

Research note

Eye gaze does not produce reflexive shifts of attention: Evidence from frontal-lobe damage

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Abstract

Humans are able to predict the behavior of others using visual information. Several studies have argued that social cues, such as eye gaze direction, can influence the allocation of visual attention in a reflexive manner. We have previously shown that a patient with frontal-lobe damage, patient EVR, can use peripheral cues to direct attention but cannot use either word cues or gaze cues to allocate attention. These findings suggest that ‘social attention’ may involve frontal-lobe processes that control voluntary, not automatic, shifts of visuospatial attention. In the current paper, we further examine ‘social attention’ in EVR and demonstrate that his failure to orient attention voluntarily cannot be attributed to either cue predictability or a ‘sluggish’ attentional system. EVR exhibits a general impairment in orienting attention endogenously, and this impairment includes orienting from gaze cues. Gaze cues direct attention in a voluntary, not a reflexive, manner.

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1. Introduction

Humans, and perhaps other higher-primates, appear to interpret another individual’s behavior by assuming that other individuals have mental states—in short, a mind—responsible for this behavior. This assumption has been referred to as a “theory of mind” (Baron-Cohen, 1995; Leslie, 1991; Premack & Woodruff, 1978). Theory of mind theories typically propose several component processes that allow individuals to attribute mental states to one’s self and to others (see Baron-Cohen, 1995). Of these component processes, eye gaze direction is thought to be a key determinant of social interactions for several reasons, including the presence of a biological basis of gaze perception (see Hoffman & Haxby, 2000; Kanwisher, McDermott, & Chun, 1997; Perrett, Hietanen, Oram, & Benson, 1992; Perrett et al., 1985; Vecera & Rizzo, 2004) and the early developmental emergence of gaze perception abilities (Vecera & Johnson, 1995).

Gaze direction is important in predicting others’ behavior because it appears to signal the upcoming target or goal of another person’s behavior, which helps predict behavior. In this vein, 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). Humans are also able to use gaze direction to orient attention: several studies have demonstrated that humans’ spatial attention is influenced by another’s gaze direction in what is termed ‘social attention’ (Driver et al., 1999; Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Kingstone, Friesen, & Gazzaniga, 2000; Langton & Bruce, 1999, 2000).

Social attention studies have drawn substantial evidence that attention can be directed to peripheral locations by different types of cues that appear before a target stimulus appears (Posner, 1980; Posner, Snyder, & Davidson, 1980). In Posner’s spatial cuing task, participants detect a visual target that appears at a peripheral location. Prior to the target, a

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cue appears. “Valid” cues correctly predict a target’s subsequent location, whereas “invalid” cues are inaccurate and cue a location in which the target will not appear. Reaction times (RTs) are faster to detect validly cued targets than invalidly cued targets.

Two types of attentional orienting have been identified in this task, exogenous orienting and endogenous orienting (Klein, Kingstone, & Pontefract, 1992; Klein & Shore, 2000). Exogenous orienting occurs in response to events in the environment (i.e., outside the viewer), whereas endogenous orienting occurs in response to internal factors, such as intentions, goals, and expectancies. Exogenous and endogenous attentional orienting are thought to occur in response to different cue types. *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 that do not predict the location of an upcoming target tap exogenous attention and appear to orient spatial attention automatically or reflexively (Jonides, 1981; Jonides & Yantis, 1988; Yantis, 1998; Yantis & Jonides, 1984). Such peripheral cues cannot be ignored and are not interfered with by symbolic cues (Jonides, 1981; Müller & Rabbit, 1989) and 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 tap endogenous attention because typically they require participants to shift attention voluntarily to the cued location. 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).

Previous research on social attention has focused on whether gaze cues orient spatial attention reflexively (exogenously) or voluntarily (endogenously). Because of the importance of using eye gaze to infer mental states of others, one might expect gaze cues to be particularly potent in orienting attention to gazed-at locations. That is, gaze should orient attention reflexively. Indeed, this prediction has been supported by several studies, which find that targets appearing at a gazed-at location are processed faster and more accurately than targets appearing elsewhere, even when eye gaze is unpredictable (e.g., Friesen & Kingstone, 1998) or counter-predictive (Driver et al., 1999; Langton & Bruce, 1999) of the target’s location.

