 s had passed. Once the first set of four probes was completed, the examiner switched positions to the other side of the computer and began a second set of four probes. We counterbalanced across participants the order of examiner position and the particular set of probes that we used. After completing both sets, we repeated the experiment with the same stimuli, order, and examiner placements.

Results and Discussion

We analyzed performance on the spatial task by using a 2 (first block vs. second block) × 2 (LH distraction vs. RH distraction) repeated-measures ANOVA. Results indicated that participants identified more letters when the LH was distracted ($M = 4.10$, $SE = 0.14$, $CI_{.95} = 3.83, 4.38$) than when the RH was distracted ($M = 3.91$, $SE = 0.13$, $CI_{.95} = 3.66, 4.17$), $F(1, 31) = 4.00$, $p = .05$, $\eta^2 = .11$. However, this effect varied across blocks of experimental trials, $F(1, 31) = 6.90$, $p < .05$, $\eta^2 = 18$. There was a large impairment from RH distraction ($M = 3.52$, $SE = 0.16$, $CI_{.95} = 3.20, 3.84$) in comparison with LH distraction ($M = 3.94$, $SE = 0.17$, $CI_{.95} = 3.60, 4.28$) during the first block, $t(31) = 2.74$, $p < .05$, whereas there was no impairment during the second block (M with RH distraction = 4.31, $SE = 0.14$, $CI_{.95} = 4.02, 4.60$; M with LH distraction = 4.27, $SE = 0.14$, $CI_{.95} = 3.99, 4.55$). These data suggest that RH visual distraction can impair performance on coordinate spatial tasks to a greater extent than can LH visual distraction. At least for the first block of trials, participants recalled significantly more letters in response to the probe cue when the examiner was in the participant's RVF (LH) than when the examiner was in the participant's LVF (RH). This finding is important in that it complements the results of Experiments 1, 2A, and 2B, in which the effect of asymmetrical visual distraction on a verbal memory task was found to be the opposite.

Some discussion is appropriate to explain why the effect of distraction location disappeared during the second block of trials. Prior researchers have suggested that the RH advantage for coordinate spatial tasks dissipates with practice (e.g., Kosslyn et al., 1989; Michimata, 1997; Rybash & Hoyer, 1992). One possibility is that participants develop new categorical labels to represent coordinate locations, making the task more appropriate for the LH and thus eliminating the RH advantage (Kosslyn et al., 1989). After a review of the existing literature, Jager and Postma (2003) argued that although it is clear that the lateralization of performance on coordinate spatial tasks changes with practice, it is unclear how or why this change occurs. Nevertheless, to the extent that practice reduces the lateralization of the task, it would make sense for practice to reduce the effect of distraction location as well.

GENERAL DISCUSSION

Eye movements serve an obvious role in cognition: They allow individuals to direct attention toward objects in the visual world. However, there are times when an individual may not want to attend to objects in the visual world, such as when the individual is engaged in a difficult cognitive task. In the present study, we hypothesized that by limiting the demand for visual processing in a particular hemisphere, lateral eye movements would enhance performance on cognitive tasks that are lateralized to that hemisphere. Consistent with this hypothesis, Experiment 1 showed that performance on a verbal memory task was more impaired more when an examiner was in the participant's RVF (LH) than when an examiner was in the participant's LVF (RH).

In Experiments 2A and 2B, we sought to identify why visual distraction to the LH may impair performance to a greater extent than might otherwise identical visual distraction to the RH. Mental imagery and visual perception rely on overlapping neural resources (e.g., Kosslyn, 2005; Kosslyn & Thompson, 2003). Researchers have also found that because the generation of mental imagery appears to depend particularly on the LH (e.g., Farah, 1984, 1995; Farah et al., 1988; Farah et al., 1989), an individual's having to attend to external visual input in the RVF may especially interfere with the use of imagery. We found, consistent with this hypothesis, that distraction to the RVF (LH) only impaired performance when participants tried to encode and retrieve words of high imageability. Because words of low imageability lack associated visual information, participants' diminished capacity to use mental imagery apparently did not impair their recall performance.

The failure to find an effect of distraction location for words of low imageability provides important evidence against several alternative explanations. For example, on the basis of the results of Experiment 1, researchers may argue that LH distraction interferes with the capacity of participants to attend to the memory task in general. Researchers may also argue that an auditory location or social interference effect caused the difference in performance across distraction conditions. However, none of these explanations can account for the observed interaction between distraction location and imageability. If differences in general attention, auditory location, or social interference were responsible for the effect of distraction location, it would be unclear why we found the effect only for words of high imageability.

Experiment 3 complemented Experiments 1, 2A, and 2B by showing that performance on a coordinate spatial task is worse when the examiner is in the participant's LVF (RH) than when the examiner is in the participant's RVF (LH). Together, these results suggest that the cognitive consequences of asymmetrical visual distraction depend on the lateralization of the cognitive task at hand. The recall of high-imageable words benefited from the removal of LH distraction, whereas a task requiring the recollection and use of coordinate spatial configurations benefited from the removal of RH distraction. Consequently, lateral eye movements appear able to facilitate cognitive efficiency by manipulating the location of distraction in the visual field; that is, by relegating cognitive tasks between asymmetrically specialized hemispheres, lateral eye movements can reduce competition between vision and other concurrent cognitive processes.

