

LOOKING WHERE YOU ARE LOOKING: EXPLORING THE TENDENCY TO IMITATE ANOTHER INDIVIDUAL'S GAZE

Paola Ricciardelli^{1,4},

Emanuela Bricolo²,

Salvatore M. Aglioti³,

Leonardo Chelazzi⁴

1. Cognitive Science Laboratory, Rovereto Branch, University of Trento, Italy

2. Department of Psychology, University of Milano Bicocca, Italy

3. Department of Psychology, University of Rome "La Sapienza" and IRCCS Fondazione Santa Lucia, Rome, Italy

4. Department of Neurological and Vision Sciences, Section of Physiology, University of Verona, Italy

Running title: Imitation of gaze direction in humans

Abstract

Distracting gaze stimuli and non biological directional cues (arrows) were presented to observers performing an instructed saccadic eye movement task. Eye movement recordings showed that observers performed less accurately when the distracting gaze and the instructed saccade had opposite directions, with a substantial number of saccades matching the direction of the distracting gaze. Static (Experiment 1) and dynamic (Experiment 2) gaze distracters, but not pointing arrows (Experiment 3), produced the effect. Results show a strong predisposition of humans to imitate somebody else's oculomotor behaviour, even when detrimental to task performance. This is likely linked to a strong, inherited tendency to share attentional states of other individuals, known as joint attention.

Key words: Imitation, Social attention, Joint attention, Gaze, Social cognition, Mirror system, Oculomotor behaviour.

Introduction

Through speech, face expressions, gestures and body postures humans spend a large portion of their lives interacting with one another and exchanging information, feelings and ideas. While doing so, they try to draw the attention of other individuals to themselves, or to relevant objects in the surrounding environment. Eyes have a distinct role in this behaviour. Researchers have described how babies become sensitive to where somebody else is looking, and may ultimately themselves come to look where another person is looking [1, 2, 3]. Developmentally, gaze-following behaviour is sometimes thought to underlie the ability to share the experiences of others [4]. But what is the mechanism responsible for such a strong tendency to imitate other people's oculomotor behaviour?

Recently, based on the discovery in monkeys' area F5 of a specific population of neurons named *mirror neurons* [5], Rizzolatti and Arbib [6] have argued for the existence of a mirror system that matches observed actions to similar, but internally generated actions, providing a bridge between the minds of different individuals. However, it is still unclear which kinds of actions can trigger the mirror system. To the best of our knowledge, to date only arm and finger movements have been shown to activate the mirror system in adult individuals [7, 8]. Nonetheless, other types of motor behaviour, such as somebody else's gaze shifts [8], may act as powerful "trigger" stimuli to engage the mirror system. No studies so far seem to have explored whether detecting a gaze deviation in another individual elicits an imitative gaze-following response in the observer. The aim of the present study is thus to fill this gap by assessing the extent to which humans follow somebody else's direction of gaze, even when not required or encouraged to do so. This may be particularly important, given that gaze deviations of another individual have been shown to elicit automatic orienting of attention in the direction of the perceived gaze stimulus - a phenomenon known as joint attention [9-11].

Experiment 1

By means of an interference paradigm, this experiment investigated whether a gaze-following response to gaze stimuli appearing in the visual field can be compulsory under some conditions. Observers were required to perform goal-directed saccades toward peripheral stationary targets. The general approach to study the intrusive effect of a distracting gaze stimulus onto the instructed saccade was to create a conflict between the direction of the instructed saccade and the direction of a distracting, deviated gaze. Congruent and incongruent conditions were compared. A violation of the instruction, in favour of the direction of the distracting gaze, would be a clear demonstration of gaze-following behaviour. In turn, such finding would provide new evidence for an unintentional imitation of gaze behaviour in human adults. A similar interference effect, though not strictly imitative in nature, would also be attested by a delay in starting the instructed saccade under incongruent compared to congruent conditions.

We tested these hypotheses by presenting the distracting gaze at different time intervals relative to the onset of the directional instruction to execute the saccade.