Although several studies have suggested that social attention operates in a reflexive (exogenous) manner, neuropsychological evidence suggests that social attention may involve controlled (endogenous) processes. Frontal-lobe areas have been implicated in voluntary control of cognitive and attentional processes. Not only do frontal-lobe patients exhibit general cognitive control impairments (Kimberg, D’Esposito, & Farah, 2000; Miller & Cohen, 2001), they also exhibit specific impairments with attentional control.

Frontal-lobe patients show difficulties in resisting distracting information (Chao & Knight, 1995), sustaining attention (Wilkins, Shallice, & McCarthy, 1987), and using advance information to direct attention from centrally presented arrow or word cues (Alivisatos & Milner, 1989; Koski, Paus, & Petrides, 1998). Further, the attentional operations that typically depend on frontal-lobe circuits—Posner’s anterior attention system (Posner & Petersen, 1990)—can be characterized as voluntary, endogenous operations.

Interestingly, the brain regions most heavily implicated in ‘theory of mind’ are frontal-lobe areas that, broadly, appear to be involved in cognitive and attentional control. There have been several reports of theory of mind impairments following frontal-lobe damage (e.g., Mah, Arnold, & Grafman, 2004; Stuss, Gallup, & Alexander, 2001) and frontal-lobe involvement in theory of mind tasks during neuro-imaging (see Frith & Frith, 1999; Shallice, 2001). There also appear to be theory of mind impairments in frontal-lobe variants of Alzheimer’s disease (Gregory et al., 2002). Thus, there seems to be a disconnect between claims of social attention being reflexive and the controlled cognitive and attentional operations supported by the frontal-lobe regions that appear to be involved in theory of mind tasks.

To determine if eye gaze cues orient attention in a reflexive or voluntary manner, we recently investigated attentional orienting in a patient with orbitofrontal damage (Vecera & Rizzo, 2004). This patient, EVR, had regions of both frontal-lobes excised during removal of a tumor and subsequently exhibited social impairments that could be likened to an acquired sociopathy (Eslinger & Damasio, 1985; Tranel, Damasio, & Damasio, 1995). EVR performed a simple spatial cuing task in which he detected the onset of a target that appeared in the visual periphery. 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), and 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. We found that EVR was able to orient attention from peripheral cues, even though these peripheral cues were not predictive of the target’s location, suggesting that EVR had intact exogenous orienting. However, EVR was unable to orient attention from either word cues or gaze cues, despite the fact that these cues predicted the target’s location on a majority of trials (i.e., these cues were 75% valid and 25% invalid), suggesting that EVR had a general impairment in voluntary, or endogenous, orienting. We concluded that social attention generally involves voluntary orienting, not involuntary or reflexive orienting.

Despite our strong evidence for voluntary social attention, there were three possible alternative explanations that could explain EVR’s impairment in orienting attention from gaze cues.

The first alternative explanation is that in our cuing task, the word and gaze cues were presented briefly (100 ms). Other studies of social attention have presented gaze cues until participants respond (e.g., Driver et al., 1999; Friesen &

Kingstone, 1998), which minimizes the large luminance transient that results when a stimulus abruptly appears (e.g., as when a face stimulus is presented at fixation) and permits the direction of gaze to be fully encoded. Our use of a brief presentation of the word and gaze cues might have captured EVR's attention at fixation and slowed the deployment of an otherwise reflexive social attentional process. Additionally, the 100 ms exposure duration may have been too brief for EVR to perceive, although our previous control data from EVR should exclude this possibility.

The second alternative explanation is that our procedure relied on short temporal delays between the cue and target (stimulus onset asynchronies (SOAs) of 100 or 200 ms). EVR may be slow to shift attention from a central cue to a peripheral target, making these SOAs too brief to observe attentional effects at peripheral target locations. This 'sluggish' attentional shift could be independent of whether a cue oriented attention in a reflexive or voluntary manner.

