OBJECT-BASED ATTENTIONAL EFFECTS IN RESPONSE TO EYE-GAZE AND ARROW CUES

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ABSTRACT

Recent studies have demonstrated that central cues, such as eyes and arrows, reflexively trigger attentional shifts. However, it is not clear whether the attention induced by these two cues can be attached to objects within the visual scene. In the current study, subjects' attention was directed to one of two objects (square outlines) via the observation of uninformative directional arrows or eye gaze. Then, the objects rotated 90° clockwise or counter-clockwise to a new location and the target stimulus was presented within one of these two objects. Results showed that independently of the cue type participants responded faster to targets in the cued object than to those in the uncued object. This suggests that in dynamic displays, both gaze and arrow cues are able to trigger reflexive shifts of attention to objects moving within the visual scene.

Keywords: spatial attention, object-based attention, gaze cue, arrow cue

Running head: SYMBOLIC CUEING AND OBJECT-BASED ATTENTION

Research Highlights:

- Attention can be directed to object with both eye gaze and arrow cues
- Object-based gaze effects occur when the object is entirely visible to the gazing face
- Object-based attention was observed in both detection and discrimination tasks

1. Introduction

The tendency to follow the direction of another individual's gaze appears very early in life and marks an important breakthrough in the development of social communication, given that gaze provides important information regarding an individual's interests and mental states (e.g., Moore & Dunham, 1975; Emery 2000; Baron- Cohen, 1995a, b). Observing averted gaze can also elicit an automatic shift of attention to the same direction of the observed gaze (e.g., Driver, Davis, Ricciardelli, Kidd, Maxwell & Baron-Cohen, 1999; Friesen, Ristic, & Kingstone, 2004; for a review, see Frischen, Bayliss, & Tipper, 2007), allowing the establishment of "joint attention" (Butterworth & Jarrett, 1991). This behaviour has been considered of great benefit to an individual and has been posited as vital in the development of social communicative skills; for example, it can support language acquisition, cultural learning and theory-of-mind development in infants (Baron-Cohen, 1995; Bruner, 1983; Tomasello, 1995).

For this reason, several recent studies have investigated the mechanisms underlying this phenomenon. In these studies a variant of a spatial cueing paradigm is used, in which a face is presented at fixation unpredictably gazing either left or right, and a target is presented afterwards either in the gazed location or in the opposite location. Participants are typically faster to detect or identify the target when the eye-gaze is directed towards the target location, as compared to when it is directed towards the opposite location (i.e., the so-called gaze cueing effect).

This effect occurs even when the gaze direction is not predictive of the subsequent target location and the time interval between the presentation of the cue and the target is short (around 100 ms; Langton and Bruce, 1999; Ristic, Friesen and Kingstone 2002; Friesen and Kingstone 2003). On the basis of these behavioural findings and the evolutionary and social significance of eye gaze (Emery, 2000), some researchers have proposed that automatic orienting to eye gaze may represent an unique attentional process and reflect the operation of a specialized cognitive mechanism (e.g. Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). However, contrary to this position, similar reflexive shifts of attention have been observed when uninformative arrows were used as central cues (Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Friesen, & Kingstone, 2002; Tipples, 2002; 2008), and independently of peripheral cueing (Martin-Arévalo, Kingstone & Lupiáñez, in press).

An important outstanding question is how objects in visual scene modulate attentional effects in response to eye-gaze and whether biologically relevant and irrelevant cues (e.g. eye-gaze versus arrows) exert qualitatively different effects on object-based attention. According to Emery's (2000) definition, "Joint attention requires that two individuals […] are attending to the same object […] based on one individual using the attention cues of the second individual" (p. 588). This definition emphasizes the importance of orienting attention to the same object of another attention direction to establish a joint attention episode. Naturalistic studies have provided compelling behavioral evidence for the importance of objects to joint attention in infants. For example, infants are able to follow their mother's gaze to the correct object in their visual field after around 12 months, and they can also orient attention to objects outside their visual fields (Butterworth & Jarrett, 1991). At about 18 months of age, young children begin also to follow the other's eye gaze to the object of interest for referential communicative purposes such as learning new words (Baldwin, 1995).

