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How the presence of persons biases eye movements

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We investigated modulation of gaze behavior of observers viewing complex scenes that included a person. To assess spontaneous orientation-following, and in contrast to earlier studies, we did not make the person salient via instruction or low-level saliency. Still, objects that were referred to by the orientation of the person were visited earlier, more often, and longer than when they were not referred to. Analysis of fixation sequences showed that the number of saccades to the cued and uncued objects differed only for saccades that started from the head region, but not for saccades starting from a control object or from a body region. We therefore argue that viewing a person leads to an increase in spontaneous following of the person's viewing direction even when the person plays no role in scene understanding and is not made prominent.

To have successful social interactions, we must take into account representations of the world of interacting partners, to disambiguate certain meanings. Lacking direct mind-reading abilities, we can only *infer* these representations from behavioral cues. This can be achieved by gaze-following (Butterworth, 1991) or head-following (Langton, 2000). The latter makes it possible to infer the locus of attention even at distances at which direct gaze information is not available. Inferring the locus of attention then makes it possible to engage in joint attention (for an overview, see Frischen, Bayliss, & Tipper, 2007). Both gaze direction (Friesen & Kingstone, 1998) and head direction (Langton & Bruce, 1999) have been shown to direct visual attention even when this is uninformative for the task.

In the paradigms of Langton (2000), Friesen and Kingstone (1998), Langton and Bruce (1999), and others, the cuing stimulus was presented in isolation and was therefore quite prominent. It is less clear whether the orienting mechanism can be observed in more complex scenes, when the cuing stimulus does not occupy central areas of the visual field, which might lead to preferential processing per se (see Dukewich, Klein, & Christie, 2008). What is more, these studies did not address whether directed visual spatial attention also modulates eye-movement control, thus leading to a shift in the gaze of the observer. Investigating the effect on overt attention is of particular interest when studying social gaze behavior. During social communication, overt attention can serve as a trigger for further social interaction by establishing a common focus of attention.

The question of whether observed gaze also leads to overt responses was addressed, for example, by Mansfield, Farroni, and Johnson (2003), as well as by Kuhn and Kingstone (2009). Again, however, gaze cuing was made prominent by having only one centrally presented face and one potential target on the screen. Furthermore, in these studies, the gaze cue (and target position) were the only events that changed across trials. Under such conditions, similar effects can be demonstrated with tongue pointing (Downing, Dodds, & Bray, 2004) or symbolic cues (Kuhn & Benson, 2007; Kuhn & Kingstone, 2009). This calls into question whether the demonstrated effect is not a more general one of spatial compatibility. Additionally, instructing participants to produce speeded eye movements to the targets might have increased the tendency for spontaneous gaze-following. To shed light on whether similar overt responses could be elicited when the cuing object is not placed prominently in the screen and participants are not asked to make speeded saccades, the present study investigated gaze behavior of observers when viewing complex natural scenes.

Orientation-Following in the Presence of Persons

In an interesting study, Kuhn, Tatler, and Cole (2009) looked at gaze-following in natural conditions. By manipulating where a magician was looking, the authors showed that observers of magic tricks often directed their gaze toward the same areas as those at which the magician was looking. However, because dynamic stimuli were presented, it was necessary to employ a head movement for gaze manipulation. This motion could therefore have made gaze more prominent. Furthermore, because the task of the participants was to detect the magic trick, this instruction could have increased the importance attributed

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to the location looked at by the magician. Therefore, this study showed that observers can be led to direct their gaze to certain locations in situations in which they are watching actions of a (prominent) person. From these studies, it is not clear, however, whether similar effects would occur spontaneously in a less task-constrained context.