The third alternative explanation is that our use of predictive gaze cues caused these cues to tap voluntary, endogenous orienting processes, instead of the reflexive, exogenous processes normally tapped by gaze cues. Although one would expect that if gaze cues were reflexive, then predictive gaze cues should retain a reflexive component in addition to a voluntary component, it might be that our highly predictive gaze cues outweighed reflexive orienting.

The goal of the current experiment was to examine these alternative explanations. EVR again performed a spatial cuing task in which targets appeared at validly and invalidly cued locations, and three cue types were investigated: peripheral, word, and gaze cues. The peripheral cues replicated our previous work; these cues were not predictive (50% valid and 50% invalid) and had short cue-to-target SOAs (100 and 200 ms). The word cues remained predictive (75% valid and 25% invalid), as in our previous paper. However, we made two changes to the word cues: (1) we extended the SOAs to 200 and 700 ms to determine if EVR could orient attention voluntarily if given sufficient time and (2) we kept the word visible for the duration of the trial to permit EVR to overcome the transient associated with the cue onset and encode the direction of the cue. Finally, the gaze cues were modified so that (1) they were not predictive (50% valid and 50% invalid), (2) they had long cue-to-target SOAs (200 and 700 ms) as did the word cues, and (3) they remained visible throughout the trial to permit EVR to overcome the transient associated with the cue's appearance and to encode the gaze direction.

Based on our earlier results, we predicted that EVR would remain sensitive to unpredictable peripheral cues and show faster RTs to validly cued targets than to invalidly cued targets. If EVR's impairments are to a voluntary (endogenous) orienting system, then the word and gaze cues should replicate our previous results. Specifically, EVR should fail to show a cuing effect following either word or gaze cues. However, if our previous procedures obscured a reflexive social attention process, then EVR should exhibit a cuing effect with the gaze cues but not with the word cues.

2. Case report

Detailed discussions of EVR can be found in several sources (e.g., Eslinger & Damasio, 1985; Tranel et al., 1995), including our previous study (Vecera & Rizzo, 2004). EVR's abilities and impairments typically have remained stable throughout testing. For example, his intelligence has remained stable and in the superior range across 13 years (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 do the executive functions tapped by the Wisconsin Card Sort task, the Stroop task, and the Tower of Hanoi puzzle (see Bechara, Damasio, Tranel, & Anderson, 1998). At the time of the current testing, EVR was 64 years old. EVR's 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.

3. Method

3.1. Participants

Both EVR and 10 older control participants performed a spatial cuing task 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 64.2 years (S.D. = 11.7 years).

3.2. Stimuli

The general methods are similar to those in Vecera and Rizzo (2004). Participants sat approximately 60 cm from a Macintosh iMac computer (15" monitor). Each trial began with a central fixation point and two 0.95° square 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 a placeholder box, and these cues appeared unilaterally 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 by 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.

To ensure that EVR could perceive all of the cues effectively, he performed the control task used in our previous study. EVR viewed a series of each cue type 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.

3.3. Procedure

In the spatial cuing task, each trial began with the fixation point and placeholder boxes visible for 1000 ms. Peripheral cues were presented for 100 ms and then extinguished. Peripheral cues were either followed immediately by a target (100 ms SOA) or by a 100 ms delay and then a target (200 ms SOA); these SOAs were intermixed and appeared equally. Word and gaze cues remained visible until EVR responded to the target. After the onset of either a word or gaze cue, there was either a 200 ms delay or a 700 ms delay before the target appeared (i.e., SOAs of 200 ms and 700 ms). The SOAs for each cue type were intermixed and appeared equally. For all cue types, 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 as quickly as possible when they detected the onset of the target.

Because the long cue-to-target intervals with the word and gaze cues are within the range of eye movements, we monitored participants' fixation position, including EVR's, to prevent any anticipatory eye movements to the cued location. These procedures were identical to those in our previous report. Eye movements were monitored 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 each 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 trials that contained a visible eye movement were excluded from further analyses. Across all participants, including EVR, eye movements excluded 5% of the total 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, gaze cues, and word cues. Control participants received blocks in the

same order as EVR to ensure that EVR's results were not due to order effects. 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 a rest after every 54 trials (48 target trials plus 6 catch trials). All trials were presented randomly. Again, peripheral and gaze cues were unpredictable (50% valid and 50% invalid), but word cues were predictive (75% valid and 25% invalid).