Method

Participants. Ten healthy adult volunteers (6 females and 4 males) took part in the experiment. All were paid to participate in the study and informed consent was obtained from each participant. All had normal or corrected-to-normal vision. Their age ranged between 20 and 32 years, with a mean of 24.

Apparatus and stimuli. Participants sat at a distance of approximately 57 cm in front of a computer monitor. Stimulus generation and presentation were controlled by a PC running the E-Prime software.

Each trial began with the appearance of a black central fixation dot (0.21° by 0.21° of visual angle), flanked by two solid black squares (the potential saccade targets; 0.43° by 0.43°), one to the right and one to the left of fixation, at an eccentricity of 10.2° (see Fig. 1a). The background was of light grey (~ 47 cd/m²). The saccade targets remained in view throughout the duration of the trial. After 1500 ms, the colour of the central dot changed either to blue or to orange, and this was the instruction cue indicating the direction of the saccade to be performed. The blue colour instructed the subject to make a saccade towards the left target, whereas the orange colour instructed a saccade towards the right target. The instruction remained visible for 50 ms and then disappeared. The fixation dot re-appeared at the beginning of the next trial. At different time intervals (stimulus onset asynchronies, SOAs: 50, 100, 150 ms) following the onset of the instruction cue, a stimulus distracter was presented at the centre of the monitor (see Fig. 1a). The distracter was a grey-scale digital photograph (6.38° by 6.76°) of a young woman's face, taken in front view, and with her eye-gaze turned to the left or to the right, or pointing straight ahead (i.e. the distracting gaze; see [12], for a detailed description of the stimuli). The gaze distracter lasted for 150 ms.

Eye position was measured binocularly by means of a video-based system (EyeLink, SensoMotoric Instruments, GmbH). Horizontal and vertical positions of each eye were sampled and stored at a rate of 250 Hz. However, only horizontal eye position will be dealt with in this report. Moreover, the system measured the 3D position of the head with respect to the computer monitor, which allowed compensation of slight head movements. Eye position was measured with a spatial resolution of at least 0.1° . In order to assure this high level of performance, calibration and drift correction of the eye tracker was repeated every 9-12 trials.

Procedure and design. Each subject was tested in one experimental session, lasting about 45 min. The session comprised 360 trials, divided into 2 equal blocks of 180 trials each, with the 18 conditions (3 SOAs by 3 Distracter types by 2 Saccade instruction cues) being equally probable, in a random sequence, and repeated 20 times each. A few minutes of rest were allowed between the

two blocks. Subjects were instructed to execute a saccade either to the left or to the right target, as indicated by the colour of the instruction cue, while completely disregarding the gaze stimulus distracter. They were also told to return to fixate the black central dot at the beginning of the next trial. A practice session of 18 trials (i.e. one trial per condition) was given prior to the beginning of each block. The practice trials were discarded from subsequent analyses.

Results

Saccadic eye movements were defined as changes in the eye position signal with velocities exceeding $30^{\circ}/\text{sec}$, and/or accelerations exceeding $8,000^{\circ}/\text{sec}^2$. Eye blinks were detected as any abrupt “loss” of the eye position signal. Our focus of interest was for the first saccade following the instruction cue which was larger than 2° along the horizontal dimension. Correct saccades were defined as those landing within $\pm 2^{\circ}$ of the designated target along the horizontal dimension.

Our main interest was for the percentage of eye movements made in the opposite direction to that indicated by the instruction cue (i.e. “antisaccades”, see Table 1). No amplitude criterion was applied to these movements, as long as they were larger than 2° . Trials were discarded when an (anticipatory) eye movement or a blink occurred during the 300-ms period preceding the onset of the instruction cue (8.8%, on average). Also trials in which the subjects blinked in the interval between the onset of the instruction cue and the first saccade were eliminated from any further analysis (0.7%, on average).

If people tend to produce saccades in the direction of the distracting gaze - as we had hypothesised, then one might predict a violation of the instruction cue and a higher proportion of direction errors (antisaccades) in the incongruent compared to the congruent condition. For each subject, performance scores were expressed as the percentage of antisaccades in each condition relative to the overall number of errors in saccade direction, in order to reduce inter-subject variability, and they were entered in a within-subjects two-way ANOVA with *Congruency* and *SOA* as the main factors.

