Spatial Simon effects and compatibility effects induced by observed gaze direction

Ulrich Ansorge

Department of Psychology, Bielefeld University, Germany

Preconditions for the processing of observed gaze direction were studied by spatial Simon and compatibility effects. In five experiments, responses in the direction of a gaze were faster than responses in the opposite direction. Gaze direction influenced response speed although its processing was not required (Experiments 1, 2, 4, and 5). The result supports the notion of an inclination to process observed gaze direction in humans. However, the processes underlying the Simon effect of observed gaze direction were relatively time-consuming: Simon effects induced by gaze direction increased with response speed. Focusing of attention seemed to be part of the necessary processes: Simon effects were eliminated if attention was focused away from the eyes (Experiment 2). Further, if the processing of observed gaze direction was required, Simon effects by faces’ observer-relative screen positions were absent (Experiment 3). Control conditions revealed that Simon effects by gaze direction can be produced with faces tilted by 90°, but that corresponding Simon effects do not result from numerical stimuli with an analogue spatial structure (Experiment 4), and that Simon effects result from gaze directions of scrambled faces (Experiment 5).

The perception of gaze direction of another individual helps to understand where the alter ego directs her or his attention, and hence what she or he is up to (e.g., Baron-Cohen, 1995; Baron-Cohen & Cross, 1992). Such processes are important in co-ordinating one’s own behaviour with that of others in reciprocal social interaction, for instance, in dancing, playing, boxing, etc. It is therefore not surprising that, in cognitive psychology, the notion of a strong inclination in humans to process spatial information delivered by observed gaze direction has been put forward under different perspectives (e.g., Baron-Cohen, 1995; Kampe, Frith, Dolan, & Frith, 2001; Langton & Bruce, 2000; Perrett & Emery, 1994; for an overview see Langton, Watt, & Bruce, 2000). For example, the inclination is

Please address all correspondence to: U. Ansorge, Department of Psychology, Bielefeld University, PO Box 100131, D-33501 Bielefeld, Germany. Email: ulrich.ansorge@uni-bielefeld.de

Supported by Grant Ne 366/6-1 from the Deutsche Forschungsgemeinschaft (DFG) to Odmar Neumann. Thanks to Carlo Umiltà, Rob Ellis, Glyn Humphreys, and Manfred Heumann for valuable suggestions, and Heike Hartwig-Jakobs for help with the final preparation of the manuscript.

© 2003 Psychology Press Ltd
http://www.tandf.co.uk/journals/pp/13506285.html DOI:10.1080/1350628024400122
reflected in the evident suitability of observed gaze direction to reflexively trigger attention shifts (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). In the Driver et al. study, reaction time (RT) to peripheral targets was facilitated by a face that was looking in the direction of the target (valid condition), although targets were less likely at the looked-at location than at an alternative location, and participants knew that (Experiment 3): A shift of attention in the direction of an observed gaze was evidently hard to suppress and hence, seems to be relatively obligatory given that the matching information is encountered. In this and a number of further respects, processing of gaze direction corresponds well to Fodor’s (1983) defining characteristics of modular or automatic processes (see Baron-Cohen, 1997).

However, gaze direction effects appear to correspond less well to another criterion of automatic or modular processing: The process seems to be not especially rapid. It is slower than other cases of automatic processing. To reliably obtain RT facilitation in the valid condition, SOAs (stimulus onset asynchronies) between cues (faces) and targets had to be greater than 100 ms (Driver et al., 1999). This is substantially longer than the less-than-50-ms-cue–target SOAs that are sufficient for automatic attentional capture by peripheral cues (e.g., Nakayama & Mackebeen, 1989; Neumann, Esselmann, & Klotz, 1993). Driver et al. reasoned that the encoding of gaze direction could be more time-consuming than the detection of an abruptly onsetting peripheral cue. This seems plausible given that to shift attention to the cue, the coding of its observer-relative position suffices. In contrast, object-inherent or context-relative spatial content, such as that of gaze direction, can presumably only be coded after attention has been shifted to the observer-relative position of the object in question (i.e., the eye), and has been focused there.

In sum, that the processing of gaze direction is relatively slow does not necessarily conflict with its interpretation as an automatic process as defined by Logan (1988, 1995). According to Logan, directing attention to previously encountered, specific information can lead to fast and efficient retrieval and activation of past processes for that information. Once attention is directed to the eyes, the processing of gaze direction might be reliably triggered.

In the present study, it was tested whether evidence for an attention-dependent and therefore slow, but otherwise efficient processing of observed gaze direction could be obtained. If observed gaze direction is processed even in the absence of an explicit intention to do so, observed gaze direction should be suitable to induce a Simon effect (Zorzi, Mapelli, Rusconi, & Umiltà, in press). Responses given to the side of a ‘‘target stimulus’’ (compatible condition, e.g., left-hand responses to stimuli on the left) are faster and less error-prone than responses given to the side opposite to a target stimulus (incompatible condition, e.g., left-hand responses to stimuli on the right; Fitts & Deininger, 1954; Fitts & Seeger, 1953; for a review see Proctor & Reeve, 1990). The Simon effect denotes the same advantages for corresponding (e.g., left-hand responses to stimuli on the
left) compared to non-corresponding conditions (e.g., left-hand responses to stimuli on the right) in situations where the processing of the target’s location is not explicitly required (for reviews see Lu & Proctor, 1995; Simon, 1990). For example, if a green target requires a right-hand response, only processing of target colour is explicitly required. Yet, responses are faster to green targets on the right than to green targets on the left (e.g., Roswarski & Proctor, 1996). The Simon effect can thus be considered to reflect automatic processing of the inducing spatial information: Processing of the target’s observer-relative position is apparently easily triggered, even if this is not explicitly required.

