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Does gaze perception facilitate overt orienting?

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Recent studies have demonstrated the facilitation of responses to peripheral targets cued by the direction of the gaze of a face. However, in the absence of data from an eye tracker, it has been unclear to what extent these effects are due to the participants making small saccades in response to the cue that bring them closer to the congruent location of the cued targets. We used an eye tracker to show that while such cue-driven saccades occur, they do not account for the main cueing effects observed. Additionally, by using the same general paradigm as has previously been used with infants, we suggest that different mechanisms underlie eye gaze cueing effects in infants and adults.

When attention is directed toward a particular location, the visual processing of targets in that location is facilitated, resulting in faster reaction times to detect or discriminate targets at that location than in locations that are not cued (Posner & Cohen, 1980). Several recent studies with adults have demonstrated that the direction of gaze of a face can cue visuospatial orienting in a viewer (e.g., Driver et al., 1999; Friesen, & Kingstone, 1998; Langton & Bruce, 1999). For example, Driver and colleagues manipulated the direction of gaze of a computerized face and found that judgements about a peripheral letter discrimination task were faster when the targets were in a location congruent with the direction of gaze. This effect was observed even when participants knew that the target letters were more likely to be presented in a location opposite to that cued by the eye gaze direction. In these and other related experiments, participants' eye movements were not closely monitored, leading Driver and colleagues to state that they could not discriminate between covert and overt orienting explanations of their results, and that in future it would be useful to monitor saccadic movements

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during such tasks. In addition to the problem of dissociating between overt and covert explanations of the cueing effect, the lack of monitoring of participants' eye movements raises the possibility of a simpler explanation for the results obtained. This possibility is that participants sometimes made saccades directly in response to the pupils of the eyes of the computer face being directed to the left or right. Such small gaze shifts could be hard to detect without an eye tracker, and may bring the location of the target closer to, or further from, the fovea, thus causing or contributing to the facilitated response times. Some evidence consistent with this possibility comes from the fact that, contrary to other spatial attention cueing paradigms, in some experiments (e.g., Driver et al., 1999, Exp. 2) the gaze cueing effect was most evident at longer SOAs (300 and 700 ms). Driver et al. interpret this delayed facilitatory effect as being due to the time required to perceive and process the direction of eye gaze. However, it is also possible that this time is necessary for the effects of small saccades in the direction of the pupil to be made. Langton and Bruce (1999) obtained similar results to those of Driver et al. (although it should be noted that their facilitatory effects occurred at a short SOA, 100 ms). In an attempt to rule out effects in which the participants attention or gaze is directed closer to the cued target location as a direct result of the different location of the pupils in the computerized face, these authors conducted an experiment with an inverted face cueing stimulus. The results of this experiment were somewhat inconclusive, and in their General Discussion the authors conclude that ''it is equally possible that the head cues produce an overt reflexive saccade in the cued direction so as to foveate the potential location of the target. The cueing effects would then represent an RT advantage on valid trials because of increased foveal sensitivity at the cued locations'' (Langton & Bruce, 1999, p. 563). Thus, there are at least three possible explanations for the cueing effects resulting from eye gaze shifts: (1) Covert shifts of attention, (2) overt shifts of attention (orienting) expressed when the target is presented, and (3) saccades that bring the fovea closer to the valid target location before it appears.

In addition to studies with adults on the effects of the perception of eye gaze, there has also been research on the effects on orienting of infants' perception of gaze direction. These experiments are mainly concerned with issues relating to the ''modular'' or otherwise nature of gaze processing, and its importance for early social development (e.g., Baron-Cohen, 1995). Unlike the experiments with adults, the studies with infants have clearly depended upon overt orienting of saccades toward targets that are either congruent or incongruent with the direction of gaze of a central computerized face (e.g., Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998). At present it is unknown whether or not the mechanisms underlying the cueing effect observed in infants are the same as those investigated in adults. However, Farroni et al. (2000) presented evidence that perceiving the motion of an eye gaze shift was critical for infants, and demonstrated that the effect was not present in situations where there was no motion, or apparent motion, of the eyes. Although most experiments demonstrating cueing in adults have used static presentations of averted gaze, there are also many other differences between the paradigms used. Since it is not feasible to administer adult covert paradigms to pre-verbal infants, for comparison between age groups it is necessary to test adults in versions of the infant paradigms.