In a less-constrained context, Castelhano, Wieth, and Henderson (2008) recorded eye movements while participants viewed a slide show in which a janitor cleaned an office. The participants' task was to understand the story. As the results showed, observers were more likely to leave the depicted head region and move their eyes in the direction of the observed gaze. Although these results are compelling, the interest in the focus of attention of the actor might have been caused by the instruction to understand the story and by the actor's central part in the depicted action. That is, the prominence of the actor and his inferred gaze direction might have been due to the task instruction. Furthermore, given that the actor directed his gaze to the manipulated objects, the higher interest in the manipulated objects might not have been caused by the actor's head orientation per se, but by the high level of movement present in this region. Even if gaze movements were caused by the actor's orientation, it is unclear whether any oriented stimulus of equal prominence could also produce the effect. Additionally, the naturalistic paradigm prevented control of object saliency (see also Fletcher-Watson, Findlay, Leekam, & Benson, 2008). The fact that the objects were, on average, fixated prior to the face region might hint at a higher low-level salience of the referenced objects. As the following sections will show, in the present experiment, we attempted to control for instruction dependency, object saliency, scene specificity, and prominence of the cuing object.

To put the social nature of reference-following to a stricter test, we also placed our objects at different heights with respect to the head. Therefore, whereas in earlier studies (e.g., Fletcher-Watson et al., 2008) orientation-following could have occurred rather mechanistically, by traversing the orientation of the head, here participants had to infer what object could have been focused upon, given the orientation of the human.

The Present Experiment

To alleviate some of the concerns regarding earlier studies, we instructed our participants to view complex natural scenes without specifying a particular task. Therefore, the depicted persons were not made prominent by the instruction—for example, by requiring the participants to report the depicted action of a scene. We controlled for object salience by keeping the objects constant within a scene and changing only the orientation of a person in the picture. If one compares identical objects with only a change in person orientation, differences in gaze behavior cannot be attributed merely to the object's salience or its specific role in the scene independent of being referenced by the person. Importantly, in contrast to earlier studies, the referenced object was not placed at a prominent position in the scene (cf. the figures in Castelhano et al., 2008, and Fletcher-Watson et al., 2008). To ensure that not just any object with a clear orientation that was repeated across scenes would direct the gaze of the observers, we replaced the person with a loudspeaker in half of the scenes. A loudspeaker was chosen because it was similar in size to the person and could appear in similar positions throughout the scenes. Another similarity between the loudspeaker and the person was that both provided directional information that had to be inferred from their orientation, in contrast to explicit cues—for example, arrows. If the loudspeaker also led to orientation-following along the direction suggested by its frontal part, this would be clear evidence against the importance of a social cue for orientation-following. On the other hand, if only the direction of a person influenced orientation-following, this would be taken as evidence for the social nature of the effect.

In the present experiment, the head region of the persons was too small to allow reliable extraction of gaze direction via the eyes. However, in situations in which eye information is not available, other directional cues, such as orientation of the head or the body, can guide gaze (Itier & Batty, 2009). Itier, Villate, and Ryan (2007), for example, have shown that the instruction to judge the orientation of a depicted head leads to saccades in the direction of the head orientation.

To measure the time aspect of prioritizing objects referenced by either an oriented loudspeaker or a person, we looked at the time of first fixation of the referenced object. To test whether object *processing* was also biased by being referenced, we analyzed the normalized proportion of fixations the objects received and the proportion of time that observers spent at the objects. To show more directly that objects are not only prioritized but also actively searched for from the referencing object, we looked at the direction of saccades that left the referencing object. We wanted to see whether more saccades would transition directly to the referenced than to the unreferenced object. Importantly in all of these tests, we maximized experimental control by manipulating only the orientation of the referencing object while holding everything else regarding the compared objects constant (i.e., identity, size).

