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What are you looking at?
Impaired ‘social attention’ following frontal-lobe damage

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Abstract

Humans are able to predict the behavior of others. Several studies have investigated this capability by determining if social cues, such as eye gaze direction, can influence the allocation of visual attention. When a viewer sees a face looking to the left, the viewer’s attention is allocated in the gazed-at direction. These ‘social attention’ studies have asked if this allocation of attention is automatic or under voluntary control. In this paper, we show that a patient with frontal-lobe damage is impaired at allocating attention to peripheral locations voluntarily, although attention can be allocated there automatically. The patient, EVR, can use peripheral cues to selectively process one location over another but cannot use symbolic cues (words) to allocate attention. EVR is also impaired in using eye gaze cues to allocate attention, suggesting that ‘social attention’ may involve frontal-lobe processes that control voluntary, not automatic, shifts of visuospatial attention.

Keywords: Attention; Frontal lobes; Eye gaze direction; Social attention; Theory-of-mind

1. Introduction

Humans appear to be endowed with the ability to make predictions regarding others’ behavior or intentions. For example, a professor may predict that an approaching student is going to ask for an extension on an assignment if the assignment is due in 2 days. Some theories label this ability as a “mind reading” ability or a “theory-of-mind” (e.g., Baron-Cohen, 1995; Leslie, 1991; Premack & Woodruff, 1978), and some theories suggest that such an ability allows humans to understand the social interactions that are important in the elaborate social hierarchies of primates (e.g., Cheney & Seyfarth, 1990).

Perception of another person’s eye gaze direction plays a key role in many theory-of-mind theories (e.g., Baron-Cohen, 1995) for several reasons. First, gaze direction may signal the upcoming target or goal of another person’s behavior, which helps predict behavior; for example, chimpanzees appear to be able to use another’s line of gaze to orient attention (Povinelli & Eddy, 1996; Povinelli, Nelson, & Boysen, 1990), although such abilities may not require an attribution of mental states (see Gagliardi, Kirkpatrick-Steger, Thomas, Allen, & Blumberg, 1995; Reaux, Theall, & Povinelli, 1999). Second, gaze perception appears to be supported by gaze-selective neural responses in a “face-cell” area in the superior temporal sulcus of the macaque (Perrett, Hietanen, Oram, & Benson, 1992), an area which may correspond to the “fusiform face area” of human extrastriate cortex (Kanwisher, McDermott, & Chun, 1997). Third, sensitivity to gaze direction emerges in early life (see Vecera & Johnson, 1995 for relevant results), suggesting a role in developing human social skills. Given these reasons, theorists such as Baron-Cohen (1995) hypothesize distinct cognitive modules for detecting eyes and perceiving another’s eye gaze direction. Initial research supporting these theories and processes came from special populations (e.g., children with autism). More recent studies of cognitively normal individuals support theory-of-mind theories by showing that visuospatial attention is influenced by another’s gaze direction (Driver et al., 1999; Friesen & Kingstone, 1998; Kingstone, Friesen, & Gazzaniga, 2000; Langton & Bruce, 1999, 2000).

Previous research on visuospatial attention has demonstrated that attention can be allocated to locations by different types of cues that appear before a target stimulus appears (Posner, 1980; Posner, Snyder, & Davidson, 1980). In Posner’s now-classic task, participants are asked to

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detect a visual target which appears at a peripheral location. Prior to target onset, a predictive cue appears. “Valid” cues correctly predict a target’s subsequent location, whereas “invalid” cues are inaccurate and misleading. Participants are generally faster to detect validly cued targets than invalidly cued targets. Also, two cue types have been studied in this task, and these cues differ in their effects on attentional orienting. *Peripheral* cues flicker briefly at the predicted target location, whereas *centrally-presented* (symbolic) cues indicate a target’s probable location by means of symbolic information such as a word or arrow. Peripheral cues appear to capture spatial attention automatically or reflexively (Jonides, 1981; Yantis & Hillstrom, 1994), cannot be ignored, and are not interfered with by symbolic cues (Jonides, 1981; Müller & Rabbit, 1989). Peripheral cues summon attention even when they do not reliably predict target location; infrequently-occurring validly cued targets are detected faster than frequently-occurring invalidly cued targets. In contrast, symbolic cues require participants to shift attention voluntarily to the cued location. These symbolic cues can be ignored and are interfered with by peripheral cues (Jonides, 1981; Müller & Rabbit, 1989), although these cues need not predict an upcoming target’s location to direct attention to a cued location (Hommel, Pratt, Colzato, & Godijn, 2001; Tipples, 2002).