However, in spite of joint attention being considered object-based, at present, relatively little is known about the importance of objects in joint attention behaviour in general, and in computerized laboratory experiments of gaze cueing, in particular. Moreover, it is not clear whether the object-based selective attention induced by eye gaze and arrow cues are similar or rather differ in some important way. In a recent study we have found that qualitatively distinct modes of attentional selection are triggered by eye-gaze and arrow cues (Marotta, Lupiañez, Martella & Casagrande, 2012). In particular, we presented a display with two rectangular objects one of which was cued at one end or another by central non-informative directional arrow or eye gaze cues. Targets followed in one of four critical conditions: at the cued direction (and object) indicated by the cue (same-location/same-object trials), in the opposite object and direction to which the cue was directed (opposite-location/opposite-object trials); at the uncued location of the same object (same-object trials) or at the uncued location in the other object (different-object trials). We found that arrow cues induced object-based selection (i.e., a same-object advantage compared to different-object trials), whereas eye-gaze cues induced space-based selection (i.e., a same-location/same-object advantage compared to same-object trials). This implies that arrow cues allow attentional shifts that spread to the entire object in the visual field, whereas gaze effects only occur in the specific direction (or part of the object) indicated by the cue. This dissociation lead the authors to suggest that whereas arrow-cueing is truly stimulus-driven, gaze-cueing might be mediated by theory of mind processes (i.e., when we see somebody clearly looking to one end of a surface, we only pay attention to this end). Nevertheless, given the specific paradigm they used, an alternative explanation could be plausible: gaze-mediated attentional orienting is location-based, whereas arrow-mediated attentional orienting is both location and object-based.

Contrary to this explanation, there are evidences to suggest that when the entire object is the current focus of interest of gaze direction, the attentional effect can be modulated by that object. For example, Bayliss, Paul, Cannon, and Tipper (2006) found that objects that are looked at by other people are more likeable than those that do not receive much attention from others. This affective preference for cued objects was not found when non-predictive arrows were used as cues. Moreover, Bayliss and Tipper (2005) also found that the magnitude of orienting to the direction of gaze can be modulated by the social relevance of the object in which the target appears. Taken together those findings indicate that gaze-mediated orienting should also object-based, when the whole object is interpreted as the goal of the gaze.

Therefore, it is important to demonstrate that attentional orienting triggered by eye-gaze cues can be allocated to the object, when the entire object is the current focus of interest of gaze direction. To this aim, we adopted a dynamic spatial cueing paradigm (or rotating displays) that has been successfully used in previous studies to evaluate the object-based representation of inhibition of return (Tipper et al., 1991; 1994). In this paradigm (see figure 1), subjects' attention was directed to either one of two whole objects (square outlines) via the observation of noninformative directional arrows or eye gaze. Then, the objects rotated 90°

clockwise or counter-clockwise to a new location and the target stimulus was presented within the cued (valid) or uncued object (invalid), which in any case was in an orthogonal position to which the cue directed attention to. The participants was required to respond to the target as soon as possible. Quicker reaction times for targets presented within validly cued objects was thought to indicate an allocation of attention to the cued objects (i.e. object-based cueing effect).

We directly tested the following prediction: if the lack of object-based attention in Marotta et al. study (2012) was due to the fact that attention can never be directed to objects via the observation of eye gaze cues gaze, then no object-based effects should be observed with gaze in the current experiments. Significant object-based effect should be only observed with arrow cues. In contrast, if the lack of effect was due to the fact that gaze-mediated attentional orienting can be allocated to the object only when the entire object is the current focus of interest of gaze direction, an object-based attentional orienting effect should be observed in these experiments with both eye-gaze and arrow cues.

2. Experiment 1: Detection Task

2.1. Method

2.1.1. Participants

Thirty female university students (mean age 24 ± 1.6 years) from the University of Granada, signed an informed consent before participating as volunteers in the study. The local ethical committee approved the study. All participants had normal or corrected-to-normal vision, and were unaware of the purpose of the experiment.