In the present experiment, in which we carefully monitored adult participants' eye movements with an eye-tracker, we address these issues in several ways. First, we assess whether adults show facilitatory effects in overt orienting to peripheral targets as a result of the perception of gaze (target-driven saccades). Although the general paradigm we used closely followed that previously used with infants, the stimulus presentation sequence did not involve motion of the eyes, and is known not to elicit a cueing effect in infants. It therefore allows us to compare adult and infant performance. Second, we examine the extent to which shifts of gaze in a computerized face directly elicit small saccades in viewers (cue-driven saccades). Cue-driven saccades could provide a basis for the fovea being closer to targets presented in the cued location. Third, we assess whether there is still an effect of the computerised face gaze shift on target-driven saccades when cue-driven saccades are excluded. If there is still an effect, we can rule out cue-driven saccades as a basis of the ''attentional'' cueing effect.

METHOD

Subjects

Twelve adult participants, six male and six female, volunteered for this study. The mean age was 24.8 years (range 18–34 years). All participants were healthy and free from any known neurological or ocular abnormality.

Procedure

The participants sat in a dimly lit room 90 cm distant from a 39 cm $\times$ 29 cm (a visual angle of 23.4° $\times$ 17.8°) monitor screen. Participants eye movements were measured using an Applied Science Laboratory Model 504, 50 Hz corneal reflection eye tracking system which is accurate to 0.5° following 9-point calibration. This system uses a remote pan/tilt infra-red camera, which was centrally positioned on a table in front of the stimulus display monitor, and 70 cm distant from the participant. To calibrate the system, participants were asked to look sequentially at nine equally spaced points on the display monitor. These points were entered as X–Y co-ordinates. After calibration the participants' Point of Gaze (POG) appeared as a cross hair superimposed on the stimulus. Eye-tracking data was coded off line by ASL eyenal software (for a full description of the technique see Johnson & Johnson, 2001). Participants were instructed to look at the face in the centre of the screen and then to look at the peripheral target as soon as it appeared. These verbal instructions were designed to generate overall performance as similar as possible to that observed previously in groups of infants.

The face stimuli were adapted from full colour still frames, some of which were used in Hood et al. (1998). The width of the faces subtended a visual angle between 5.1° and 6.3°. At the start of each trial the eyes within the face blinked (by means of two-edited video frames) with each still frame being presented for 500 ms (see Figure 1). After one cycle of blinking, the eyes were opened already shifted either right or left. After 300 ms of averted gaze, a conspicuous target (visual angle = 1.3° × 2.9°) was presented either in a location congruent or incongruent with the face gaze, and 8.8° from the midline of the face. The target remained until the end of the trial, after a further 800 ms. This procedure closely corresponded with that used in Experiment 3 of Farroni et al. (2000). 120 trials were administered in two blocks of 60 trials with a brief break in between.

Data analysis

Video of the POG was analysed by half frames (20 ms). The latencies and direction of saccades were coded from the onset of the gaze shift cue and from the onset of the target. Note was also made of whether the POG was on the face