These results also have important implications for understanding memory processes in the brain. For example, Jonides, Lacey, and Nee (2005) argued that the storage and rehearsal of items in working memory are mediated by the same neural structures responsible for attending and processing external perceptual information. Our results appear to be consistent with that claim. It is possible that in our study, RVF distraction taxed resources in the posterior LH that would have otherwise aided in the maintenance of to-be-remembered items in working memory. Rehearsal functions improve when items are activated at numerous levels of representation. Therefore, activating the visual features associated with words may have increased the likelihood of those words' being maintained in working memory and recalled after the delay. However, a simultaneous need to process external visual stimuli may have interfered with the activation of relevant visual features and thereby led to impaired performance on the memory task.

Many lateral eye movement researchers have assumed that changes in eye gaze are the automatic consequences of asymmetrical neural activity (Kinsbourne, 1972). However, many different influences can affect looking behavior. For example, Baker (1989) demonstrated that visual asymmetry influenced direction of gaze, with participants consistently making eye movements away from the closest wall in the room. Rodin and Singer (1976) found that even if people predominately look to the right, they will stop doing so if another person is standing there. These findings and others share the observation that people try to avoid looking at distracting stimuli, which is consistent with the more recent work showing that people will avert their gaze to remove excessive visual stimulation and enhance cognitive efficiency (e.g., Doherty-Sneddon et al., 2001, 2002; Glenberg et al., 1998).

The present experiments may have provided evidence that lateral eye movements can facilitate certain types of cognitive processes, but none have provided evidence that people actually use them to facilitate such processes. Researchers have suggested that people make eye movements toward the visual field contralateral to the hemisphere that a specific cognitive task engages. Some researchers have argued that LH cognitive processes induce eye movements to the right, whereas RH cognitive processes induce eye movements to the left (e.g., Kinsbourne, 1972). By showing that lateral eye movements play a functional role in facilitating the same cognitive processes that researchers once argued elicit them, we have either demonstrated a coincidence or added a necessary and overdue piece to the puzzle.

If the lateral eye movements that prior researchers have observed reflect the tendency for people to remove visual distraction from a specific hemisphere, researchers should expect certain patterns to emerge from the literature. Specifically, lateral eye movement effect should disappear when researchers remove distraction (e.g., by removing the examiner from the participant's view or asking participants to close their eyes). Although several researchers have failed to replicate the effect under such conditions (e.g., Gumm et al., 1982; Hiscock, 1977; Takeda & Yoshimura, 1979), a substantial number of researchers have replicated it (e.g., Griffiths & Woodman, 1985; Gur et al., 1975; Kinsbourne, 1972; O'Gorman & Siddle, 1981; Raine et al., 1988). Further, direct attempts to show a relation between visual distraction and the direction of looking have largely been unsuccessful (e.g., Ehrlichman, 1981; Ehrlichman & Barrett, 1983). Thus, there is not sufficient evidence for researchers to conclude that the lateral eye movement phenomenon in prior research is related to the cognitive function that we have demonstrated here.

The eyes may be the window to the world, but they are also a window to potential interference. However, by controlling how interference passes through that window, eye movements can have important cognitive consequences. In the experiments in this study, participants engaged in either a verbal memory task or a coordinate spatial task while the examiner was to the right or left of where the participants were looking. Our placing the examiner in the participant's RVF (LH) impaired performance on a verbal recall task for words of high imageability significantly more than did placing the examiner in the participant's LVF (RH). This pattern of results reversed for performance on the coordinate spatial task, suggesting that the extent to which visual distraction interferes with cognition depends on both the location of distraction in the visual field and the lateralization of the task. Not only does this finding provide a novel perspective on understanding three decades of inconclusive lateral eye movement research, it also provides a novel perspective on understanding the complicated relations and interactions between vision and cognition.

AUTHOR NOTES

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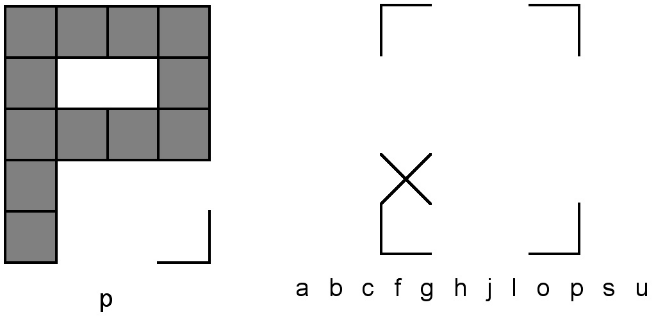
APPENDIX
Sample Coordinate Spatial Task



Note. Participants first learned the spatial configuration of 12 uppercase block letters (as shown on the left). In the test trials that followed, participants recalled which block letters would have covered a probe (x) that appeared within the brackets (as shown on the right). Each probe appeared for 1 s, and participants had a total of 5 s to respond.

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