METHOD

Participants, Apparatus, and Stimuli

In total, 16 participants (11 female; mean age, 26 years) took part in the study. Eye movements were recorded with an EyeLink1000 tower system (SR Research, Mississauga, Ontario, Canada), sampling at 1000 Hz. Calibration was performed at the beginning of the experiment and when necessary. Eighty outdoor and indoor color scenes rendered in 3-D served as stimuli subtending visual angles of 36º (horizontal) and 28º (vertical) at a screen distance of 55 cm. These stimuli were created from 20 base scenes (Võ & Henderson, 2009; Võ & Schneider, 2010), which, in half of the instances, were edited to contain a person and, in the other half, a loudspeaker of approximately the same size at the same location and with one of the two possible orientations (Figure 1). The placement of the person/loudspeaker varied between central and peripheral locations within the scenes. Note that the eye region of the person was too small to allow extraction of gaze direction. Every stimulus displayed two objects, one of which lay in the facing direction of the person or loudspeaker (the cued object); the other was located in a different direction, but at the same distance (the uncued object). The vast majority of these objects were small, easy to grasp objects, such as, for example, bottles, pans, and toys.

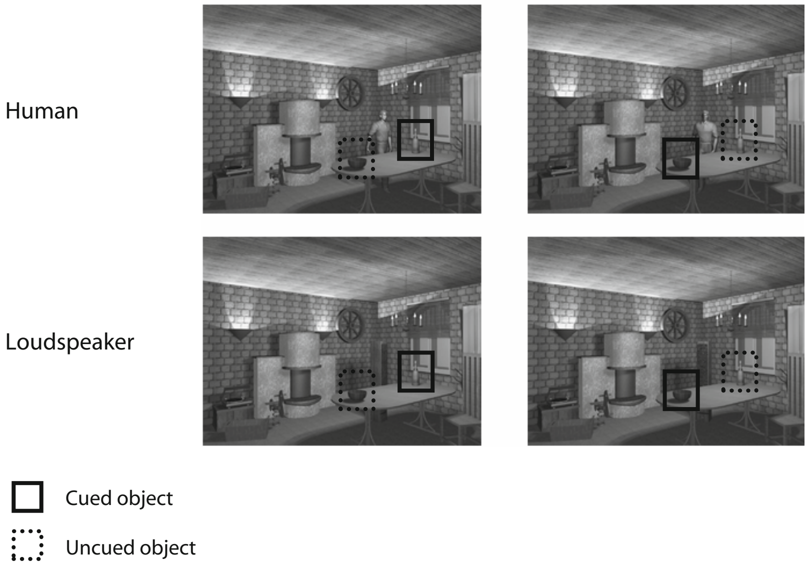

Figure 1. Four stimuli generated from one exemplary basic scene. Each scene occurred twice with a person (top) and twice with a loudspeaker (bottom). The same object that was cued in one stimulus was the uncued object in the other stimulus (left vs. right stimuli). All scenes were displayed in color; rectangles are displayed for illustration but were not visible during the experiment.

However, some of the objects would also have been difficult to carry, such as, for example, a harp or a big plant. Mean object-to-human/loudspeaker distance was 7º.

Design and Procedure

Cue type (person/loudspeaker) and object role (cued/uncued) were manipulated within participants. Presentation order was pseudorandomized and, unbeknownst to the participants, divided into four blocks. Each block contained one stimulus of each basic scene: Half of the stimuli of each block contained a person, and the other half a loudspeaker. Cued and uncued objects exchanged their roles between the presentations of the same scene/cue type combination. Scene presentation started as soon as participants fixated a central fixation cross for more than 500 msec. The scenes were presented for 7 sec to allow investigation of the pictures without time pressure, and participants were instructed to view the stimuli as they would view photos.

Data Analyses

Rectangular interest areas around objects of interest were defined to evaluate gaze locations. Fixation latency, fixation frequency, and time proportions that differed by more than three standard deviations from the respective mean of the participant were regarded as outliers and subsequently excluded. Proportions were arcsine transformed to deal with the nonnormality of proportions (e.g., Winer, 1971).

RESULTS

Exclusion of outliers led to rejection rates of 0.11%, 1.48%, and 1.25% for the fixation latency, fixation frequency, and time proportion values, respectively.