An important question is whether gaze cues orient spatial attention reflexively, as peripheral cues, or voluntarily, as symbolic cues. If eye gaze is critical to inferring another’s mental state, as suggested by theory-of-mind accounts, then one might expect gaze cues to summon attention automatically to gazed-at locations. This prediction finds some support: When another person’s eyes are gazing to our left, validly cued targets that appear there are processed faster and more accurately than invalidly cued targets that appear to our right (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). Further, eye gaze can affect attentional orienting when a target appears at the gazed-at (validly cued) location infrequently, suggesting that gaze cues orient attention in a reflexive manner. Attention is summoned to a cued (i.e., gazed at) location even when the target is more likely to appear at the uncued (i.e., not gazed at) location. When the gaze cue is counter-predictive, gaze cues, like peripheral cues, cannot be ignored, and attention is driven to the gazed-at location (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999).

Several issues remain to be addressed before we conclude that gaze direction cues automatically influence the orienting of spatial attention. For example, if participants in a gaze precuing study are good “mind readers,” they might correctly guess the expected outcome of the experiment and adjust their behavior accordingly (i.e., *voluntarily* orienting attention in the direction of the gaze cue). Also, in many social situations, reflexive orienting by gaze is inappropriate or unwarranted, such as when a speaker casually glances upward during conversation. Such casual glances differ from more meaningful glances that would be important for attentional allocation. Purely reflexive orienting to gaze would not allow different social contexts to influence attentional allocation; in contrast, voluntary orienting could allow social context to modulate attentional orienting based on gaze direction. Current reflexive accounts of gaze-directed attention do not explain how attention can distinguish between appropriate and inappropriate contexts.

Neuropsychological data can provide additional evidence regarding the orienting produced by eye gaze cues. We focus on patients with frontal-lobe lesions, who exhibit a variety of cognitive impairments that can broadly be classified as problems with cognitive control (see Kimberg, D’Esposito, & Farah, 2000; Miller & Cohen, 2001, for recent reviews). Some of these impairments in cognitive control appear as attentional impairments. Patients with frontal-lobe lesions are distracted by irrelevant stimuli (Chao & Knight, 1995), are impaired at voluntarily sustaining attention (Wilkins, Shallice, & McCarthy, 1987), and are impaired at using advance information in a variety of tasks, including spatial cuing tasks (Alivisatos, 1992; Alivisatos & Milner, 1989; Koski, Paus, & Petrides, 1998). Because frontal-lobe patients do not appear to be impaired in highly-practiced, automatic tasks, these patients can be studied to explore dissociations between automatic and voluntary attentional processes.

Studies investigating voluntary attention in frontal patients have used variants of Posner’s spatial cuing task with symbolic cues. For example, Alivisatos and Milner (1989) presented patients with word cues that either signaled the upcoming target’s location (valid trials) or provided no information about the target’s location (neutral trials). Frontal-lobe patients showed a smaller attentional benefit (the difference in performance between valid and neutral trials) than either control participants or temporal lobe patients. Koski et al. (1998) reported similar results from centrally-presented arrow cues that either validly predicted the upcoming target’s location or did not predict the target’s location. Again, frontal patients showed smaller attentional benefits than both control participants and temporal lobe patients. In the foregoing studies, the frontal patients had varied lesion locations that included dorsolateral and ventromedial frontal areas.

To determine if eye gaze cues orient attention in an automatic or voluntary manner, we investigated attentional orienting in patient EVR, who had regions of both frontal lobes excised during removal of a tumor (Eslinger & Damasio, 1985). EVR performed a simple spatial cuing task in which he detected the onset of a target that appeared in the visual periphery (see Fig. 1). The target was preceded by a spatial cue that either predicted the target’s location (valid cue) or did not predict the target’s location (invalid cue). As shown in Fig. 1, we tested EVR with three types of spatial cues to assess his attentional orienting: peripheral cues, symbolic cues (e.g., words, such as “left”), and gaze cues. Previous findings from frontal-lobe patients (Alivisatos & Milner, 1989; Koski et al., 1998) lead us to hypothesize that EVR would be unable to use symbolic word cues to