2.1.2. Apparatus

Stimuli were presented on a 21-inch colour VGA monitor. An IBM-compatible PC running E-Prime software controlled the presentation of the stimuli, timing operations, and data collection. Responses were gathered with a standard keyboard.

2.1.3. Stimuli

Stimuli and trial sequences are illustrated in the Figure 1.

In the gaze cueing condition, the fixation was a central face (3° x 2.5° degree of visual angle) with the pupils' straight, while the spatial cue was the same central face with the pupils directed to one of four possible directions (upward, downward, left, or right). In the arrow cueing condition a cross (0.5° x 2°) was used as fixation. An arrow-head directed to the left, to the right, upward or downward was used as arrow-cue. Target stimuli were the "X" or "O" (0.9° x 0.9°) letters. All stimuli were black on a white background.

2.1.4. Procedure

Participants were seated at the distance of about 56 cm in front of a computer monitor, in a dimly lit, sound-attenuated room, and their heads were held steady with a chin/head rest. A trial sequence of the procedure is shown in Figure 1. Each trial began with a display consisting of two peripheral boxes and a central fixation stimulus that differed depending on the cue types (i.e., the straight looking face or the cross respectively for gaze and arrow condition), and was presented for 700 ms. Then the cue was presented for 150 ms as the movement of the eyes randomly to one of the two peripheral boxes, or the appearance of arrow-heads at one of the cross sides. Both gaze and arrow cues were not predictive of target location. The boxes originally presented to the right and to the left or above and below fixation began to rotate (either clockwise or counterclockwise) around the central fixation stimulus. The apparent motion was achieved by switching of the graphics frames to produce the appearance of smooth motion of the peripheral boxes. The peripheral boxes moved 22.5° (in polar coordinates) between frames and remained visible for 50 msec. After four frames of movement (90° in polar coordinates), the motion ceased, and the target was presented in one of the peripheral boxes. The SOA between cue and target was 300 msec. The target remained on the screen until a response was given or until 1500 ms had elapsed. A blank screen was then presented for 700 ms after each trial. Participants were instructed to respond by pressing the spacebar as soon as they detected the target. They were also informed that the location signalled by central cues did not predict target location, and that they should ignore it, while maintaining central fixation throughout each trial.

Participants completed 10 practice trials and 128 experimental trials. Eight catch trials in which no target stimulus was presented occurred randomly throughout the experiment. Cue direction, target location and rotation direction were randomly selected within each block of trials.

[INSERT FIGURE 1 ABOUT HERE]

2.1.5.Design

The experiment had a two-factor repeated measure design. Cue Type had two levels: gaze and arrow. Validity had two levels: valid trials (the target appeared in the cued pheripheral box) and invalid trials (the target appeared in the uncued box). Planned comparisons were used for the analysis of interactions following our predictions.

2.3. Results and discussion

RTs shorter than 100 ms or longer than 1000 ms (3% of the trials) were excluded from the RT analysis. A two-factor repeated measures ANOVA was used to analyse the median RTs, and showed that the main effect of *Validity* reached significance ($F_{1,29}$=6.01; p=.021), with faster responses for valid trials (333ms vs. 338ms). The effect of *Cue Type* was not significant ($F_{1,29}$=1.08; p>.305). Of interest, the interaction *Validity x Cue Type* was not significant either (F<1; see figure 2): cueing effects were very similar for gaze an arrow cues (4ms vs. 5ms, respectively). The results of this experiment show, for the first time, that cueing effects triggered by either eye-gaze or arrow cues can be attached to the objects moving within the visual scene. As such, participants were faster to respond to the previously cued box compared to the uncued box, even though successively to the apparent rotation, the cued and uncued boxes were at the same distance from the previously signalled location. However, because this effect is relatively small and different from anything else in the gaze-cuing literature, it is essential that it is replicated and extended to other procedures. Therefore, in the next experiment we attempt to replicate this object effect in a task requiring target discrimination rather than detection.