Recently, Simon effects induced by observed gaze direction have been reported (Zorzi et al., in press). Whether the Simon effects of observed gaze direction depend on time-consuming processes, such as the focusing of attention on the eyes, was tested in the current study by the following predictions. First, if the processing of gaze direction is slow and contingent on a prior focusing of attention on the eyes, a Simon effect induced by gaze direction might increase with increasing RT (Experiments 1, 2, 4, and 5). In line with this prediction, it seems as if in the course of the target’s processing, observer-relative, egocentric spatial content generally gives way to object-inherent spatial content (e.g., Pisella & Rossetti, 2002). Also, partly confirming the prediction, object-inherent or context-relative spatial code can lead to Simon effects (or related spatial effects) that at least do not decrease with increasing RT (Ansorge, in press; Danziger, Kingstone, & Ward, 2001), whereas the Simon effect that is induced by observer-relative spatial code does (Hommel, 1993, 1997).

Second, if attention is part of the necessary processes to derive object-inherent or context-relative spatial code, that means, if attention needs to be focused on the eyes to obtain spatial code from observed gaze direction, focusing attention away from the eyes should lead to an abolition of the Simon effect (Experiment 2). Third, a Simon effect that is induced by the observer-relative left or right positions of faces should be eliminated if the processing of gaze direction is explicitly required by the instructions. It is known that Simon effects depend on where a stimulus is located relative to the focus of attention (e.g., Nicoletti & Umiltà, 1989; Stoffier, 1991; Stoffier & Yakin, 1994; Umiltà & Liotti, 1987). For instance, Nicoletti and Umiltà demonstrated that a Simon effect is determined by where the target appears relative to the focus of attention rather than by where the target appears relative to the centre of the screen. If attention is focused on a left or right target prior to response selection the target’s position is defined anew as neutral (i.e., as being in the focus of attention): Simon effects induced by the observer-relative left and right positions of targets are abolished, if targets are shown at attended locations (Stoffier & Yakin, 1994; Umiltà & Liotti, 1987). Likewise, in the current study, the need to focus attention on the eyes to encode gaze direction prior to the response selection should prevent observer-relative Simon effects of the screen-side positions of the target faces (Experiment 3).
In the final experiments of the present study, the mechanisms responsible for the Simon effect of gaze direction are studied in more detail. In Experiment 4, it is tested whether Simon effects of gaze direction indeed depend on object-relative spatial code or whether they depend on the direction of the final attention shift prior to the response. Also, control conditions are employed to check whether corresponding Simon effects can be induced by other stimuli with an inherent spatial structure: Previous research has shown that central stimuli besides gaze directions of eyes, such as arrows, can induce attention shifts (Eimer, 1997) or Simon effects (Masaki, Takasawa, & Yamazaki, 2000). Finally, in Experiment 5, scrambled faces are employed. This experiment should provide some evidence with regard to the question of whether gaze direction effects depend on a successful concomitant face perception.

EXPERIMENT 1

Cartoon faces that look to the left or to the right are presented on the vertical meridian of a CRT. It is tested whether spatial information delivered by observed gaze direction is derived automatically. Is spatial information inherent to gaze direction processed if its processing is not explicitly required? Does it lead to a Simon effect? To answer these questions, participants respond to the colours of irises (i.e., whether irises are red or green), irrespective of where the eyes are looking. A Simon effect induced by gaze direction should show up as shorter RT in conditions where response side and gaze direction correspond (corresponding condition) compared to conditions where response side and gaze direction do not correspond (non-corresponding condition). For instance, if green irises require a right-hand response, responses should be faster if a green-eyed face looks to the right than if a green-eyed face looks to the left (Zorzi et al., in press).

More importantly, the Simon effect induced by gaze direction is investigated as a function of absolute RT by vincentizing correct responses in corresponding vs non-corresponding conditions (Hommel, 1997; Ratcliff, 1979). Previous research has shown that Simon effects induced by spatial code derived from observer-relative positions of the targets decrease with increasing RT due to a rapid decay of the irrelevant observer-relative position information over time (e.g., Hommel, 1993, 1997). However, in the present experiment, a Simon effect induced by gaze direction might increase with increasing RT, because it is assumed that a Simon effect induced by observed gaze direction is contingent on a prior focusing of attention on the eyes, which itself takes time, so that the chances for a successful focusing on the eyes increase with increasing RT, too. Note, that in the current experiment, focusing of attention on the eyes is not necessitated by the task itself: Likely, colours can be discerned if attention is relatively broadly distributed across many positions on the screen (e.g., Treisman & Gelade, 1980).
Method

Participants. Eight students (four female) of Bielefeld University participated in Experiment 1. They had a mean age of 27.3 years. Here and in the following experiments, participants had normal or fully corrected vision, and were paid for their participation.