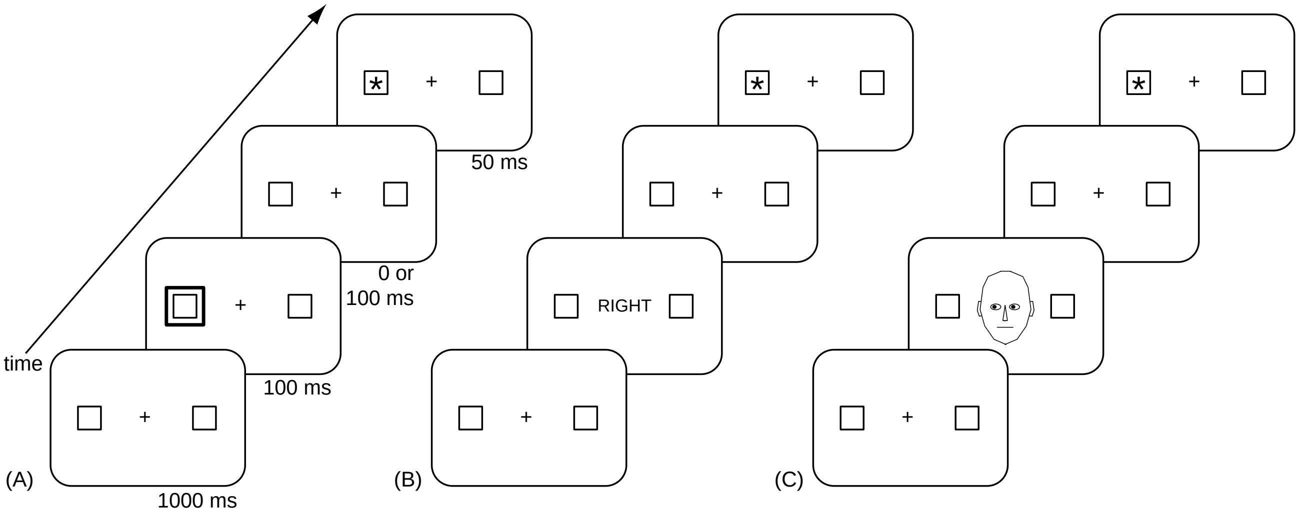

Fig. 1. Sequence of events in the experiment. (A) A valid peripheral cue. (B) An invalid word cue. (C) A valid eye gaze cue (note: stimuli not drawn to scale).

orient attention. Further, we expected to find that EVR would have no difficulty orienting to peripheral cues because peripheral cues orient attention automatically (e.g., Jonides, 1981; Müller & Rabbit, 1989; Yantis & Jonides, 1984) and because frontal-lobe patients typically do not have impairments in 'automatic' performance. The critical issue concerns gaze cues. If gaze cues summon attention automatically, then EVR should be unimpaired orienting to gaze cues. Specifically, he should be faster to detect targets validly cued by gaze than targets invalidly cued by gaze. If gaze cues orient attention in a voluntary manner, however, then EVR should be impaired orienting to gaze cues (in addition to being impaired orienting to symbolic cues).

2. Case report

At age 35, EVR was diagnosed with a cerebral tumor, a large orbitofrontal meningioma. The tumor was surgically removed, and EVR recovered. EVR's frontal-lobe damage in the chronic phase of recovery corresponded to regions F07, F11, and F12 in Damasio and Damasio's (1989) lesion analysis schema. The removal of the tumor and frontal-lobe tissue left EVR with lasting impairments in decision making, personality, and some forms of cognitive control. For example, EVR seems to have an impairment with goal-directed behaviors—when waking up, he does not automatically generate the goals of showering and eating as he used to (Eslinger & Damasio, 1985). When making decisions, EVR often labors over minutia and fails to appreciate the global purpose (i.e., the goal) of reaching a decision.

Despite his noted cognitive impairments, EVR appears normal on many cognitive functions. EVR's intelligence has remained stable and in the superior range since his case was initially presented (WAIS verbal IQ of 120 in 1985; 131 in 1998). His working memory span, speech, verbal fluency, verbal comprehension, and face perception all appear to be normal, as does his executive function (as measured by the Wisconsin Card Sort task, the Stroop task, and by his performance on solving the Tower of Hanoi puzzle; see Bechara, Damasio, Tranel, & Anderson, 1998).

Despite EVR's preserved performance on classic 'frontal-lobe tasks' (e.g., Wisconsin Card Sort), he demonstrates a long-lasting difficulty in generating learned responses to complex visual stimuli (Tranel et al., 1995). For example, EVR's skin conductance responses do not discriminate between familiar and unfamiliar faces, although his perception and recognition of faces is flawless (Tranel et al., 1995).