Prioritizing

Fixation latency was measured as the time to first fixation of the cued/uncued object relative to scene onset. If no fixation to the objects occurred, the data were ignored. For the person cue type condition, the cued object was fixated in 77% and the uncued object in 73% of all trials [$t(15) = 2.44, p < .05$]. The corresponding values were 77% and 78% for the loudspeaker cue type condition [$t(15) = 0.73, p > .10$].

However, no effects were found in a corresponding ANOVA [cue type, $F(1,15) < 1$; object role, $F(1,15) = 4.24$, $MS_e = 0.002$, $p < .10$; cue type $\times$ object role, $F(1,15) = 3.41$, $MS_e = 0.005$, $p < .10$].

Table 1 shows that the first fixation of the cued object (fixation latency) occurred considerably earlier than the first fixation of the uncued object in person but not in

Table 1
Mean Fixation Latency (FL, in Milliseconds), Normalized Fixation Frequency (FF), and Time Proportion (TP) As a Function of Condition (Person, Loudspeaker) and Object (Cued, Uncued)

	Condition											
	Person						Loudspeaker					
	Cued		Uncued		Difference		Cued		Uncued		Difference	
Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
FL	3,588	133	4,008	166	−420	128	3,676	159	3,572	143	104	128
FF	5.89	0.37	5.24	0.34	0.65	0.22	6.14	0.38	6.64	0.33	−0.50	0.35
TP	.08	.01	.07	.01	.01	.00	.08	.00	.08	.01	−.01	.00

Note—The difference between cued and uncued objects is given in the "Difference" column.

loudspeaker cue type trials. This was statistically verified by a significant interaction between cue type and object role [$F(1,15) = 12.24$, $MS_e = 89{,}612$, $p < .01$; main effect of cue type, $F(1,15) = 5.28$, $MS_e = 92{,}065$, $p < .05$; object role, $F(1,15) = 3.77$, $MS_e = 105{,}492$, $p < .10$]. The planned *t* tests between cued and uncued objects were significant for the person condition [$t(15) = 3.28$, $p < .05$] but not for trials with the loudspeaker [$t(15) = 1.16$, $p > .05$].

The number of fixations that fell on an object during scene presentation was divided by the total number of fixations during the scene to derive a measure of fixation proportion. To allow easier comparison with other studies, the fixation proportions were size-normalized by multiplying them with the total area of the scene divided by the area of the object (Fletcher-Watson et al., 2008). A value of 1 means that the area of interest was fixated as often as would be expected by chance alone, assuming a uniformly distributed gaze pattern. Higher values show deviations from this uniformity assumption.

On average, the person had a higher normalized fixation value (5.65) than the loudspeaker (2.94). This difference was significant [$t(15) = 4.74$, $p < .01$]. On average, the head area had a higher normalized fixation proportion (13.40) than the body (4.06) [$t(15) = 6.07$, $p < .01$].

Normalized fixation proportion on the objects was generally higher in the loudspeaker than in the person condition. This was probably caused by the higher number of fixations to the person than to the loudspeaker, which reduced the fixations to other objects. Importantly, the normalized fixation proportion in the person cue type condition was higher for the cued than for the uncued object (Table 1). This difference was not observed for the loudspeaker condition. A significant main effect of cue type [$F(1,15) = 7.77$, $MS_e = 1.40$, $p < .05$] but not object role [$F(1,15) < 1$] and a significant interaction [$F(1,15) = 8.00$, $MS_e = 0.66$, $p < .05$] confirmed this observation. The difference between object roles was significant for the person [$t(15) = 2.91$, $p < .05$] but not the loudspeaker [$t(15) = 1.43$, $p > .05$] cue type condition.