[INSERT FIGURE 2 ABOUT HERE]

3. Experiment 2: Discrimination Task

Having shown that reflexive attentional orienting triggered by gaze and arrow cues can be attached to moving object in a target detection task with rather low response-related demands, we went on to determine if this effect can also be found in a two-choice discrimination task. Target discrimination tasks have been widely used in eye-gaze cueing paradigms (e.g. Bayliss, Di Pellegrino & Tipper, 2005; Driver et al., 1999; Marotta et al., 2012; McKee, Christie, & Klein; 2007). Therefore, this task seems like an appropriate method to be used in our attempt to confirm the results observed in Experiment 1. Moreover, the use of a discrimination task could be useful for future research with physiological measures to test more adequately the possibility that object-based orienting might modulate early visual processing, since such task requires a more detailed perceptual analysis than do detection tasks.

3.1. Method

A different group of 32 female university students (mean age 24 ± 4.6 years) participated in this experiment, with the same characteristics of those of the previous Experiment. Stimuli and procedure were similar to the ones used in Experiment 1, except that binary-choice reactions were made by pressing one of two keys of the computer keyboard. In particular, participants were instructed to respond to the presentation of the target by pressing either the "C" key (with the left hand) or the "M" key (with the right hand) on the computer keyboard depending on the target letter that was presented. Half of participants pressed "C" for the letter "X" and "M" for the letter "O", whereas the other half received the reversed mapping.

3.2. Results and Discussion

RTs shorter than 200 ms or longer than 1200 ms (1% of the trials) as well as incorrect responses (4% of the trials), were excluded from the RT analysis. The median RTs were analysed with a two-factor repeated measures ANOVA. The effect of Cue Type was not reliable ($F_{1,31}$=3.46; p=.072). As in Experiment 1, however, there was a significant Validity effect ($F_{1,31}$=4.96; p=.033), with faster responses for valid trials (499ms vs. 506ms). And again, as in Experiment 1, the interaction *Validity x Cue Type* was not significant (F<1; see figure 3): cueing effects were similar for gaze an arrow cues (9ms vs. 6ms, respectively). Thus, this result replicates the findings of Experiment 1 and shows that, like cueing effect observed in traditional spatial cueing paradigms, attentional orienting to moving objects evoked by gaze and arrow cues is not limited to tasks with low response-related demands.

[INSERT FIGURE 3 ABOUT HERE]

3.4. Combined analysis of Experiments 1 and 2

A 2x2x2 ANOVA with the factors experiment (1-Detection task and 2-Discrimination task), Validity, and Cue Type was performed on median RTs. The analysis found a significant main effect of Experiment ($F_{1,60}$=151.68; p<.001), with shorter RTs in Experiment 1 than in Experiment 2. Moreover, the main effect of Validity was significant ($F_{1,60}$=151.68; p<.001). Again, the interaction *Validity x Cue Type* was not significant (F<1): planned comparisons revealed that cueing effects were significant for both gaze and arrow cues ($F_{1,60}$=5.58; p<.003 and $F_{1,60}$=5.07; p<.003, respectively). No interaction with Experiment was significant (F<1).