At the time of the current testing, EVR was 62 years old. His low-level visual functions were preserved; his corrected acuity was 20/25, and he had no visual field defects (e.g., scotomas). EVR's contrast sensitivity was within the normal limits, and he was able to detect coherent motion against a static background within normal limits. High-level visual functions also appeared to be intact in EVR. For example, face recognition, two- and three-dimensional block construction, and copying the Rey-Osterreith complex figure were all performed within the normal range. EVR showed a subtle attentional impairment on a standardized dual attention task: EVR's performance was outside the normal range when he simultaneously performed a visual discrimination at fixation and a peripheral target localization task, although his performance on the central discrimination task alone was within the range of normal control participants. EVR's impaired dual-task performance suggests a difficulty with high-level, "executive" attentional processes (e.g., Baddeley, 1996), processes that are important for executing goal-directed behaviors and in generating previously learned responses.

3. Method

3.1. Participants

Both EVR and ten older control participants performed a spatial cuing task (Fig. 1) in which a target appeared at a peripheral visual location. Prior to the target, a cue appeared. Three cues were tested in different blocks of trials: peripheral cues, symbolic word cues, and eye gaze cues. The control participants had a mean age of 69.3 years (S.D. = 4.6 years).

3.2. Stimuli

Participants sat approximately 60 cm from a Macintosh iMac computer (15 in. monitor). Each trial began with a central fixation point and two $0.95^\circ \times 0.95^\circ$ boxes which appeared 6.1° of visual angle to the left and right of fixation. The peripheral cues were a 1.6° box that appeared around the placeholder boxes. Peripheral cues were single cues that appeared around the left or right placeholder box. The symbolic cues were the words "left" and "right" that appeared at fixation in 36 point Helvetica font; the words ranged from 2.8 to 3.7° wide. The eye gaze cues consisted of a schematic face that appeared at fixation and had eyes looking left or right. The face measured 5.7° tall and 4.4° wide. Each individual eye measured 0.50° tall and 0.77° wide; the averted gaze directions were created by moving the pupils 2 mm to the left or right of the eye's center. The target was a small asterisk that measured approximately 0.40° tall and 0.40° wide. All stimuli were drawn in black and presented on a white background.

In a control task, EVR viewed the cues only and was asked to report (1) if the peripheral flash occurred to the left or right, (2) if a letter string was the word "left" or "right," and (3) if the eyes were looking to the left or right. The stimuli were identical to those used in the spatial cuing task. The control participants were not tested on these control tasks.

3.3. Procedure

In the spatial cuing task, each trial began with the fixation point and placeholder boxes visible for 1000 ms. A cue then appeared for 100 ms; after the cue disappeared, a target appeared. On half of the trials, the target appeared immediately after the cue disappeared (100 ms stimulus onset asynchrony (SOA)) or after a 100 ms delay (200 ms SOA). Two SOAs were used to discourage anticipation of the target's appearance following the cue. The target appeared for 50 ms, and it appeared in the left placeholder box on half of the trials and in the right placeholder box on half of the trials. Participants pressed the spacebar on a standard keyboard when they detected the onset of the target.

The cue-target intervals in this procedure and the 50 ms target presentation are too brief to permit eye movements. Nevertheless, we monitored eye movements to prevent any anticipatory eye movements to the cued location. Eye movements were monitored in both EVR and control participants using an ETL-500 head mounted eye tracking system from ISCAN Inc. (Burlington, MA). Participants wore a baseball cap containing a miniature scene camera and a miniature eye camera. The eye camera monitored the pupil using corneal reflection of the participant's left eye. Eye position was indicated by a crosshair on a remote video screen; eye position was monitored continuously throughout the experiment and was recorded on videotape for post hoc analysis. Eye position was monitored for each trial, and any trials that contained a visible eye movement were excluded from further analyses. This monitoring excluded less than 0.5% of the trials, and when eye movements were made, they were highly visible saccades that ended on or near the peripheral placeholders.

There were three blocks of trials, one for each cue type. The three blocks were shown to EVR in a fixed order because of limited testing time that prevented full counterbalancing of block order; the fixed order was: peripheral cues, word cues, and gaze cues. The control participants viewed the three blocks in the same order as EVR to control for any order effects.