Apparatus, procedure, and design. Stimulus presentation (on CRT) and response registration were controlled by a personal computer. Stimuli were presented in white/red or white/green on black.1 RT was measured to the nearest millisecond from the beginning of the stimuli (faces). Participants sat upright in a dimly lit room with their lines of gaze straight ahead and their heads in a chin-rest, 65 cm in front of the monitor. Response keys for the left and right index fingers, respectively, were the left and right mouse buttons. The mouse was placed in the middle of a table in front of the participants.

In each trial, a cartoon face was presented centred on the vertical meridian of a CRT for 500 ms, either 3.77° above or below the screen’s centre. Each face consisted of eyes, nose, and mouth. The eyes comprised two bigger empty circles (1° diameter) as outlines, that enclosed smaller filled circles (0.2° diameter) as irises. Right and left gaze directions were produced by presenting irises shifted relative to the encompassing outline circles (see also Figure 1). The nose consisted of a vertical line (0.4° long), presented directly below the eyes. The impression of a smiling mouth was evoked by an upward bent semicircle (1° diameter), presented immediately below the nose. Faces were white, with the exception of the irises, which were either red or green. In each trial, a fixation mark (a rectangle, 0.1° in height × 0.14° in width) was presented prior to a face for 800 ms at the centre of the screen. If participants gave an incorrect response, the message “Wrong key!” was presented in German (“Falsche Taste!”), and if a response was slower than 750 ms, the message “Faster!” was presented in German (“Schneller!”) for 750 ms centred on the screen. The inter-trial interval was fixed at 2100 ms.

Participants responded to the colours of irises. Half of the participants responded to red irises by pressing the right mouse key with their right index finger, and to green irises by pressing the left mouse key with their left index finger. For the other half of the participants this stimulus–response mapping-rule was reversed. In the gaze-direction corresponding condition, gaze direction and response side corresponded (i.e., both were left or both were right). In the gaze-direction non-corresponding condition, gaze direction and response side did not

---

1 Spatial information delivered by eyes in which iris–sclera contrasts are inverted might be less precise than the corresponding information provided by eyes with more natural iris–sclera contrasts (Ricciardielli, Baylis, & Driver, 2000). If anything, this means that, in the current study, conditions could have been unfavourable for a Simon effect induced by gaze direction to result.
Figure 1. Succession of events in a trial (from lower left to upper right). A trial started with the presentation of a fixation mark. Depicted are several different conditions. After fixation, an upright face (Experiments 1, 2, 3, and 5, see upper left corner), a face tilted by 90° of arc either to the left or to the right (Experiment 4, see upper right corner), a row of numbers with a corresponding spatial structure tilted by 90° of arc to the left or to the right (Experiment 4, see lower left corner), or a scrambled face (Experiment 5, see lower right corner) was presented. Gaze direction of the face was either to the left or to the right (depicted). Faces were presented either below or above fixation (depicted; Experiments 1, 2, 4, and 5), or left or right of fixation (Experiment 3). For further information see text.

correspond (i.e., gaze direction was to the right and a left response was required, or gaze direction was to the left and a right response was required).

Each of the resulting 8 conditions (2 Gaze directions × 2 Colours × 2 Positions) was repeated 30 times, leading to 240 trials. Together with a brief practice consisting of two repetitions of each condition the whole experiment took about 25 mins.

Results

Responses faster than 100 ms and slower than 1000 ms were excluded from the analyses (0.9%). Simon effects were tested for significance by comparing mean RTs and arc-sine transformed error rates of the corresponding and the non-
corresponding conditions by one-tailed t-tests for dependent samples. RT was significantly shorter in the corresponding (508 ms) than in the non-corresponding condition (538 ms), t(7) = 2.953, p < .05. The effect was not significant in the analysis of the error rates (corresponding: 2.7%; non-corresponding: 5.8%), t(7) = 1.857, p = .05.

Mean RTs of correct responses were vincentized separately for corresponding and non-corresponding conditions (Hommel, 1997): Individual mean RTs were derived for each quintile of the rank-ordered raw RT data, and analysed by an ANOVA with the two within-participants factors of gaze-direction correspondence (corresponding vs non-corresponding), and quintile of the RT distribution (1st to 5th). Significant main effects of gaze-direction correspondence, F(1, 7) = 8.61, p < .05, quintile, F(4, 28) = 176.9, p < .001, and a significant interaction between these factors resulted, F(4, 28) = 19.24, p < .01 (see also Figure 2). Responses were faster in the corresponding (508 ms) than in the non-corresponding condition (538 ms), and increased across quintiles (1st: 413 ms, 2nd: 470 ms, 3rd: 510 ms, 4th: 558 ms, 5th: 665 ms). Pair-wise comparisons of corresponding and non-corresponding mean RTs for each bin by t-tests for dependent samples (one-tailed) revealed significant Simon effects in all quintiles but the first one, t(7) > 2.275, p < .05.