The results of the ANOVA showed a significant main effect of SOA ($F(2,18)=7.94$; $p=0.003$) and a marginal main effect of congruency ($F(2,18)=3.4$; $p=0.056$). Of major interest, there was also a significant interaction between SOA and congruency ($F(4,36)=2.66$; $p=0.048$). Post-hoc comparisons (Duncan test) showed that the interaction was due to a significantly higher percentage of antisaccades in the incongruent than in the congruent condition ($p<0.01$) at the 50-ms interval, but not at the 100-ms and 150-ms time intervals. Congruent and neutral conditions did not differ from one another at any SOA (see Table 1). Finally, in this and the subsequent experiments error saccades were too few to allow in-depth analysis of their metrics.

These findings indicate that: 1) the distracting gaze stimulus is capable of triggering a gaze imitative response, and also 2) the effect vanishes when sufficient time for the programming of the instructed saccade is allowed prior to the onset of the distracting gaze.

Reaction times of saccades (sRT) in the correct, instructed direction were similarly analysed. The results showed a significant main effect of congruency ($F(2,18)=7.63$, $p=0.004$), reflecting shorter latencies for congruent compared to neutral and incongruent saccades (398 ms vs. 402 ms and 409 ms, respectively, $p<0.05$ in all cases), and a significant main effect of SOA ($F(2,18)=11.52$, $p=0.0006$), reflecting overall shorter latencies at the 50-ms compared to the 100-ms and 150-ms intervals (391 ms vs. 404 and 414 ms, respectively, $p<0.05$ in all cases). No significant interaction was found between time interval and congruency ($F<1$).

Experiment 2

Perception of a dynamic gaze-shift may provide on-line naturalistic cues, which in turn may trigger a hypothetical mirror system more potently than perception of a static gaze deviation. In this experiment we thus tested the distracting effect of dynamic gaze upon instructed saccadic eye movements. Moreover, we further explored the time course of the gaze-following behaviour

revealed in the previous experiment. We conjectured that, if there is a tendency to imitate someone else's oculomotor behaviour, the effect might actually be greater when the distracting gaze is presented before the onset of the instruction to saccade, due to prior entry of the distracting information relative to the saccadic instruction. To assess this possibility, we used five different time intervals, two preceding and two following the instruction onset and one simultaneous to it.

Method

Participants. Fourteen healthy adult volunteers (7 females and 7 males) were recruited, all with normal or corrected-to-normal vision. All were paid to participate in the study and informed consent was obtained from all of them. Their age ranged between 21 and 29 years, with a mean age of 23.

Apparatus and materials. Dynamic gaze distracting stimuli were obtained by generating an apparent motion of the eyes, i.e. by presenting two frames showing the same face with different gaze directions in rapid succession. The eyes in the first frame were always looking straight at the experimental subject, while they were deviated either to the right or to the left in the second frame (see Fig. 1b). As a consequence, the potentially distracting information became only apparent when the second frame replaced the first. In the present experiment we eliminated the neutral condition (i.e. gaze always looking straight ahead) employed in the previous experiment, as this would not entail any dynamic change in gaze direction between consecutive frames, and it would thus differ very substantially from the other conditions (with diverted gaze).

The stimulus distracter (with straight-ahead gaze) was in view from the beginning of each trial. In order to explore the time course with which the distracting gaze-shift could intrude into task performance, the onset of the saccade instruction preceded (-150 ms, -75 ms), followed (150 ms, 75 ms), or was simultaneous (0 ms) with the change in gaze direction.

In this experiment the black fixation dot was superimposed onto the nose of the face distracter. The saccade targets, one to the right and one to the left of fixation, were the same as in the previous experiment. Background luminance was now set at $\sim 11 \text{ cd/m}^2$.

Procedure and design. Subjects were presented with a total of 400 trials, consisting of 20 repetitions of each of 20 conditions (5 SOAs by 2 Distracter types by 2 Saccade instruction cues). Trials were divided into 2 blocks of 200 trials each, with all conditions being equally probable within each block and presented in a random sequence. Subjects were instructed to execute a saccade in the direction indicated by the colour of the cue, as in the previous experiment, and to ignore any change occurring to the face during the course of the trial. Twenty practice trials were given at the beginning of each block, one for each experimental condition.