To increase the likelihood of observing a cuing effect in EVR with the word and gaze cues, valid cues appeared more frequently than invalid cues for the word cues and gaze cues. For these cue types, 75% of the cues were valid and 25% were invalid, a ratio which should encourage participants to orient attention in the cued direction. Further, to provide the most stringent test of automatic orienting in all participants, the peripheral cues were uninformative (50% valid and 50% invalid). Based on these cue probabilities, we increased our chances of observing a cuing effect with the word and gaze cues and decreased our chances of observing a cuing effect with peripheral cues—observations that would run counter to our hypothesized results. Thus, we created an experimental situation that works to falsify our hypotheses.

All participants viewed three blocks of trials, with cue type held constant within each block. Each block consisted of 192 trials in which a target appeared and 24 "catch" trials in which a cue appeared but no target followed. Participants were instructed to withhold their responses on these catch trials. Within each block, participants were given rests after every 54 trials (48 target trials plus 6 catch trials). All trials were presented randomly.

Finally, in the control tasks administered only to EVR, a cue was presented for 100 ms. EVR verbally reported the direction or location of the cue (left or right) after the cue disappeared, and the experimenter recorded his response. EVR performed the control tasks before performing the spatial cue task to ensure that he could correctly perceive the cue.

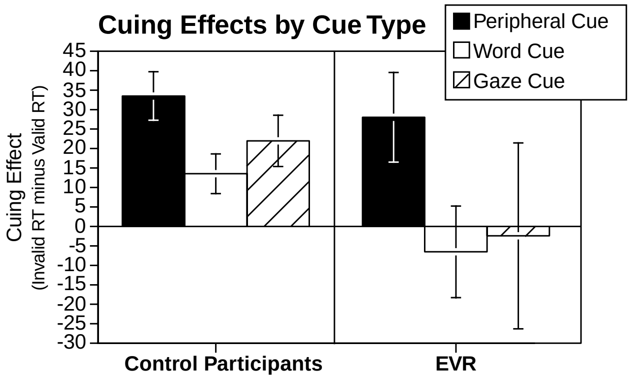

Fig. 2. Cuing effects (invalid trial RTs minus valid trial RTs) from 10 neurologically normal older control participants and patient EVR. Error bars are 95% confidence intervals on the comparison between the cuing effect and 0 ms; error bars that do not overlap 0 ms indicate a statistically significant cuing effect in which validly cued targets are detected faster than invalidly cued targets.

4. Results

4.1. Control participants

Reaction times (RTs) over 1000 ms were excluded from the analyses as outliers, and this trimming excluded less than 2% of the data. There was no evidence of any systematic anticipatory responses (RTs < 150 ms). The control participants made few catch trial errors ($<2\%$). For each participant, we computed the cuing effect across each cue type (peripheral, word, or gaze), collapsed across SOA. The cuing effect was defined as the invalid cue RT minus the valid cue RT; positive scores indicated a cuing effect in which the participant was faster to detect validly-cued targets than invalidly-cued targets. Preliminary analyses indicated that SOA did not interact with any factors, so we collapsed across SOA. The average cuing effects for the control participants appear in Fig. 2. For the sake of completeness, all RTs for the control participants appear in Table 1.

Fig. 2 shows that the control participants exhibited statistically significant cuing effects for each of the cue types: following peripheral cues, control participants were 33.5 ms faster to detect validly cued targets than invalidly cued targets, $t(9) = 6.1$, $P < 0.0005$. Following word cues, control participants were 13.5 ms faster to detect validly cued targets than invalidly cued targets, $t(9) = 3.0$, $P < 0.02$. Following gaze cues, control participants were 22.0 ms faster to detect validly cued targets than invalidly cued targets, $t(9) = 3.8$, $P < 0.005$.

An inspection of individual control participant's results was consistent with the averaged group responses. For peripheral cues, all of the control participants responded faster to validly-cued targets than to invalidly-cued targets. For word cues, two control participants showed slightly (but not significantly) faster to detect invalidly-cued targets than validly-cued targets; for one participant, invalidly-cued targets were detected 2.2 ms faster than validly cued targets, and for the other participant, invalidly-cued targets were detected 3.9 ms faster than validly-cued targets. Finally, for gaze cues, all participants detected validly-cued targets faster than invalidly-cued targets.

These results generally replicate previous studies from spatial precuing tasks. All cue types showed faster detection times to validly cued targets than invalidly cued targets. These cuing effects are important because they indicate that our procedure is sensitive to such effects in older control participants.

4.2. EVR

EVR performed flawlessly in the control tasks, indicating he could perceive and interpret the direction of the three different cue types.