Figure 2. Reaction time (RT) in ms as a function of gaze-direction correspondence (squares: Gaze-direction corresponding, crosses: Gaze-direction non-corresponding) and quintile of the RT distribution (1st to 5th) of Experiment 1 (on the left) and condition arises of Experiment 2 (on the right).

\(^2\)Where appropriate, degrees of freedom were corrected by Greenhouse-Geisser coefficients ε and the corrected alpha levels are given (Hays, 1988).
Discussion

A Simon effect induced by the spatial relation between gaze direction and overt response was obtained. Hence, spatial information delivered by observed gaze direction was processed although this was not explicitly required by the instructions. The result supports the notion of a bent in humans towards the processing of observed gaze direction.

Moreover, the Simon effect induced by gaze direction increased with increasing RT, and was only significant among the slower responses. The result is in line with the assumption that a Simon effect induced by gaze direction is contingent on a focusing of attention on the eyes prior to response selection. However, as the faces were presented centred on the vertical meridian, irises were minimally shifted on the screen: With gazes directed to the left, irises on both sides of the vertical meridian were presented shifted to the left, and with gazes directed to the right, irises were presented shifted to the right. Hence, the Simon effect of gaze direction could have been due to observer-relative positions of the irises per se rather than to gaze directions. This might be considered an implausible assumption in the light of the increment of the Simon effect with increasing RT. Typically, Simon effects of a target’s observer-relative position decrease rather than increase as a function of RT (Hommel, 1993, 1997). Nevertheless, in Experiment 2, it is tested whether a Simon effect induced by gaze direction can be obtained with the irises centred on the screen, too.

EXPERIMENT 2

In Experiment 2, left- and right-looking faces are presented with the irises centred on the vertical meridian. Hence, faces are shifted with respect to the centre of the screen in the opposite direction of the gazes: With gazes to the right, faces are slightly shifted to the left, and with gazes to the left, faces are slightly shifted to the right. In one block, participants respond to the colours of the irises, irrespective of where the eyes are looking. Again, if gaze direction is processed automatically in the sense described by Logan (1988, 1995), a Simon effect induced by gaze direction should result, at least among the slower responses. Note, that in the present experiment, if anything, a Simon effect induced by the faces’ observer-relative screen positions should diminish a Simon effect of gaze direction.

To test whether attention needs to be focused on the eyes for gaze direction to be processed, participants respond to a region away from the eyes in a second block of Experiment 2. In these blocks, participants respond to the mouths (i.e., whether mouths are upwardly or downwardly bent). It is expected that this necessitates a focusing of attention on the mouths, and that therefore an occasional focusing of attention on the eyes and a resulting Simon effect induced by the spatial code of gaze direction will be prevented.
Method

Participants. Eight students (all female) of Bielefeld University participated in Experiment 2. Participants had a mean age of 23 years.

Apparatus, stimuli, and procedure. These were equal to Experiment 1 with the following exceptions. First, faces were presented with the irises centred on the vertical meridian. Second, faces with upwardly and downwardly bent semicircles as mouths were presented equally often. Third, in one block, participants responded to colours of irises (condition irises). In another block, participants responded to whether mouths were upwardly or downwardly bent (condition mouths). In the latter blocks, half of the participants responded to upward bent mouths by pressing the left key, and to downward bent mouths by pressing the right key. This stimulus–response mapping-rule was reversed for the other half of the participants. The order of the blocks was balanced across participants.

Results

0.7% of the responses were excluded as outliers. Mean vincentized RTs of correct responses in conditions irises and mouths were submitted to separate ANOVAs with the two within-participants factors of gaze-direction correspondence (corresponding vs non-corresponding), and quintile of the RT distribution (1st to 5th). Only in condition irises, a significant interaction of gaze-direction correspondence and quintile resulted, $F(4, 28) = 6.02, p < .05$ (see also Figure 2): Evidence for a Simon effect induced by gaze direction was restricted to the slowest responses in condition irises (RT corresponding—RT non-corresponding in the 5th quintile) $t(7) = 2.203, p < .05$, one-tailed. Significant main effects of quintile resulted in both conditions, irises, $F(4, 28) = 97.75, p < .001$, and mouths, $F(4, 28) = 147.74, p < .001$: RT increased across quintiles (irises: 1st: 386 ms, 2nd: 429 ms, 3rd: 462 ms, 4th: 501 ms, 5th: 597 ms; mouths: 1st: 425 ms, 2nd: 474 ms, 3rd: 511 ms, 4th: 556 ms, 5th: 661 ms). All other effects were not significant (all other $p > .28$).

Arc-sine transformed error rates were also submitted to a repeated-measures ANOVA with the two factors gaze-direction correspondence (gaze-direction corresponding vs gaze-direction non-corresponding) and target (irises vs mouths). No significant effects were observed in this analysis (irises/corresponding: 2.7%; irises/non-corresponding: 3.5%; mouths/corresponding: 4.6%; mouths/non-corresponding: 5.7%).