4. General Discussion

The purpose of the present study was to determine whether object-based attention is equally observed with both arrow and gaze in a dynamic variant of the spatial cueing paradigm. In two experiments, it was found that spatially nonpredictive gaze and arrow cues can influence target detection and discrimination (Exp1 and Exp2, respectively), such that targets appearing at a previously gazed of arrow-cued moving object were responded to more quickly than targets appearing at not attended object. In other words, arrows and eyes triggered very similar effects on object attentional cueing in this dynamic variant of the spatial cueing paradigm. Those results are consistent with the literature which has generally reported similar behavioural effects between gaze and arrow cueing in the normal population (for a review, see Birmingham & Kingstone, 2009). However, at first sight, they would seem in contrast with the findings of our recent study (Marotta et al., 2012), in which it was observed that only arrow cues allow attentional shifts that spread to the entire object in the visual field, whereas gaze effects only occur in the specific direction (or part of object) indicated by the cue. From our point of view, these discrepancies might be explained by the view according to which a joint attention episode requires not only the encoding of gaze direction, but of the correct object of another's attention (Emery, 2000; Emery et al., 1997). Thus, in the present study orienting to eye-gaze cues was directed to objects because the entire placeholder box was signaled by gaze cues. In contrast, in our precedent study (Marotta et al., 2012) attentional shifts allowed by gaze cues did not spread to the entire object surface because only the extreme part of a lateralized object was cued. Therefore, taken together, those findings seems to suggest that although attention can be directed to object with both eye gaze and arrow cues, eye-gaze produce object-based attentional effects only when the entire object is the focus of interest of another's attention. This aspect of gaze-mediated attentional orienting may support important functions of the joint attention system; for example, it may explain why the language learning in human infants is correlated with the development of joint attention skills (Baldwin, 1995), since a crucial stage in language development is the process of associating a word with the physical object. This stage of language may be difficult to achieve without the ability to orient attention to a specific objects of the caregiver attention, hence making longer the process of vocabulary acquisition.

In conclusion, the present study demonstrates that in a dynamic spatial cueing paradigm central non-predictive gaze and arrow cues can produce similar object-based attentional effects, despite the differences found between them in other paradigms (Marotta, Lupiáñez, and Casagrande, 2012; Marotta, Lupiáñez, Martella, and Casagrande, 2012). The origin of any differences between object-based attentional effects triggered by eyes and arrow cues will be clearly of importance to further research in this area.

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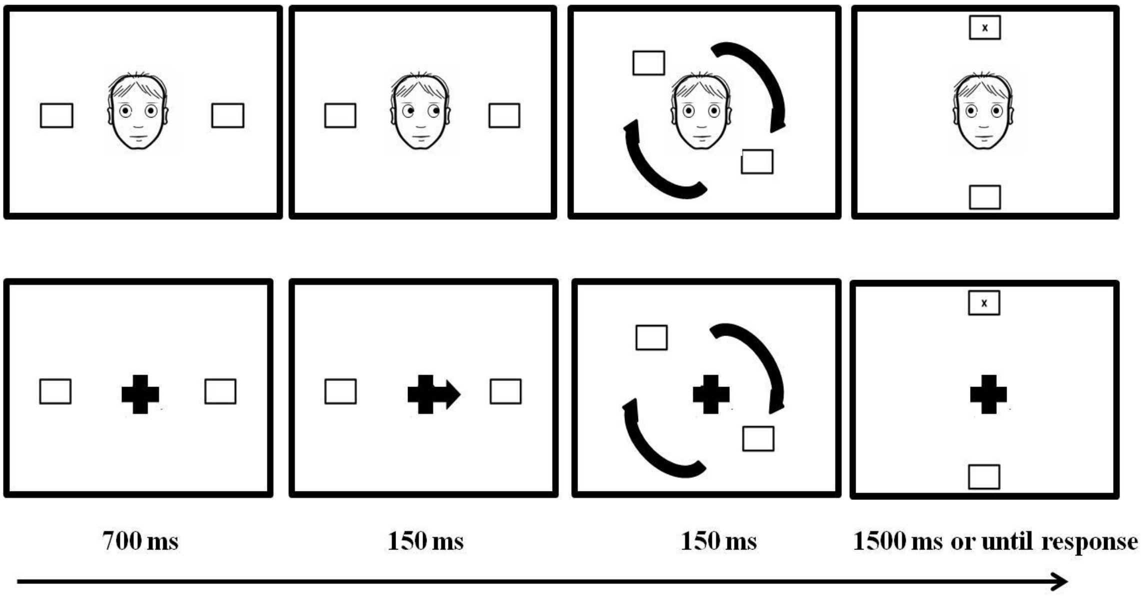

Figure 1. Illustration of the trial sequence. The panel above depicts the displays observed in the gaze cue condition, and the panel below depicts those in the arrow cue condition. The target appears in the uncued object in both panels. See text for details.