As with control participants, RTs over 1000 ms were excluded from the analyses, and this trimming excluded less than 1% of EVR's data. EVR made few errors on catch trials ($<1\%$). We performed two analyses on EVR's results to assess his ability to orient attention from the various cue types. We first performed an analysis on his RTs to determine if he exhibited cuing effects for the three cue types; that is, we compared RTs on validly cued trials to RTs on invalidly cued trials. As one reviewer noted, however, such an analysis may be problematic because of serial effects in the RT data which violate the independence assumption of standard statistical tests. To overcome such difficulties, we also compared EVR's mean cuing effects to the control participants' cuing effects to determine if EVR differed from the control participants.

4.2.1. Cuing effect analysis: valid versus invalid trials

EVR's cuing effects were compared with *t*-tests between valid and invalid trials for each cue type. These cuing effects are plotted in Fig. 2, and, for the sake of completeness, all of EVR's RTs appear in Table 2.

Table 1
Control participants' mean RTs (in ms) for all conditions

Cue type	Peripheral		Word		Gaze	
	100 ms SOA	200 ms SOA	100 ms SOA	200 ms SOA	100 ms SOA	200 ms SOA
Valid	460.1 (22.4)	435.7 (23.8)	470.6 (17.1)	418.0 (20.1)	444.1 (24.4)	402.8 (21.2)
Invalid	503.2 (26.3)	460.2 (26.0)	474.3 (23.8)	441.5 (20.1)	461.5 (25.7)	429.0 (20.7)

Note: Standard errors appear in parentheses.

Table 2
EVR’s mean RTs (in ms) for all conditions

Cue type	Peripheral		Word		Gaze	
	100 ms SOA	200 ms SOA	100 ms SOA	200 ms SOA	100 ms SOA	200 ms SOA
Valid	436.8 (13.9)	383.2 (11.6)	469.3 (7.6)	421.1 (7.6)	467.7 (7.4)	435.6 (9.0)
Invalid	447.4 (8.4)	428.4 (11.5)	454.9 (10.5)	422.5 (17.6)	462.6 (12.6)	438.3 (15.7)

Note: Standard errors appear in parentheses.

EVR exhibited large cuing effects for peripheral cues, responding 28 ms faster to validly-cued targets than to invalidly-cued targets, $t(190) = 2.4$, $P < 0.02$. Unlike his responses to the peripheral cues, EVR did not exhibit any cuing effects for either word cues (he was 6.5 ms *slower* to detect validly-cued targets than invalidly-cued targets), $t(190) < 1$, or gaze cues (he was 2.4 ms *slower* to detect validly-cued targets than invalidly-cued targets), $t(190) < 1$. These failures to find cuing effects to word and gaze precues occurred despite these cues being highly predictive of the target’s location. Had EVR responded on the basis of the cue’s frequency only, he should have been faster to detect validly-cued targets than invalidly-cued targets. EVR’s lack of a cuing effect with word and gaze cues replicates previous work that demonstrates diminished attentional orienting from symbolic cues in patients with frontal-lobe damage (Alivisatos & Milner, 1989; Koski et al., 1998).

4.2.2. *Comparison to control participants*

For converging evidence of EVR’s lack of a cuing effect for the word and gaze cues, we compared his cuing effects to those from the control participants (see Fig. 2). We compared the control participants’ cuing effect against EVR’s cuing effect (i.e., we used EVR’s cuing effect as the hypothesized mean). For the peripheral cues, EVR’s cuing effect was well within normal limits (28 ms) and did not differ from the control participants’ cuing effect (33.5 ms), $t(9) < 1$. For the word and gaze cues, however, EVR’s cuing effect was significantly smaller than the control participants’ effects. For the word cues, the control participants had a 13.5 ms cuing effect and EVR had a −6.5 ms cuing effect, and these cuing effects were significantly different, $t(9) = 4.4$, $P < 0.005$. The gaze cues produced similar results: control participants had a cuing effect of 22.0 ms and EVR had a cuing effect of −2.4 ms, and these cuing effects were significantly different, $t(9) = 4.2$, $P < 0.005$. As with the above analysis of EVR’s RTs, EVR appears unable to orient attention voluntary symbolic cues such as words and eye gaze, suggesting that gaze cues may require voluntary, not automatic, attentional orienting.