A similar pattern was observed for time proportion—that is, time spent within one interest area divided by total time of one scene presentation. Participants spent more time gazing at the cued, in comparison with the uncued, object in the person cue type condition, but not in the loudspeaker condition (Table 1). No main effect of cue type [$F(1,15) = 4.33$, $MS_e = 0.001$, $p < .10$] or object role [$F(1,15) = 1.81$, $MS_e = 0.0003$, $p > .10$] but a significant interaction [$F(1,15) = 8.16$, $MS_e = 0.0004$, $p < .05$] was found. Also, the difference between object roles was significant in the person condition [$t(15) = 3.09$, $p < .05$] but not in the loudspeaker condition [$t(15) = 1.15$, $p > .05$].

Direction of Leaving Saccades

The number of saccades that landed directly on the cued/uncued object after leaving the referencing object was divided by the number of all saccades that left the referencing object. Using this method, we obtained the probability of landing on the cued/uncued object given that the referencing object was left. This makes the measure independent from the fixation frequency to the referencing object, which is important because fixation frequency might depend on size and saliency.

Table 2
Number of Saccades That Landed Directly on the Cued and Uncued Object Starting From Parts of the Person or Loudspeaker Divided by the Number of Saccades That Left the Starting Region

Starting Region	Object Role: Cued		Uncued		Difference	
	M	*SE*	*M*	*SE*	*M*	*SE*
Person						
Full	.17	.01	.14	.01	.03	.02
Head	.14	.01	.09	.01	.06	.01
Body	.11	.01	.12	.01	−.02	.02
Loudspeaker						
Full	.13	.01	.15	.01	−.02	.02
Top	.08	.02	.08	.02	.00	.03
Base	.12	.02	.14	.02	−.01	.02

Note—The sum of the values for the two parts does not equal the value of the full part, because, for example, saccades from a top to bottom part would not be qualified as leaving saccades in the full condition.

Table 2 shows that more saccades landed on the cued than on the uncued object in the person condition. No such effect was found for the loudspeaker condition. Simply on the basis of the size of the objects, only 2% of saccades should be directed to the objects. However, when comparing these values with the obtained values, one has to take into account (1) the salience of objects in comparison with empty space and (2) other variables such as, for example, color contrast. A repeated measures ANOVA with the factors of cue type (person, loudspeaker) and object role (cued, uncued) revealed a significant interaction [$F(1,15) = 6.33$, $MS_e = 0.025$, $p < .05$] but no main effects [cue type, $F(1,15) = 2.09$, $MS_e = 0.00323$, $p > .05$; object role, $F(1,15) < 1$]. To see which part of the person caused this orientation-following, we partitioned the person into body and head area. A repeated measures ANOVA with the factors of parts (body, head) and object role (cued, uncued) showed a significant main effect of object role [$F(1,15) = 5.22$, $MS_e = 0.004$, $p < .05$] that was modified by a significant interaction [$F(1,15) = 10.55$, $MS_e = 0.0046$, $p < .01$]. No main effect of part was found [$F(1,15) < 1$]. Whereas the influence of object role was significant for the head area [$t(15) = 4.19$, $p < .01$], no such effect was found for the body area [$t(15) = 0.84$, $p > .05$]. To exclude the possibility that we had missed an effect in the loudspeaker condition that might be present, although much smaller, we divided the loudspeaker area, artificially mirroring the same ratio as that of head to body in the person condition. However, only a main effect of part was found[1] [$F(1,15) = 14.38$, $MS_e = 0.015$, $p < .05$]; no other effect was significant (*F*s < 1).

DISCUSSION

The main purpose of this study was to investigate whether the attentional focus of depicted persons is spontaneously prioritized even when the person/attentional focus is not made prominent by the task. We used complex naturalistic scenes to depict real-world situations. Similarly to, for example, Birmingham, Bischof, and Kingstone (2008) and Birmingham, Bischof, and Kingstone (2009), we found that fixations landed predominately on the human head region. More relevant to the present question, when a person was present, participants' gaze fell sooner on an object that was cued by the person in the scene than when the same object was not cued.