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. There were three control blocks, one for each cue type, and there were 24 trials in each control block.

4. Results

4.1. Control participants

Reaction times over 1500 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%). All RTs for the control participants appear in Table 1, which shows that the control participants exhibited cuing effects for each of the cue types. For both word and gaze cues, the control participants showed significant cuing effects, collapsing across both SOAs. In the word cue condition, validly cued targets were detected faster than invalidly cued targets (442.8 ms versus 450.1 ms, respectively), $t(9) = 2.9$, $p < .02$. Similarly, in the face cue condition, validly cued targets were detected faster than invalidly cued targets (444.4 ms versus 459.6 ms, respectively). $t(9) = 2.4$, $p < .05$. We should note that although the cuing effect for gaze stimuli is relatively small, such small effects consistent with the effect sizes reported in studies with college-aged participants. Finally, for peripheral cues, the control participants exhibited a cuing effect for the short SOA (100 ms); validly cued targets were detected faster than invalidly cued targets (449.8 ms versus 469 ms, respectively), $t(9) = 2.5$, $p < .04$. The control participants did not exhibit a

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

	Peripheral		Word		Gaze	
	100 ms SOA	200 ms SOA	200 ms SOA	700 ms SOA	200 ms SOA	700 ms SOA
Cue type						
Valid	449.8 (27.1)	433.1 (26.4)	425.8 (24.4)	459.9 (24.9)	434.4 (25.2)	454.4 (20.2)
Invalid	469.0 (27.1)	426.3 (26.0)	439.5 (28.0)	460.7 (21.4)	450.7 (25.7)	468.6 (31.3)

Note: Standard errors appear in parentheses.

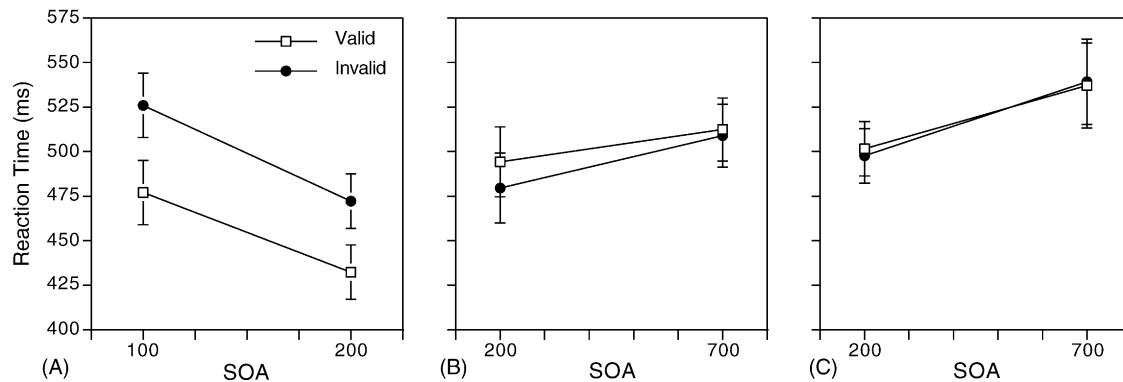


Fig. 1. EVR's results for (A) peripheral cues, (B) word cues, and (C) gaze cues. EVR exhibits statistically significant cuing effects for peripheral cues but not for word or gaze cues. Error bars are 95% confidence intervals on the valid–invalid comparison at each SOA.

cuing effect at the long SOA (200 ms). Here, validly cued targets were detected slightly slower than invalidly cued targets (433.1 ms versus 426.3 ms, respectively), although this difference was not significant, $t(9) = 1.2$, $p > .25$. The lack of a cuing effect with the peripheral cues at the long SOA was likely because inhibition of return (IoR) had started to emerge. IoR can emerge as early as 200 ms following the onset of a peripheral unpredictable cue (see Posner & Cohen, 1984).