5. Discussion

EVR demonstrated significant cuing effects to peripheral cues at short cue-target intervals, indicating that his spatial attention can be summoned ‘automatically’ to a peripheral location. However, EVR could not reliably use centrally-presented word cues to allocate visual attention to peripheral locations, despite preserved perception of these cues, replicating the results of previous studies that reported frontal-lobe patients’ inability to orient attention from symbolic cues (Alivisatos & Milner, 1989; Koski et al., 1998). Most important, EVR could not reliably allocate attention using eye gaze cues, indicating that gaze cues share attentional mechanisms with known voluntary cues such as words. Our findings indicate that there are at least two dissociable components to attentional orienting, automatic orienting from peripheral cues and voluntary orienting from symbolic cues. Gaze cues appear to affect attention in a voluntary or controlled manner, not in an automatic or reflexive manner. These results are supported by two separate analyses—a comparison of EVR’s reaction times and a comparison of EVR’s cuing effects to those of age-matched control participants.

One important issue to consider is if EVR might exhibit cuing effects for the word and gaze cues if given additional time to orient attention. That is, EVR’s impairment may be a slowing of attentional deployment following word and gaze cues (and, presumably, other symbolic cues). We have unpublished results that argue against a delayed orienting account. We tested EVR in a spatial cuing task that used longer delays between the cue and target (650 ms SOA) with eye movement monitoring and found that he was no faster to detect a validly-cued target than a neutrally-cued target for gaze cues (451.9 ms for validly-cued targets versus 441.1 ms for neutrally-cued targets, $P > 0.40$). Moreover, although EVR might have ‘sluggish’ attentional orienting, such an impairment does not affect our main point in this paper—that gaze cues orient attention in a voluntary, controlled manner, similar to word cues (and dissimilar to peripheral cues). If EVR’s attentional difficulties do stem from slowed attentional orienting, then orienting is slowed for both word and gaze cues but not for peripheral cues. Thus, a generalized slowing account would not explain our results fully, and the conclusion remains that word cues and gaze cues behave similar to each other and differently from peripheral cues. In general, this same conclusion holds for other differences among cue types, such as the possibility that gaze cues (and, presumably, word cues) are somehow less salient than peripheral cues.

There are other, alternative accounts that could explain our dissociation between automatic peripheral cues and gaze cues. As with the ‘sluggish’ attention alternative discussed above, these other alternative accounts do not fully explain the present results. For example, readers could be concerned with our use of schematic face stimuli and our procedure of presenting these faces briefly (as opposed to leaving them visible, as is done in many studies that examine cuing by gaze). However, schematic faces can readily direct attention in younger participants (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), and our control participants could direct attention from the gaze cue. Further, although our gaze and word cues were presented briefly, our control participants could orient from these cues; we also have unpublished results from younger participants that replicate the gaze-cuing effects using schematic stimuli that are presented briefly (Vecera, in preparation).

Another possible concern with the present results is that our gaze and word cues predicted the upcoming target's location on 75% of trials. Thus, these cues may have tapped endogenous (voluntary), not exogenous (automatic) attentional processes. Our failure to find gaze- and word-cuing effects in EVR could result if he had an impairment in allocating attention voluntarily; gaze cues could orient attention automatically in general, but this effect is absent in EVR because of a damaged endogenous control system. One difficulty with this interpretation is that the automatic, exogenous component of gaze cues should have elicited attentional orienting in EVR. Other studies have demonstrated that frontal-damaged patients show impairments in voluntarily orienting attention, even when valid cue appear as often as neutral cues (Alivisatos & Milner, 1989; Koski et al., 1998). Finally, in our unpublished results from EVR discussed above, we found that he exhibits intact orienting from unpredictive peripheral cues but not from unpredictive gaze or word cues, suggesting that his impairment in orienting attention voluntarily is not restricted to the use of predictive cues.

A further issue for discussion is if EVR's lesions are extensive enough to disrupt two attentional processes, one for orienting from word cues and one for orienting from gaze cues. Such an alternative explanation does not explain why EVR could orient from peripheral cues, which tap automatic orienting. Of course, one could propose separate mechanisms for automatic orienting to peripheral cues and gaze cues. However, our proposal that gaze cues tap voluntary attentional processes is more parsimonious than an account that proposes a unique automatic attentional process for gaze cues. Our proposal makes the strong prediction that orienting to symbolic cues and gaze cues should not be doubly dissociable. Studies of other patients will be required to test this prediction. Evidence against our position would need to show that attentional deficits are not caused by perceptual impairments. That is, to reflect an attentional impairment in using gaze cues, the perception of these gaze cues must be intact. Future work must also be sensitive to the possibility that some symbolic cues, such as arrows, might tap reflexive orienting: An arrow centered on fixation with an arrowhead to the left or right of fixation might capture attention in the direction the arrow points because the arrowhead falls closer to the validly cued target location than the invalidly cued target location. In general, although our present results strongly suggest that gaze cues rely on a voluntary orienting of attention, there are many unresolved issues regarding the status of gaze cues, and future studies might support a more 'automatic' status for gaze cues.

