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Abstract

The aim of the present study was to investigate whether the biological relevance of the stimulus could enhance task-irrelevant spatial information delivered by a pair of bilateral stimuli. Participants had to perform a Simon-like task in which they were required to respond to the color of two framed squares (on and off-centered), two framed arrows, or two schematic eyes by pressing one of two keys on the left and on the right of the body midline. Results showed that regardless of stimulus type responses towards the direction indicated by the stimuli (corresponding stimulus-response pairings) were faster than responses against it (non-corresponding stimulus-response pairings). It is argued that the biological relevance of the stimuli does not seem to play a crucial role in the automatic processing of stimulus inherent spatial properties.

Introduction

Spatial directional stimuli have been shown to influence our performance in a variety of tasks. In daily life, for example, arrows are commonly used by humans to convey spatial information and have acquired a symbolic and directional meaning. Indeed, central arrows have been also employed as cues to study the voluntarily orienting of visual-spatial attention (e.g., Posner, 1980), suggesting that their spatial and directional meaning can influences people's attentional behavior. Moreover, there is evidence that spatial information is processed automatically and cannot be ignored even in many situations for which it is irrelevant to the task to be performed (e.g., Tsal &Lavie, 1993).

Spatial coding has been studied most extensively in the Simon task where irrelevant spatial information is processed, even though participants are clearly instructed to select the response exclusively on the basis of the relevant, non-spatial stimulus feature (i.e. color or shape) (Simon and Rudell 1967; see Hommel & Prinz, 1997; Lu & Proctor 1995, for reviews). In a typical Simon task stimuli appear in one of two right-left locations and participants respond with right or left effectors. Even if stimulus location is task-irrelevant, when stimulus and response positions are on the same side (e.g., right-right or left-left; i.e. corresponding pairings) performance is faster and more accurate than when they are on opposite sides (e.g., stimulus on the right side and response on the left side, or vice versa; i.e. non-corresponding pairings). Thus, in the Simon task, the irrelevant spatial information is processed, even though participants are clearly instructed to select the response exclusively on the basis of the relevant, non-spatial stimulus dimension.

Recent works have demonstrated that also symbolic centrally presented stimuli such as an arrow can produce the Simon effect (e.g., Masaki, Takasawa, & Yamazaki, 2000; Proctor, Marble, & Vu, 2000).

Intriguingly, Simon effects have also been reported for gaze direction (Zorzi, Mapelli, Rusconi, & Umiltà, 2003 ; Ansorge, 2003b). Therefore, it seems that also spatial information intrinsic to many different categories of visual objects (e.g., central arrows and gaze) is automatically coded and affects performance.

An interesting question is whether different stimulus types convey different amounts of spatial information. For instance, it may be the case that the spatial salience of certain stimuli and objects is more pronounced by virtue of the symbolic or biological meaning they convey, and thus exert a greater influence on performance. Gaze direction can be one of these stimuli given its biological and social value. Indeed, eye gaze has been referred to by several authors as a unique visual stimulus (e.g., Ricciardelli, Baylis, & Driver, 2000; Ristic, Friesen, & Kingstone, 2002; Kingstone, Tipper, Ristic, & Ngan, 2004).

Recently, Ricciardelli, Bricolo, Aglioti, and Chelazzi (2002) reported that irrelevant biological (averted eye gaze) and irrelevant symbolic (a pair of pointing arrows) stimuli presented bilaterally to a central fixation point influenced oculomotor RTs. In an instructed saccadic eye movement task, saccadic latencies were faster when the direction of the instructed saccade corresponded to the direction of pointing arrows compared to when the instructed saccade had the opposite direction. Interestingly however, the biological and symbolic distracters had different effects on the observers' gaze-following behavior. That is, observers made a substantial number of erroneous saccades matching the direction of the distracting gaze. Crucially, such effect was found only with the biological distracters suggesting that both eye gaze and symbolic directional stimuli automatically convey distracting spatial information which influence correct saccadic response times, yet they have a different degree of impact on the observers' reflexive orienting behavior. This difference is likely to be due to the biological relevance of gaze direction.