As in our previous paper (Vecera & Rizzo, 2004), individual control participants showed a pattern of results that was consistent with the averaged group responses. Overall, the results from the control participants generally replicate previous studies using spatial cuing tasks and replicate our previously reported results (Vecera & Rizzo, 2004). Demonstrating these cuing effects in control participants is important because it indicates that our procedure is sensitive to such attentional effects in older control participants. Moreover, these results suggest that the order of presentation of the different cue types cannot explain any discrepancies between the control results and EVR's results.

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 the control participants, RTs over 1500 ms were excluded from the analyses, and this trimming excluded less than 1% of the data. EVR made one catch trial error in the entire experiment.

EVR's mean RTs for each cue by SOA condition appear in Fig. 1. As is evident from this graph, EVR shows a clear cuing effect following peripheral cues, but no cuing effects following word or gaze cues. These findings replicate our previous observations. We corroborated these conclusions by comparing RTs on validly cued trials to RTs on invalidly cued trials for each SOA for the three cue types. We also compared EVR's current pattern of results to those he exhibited in our previous study.

For peripheral cues, EVR detected validly cued targets faster than invalidly cued targets at both the 100 ms SOA (477.0 ms versus 525.9 ms), $t(93) = 2.7$, $p < .01$, and at the 200 ms SOA (432.3 ms versus 472.2 ms), $t(93) = 2.6$, $p < .01$. Interestingly, EVR continued to show a cuing effect at the 200 ms SOA, whereas the control participants exhibited some degree of inhibition of return at this delay. This difference between EVR and the control participants is beyond the scope of the current paper, but these observations are consistent with recent reports, which suggest that orbitofrontal cortex is involved in inhibition of return (Hodgson et al., 2002).

For word cues, EVR failed to exhibit a cuing effect, replicating our previous observations. At the 200 ms SOA, his RT for detecting validly cued targets was 494.2 ms, and on invalidly cued targets his detection time was 479.5 ms; this difference was not statistically significant, $t(92) < 1$. Similarly, at the 700 ms SOA his RT for detecting validly cued targets was 512.4 ms, and on invalidly cued targets his detection time was 508.9 ms; this difference was not statistically significant, $t(85) < 1$. Finally, for unpredictable gaze cues, EVR failed to exhibit a cuing effect, replicating our previous observations with predictive gaze cues. At the 200 ms SOA, his RT for detecting validly cued targets was 501.6 ms, and on invalidly cued targets his detection time was 497.6 ms; this difference was not statistically significant, $t(87) < 1$. Similarly, at the 700 ms SOA his RT for detecting validly cued targets was 537.0 ms, and on invalidly cued targets his detection time was 539.2 ms; this difference was not statistically significant, $t(85) < 1$.

The current pattern of cuing effects (invalid minus valid RTs) parallels our previous report from EVR, and the cuing effects from both studies appear in Fig. 2. In both studies, EVR shows a large cuing effect with peripheral cues, but no significant cuing effects with either word or gaze cues. The absence of a cuing effect with word and gaze cues replicates previous studies which have reported that frontal-lobe patients appear unable to orient attention from centrally presented symbolic cues, such as arrows or words (Alivisatos & Milner, 1989; Koski et al., 1998).

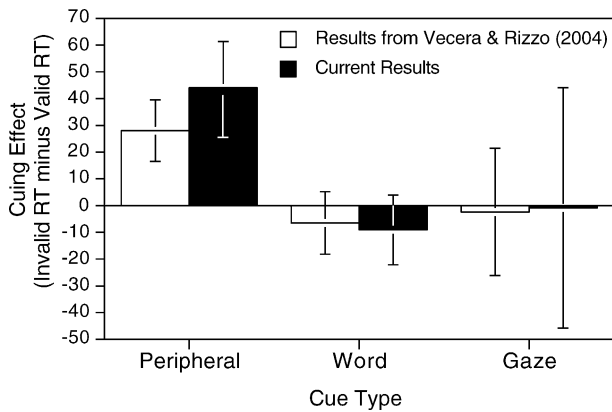


Fig. 2. Comparison of EVR's current results (unpredictive peripheral cues and gaze cues; predictive word cues) with his results from our previous work (unpredictive peripheral cues; predictive gaze and word cues). EVR shows the same overall pattern of results, irrespective of the cue predictability and SOA differences across the studies, suggesting that EVR has a lasting impairment in orienting attention voluntarily from centrally presented symbolic cues.