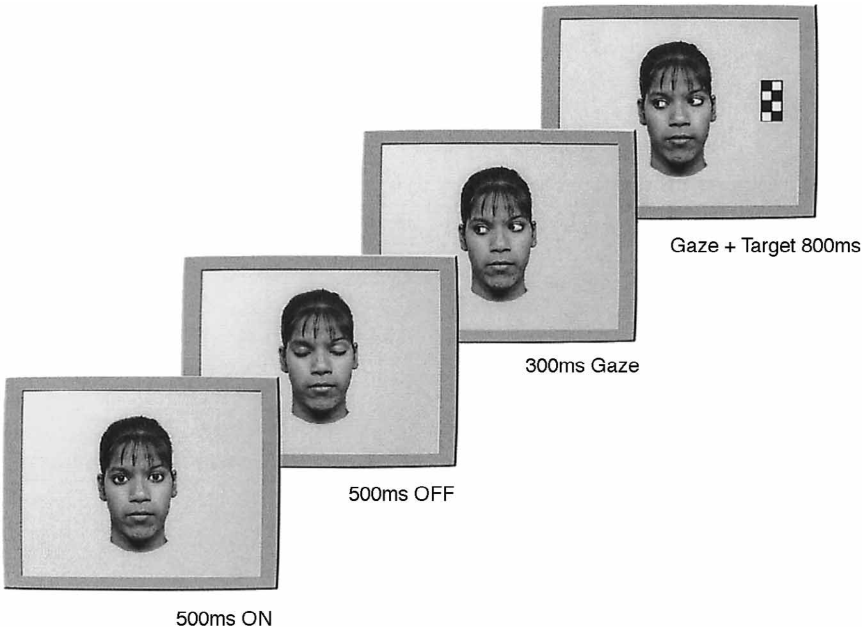

Figure 1. A schematic illustrating the stimulus sequence. In the trial illustrated the target appears on the incongruent side.

at target onset and only saccades originating within the face were subsequently coded. Trials were rejected where the POG disappeared. Scanning saccades of the face tended to be confined within its boundaries.

Saccades as seen by the POG cross hairs were defined as follows: Cue-driven saccades were definite saccades made beyond the edge of the face between 60 ms and 300 ms after cue onset. Cue-driven saccades were made either towards or opposite to the direction of the cue. Target-driven saccades were classified as those made between 60 ms and 500 ms after target onset. To be scoreable saccades had to reach at least halfway to the target (a visual angle of 4.4°).

RESULTS

The average number of target-driven saccades scored was 80.3 (40.5 in the congruent condition and 39.8 in the incongruent condition). The average number of scoreable trials that were not preceded by a prior cue-driven saccade was 34.0 in the congruent condition and 33.2 in the incongruent condition. The vast majority of the remaining trials were excluded due to loss of the POG for one frame or more during the trial, or due to participants blinking at some point during the trial. More rarely, trials were excluded because participants made a saccade in the wrong direction (mean of 3.1), or because the POG was not in the centre of the face when the gaze shift occurred. Table 1 shows the number of saccades recorded for each participant during time bins from cue onset until well after target onset. Time bins are 120 ms except for those around the time of target onset. The left-hand side of the table shows the number of saccades needed before target presentation. The right-hand side shows those recorded after target presentation.

Cue-driven saccades

Saccades made between 60 ms and 300 ms to the averted eye gaze were scored. Participants made significantly more cue-driven saccades in the direction of the cue, $t(11) = 2.3$, $p = .04$; 7.0 to cue, 4.4 opposite. As expected, the direction of these saccades was at chance with respect to the subsequent target location (congruent or incongruent trials).

Target-driven saccades

Average saccadic reaction times to the peripheral target were calculated for each subject for both the congruent and incongruent conditions (see Table 2). A paired *t*-test revealed a significant difference in the mean latencies between the two conditions, $t(11) = 6.7$, $p = .0001$. A near identical result was obtained when only the target-driven saccades that were not preceded by an earlier cue-driven saccade were examined, $t(11) = 6.2$, $p = .0001$, and when a less restricted range of reaction times was examined (range 0–800 ms), $t(11) = 6.9$, $p = .0001$.