Two previous studies have suggested that the automatic spatial code elicited by schematic eye-gaze stimuli can be specific in at least two ways. First, Zorzi et al. (2003) found that the lateralized position of eye gaze stimulus is coded independently from gaze direction coding thus suggesting that spatial information from different eye gaze stimulus features is processed by different mechanisms. Second, Ansorge (2003b) showed that gaze direction coding is time-consuming as the interference induced by processing gaze direction increased with response speed, whereas spatial interference stimulus position decreased over time (e.g., Hommel, 1993). However, none of these studies (Zorzi et al., 2003; Ansorge, 2003b) has directly compared whether other kinds of non-biological symbolic stimuli (such as arrows) could produce the same spatial influence as previously shown for eye gaze stimuli.

In the present study we directly compared in the same experiment different types of stimuli (geometrical, symbolic and schematic eyes) in order to test whether or not they generate an automatic stimulus spatial code that influence the lateralized spatial response code to the same extent. We employed a Simon-like task in which participants had to respond to the color of different bilateral symmetrical stimuli. If the biological relevance of the stimulus does not play a role in generating an automatic spatial code, then we expected that non-biological and schematic eye stimuli elicited a similar amount of spatial influence.

If the direction indicated by the stimuli influenced participants' response times, faster response times should be expected for the corresponding than non-corresponding stimuli.

Moreover, if the biological relevance of gaze direction has an effect in modulating the amount of spatial interference in response selection, then we should expect a different amount of interference for gaze-like stimuli. On the contrary, if the spatial information delivered by gaze direction is processed independently of its biological relevance, then we expect to find the same amount of interference for the all three types of stimuli (i.e. geometrical, symbolic and gaze like-stimuli).

Method

Three different types of stimuli (i.e. on and off-center framed squares, framed pointing arrows and schematic eyes) were presented bilaterally to a central fixation cross and were used in a Simon-like task. The subjects had to respond to the color of the stimuli (green or blue) by pressing the designated key on the left or on the right of the body midline using the corresponding hand. The direction indicated by the stimuli could be corresponding, neutral, or non-corresponding in relation to the color response key.

Stimuli appeared on a computer monitor and responses were made by pressing either the "L" or "D" button on the computer keyboard. One key was assigned to the left of the body midline and the response was made by the left index finger, while the other key was assigned to the right and the response was made by the right index finger. Participants were seated at about 60 cm from the computer monitor. The experiment was divided into three different blocks of 120 trials each. Different types of stimuli were presented in each block but within each block the kind of stimuli presented was the same. The presentation order of the blocks was fixed and was as follows: framed squares, gaze-like stimuli, and pointing arrows. This sequence was chosen so that the sight of the gaze-like stimuli would not induce the framed square stimuli to look like eye gaze. Indeed, contextual top-down effects have been shown in the interpretation of simple stimuli (Bentin, Sagiv, Mecklinger, & Friederici, 2002).

Every block was preceded by a practice session of 12 trials in which only the stimuli that would be presented in the following block were shown.

Each trial began with the exposure of a black central fixation cross on a white background (0.5 x 0.5 cm) lasting 450 ms. After 50 ms from the central fixation offset the imperative stimulus was presented centrally and lasted until response. The stimuli presented in the first block (Fig. 1, top panel) consisted of two colored filled squares (i.e. blue or green, 1 x 1 cm) each one surrounded by a squared frame (3 x 2.8 cm). The overall stimulus configuration was presented in the centre of the display and measured 7.2 x 2.8 cm. The filled squares could be both located in the centre of the frame (neutral condition), shifted leftwards, or rightwards. In the second block the stimuli consisted of two elliptic frames of exactly the same size as the squared frames. The size of the colored targets (two inner circles resembling the iris) was identical to that of the colored squares (Fig. 1, middle panel). In addition, the size of the whole configuration was the same as in the first block. In the third block the stimuli were the same as in the first block but the off-centered filled squares were replaced by filled arrows pointing either to the subject's left or to the right, whereas the centered filled squares were replaced by a double pointing arrow (neutral condition) (Fig. 1, bottom panel).