Finally, one pattern of results shown in Fig. 1 deserves mention. EVR, unlike college-aged participants, shows longer RTs at the longer SOAs in the word and gaze conditions. College-aged participants typically show a reversed pattern, with faster RTs at longer SOAs, a result that is likely caused by increases in alertness or expectancy over time. Our older control participants show the same effect (see Table 1), suggesting that expectancy effects may decline with normal aging.

5. Discussion

EVR demonstrated significant cuing effects to peripheral cues at short cue–target intervals, indicating that his spatial attention can be summoned rapidly to a peripheral location. However, EVR could not reliably use centrally presented word or gaze cues to allocate visual attention to peripheral locations. This failure to use central cues occurred despite experimental conditions that increased the opportunity of seeing a cuing effect in these conditions. Specifically, for both word and gaze cues, we lengthened the longest SOA to 700 ms, and we allowed the cue word to remain visible throughout the trial. Additionally, for gaze cues we made the cues unpredictable to minimize the possibility that our previous use of predictive gaze cues somehow obscured the operation of a reflexive social attention process. The current results replicate both our previous findings from EVR and previous studies that reported frontal-lobe patients' inability to orient attention from symbolic cues (Alivisatos & Milner, 1989; Koski et al., 1998). The current pattern of results continues to suggest that gaze cues share attentional processes with known voluntary cues such as words. Both word and gaze cues appear to orient attention through voluntarily, endogenous processes, and this endogenous component is disrupted in

EVR. Peripheral cues orient attention via automatic, exogenous processes that are intact in EVR.

The current results answer important questions that were raised regarding our first report from EVR. EVR's inability to use gaze cues is unlikely to be the result of a sluggish attentional process that disproportionately affects word and gaze cues. Further, our previous lack of a gaze cuing effect was not due to our use of predictive cues. EVR failed to show a gaze cuing effect with the non-predictive gaze cues used here. There does, however, remain one lingering issue: it might be possible that EVR's lesions are extensive enough to disrupt two attentional processes, one for orienting from word cues and one for orienting from gaze cues (Vecera & Rizzo, 2004). Such an alternative explanation would require the unsupported assumption that processing of peripheral cues in EVR relies on yet another intact attentional process, a view that is less parsimonious than our account in which attention is oriented through two control processes—exogenous (automatic) and endogenous (voluntary) processes (also see Klein et al., 1992; Klein & Shore, 2000; Posner & Petersen, 1990). The current results continue to support the prediction that orienting to symbolic (e.g., word) cues and gaze cues should not be doubly dissociable, provided that secondary problems (e.g., perceptual impairments) do not produce the dissociation (for extensive discussion on this point see Vecera & Rizzo, 2004).

Another relevant issue is if EVR is somehow special in his loss of orienting from both word and gaze cues. Do EVR's results generalize to other patients with orbitofrontal damage? As we have discussed elsewhere (Vecera & Rizzo, 2004), the brain regions affected by EVR's 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), suggesting that EVR is unlikely to be isolated or special case. Of course, data from other orbitofrontal patients will ultimately decide this issue.

5.1. An 'association' hypothesis

Given our current and previous results from EVR, one might speculate that both word and gaze cues are socially relevant and that EVR, and perhaps other patients with orbitofrontal damage, have general deficits in attending to socially relevant stimuli. Although such an account is theoretically interesting, it does not contain an explanatory mechanism by which these socially relevant cues direct attention. If both word and gaze cues were socially relevant stimuli, such stimuli could continue to orient attention in a voluntary, endogenous manner, not in a reflexive, exogenous manner. Thus, postulating that words, like gaze direction, are socially relevant does not explain away our evidence for voluntary shifts from word and gaze cues.