Discussion

Evidence for a Simon effect induced by gaze direction was restricted to the slowest responses of condition irises, and was much weaker in the present than
in the previous experiment. This is not surprising, because in Experiment 2 the Simon effect induced by gaze direction was susceptible to a Simon effect of the faces’ observer-relative positions on the screen that was in the opposite direction. Also, in Experiment 1, a Simon effect by the irises’ positions on the screen could have enhanced a Simon effect induced by gaze direction as both effects would have been in the same direction. Importantly, in both experiments, evidence for the Simon effect of gaze direction was only obtained for slower responses as was expected due to its contingency on a prior focusing of attention on the eyes. That the focusing of attention on the eyes is indeed a necessary precondition for the processing of gaze direction was also suggested by the results of condition mouths. There, attention likely needed to be focused on a region of the faces away from the eyes, and a Simon effect of gaze direction was prevented.

EXPERIMENT 3

It is tested, whether attention is routinely focused on the eyes if the processing of observed gaze direction is required by the instructions. This should be the case if deriving object-inherent spatial content from observed gaze direction depends on such prior focusing of attention on the corresponding region of the face. Participants have to respond to gaze direction either by giving spatially compatible responses (e.g., if the gaze is to the right press the right key), or by giving spatially incompatible responses (e.g., if the gaze is to the left press the right key). In this situation, processing of gaze direction is explicitly required: It has to be processed to determine the appropriate response.

To test whether under these conditions attention is focused on the eyes, faces are presented to the left and to the right of the centre of the screen. If attention is focused on the eyes prior to response selection, no Simon effect of the faces’ observer-relative positions on the screen should be obtained: Focusing attention on the eyes should render the initially shifted positions of the faces spatially neutral (e.g., Stoffler & Yakin, 1994; Umiltà & Liotti, 1987). However, if attention is not focused on the eyes prior to response selection, a Simon effect induced by the faces’ observer-relative positions on the screen should result.

Method

Participants. Twelve students (eight female) of Bielefeld University with a mean age of 27.2 years participated in Experiment 3.

Apparatus, stimuli, and procedure. These were equal to Experiment 1 with the following exceptions. Faces were presented on the horizontal meridian, shifted by 3.77° either to the right or to the left. Half of the participants responded compatibly to gaze directions: If a face looked to the right they had to press the right key, and if it looked to the left they had to press the left key. The
other half of the participants responded incompatibly to gaze directions: If a face looked to the right they had to press the left key, and if it looked to the left they had to press the right key. Left- and right-looking faces were presented equally often on the left and on the right.

Results

0.5% of all responses were excluded as outliers. Separate mixed-model ANO-VAs of mean RTs and arc-sine transformed error rates with the between-participants factor gaze-direction compatibility (gaze-direction compatible vs gaze-direction incompatible), and the within-participants factor observer-relative correspondence (observer-relative corresponding vs observer-relative non-corresponding) revealed a significant main effect of gaze-direction compatibility on RT, $F(1, 10) = 8.78, p < .05$. Responses were faster in gaze-direction compatible (494 ms) than in gaze-direction incompatible conditions (555 ms). No other effects or interactions resulted in the analyses of RTs and error rates (all other $F$ < 1; see also Figure 3).

Discussion

A compatibility effect which was induced by the spatial relations between gaze directions and overt responses was observed in the absence of a Simon effect by the faces’ observer-relative screen positions. It is known that Simon effects depend on where a stimulus is located relative to the focus of attention of the observer (e.g., Nicoletti & Umiltà, 1989; Umiltà & Liotti, 1987). As assumed,
focusing of attention on the eyes prior to response selection presumably rendered the faces’ lateral positions neutral (i.e., centred at the focus of attention). Therefore, attention is seemingly routinely focused on the eyes if gaze direction has to be processed. The result is in line with the assumed contingency of the processing of observed gaze direction on a prior focusing of attention on the eyes.

One might wonder how a Simon effect induced by the observer-relative positions should have possibly contributed to the results of Experiments 1 and 2 (as was claimed), if focusing attention on the eyes prevents such observer-relative Simon effects. As explained, if search was for colour targets in Experiments 1 and 2, attention was presumably focused less narrowly on the eyes in at least a sub-set of all trials, because colour can be searched for in a more parallel fashion across the screen (e.g., Treisman & Gelade, 1980). Hence, reference frames of spatial codes that contributed to the overall Simon effect likely have been more variable to include code from observer-relative positions of the faces in at least some of the trials. In line with this assumption, if responses are to the colours of the irises, additive Simon effects of both, object-inherent spatial code from gaze direction and observer-relative spatial code from eye positions can be found (Exp. 4 of Zorzi et al., in press).

**EXPERIMENT 4**

So far the data are not conclusive with respect to the exact mechanism that is responsible for the Simon effect of gaze direction. First, as assumed, *object-relative spatial code* corresponding to the irises’ positions within the faces could have produced the Simon effect. From a logical point of view, left and right gaze directions must be determined relative to a top-down axis of the context, and evidence suggests that the corresponding top-down axis can be provided by the encompassing facial features: Simon effects of face-relative left and right target positions have been observed with faces tilted by 90° of arc (Hommel & Lippa, 1995; Proctor & Pick, 1999). As explained, the selective presence of the Simon effect among the slower responses would be entailed by the relatively slow determination of the responsible object-relative code (e.g., Pisella & Rossetti, 2002).