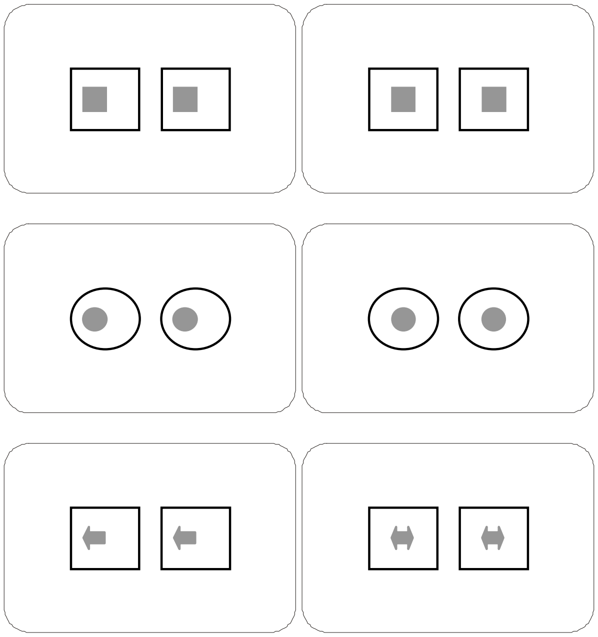

Figure 1: Example of stimuli (blue or green) used, here reduced in size.

Fifteen participants performed a color discrimination (i.e. blue vs. green) task, ignoring any other aspects of the stimuli. Eight participants were instructed to respond to the blue color by pressing the right key (labeled "B") and to the green color (i.e. "Verde" in Italian) by pressing the left key (labeled "V"), whereas the remaining ones received the opposite instructions. The blue and green stimuli were evenly distributed among all conditions within each block. At the end of the experimental session all participants were asked to describe and name the stimuli they had just seen to test whether they had correctly recognized the stimuli.

Results

Errors were quite rare (3%) and were not analyzed. For each subject the overall mean RTs and standard deviation for correct responses were calculated. RTs that exceeded two standard deviations from the overall mean were filtered out from the data sample so to exclude delayed responses. Then, mean RTs were calculated as a function of spatial correspondence (corresponding, neutral and non-corresponding) and stimulus type and entered into a repeated measures analysis of variance (ANOVA). There was a significant main effect of spatial correspondence, [F(2,28) = 23.8, *MSe* = 346.5, p <.001]. Corresponding stimuli produced significantly faster RTs than non-corresponding (495 ms vs. 522 ms respectively, t(14) = 5.6, p <.001 corrected for multiple comparisons) and neutral stimuli (495 ms vs. 508 ms respectively, t(14) = -5.2, corrected p <.001), which in turn were significantly faster than RTs for non-corresponding stimuli (508 ms vs. 522 ms respectively, t(14) = -3.4, corrected p <.01). The effect of the type of stimuli did not reach significance, and the two factors did not interact significantly.

All participants correctly recognized the stimuli. All of them described the pointing arrows and freely reported the relative right/left position of the squares within the central frames. More importantly, they spontaneously referred to the circled stimuli as eyes.

Intriguingly, the biological relevance of the stimulus did not seem to affect the magnitude of the spatial correspondence effect (i.e. the difference between non-corresponding and corresponding responses), as the perceived gaze direction produced a similar amount of spatial interference compared to that elicited by the non-biological stimuli [F(4,56) = 1.2, *MSe* = 166.5, p = 0.3, n.s.] (see Table 1). Therefore, in that respect eye gaze does not seem to be a special stimulus.

Table 1. Mean RTs (ms) C = corresponding, N = neutral, NC = non-corresponding, SE = Simon effect (NC – C)

Stimuli	C	N	NC	SE
Squares	498	504	523	25
Gaze-like	491	505	515	24
Arrows	497	517	528	31

General discussion

Our findings consistently show that a Simon effect of similar magnitude occurs with bilateral non-biological spatial cues (i.e. on and off-center framed squares and pointing arrows) as well as with biological ones (i.e. gaze direction). Faster response times towards the direction indicated by the stimuli (corresponding) rather than against it (non-corresponding) were found despite the type of the stimuli used. As the stimulus spatial feature was irrelevant to the task, the results clearly indicate automatic response activation evoked by all types of stimuli used. Interestingly, therefore, gaze-like stimuli evoke an automatic spatial coding that is not different from that produced by other directional stimuli.

The present results seem to be at odds with previous claims which regarded gaze direction as a unique spatial cue, capable also of automatically orienting the observer's visual attention (e.g., Friesen & Kingstone 1998; Driver et al., 1999). How can the present findings be reconciled with previous work? The fact that arrows, for example, exert a similar amount of interference to that elicited by gaze direction is in agreement with the increasing evidence that automatic attentional cueing effects can be produced not only by gaze cues (e.g., Langton & Bruce 1999; 2000) but also by other directional stimuli, biologically relevant or not, such as arrows and words (e.g., Hommel et al., 2001; Tipples, 2002). Therefore, in this respect the fact that arrow stimuli exert a similar effect to that elicited by gaze-like stimuli is not contradictory.