Gaze was directed to the cued object not only sooner, but also more frequently and for a longer amount of time. This cuing effect was found only for the presence of a person, and not for another oriented object—a loudspeaker, of about the same size and orientation. This argues against an interpretation according to which any oriented and repeatedly shown object would lead to a cuing effect. Note that even though repeating persons across the scenes could have made the persons more prominent, the same would hold for loudspeakers.

There was also a tendency for cued objects to be fixated in more trials than were uncued objects in the human but not in the loudspeaker condition. We can only speculate about why the interaction failed to reach significance. Probably, obtaining a single measure per trial (object fixated or not fixated) is too insensitive a measure because it does not distinguish between one fixation of the object—possibly by chance—and longer and more frequent fixations.

Comparing identical objects as a function of focus allowed exclusion of alternative interpretations that could be leveled against earlier studies. For example, the effect cannot be attributed to the objects' having a higher saliency or being at a central position (e.g., Fletcher-Watson et al., 2008), being at the location of most movement activity (e.g., Castelhano et al., 2008), or varying in size (e.g., Fletcher-Watson et al., 2008).

The analysis of the direction of leaving saccades showed that the cued object was more likely to be a target of fixation than the uncued object after saccades left the head area, an effect that was not found for other starting areas. To our knowledge, this distinction has not been made in prior studies, but it is important for a more detailed understanding of orientation-following because it shows that it is the head that biases gaze to the referenced object. In addition, it allows exclusion of saliency of the cuing stimulus as the only explanation for orientation-following. Even though the person was fixated more often than the loudspeaker, we accounted for this difference in saliency by calculating the probability that a saccade would be made to the cued/uncued object *given* that a saccade left the referencing region. Otherwise, by ignoring the number of saccades that leave a referencing object, it would be difficult to exclude the possibility that objects of lower saliency would not also cue gaze direction. The effect could simply be overlooked due to the infrequent fixations to the potentially cuing object. As the directions of the leaving saccades showed, simply fixating any oriented object does not lead to cuing.

In the present experiment, body and head conveyed the same directional information. Therefore, in principle, participants could also have used the information about the body orientation when they started from the head area. However, landing on the body did not encourage participants to follow its orientation, whereas landing on the head region did. Given that the body, due to its bigger size, would be easier to perceive and could therefore deliver more reliable information, this further implies that it is not the extraction of orientation information per se that guides the eyes, but the extraction of *social* information as conveyed by head directions in complex scenes.

Looking at Table 2, it is somewhat surprising to find similar proportions of saccades for the head and base areas. We think that our object placement might have favored the base condition because the cued objects were typically at a different height level than the head. Therefore, more or less random horizontal scanning movements would not result in saccades to the objects. This was different for the base condition with the larger height extension, where horizontal scanning movements would land on the objects.

The fact that participants preferred referenced objects that were not placed at the same height as the head strengthens the conclusion that observers did not simply engage in mechanical orientation-following but tried to figure out which object would be consistent with the orientation of the person.

The present results differ from those of Dukewich et al. (2008), who reported only a small effect of gaze-following and nearly the same number of saccades being directed in the direction opposite to that of the observed gaze. This is surprising, given that the authors selected their stimuli on the basis of the presence of a *central* gaze cue. One reason could have been that only a rather coarse measure was used; right or left parts of the stimuli were compared, but the exact locations of the objects being looked at were not taken into account. Another reason for this small effect could have been that the stimuli often depicted various socially interacting persons, which could have dictated gaze patterns.

Taken together, the present study provides evidence that the presence of a person changes eye-movement behavior by making the referenced location a more likely destination for the observer's gaze. Prioritizing occurred even though the picture contained no direct gaze information, the person did not occupy a prominent role in it, and participants had no task to accomplish that would encourage specific observation of the person or the referenced object. This extends the finding of gaze cuing in a rather artificial situation to gaze cuing in more naturalistic environments. Whether similar effects would have been obtained with other animate stimuli—for example, animals—will be the subject of further studies that will help dissociate social and animate processes.

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NOTE

1. The top of the loudspeaker received only a few fixations, which might make this measure not very reliable.

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