A more straightforward view of our results from EVR is that orbitofrontal areas are responsible for learning various associations, including the associations between words and the locations to which they refer and between gaze direction

and the locations to which they ‘refer’ (i.e., point). These associations may involve an unclear, unreliable, or perhaps arbitrary relationship between the symbol (word or gaze) and the location to which the symbol refers. We propose that damage to orbitofrontal cortex might impair attentional orienting because either (1) associations cannot be acquired during an experiment for the purpose of directing attention or (2) previously learned associations cannot be used to direct attention. In either case, damage to orbitofrontal cortex would result in attentional impairments (also see Tranel et al., 1995). Our results cannot disentangle these two mechanisms, although such issues might be examined using training studies in which participants learn novel cue–target associations.

Our proposal for attentional impairments following EVR’s orbitofrontal damage is consistent with neurobiological approaches to orbitofrontal cortex, which show that this brain region is important for learning about the reward contingencies of various stimuli, including visual stimuli, and for guiding behavior when these contingencies change (see Krangelbach & Rolls, 2004; Rolls, 2000, 2004). These reward contingencies apply to both social and non-social stimuli and events. For example, patients with orbitofrontal damage have difficulties learning contingency reversals in non-social gambling tasks (Bechara, Tranel, & Damasio, 2000; Fellows & Farah, 2003; Hornak et al., 2004), and fMRI studies of orbitofrontal cortex demonstrate a role for this area in learning contingency reversals generally (O’Doherty, Krangelbach, Rolls, Hornak, & Andrews, 2001), including reversals of social stimuli (Krangelbach & Rolls, 2003). The emotional disturbances that follow damage to orbitofrontal cortex, such as those exhibited in the classic case of Phineas Gage (Harlow, 1848) and, to a lesser extent in EVR (Eslinger & Damasio, 1985), could also be the result of a breakdown of learned associations. The classic James–Lange theory of emotion (e.g., James, 1890), recently revived and extended in Damasio’s (1994, 1999) somatic marker hypothesis, suggests that emotional experience involves the association between an emotional stimulus (e.g., a tiger) and the physiological signals produced by that stimulus (e.g., increased heart rate and muscle tension).

The finding that younger, neurologically normal participants appear to orient attention reflexively in response to gaze (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999) and perhaps arrows (Hommel et al., 2001) is readily explained by our ‘association’ proposal. Both gaze direction and arrows are highly over-learned stimuli in which there are repeated presentations of the stimulus (gaze or arrow) and a consequence (reinforcer or punisher) at the corresponding location. Based on this learning history, both gaze and arrow cues are rapidly accessible for deploying attention, particularly when there are no competing cues (e.g., two cues pointing in different directions). Although gaze cues (and perhaps arrow cues) appear to direct attention reflexively under such conditions, this apparent reflexivity simply may be the result of over-learning the association between

the cue and its referent (i.e., the location to which the cue refers). Importantly, such a rapid deployment of attention independent of the cue predictability is only one criterion for assessing the reflexivity of attentional orienting (see Jonides, 1981), and other criteria should be examined. We have unpublished results that suggest unpredictable gaze cues do not direct attention to a peripheral location when an arrow cue incompatible with the gaze direction appears above the gaze cue. Peripheral cues can continue to direct attention in the face of an incompatible arrow cue, however (Müller & Rabbit, 1989). One straightforward explanation of our results is that the pairing of incompatible gaze and arrow cues creates a conflict between two over-learned associations—the association of the gaze direction and the location to which it refers and the arrow direction and the location to which it refers.