Interestingly, so far the main difference between gaze stimuli and arrows seems to rest solely on the cortical mechanisms underlying the attentional shifts in response to gaze and arrow stimuli (Kingstone, Friesen, & Gazzaniga, 2000; Ristic et al., 2002). More precisely, it was shown that both types of non-predictive gaze and arrow cues equally triggered visual attention in adults. However, in a split-brain patient non-predictive arrows produced orienting of attention in both hemispheres (Ristic et al. 2002), whereas non-predictive gaze cues produced reflexive orienting only in the hemisphere specialized for face-processing (Kingstone et al., 2000). These studies strongly indicate that although gaze and arrow cues may produce similar behavioral effects, they are sub-served by different brain systems.

A similar argument could be made to account for the fact that not just arrow and gaze stimuli produced similar Simon effects in the present study but so did geometrical stimuli (i.e. off-centre framed squares). Kato, Matsuo, Matsuzawa, Moriya et al. (2001) used bilaterally presented schematic eyes, squares, and arrows as three symbolic pointers to study cortical activation during endogenous orienting of visual attention. They found different anatomical activations depending on the type of stimuli. However, the authors did not report any behavioral difference across the three cue types. Different findings between squares and schematic eyes were reported by Zorzi et al. (2003) who found the Simon effect only for eye-like stimuli but not for geometrical square stimuli which were used in a control experiment. However, their control experiment showed a marginally significant Simon effect for square stimuli which was primarily based on the interference effect (i.e. the difference between non-corresponding and neutral responses), as has also been suggested in the present study. Thus, the unique nature of a “gaze direction Simon effect” seems to be still a matter of debate. One plausible reason against the unique nature of a “gaze direction Simon effect” can be advanced following Ansorge (2003a), who showed that even when upright alphanumeric stimuli are used, a Simon effect can be elicited depending on their context-relative spatial code. Indeed, in the present study the context-relative spatial position of the bilaterally presented stimuli may, at least, explain the Simon effect that emerged in response to both the gaze-like stimuli and the colored squares. As the stimulus location can be automatically coded with respect to multiple reference frames (e.g., Lamberts, Tavernier, & D’Yedewalle, 1992), it is plausible to argue that in some circumstances it is the context-relative frame which is dominant in determining spatial coding (for the role played by the context frame in the gaze cueing effect see Bayliss, Di Pellegrino, & Tipper, 2004).

This could be especially true in the case of bilateral stimuli in which the body midline can play only a marginal role as a frame of reference. In this framework, our results can be explained by considering that when the colored squares (or circles) were off-centered to the left or to the right they may have activated a left or right spatial code, respectively (see Danziger, Kingstone, & Ward, 2001).

The crucial issue to address in future work is whether or not the neural mechanisms involved in task-irrelevant spatial information effects are the same depending on the stimulus spatial characteristics (i.e. location, direction), or on its biological relevance (i.e. biological stimuli, symbolic pointers). Recently, an event-related fMRI study (Peterson, Kane, Alexander, Lacadie et al., 2002) investigated how the brain processes task-irrelevant information and resolves competing task demand in two different conflict tasks (i.e. the Simon and the Stroop tasks). Intriguingly, similar brain activations and time courses were found across tasks regardless of the differences in nature of the stimuli and the responses used, thus suggesting that it is likely that the systems giving rise to the behavioral interference are also similar. Therefore, it might well be the case that a common mechanism generates a spatial code from any directional stimuli despite their biological relevance. This might also imply that the spatial code could be extracted prior to the information about the type of the stimuli. However, further experiments are needed in which the degree of biological relevance is varied more extensively than in the present study, by employing, for example, more realistic gaze stimuli, and/or dynamic face context.

In conclusion, we have brought behavioral evidence indicating that different types of bilateral symmetrical stimuli can automatically drive spatial coding despite their biological relevance. Further investigation within this research domain is needed to understand the relationship between the processing of the spatial meaning of symbolic and biological relevant stimuli and the functioning of the basic and cognitive spatial mechanisms underlying their processing.

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