Second and alternatively, the Simon effect might be due to the spatial code provided by the *direction of the final attention shift* prior to the response: Attention shifts can induce Simon effects (Rubichi, Nicoletti, Iani, & Umiltà, 1997), and as mentioned, attention shifts triggered by observed gaze direction require some prior processing time (Driver et al., 1999). In effect, Simon effects which are induced by attention shifts in the direction of gazes might influence primarily the slowest responses: In these conditions, gaze-induced attention shifts might have more frequently taken place prior to the response compared to situations in which responses are fast.
The two possible explanations of the Simon effect are tested in Experiment 4. Faces are presented tilted by 90° of arc either to the left or to the right. Predictions are straightforward. If the context-relative or object-inherent coding of gaze direction relative to the facial top-down axis is responsible for the Simon effect (among the slowest responses), once again, the effect should be observed: Tilting the faces leaves the spatial code of left and right gaze directions relative to the top-down axes of the context-faces unchanged (e.g., Hommel & Lippa, 1995). However, if the direction of the final attention shift produces the Simon effect (among the slowest responses), the effect should be absent: As before, responses are to the left and to the right, but the final attention shift will be upward (for left-looking faces tilted by 90° to the right, and for right-looking faces tilted by 90° to the left) or downward (for right-looking faces tilted by 90° to the right, and for left-looking faces tilted by 90° to the left). Hence, the correspondence between the direction of the attention shift and the response side will be low and about the same in all conditions.

Also, a control condition is employed to test whether the Simon effect which is induced by gaze direction is gaze- or face-specific, or whether an analogue effect can be obtained with other targets that have similar context-relative or object-inherent spatial content (e.g., Ansorge, in press). To that end, in separate blocks, two red or two green numbers are presented shifted to the left or to the right relative to an encompassing row of four white numbers, so that the positions of the response-relevant, coloured target numbers correspond to the locations of the coloured irises, and the positions of the white context numbers correspond to those of the white encompassing eye outlines (see Figure 1). The number configurations are also presented tilted by 90° of arc to the left or to the right. Numbers, like faces, have inherent top-down axes. Therefore, if configurations that encompass top-down-axis-relative and attended-to left or right feature positions generally induce Simon effects in relation to left and right responses, these Simon effects should be evident with both kinds of targets, numbers and faces.

Method

Participants. Sixteen students (twelve female) of Bielefeld University with a mean age of 23.9 years participated in Experiment 4.

Apparatus, stimuli, and procedure. These were equal to Experiment 1 with the following exceptions. First, faces were presented with the irises centred on the screen, and tilted by 90° of arc to the left or to the right. Second, in one block, faces with red and green irises were presented as before (condition irises). In a second block, rows of six numbers (presented in an area subtending a visual angle of 0.25° length by 0.39° height) plus two blanks (of similar area) were presented (conditions numbers). Four of these numbers, the outer two and the
inner two, were white and formed a spatially neutral and left–right symmetrical reference frame that encompassed the blank spaces and the remaining two coloured target numbers, which were either both red, or both green. Within each trial, both target numbers were shifted in the same direction either to the left or to the right relative to the spatially neutral frame of white numbers (see Figure 1). Like faces, the number rows were presented tilted by 90° to the left or to the right.

In both blocks, participants responded to the colours of the targets. Either they had to press the left mouse key in response to red irises and numbers and the right mouse key in response to green irises and numbers, or vice versa. Half of the participants received faces and number rows tilted to the left. The other half received faces and number rows tilted to the right. The order of the blocks (irises first vs numbers first) was balanced across participants. In the blocks, each of the four possible combinations (two Colours × two Directions) was repeated 40 times. Together with a short prior practice, the experiment took about 45 min.

Results

0.3% of the responses were excluded as outliers. Mean vincentized RTs of correct responses in conditions irises and numbers were submitted to separate ANOVAs with the two within-participants factors of direction correspondence (corresponding vs non-corresponding), and quintile of the RT distribution (1st to 5th). Only in condition irises, a significant interaction of direction correspondence and quintile resulted, $F(4, 60) = 5.85, p < .05$ (see also Figure 4): Evidence for a Simon effect induced by gaze direction was again restricted to the slowest responses in condition irises (RT non-corresponding—RT corresponding in the 4th and 5th quintile): $t(15) > 1.79, p < .05$, one-tailed. Significant main effects of quintile resulted in both conditions, irises, $F(4, 60) = 150.65, p < .001$, and numbers, $F(4, 60) = 112.27, p < .001$: RT increased across quintiles (irises: 1st: 348 ms, 2nd: 386 ms, 3rd: 418 ms, 4th: 458 ms, 5th: 546 ms; numbers: 1st: 332 ms, 2nd: 371 ms, 3rd: 405 ms, 4th: 443 ms, 5th: 536 ms). All other effects were not significant (all other $p > .15$).