The sequence of events was as follows (see Fig. 1b). The stimulus distracter (the same face used in the previous experiment) with the black fixation dot on its nose and flanked by the two saccade targets appeared at the centre of the screen and remained visible until the end of the trial. This first frame (with straight-ahead gaze) lasted for at least 1500 ms, depending on the SOA in the trial. Subsequently, the eyes appeared to look either to the left or to the right target (dynamic distracting gaze). The second frame lasted until the end of the trial.

Results

From the total trials an average of 19.6% were eliminated due to anticipatory saccades or blinks.

Percentages of antisaccades in the different conditions were computed from the raw data as in the previous experiment (see Table 2). A within-subjects two-way ANOVA on the percentages of antisaccades revealed a significant main effect of SOA ($F(4,52)=3.63$; $p= 0.011$) and a significant main effect of congruency ($F(1,13)=23.35$; $p= 0.0003$), while the interaction between SOA and congruency fell just short of significance ($F(4,52)=2.34$; $p= 0.066$). Post-hoc analyses (Duncan

Test) for the incongruent condition showed that the percentage of antisaccades at the -75 -ms and 0 -ms SOAs (which did not differ from one another) was significantly ($p < 0.01$) greater than at the 75 -ms and 150 -ms SOAs (which again did not differ from one another). The percentage of antisaccades in the same condition at the -150 -ms SOA was not reliably different from that at any other SOA.

To further explore the difference in performance between congruent and incongruent trials as a function of SOA, the difference scores between the two conditions were directly compared against the null hypothesis at each SOA. A significant difference between incongruent and congruent conditions was found at -75 ms ($t(13)=3.8$, $p=0.002$) and at 0 ms ($t(13)=3.4$, $p<0.005$), but not at the other SOAs (see Fig. 2a). This indicates that the intrusive effect of the distracting gaze is maximal within a time window of about 75 ms preceding the onset of the saccade instruction, and then quickly vanishes for positive intervals, i.e. when the distracting gaze shift follows the instruction to execute the saccade.

The saccadic latencies (sRT) of correct eye movements were analysed as in the previous experiment. The ANOVA showed a significant main effect of SOA ($F(4,52)=10.78$, $p<0.001$) and congruency ($F(1,13)=38.86$, $p<0.001$), the latter reflecting shorter latencies for congruent compared to incongruent saccades (354 ms vs. 369 ms, respectively). The interaction between SOA and congruency was also significant ($F(4,52)=3.30$, $p=0.017$), reflecting a significant difference between congruent and incongruent conditions at all but the longer SOA.

Experiment 3

In this experiment we addressed the crucial issue of whether the above interference effects are exerted only by gaze stimuli (and perhaps other biological stimuli) or similarly by any other directional cues, such as for instance pointing arrows. If the interference effects were absent with distracters consisting of non-gaze (non-biological) stimuli, that would provide strong evidence in

favour of the distinct imitative nature of the gaze-following responses induced by the perception of somebody else's gaze direction.

Method

Participants. Twelve healthy adult volunteers (5 females and 7 males) were paid to participate in the experiment and informed consent was obtained from all of them. All had normal or corrected-to-normal vision. Their age ranged between 20 and 46 years, with a mean of 25.

Apparatus and materials, design and procedure. These were exactly the same as in Experiment 2, except that now the stimulus distracter was not a distracting gaze. Two X stimuli (each measuring $0.47^{\circ} \times 0.47^{\circ}$ in size), flanking the black fixation point, appeared exactly in the same position in which the eyes of the distracting face appeared in the previous experiments. At the same time intervals as in Experiment 2 (i.e. -150, -75, 0, 75, 150 ms, relative to when the fixation target changed colour to reveal the instruction) the two Xs turned into two distracting arrows (“>”, or “<”) pointing either to the right or to the left. This was obtained by removing half the segments of each X stimulus (see Fig. 1c).