TABLE 1
Number of saccades in time bins for each subject over whole trial

	Cue			*Target*						
Subject	*0–59*	*60–179*	*180–299*	*0–59*	*60–179*	*180–299*	*300–419*	*420–539*	*540+*	
Congruent trials										
1	4	5	2	0	4	6	13	6	4	
2	1	5	3	0	3	39	11	0	1	
3	26	15	4	1	11	24	7	2	2	
4	1	2	0	1	4	42	3	0	0	
5	1	4	5	6	15	14	5	1	0	
6	0	0	0	1	1	5	1	0	0	
7	0	0	0	1	6	25	3	0	0	
8	4	4	3	0	9	32	0	0	0	
9	0	1	1	3	6	38	6	3	0	
10	0	0	3	8	15	25	4	0	0	
11	0	0	1	4	13	33	7	0	0	
12	7	5	2	2	9	36	9	1	0	
Sum	44	41	24	27	96	319	69	13	7	640
Mean	3.7	3.4	2.0	2.3	8.0	26.6	5.8	1.1	0.6	
Tot%	7%	6%	4%	4%	15%	50%	11%	2%	1%	100%
Incongruent trials										
1	10	9	4	0	0	3	14	7	8	
2	0	0	2	0	0	34	13	2	0	
3	25	14	6	2	4	32	9	2	2	
4	1	3	2	0	3	41	10	0	0	
5	0	6	2	2	5	14	6	3	0	
6	0	0	2	0	0	6	3	0	0	
7	1	0	1	0	0	17	15	0	1	
8	1	1	1	0	1	39	0	0	0	
9	0	0	0	0	2	37	13	1	0	
10	0	1	5	1	7	30	5	0	0	
11	0	0	1	0	2	43	8	0	0	
12	5	6	2	0	0	34	15	1	1	
Sum	43	40	28	5	24	330	111	16	12	609
Mean	3.6	3.3	2.3	0.4	2.0	27.5	9.3	1.3	1.0	
Tot%	7%	7%	5%	1%	4%	54%	18%	3%	2%	100%

TABLE 2
Average reaction times (and associated standard errors) for target-driven saccades

	Congruent trials	*Incongruent trials*
All target-driven saccades	231.3 (7.9)	267.2 (11.3)
Target-driven saccades not preceded by a prior saccade to the gaze cue	231.7 (9.1)	263.3 (7.8)

DISCUSSION

The present study replicates previous work with adults demonstrating the facilitation of responses to peripheral targets cued by the direction of the gaze of a stimulus face (e.g., Driver et al., 1999; Langton & Bruce, 1999). Our results extend these previous findings with adults in two ways: First, we show that facilitation effects are observed in an overt orienting (saccadic) paradigm, and second, we have ruled out a potentially important artefactual explanation of the previous studies.

The use of an eye tracker allows us to rule out a potentially important alternative explanation of eye gaze cueing effect. Driver et al. (1999) and Langton and Bruce (1999) did not measure whether participants made saccades in response to the cue, and thus they could not rule out that targets congruent with gaze direction were, in fact, presented closer to the participants' fovea. In our study, an eye tracker provided us with a precise registration of the participants' eye movements, allowing this question to be examined in detail. Cue-driven saccades were observed, and it was demonstrated that the stimulus face eye gaze shift did, in fact, elicit small saccades in the direction of gaze in some trials. However, when trials containing cue-driven saccades were removed from the analysis the differences in saccadic latencies to the target still remained. Our results therefore allow us to rule out cue-driven saccades as a significant contributor to the main effect observed in this and previous studies. In adults, therefore, we can be confident that the presentation of a face with averted gaze cues covert or overt attention to targets appearing within the direction of gaze. Our results do not allow us to decide between other overt orienting accounts, and covert shifts of visual attention.

Another aim of the present study was to allow us to compare adult data with infant data from the same task in order to asses whether the apparently similar behavioural effects are supported by the same underlying mechanisms. Specifically, for infants the perceived movement of the eyes in the stimulus face is essential for cueing effects to be observed (Farroni et al., 2000), whereas the paradigms successfully used with adults have employed static presentations of averted gaze. In the present experiment we used a procedure with adults very similar to that in Experiment 3 of Farroni et al. (2000), in which infants failed to show a cueing effect due to the lack of motion of the pupils (an already averted gaze was presented). In contrast to infant performance, adults showed a strong cueing effect. These results suggest that different mechanisms underlie infant and adult performance in these tasks. Whether the effects observed in infants are specific to motion of the pupils, or are the result a more general motion cueing, is currently the topic of further investigation. Another issue that requires further investigation is whether the addition of pupil motion in adults will increase the magnitude of the effect still further. Finally, in the present experiment with adults we issued verbal instructions to ensure that consistent performance between participants was obtained. Although this is an obvious difference between the adult and infant paradigms, in our experience in the absence of verbal instruction adults tend to adopt individualistic strategies that lead to variable performance. In future research, the effects of different verbal instructions to adults could be examined.

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