A natural question regarding our association proposal is why gaze, word, and arrow cues generally involve voluntary, not reflexive, shifts of attention. These cues might involve voluntary attentional processes for at least two reasons. First, such cues are acquired by learning and do not have a direct, explicit association with a location, unlike peripheral cues which appear at a specific location. In short, gaze, word, and arrow cues are under constrained in that they provide no information regarding the magnitude of an attentional displacement into the periphery. Leftward gazing eyes, the word ‘left,’ or a leftward pointing arrow each indicate ‘left-ness,’ but they do not indicate the specific location that should be attended (e.g., how far left). Although the amount of displacement of the iris can provide some location information regarding an object, the distance to this object (i.e., is it close to or far from the person?) remains unclear. In the context of the stimuli used in gaze cuing studies, leftward gazing eyes do not tell an observer if a target will appear at a near location or at a far location along the path of gaze. Second, gaze, word, and arrow cues may be subject to occasional reversals or ambiguities between the cue and the location to which the cue refers. For example, individuals can use gaze direction to deceive others. Arrows do not always have a direct relationship to the environment, as when arrows appear on a building directory to guide visitors to an information booth. Because of these possible violations of the cue–location relationship, these cues might tap voluntary attentional process to allow individuals to modify their use of the cue depending on context, current behavioral goals, or the anticipated intentions of others.

5.2. Reflexive and voluntary orienting

Although we can argue convincingly for why gaze and word cues might rely on voluntary orienting processes, there are other factors that might distinguish gaze cues from word cues. For example, gaze can be dynamic, as when someone moves her eyes from a central gaze to an averted gaze. An observer viewing a dynamic movement of gaze might be more captured by gaze than when gaze is static, as in

our current stimuli. In our current study, EVR may fail to use gaze cues because our stimuli were static; when the face stimuli appeared, the eyes were already averted to a peripheral location. It is possible that EVR could exhibit gaze cuing effects from dynamic cues, thereby demonstrating a dissociation between gaze cues and word cues. Although this is an intriguing possibility, there are no data to support it. Both younger participants and our older control participants orient readily from static gaze cues. Moreover, experiments investigating dynamic gaze cues need to be cautious: dynamic (i.e., moving) gaze cues could direct attention based on the onset of movement (Abrams & Christ, 2003) and might have little to do with the ‘special’, or ‘reflexive’ nature of gaze cues. Indeed, in developmental studies of so-called social attention, infants’ ability to orient from gaze cues (Hood, Willen, & Driver, 1998) has been shown to be a consequence of orienting to directional motion, not gaze direction (Farroni, Johnson, Brockbank, & Simion, 2000).

Some might argue that a simple ‘voluntary’ versus ‘reflexive’ (or automatic) dichotomy may be too simplistic because these modes of orienting mutually influence one another. This mutual influence makes it difficult to disentangle the two modes of orienting. For example, several studies have demonstrated that abruptly appearing peripheral cues, thought to be automatic, can nevertheless be influenced by expectations, context, and other more voluntary characteristics of attention (e.g., Folk, Remington, & Johnston, 1992; Yantis & Jonides, 1990). One could argue that gaze cues direct attention automatically, but that these cues can be influenced by voluntary attention, and such an influence is what we have observed in EVR.

We agree that more automatic cues (e.g., peripheral onset cues) can be modulated expectations and context. However, we claim that such modulation need not be invoked to understand EVR’s results (or results from college-aged participants). Instead, we claim that gaze cues do not direct attention reflexively. This view is simpler than proposing that gaze cues are reflexive but under some form of higher-level control. Moreover, we should point out that most of the social attention literature has tended to assume a simple dichotomy between ‘automatic’ and ‘reflexive,’ as evidenced by the titles of papers in this field which claim that gaze triggers reflexive shifts of attention (Driver et al., 1999; Friesen & Kingstone, 1998, 2003; Hood et al., 1998; Kingstone et al., 2000; Langton & Bruce, 1999) or that the eyes may be ‘special’ in directing attention (Ristic, Friesen, & Kingstone, 2002). Before accepting more complex theoretical views, such as one involving modulation of reflexive orienting, it seems prudent to explore a voluntary orienting hypothesis for gaze cues. Only when such a view can be readily refuted should the modulation hypothesis be explored.

5.3. Conclusions

Our view that gaze cues direct attention voluntarily does not diminish the theoretical interest or the importance of such

cues. Indeed, our association account proposes a theoretically novel perspective on such cues and relates them to a specific learning process that appears to have a biological basis in orbitofrontal cortex. Based on this theoretical view, the next generation of studies on so-called ‘social’ attention could more closely examine the learning of new associations (e.g., between an arbitrary color and a location), reversals of these associations, or weakening these associations.

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