Results

From the total trials an average of 15.1% were eliminated due to anticipatory saccades or blinks.

Data were sorted and analysed in the same way as before (see Table 2). Percentages of antisaccades were entered into a within-subjects two-way ANOVA. No significant effect of either SOA or congruency, nor a significant interaction between them, were found (all $ps > 0.1$, see Fig. 2b), showing no, or only minimal, imitative response when the directional distracter was represented by pointing arrows. Multiple comparisons of the difference between incongruent and

congruent conditions against the null hypothesis at each time interval confirmed no significant effects (all $ps > 0.1$).

The saccadic latencies (sRT) of the correct eye movements were also analyzed and entered into a within-subjects two-way ANOVA. This revealed a significant main effect of SOA ($F(4,44)=7.99$, $p < 0.001$) and a significant main effect of congruency ($F(1,11)=5.65$, $p < 0.05$). The latter effect was due to shorter latencies for congruent saccades compared to incongruent ones (364 ms vs. 374 ms, respectively). The interaction between SOA and congruency did not reach significance, although there was a trend ($F(4,44)=2.18$, $p = 0.09$).

Discussion

The present findings reveal an automatic imitative response in human adults elicited by the perception of somebody else's direction of gaze. This was attested by a considerable proportion of mistaken saccades matching the direction of the distracting gaze stimulus when this was opposite to the saccade direction indicated by the instruction cue. Such an effect is quite remarkable if one considers that the distracting gaze stimulus was entirely task-irrelevant and subjects were explicitly told to ignore it. Most importantly, the effect was not found when a non-biological directional cue (i.e. a pair of pointing arrows) was used as the distracter, suggesting that the gaze-following response is specifically triggered by eye-gaze stimuli.

An alternative but highly compatible explanation is that people are particularly poor at inhibiting an imitative oculomotor response elicited by biologically significant stimuli (e.g. gaze direction), while they are capable of inhibiting any influence on their oculomotor behaviour of non-biological directional cues. Interestingly, Baron-Cohen [4] has proposed that perception of gaze, and the consequent gaze-following response, operate in an obligatory manner, under the control of specialized Fodorian modules. This might explain why it appears to be so difficult to inhibit such gaze-following responses.

In humans evidence for the existence of a mirror system has so far been only indirect. It is assumed that under normal conditions the cortical motor activation elicited by an observed action does not translate into overt motor behaviour (the imitative response), presumably due to the intervention of inhibitory mechanisms [13, 14]. Our results, instead, provide the first direct behavioural evidence that perception of gaze direction may act as a powerful trigger for involuntary imitation.

The hypothetical failure of an inhibitory mechanism could also be applied to explain the time-course of the observed effects. In this regard, the results of Experiment 1 and 2 suggest the existence of a critical time window (between around 75 ms before and 50 ms after the onset of the instruction to saccade) within which the distracting gaze can automatically elicit a saccade in the same direction. This could reflect a failure within the critical time window to inhibit the oculomotor program induced by the early gaze distracter, whereas no such inhibition would be needed when the instructed saccadic program has time to develop before the appearance of the distracting gaze.

The results of the present study suggest some interesting similarity between the effects of gaze stimuli and those elicited by abrupt visual onsets. In a recent study by Theeuwes and colleagues [15] a task-irrelevant abrupt onset was shown to capture attention and, in many instances, an eye deviation towards its location. Interestingly, the number of saccades toward the location of the abrupt onset decreased when the onset appeared enough time after the target, indicating some kind of competition between automatic and controlled processes in the guidance of eye-gaze.

The fact that the latency of correct saccades was shorter for congruent than for incongruent conditions in all 3 experiments could be explained in terms of a kind of spatial stimulus-response compatibility effect, which may be caused by the directionality of both stimulus distracters, gaze and arrows. In other words, the direction of both types of distracting stimuli might elicit the automatic creation of a spatial code, which in turn, if incongruent, might interfere with the spatial code required to execute the instructed saccade. Interestingly, while the different distracters (gaze

and arrows) had a clearly different ability to elicit “antisaccades”, they appeared to exert a similar effect on saccadic latency. Further investigation is needed to better clarify this aspect of the data.