Two recent studies (Kingstone et al., 2000; Ristic, Friesen, & Kingstone, 2002) appear at odds with our strong claim that there should be no double dissociation between orienting from gaze cues and from word cues. In these studies, split-brain patients were able to use arrow cues to orient attention when those cues were presented in either visual field (Ristic et al., 2002), but these patients could use gaze cues to orient attention when those cues were presented in a single visual field (Kingstone et al., 2000). These two studies suggest that orienting attention (presumably voluntarily) from arrow cues occurs in both hemispheres whereas orienting attention (presumably reflexively) from gaze cues occurs in a single hemisphere only. Although these results are provocative, the hemispheric differences between arrow cues and gaze cues could be based upon perceptual processing differences. If face processes are more lateralized than processes for other stimuli such as arrows, then the nonspecialized hemisphere might be 'blind' to face and gaze stimuli and thereby prevent *any* attentional orienting. The results from split-brain patients are consistent with the conclusion that the perceptual inputs to a voluntary attentional orienting system are different for gaze cues and arrow cues. These studies have not, however, demonstrated differences in attentional orienting per se between gaze and arrow cues.

Our results and conclusions from EVR raise a question regarding studies of gaze cuing in neurologically normal participants. Why do studies of neurologically normal participants appear to indicate that eye gaze cues orient attention automatically (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999)? Normal participants are faster to respond to validly cued targets than invalidly cued targets, even when the validly cued targets appear on a minority of trials. However, in the studies just cited, only one cue (a small face) was presented. Neurologically normal participants may voluntarily orient attention from the gaze cue because there is only one cue and no competing information (e.g., another cue, such as a word or arrow). Participants might assume that they are expected to orient based on the gaze cue, and they adjust their behavior accordingly. One method for circumventing participants' strategies would be to present two central symbolic cues, such as a face and an arrow. When the two cues point in different directions, participants should orient toward the gazed-at location if gaze cues orient attention automatically. In a recent study (Vecera, in preparation), we displayed face and arrows cues together and found that approximately half of the participants use the gaze cue to orient attention and half use the arrow cue to orient attention, suggesting that gaze cues do not have a special status compared to other symbolic cues (e.g., words or arrows). These findings with normal participants provide converging evidence that suggests gaze cues may involve voluntary attentional orienting.

Although single-case studies can yield important neuropsychological information (Shallice, 1988), an ever-present concern is the generalizability of results. In EVR's case, the brain regions affected by his lesions are similar to those of other frontal-lobe damaged patients who have been studied in spatial cuing tasks (Alivisatos & Milner, 1989; Koski et al., 1998), and EVR's results replicate previous studies that have investigated word cues in larger patient groups (Alivisatos & Milner, 1989). Thus, EVR exhibits reduced cuing effects following symbolic cues as do other frontal-lobe patients, suggesting that he is not an isolated case.

Some patients with frontal-lobe damage have impairments in theory-of-mind tasks (Channon & Crawford, 2000; Rowe, Bullock, Polkey, & Morris, 2001; Stone, Baron-Cohen, & Knight, 1998; Stuss, Gallup, & Alexander, 2001). EVR's impairment in orienting attention from eye gaze cues could be explained by such an impairment. However, a theory-of-mind impairment does not readily explain EVR's inability to orient from word cues. Based on EVR's results, and the results from other frontal patients, it appears that voluntary attentional control processes may be disrupted following frontal-lobe damage. Such attentional control processes are necessary for a wide range of cognitive performance, including spatial orienting from symbolic cues and, perhaps, making predictions about others' behavior that some refer to as a 'theory-of-mind.' Given the proximity between brain mechanisms for voluntary attentional control and for 'theory-of-mind' tasks (Frith & Frith, 1999; Shallice, 2001), at least some 'theory-of-mind' impairments might reflect impairments in the voluntary control of selective attention. The present results indicate that sensitivity to social information, such as gaze direction, and sensitivity to evolutionarily-recent symbolic information, such as words, appear to require voluntary attentional processes.

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