Arc-sine transformed error rates were submitted to a repeated-measures ANOVA with the two factors direction correspondence (direction corresponding vs direction non-corresponding) and target (irises vs numbers). No significant effects were observed in this analysis (irises/corresponding: 4.6%; irises/non-corresponding: 4%; numbers/corresponding: 4.5%; numbers/non-corresponding: 4.3%).

Discussion

Results of the preceding Experiments 1 and 2 were basically replicated: Evidence for a Simon effect induced by gaze direction was again restricted to the
slowest responses of condition irises. As the interaction of correspondence and quintile resulted with tilted faces, attention shifts were never in the direction of the responses. Therefore, directions of the attention shifts do not account for the Simon effect of gaze direction. Rather, left–right gaze directions relative to the context’s (i.e., facial) top-down axis were apparently responsible for the Simon effect (see also Hommel & Lippa, 1995; Proctor & Pick, 1999).

Evidence for a corresponding Simon effect was not observed with number rows which have inherent spatial top-down and left-right axes, too. Tentatively, one might conclude that gaze direction is a special stimulus: It induces object-inherent or context-relative Simon effects more readily than other spatial configurations. However, context-relative Simon effects induced by rows of alphanumeric characters which are presented centred and upright can be obtained (e.g., Ansorge, in press). Also, given the wide variety of conceivable control conditions that could have been employed in the current experiment, the conclusion is far from safe. For instance, other stimuli with an object-inherent spatial structure which resemble frequently encountered or “animate” objects might equally reliably induce Simon effects, even if tilted.

EXPERIMENT 5

In Experiment 5, it is tested which aspects of the stimuli employed in the previous experiments are mainly responsible for the Simon effect of gaze direction. To that end, Simon effects induced by gaze directions of intact faces
are compared to those of scrambled faces. In Experiment 4, it was demonstrated that gaze direction can be determined relative to facial top-down axes, and that other stimuli (number rows) do not induce an analogue to this Simon effect. Therefore, it could be that the Simon effect of gaze direction is a by-product of the concomitant processing that ultimately leads to successful face perception. Evidence from neurophysiology suggests that areas of the primate brain are dedicated to the processing of faces (e.g., Perrett, Hietanen, Oram, & Benson, 1992; Perrett, Mistlin, & Chitty, 1987). The relatively automatic processing of gaze direction might be an indirect consequence of this more general sensitivity to faces, and might be contingent on a successful match of the encompassing stimulus to the face-specific information-processing module(s). If true, the Simon effect of gaze direction might be stronger with intact than with scrambled faces.

On the other hand, it could be that the processing system is highly sensitive to eye-like stimuli themselves. For instance, self-protection of butterflies such as the common buckeye results from eye spots on their wings, which might or might not make the whole butterfly appear like the face of a bigger animal. In other words, eye-like stimuli seem to be reliably processed prior to, or even without proper face perception. Also, anecdotal evidence suggests that humans are quite capable to derive gaze direction information from eyes in the absence of further evident facial features, for instance, if eyes are seen peeping through a notch within an opaque surface, or if eyes of faces that are otherwise covered by veils or stocking masks are observed. Of course, a top-down axis must be used to define gaze directions in these situations, too, and the choice of this top-down axis might be more variable, depending on what alternative signals are available in the context. However, in any case, if the derivation of spatial code from gaze direction does not require the concomitant perception of a proper face-like stimulus, a resulting Simon effect might be of similar strength with both, intact (though schematic) and scrambled faces.

Method

Participants. Sixteen students (twelve female) of Bielefeld University with a mean age of 24.7 years participated in Experiment 5.

Apparatus, stimuli, and procedure. These were equal to Experiment 1 with the following exceptions. First, faces were presented with the irises centred on the screen. Second, in half of the trials, scrambled faces were presented (see Figure 1). Each of the eight possible combinations (two Targets [faces vs scrambled faces] × two Colours of the irises [red vs green] × two Gaze directions [left vs right]) was repeated 40 times. Together with a short prior practice, the experiment took about 45 min.
Results

2% of the responses were excluded as outliers. Mean vincentized RTs of correct responses were submitted on an ANOVA with the three within-participants factors of gaze-direction correspondence (corresponding vs non-corresponding), targets (faces vs scrambled faces), and quintile of the RT distribution (1st to 5th). An interaction between gaze-direction correspondence and quintile, $F(4, 60) = 3.48, p < .05$, and a significant main effect of quintile resulted, $F(4, 60) = 299.92, p < .001$ (see also Figure 5). Once again, evidence for a Simon effect induced by gaze direction was restricted to the slowest responses (RT non-corresponding—RT corresponding in the 5th quintile): $t(15) = 2.24, p < .05$, one-tailed, and RT increased across quintiles (1st: 375 ms, 2nd: 421 ms, 3rd: 457 ms, 4th: 504 ms, 5th: 615 ms). The significant two-way interaction was not qualified by the target type (Gaze direction correspondence $\times$ Target $\times$ Quintile): $F(4, 60) = 0.22$. All other main effects and interactions were also not significant (all other $p > .12$).