Figure

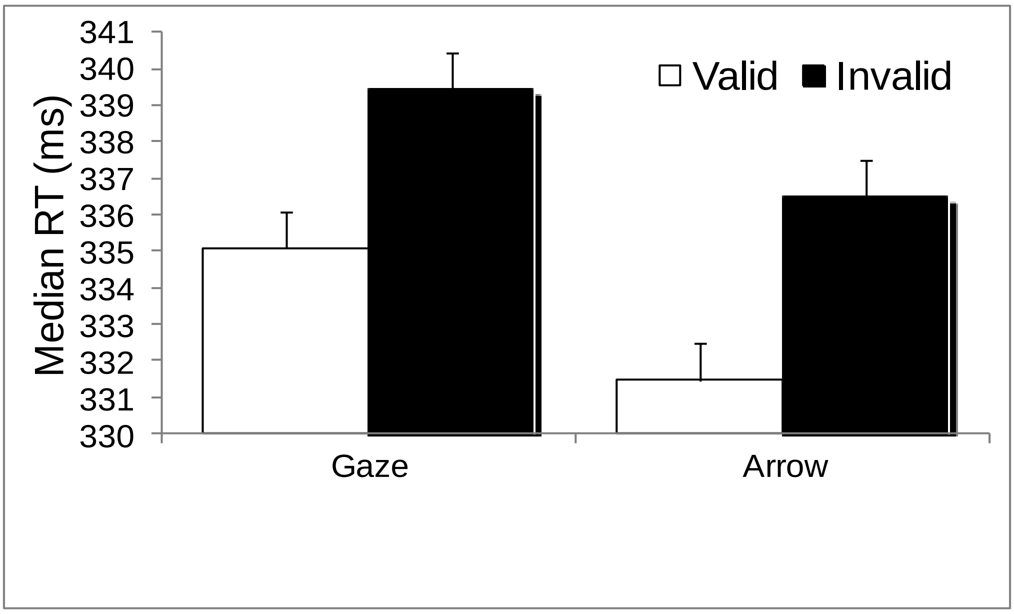

Figure 2. Reaction times (RTs) results from Experiment 1. Means of (individual) median reaction times presented for valid and invalid conditions as a function of a cue type condition (gaze and arrow).

Figure

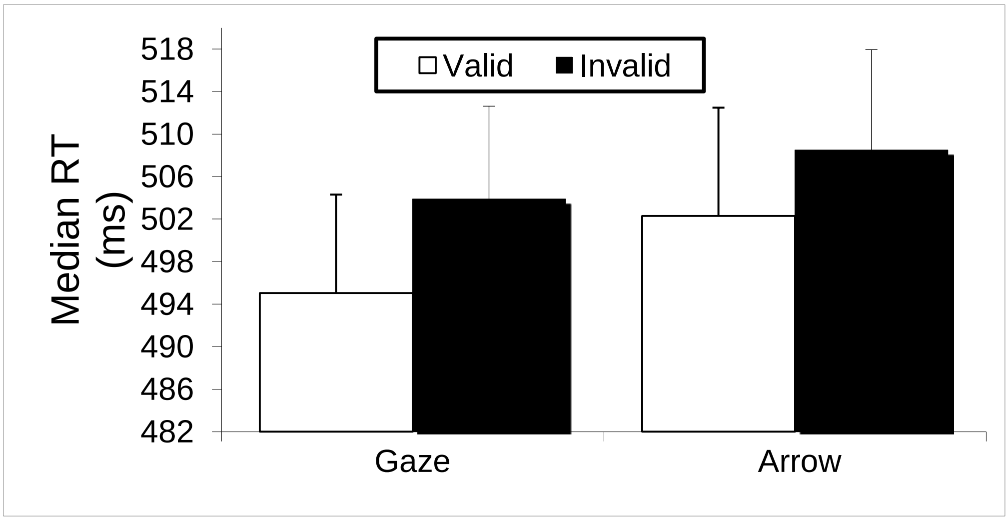

Figure 3. Reaction times (RTs) results from Experiment 2. Means of (individual) median reaction times presented for valid and invalid conditions as a function of a cue type condition (gaze and arrow).