The interesting implications of the present results are that brain structures implicated in oculomotor control may receive information regarding the gaze direction of another individual and may directly translate it into a matching oculomotor command. The actual release of this command would manifest itself as gaze-following behaviour. Neurones selective for gaze direction have been described in the superior temporal sulcus of the macaque [16], and lesions of the same region in monkeys impairs their ability to discriminate gaze direction [17]. There is some evidence in monkey that this area connects to regions of posterior parietal cortex implicated in oculomotor control [18].

Conclusions

An imitative gaze-following response as that reported in the present study likely represents a key element of joint attention, as imitating someone else’s gaze direction also entails deployment of attention in the same direction. Several recent studies have documented strong attentional cueing effects of perceived gaze direction, with faster detection of visual stimuli presented in the direction of a diverted gaze [9-11]. Since none of those studies monitored eye position in their subjects, the possibility should be entertained that at least part of the effect was mediated by gaze-following responses in the direction of the perceived gaze, i.e. by overt orienting of attention. At any rate, the present results, in combination with the results of the above studies, demonstrate that someone else’s gaze direction is able to trigger both overt and covert shifts of attention.

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Figure Legends

Figure 1.

Example displays from Experiment 1 are shown in (a). At the start of the trial (first panel to the left) a fixation mark and two peripheral saccade targets are presented. Following a delay, the fixation mark changes colour to orange, revealing the direction of the required saccade (in this case, to the right target; middle panel). Following a further delay, a distracting face with gaze diverted to the left is presented at the center of the monitor (panel to the right). The example sequence thus depicts a condition in which saccadic instruction and distracting gaze had opposite, incongruent directions.

Example displays from Experiment 2 are shown in (b). At the start of the trial (first panel to the left) the fixation mark and the peripheral saccade targets are presented, together with the distracting face. In this phase, gaze direction of the distracting face was always straight toward the subject. Following a delay, the distracting gaze is deviated to the right (middle panel). Following a further delay, the fixation mark changes colour to blue, revealing the direction of the required saccade (in this case, to the left: panel to the right). Thus, the example sequence depicts a condition where the distracting gaze deviation precedes the saccadic instruction and they had opposite directions.

Example displays from Experiment 3 are shown in (c). At the start of the trial (first panel to the left) the fixation mark and the peripheral saccade targets are presented, together with a pair of “X” distracters, one on each side of fixation. . Following a delay, the fixation mark changes colour to blue, revealing the direction of the required saccade (in this case, to the left target; middle panel). Following a further delay, the “X” distracters are changed to a pair of pointing arrows (> >), revealing the directional distracter. Thus, the example sequence depicts a condition where the saccadic instruction preceded the distracting directional cue (> >) and they again had opposite directions.

Figure 2.

Differences between the normalised percentage of antisaccades made in the incongruent vs. congruent conditions plotted as a function of SOA in Experiment 2 (a) and 3 (b).

Table 1

Raw mean percentages of antisaccades by condition in Experiment 1. Standard deviations are reported in brackets.

SOA(ms)	50	100	150
Incongr	8.5 (3.4)	2.8 (3.0)	4.5 (3.0)
Neutr	4.3 (3.3)	4.1 (4.0)	3.5 (3.6)
Congr	4.5 (3.3)	3.5 (1.7)	3.3 (3.7)

Table 2

Raw mean percentages of antisaccades by condition in Experiment 2 and 3. Standard deviations are reported in brackets.

	SOA (ms)	-150	-75	0	75	150
Exp. 2	Incongr	7.7	8.4	6.3	2.9	2.3
		(11.4)	(10.2)	(7.1)	(3.2)	(3.0)
	Congr	3.0	1.8	1.4	1.3	2.3
		(2.8)	(2.1)	(2.3)	(1.6)	(3.5)
Exp. 3	Incongr	5.6	3.4	3.3	1.5	2.3
		(8.4)	(4.9)	(4.3)	(2.0)	(3.3)
	Congr	2.5	2.4	1.5	2.1	1.9
		(2.8)	(3.3)	(1.7)	(2.0)	(2.4)