There were no significant effects in the ANOVA of the arc-sine transformed error rates with the two within-participants factors of gaze-direction correspondence and target (faces/corresponding: 5.4%; faces/non-corresponding: 6%; scrambled faces/corresponding: 5.2%; scrambled faces/non-corresponding: 7%).

![Figure 5](image_url)

**Figure 5.** Reaction time (RT) in ms as a function of gaze-direction correspondence (squares: Gaze-direction corresponding, crosses: Gaze-direction non-corresponding) and quintile of the RT distribution (1st to 5th) of condition faces (on the left) and condition scrambled faces (on the right) of Experiment 5.
Discussion

Evidence for a Simon effect induced by gaze direction was again restricted to the slowest responses. The effects resulted, irrespective of whether eyes were presented within intact (but schematic) faces or within scrambled faces (see Figure 5). Presumably, in the present experiment, participants aligned the top-down axis in relation to which left and right gaze directions must have been coded in scrambled-face conditions with the top-down axis of the screen, or with the top-down axis of the alternative targets (i.e., the intact faces). However, despite that, gaze direction information from the more isolated eyes of the scrambled faces was apparently as effectively processed as gaze direction information from eyes presented as parts of proper faces. As explained, the implied sensitivity to gaze direction information from eyes within scrambled faces might be a by-product of the need to code gaze direction independently of other facial features to successfully perceive biological agents in a number of non-laboratory situations. Of course, the data are also in accord with the assumption that the Simon effect of gaze direction reflects a more general ability to code object-inherent spatial content from a variety of stimuli.

GENERAL DISCUSSION

In the current study, it is shown that humans have a strong inclination to process observed gaze direction (Baron-Cohen, 1995; Driver et al., 1999; Langton et al., 2000). Spatial code derived from gaze direction induced an RT Simon effect. Therefore, gaze direction was processed even when this was not explicitly required (Experiments 1, 2, 4, and 5): Among the slow reactions, responses were faster in spatially gaze-direction-corresponding conditions (e.g., right-hand responses to faces that are looking to the right) than in spatially gaze-direction-non-corresponding conditions, although correct responses were determined by the colours of the irises. It seems as if the processing of observed gaze direction was readily evoked on the side of the observer by the presence of the appropriate, and matching information, that is, the eyes (see also Zorzi et al., in press).

Also, several lines of evidence suggest that the evoking information (gaze direction) has to be present at the focus of attention. First, Simon effects induced by gaze direction increased with increasing RT (Experiments 1, 2, 4, and 5), whereas Simon effects induced by the targets’ observer-relative positions are known to decrease with increasing RT (Hommel, 1993, 1997). Second, focusing attention on a spatial region away from the eyes abolished Simon effects induced by gaze direction (Experiment 2). Third, a compatibility effect induced by gaze direction was present when a Simon effect induced by the faces’ observer-relative positions was absent (Experiment 3). Presumably, the focusing of attention on the eyes that was necessitated by the requirement to derive spatial code from gaze direction rendered the targets initially shifted positions neutral.
In conclusion, although the processing of gaze direction is relatively slow, it seemingly is also automatic in a sense described by Logan (1988, 1995) in his instance theory of automatic processing: The processing of gaze direction (i.e., the positions of irises within the eyes) was easily evoked provided that the appropriate information was attended to. The derivation of context-relative or object-inherent spatial content might simply be relatively time-demanding compared to the derivation of observer-relative spatial content (e.g., Pisella & Rossetti, 2002).

That indeed context-relative or object-inherent spatial code rather than spatial code inherent to the direction of an attention shift was responsible for the Simon effect of gaze direction was confirmed in Experiment 4: The Simon effect of gaze direction was observed with faces tilted by 90° of arc. In these conditions, the attention shifts were either upwards or downwards but still the speed of the left and right responses was influenced by the top-down relative left and right gaze directions. Thus, left and right codes derived from gaze direction that contributed to the Simon effect must have been defined relative to the context-faces’ top-down axes (see also Hommel & Lippa, 1995; Proctor & Pick, 1999).

Results from control conditions revealed further aspects of the mechanisms that are responsible for the Simon effect of gaze direction. If tilted, arrays of numbers with inherent top-down and left–right axes did not induce an analogue Simon effect (Experiment 4). Therefore, it seems that the set of stimuli apt to induce the Simon effect is restricted. However, whether gaze direction is unique in this respect can be doubted. For instance, if presented upright, object-inherent or context-relative spatial code derived from alphanumeric stimuli can induce a Simon effect (Ansorge, in press). Also, other object-inherent spatial code of frequently encountered or “animate” stimuli might lead to Simon effects, even if tilted.

In line with this cautious conclusion, a proper perception of the eyes sufficed to induce the Simon effect (although other facial features may be routinely used to determine the top-down axis in relation to which gaze direction is coded): Gaze direction effects were observed even with scrambled faces (Experiment 5). Therefore, Simon effects induced by gaze direction should not be considered to be merely by-products of the primate visual system’s high sensitivity to the encompassing face-like stimuli. But by the same token, this must be considered as evidence for that the Simon effect of gaze direction could have reflected a more universal capacity to derive object-inherent spatial content.

REFERENCES


*Manuscript received February 2002
Revised manuscript received July 2002*