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The directional flow of visual information transfer between pedestrians

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Close behavioural coupling of visual orientation may provide a range of adaptive benefits to social species. In order to investigate the natural properties of gaze-following between pedestrians, we displayed an attractive stimulus in a frequently trafficked corridor within which a hidden camera was placed to detect directed gaze from passers-by. The presence of visual cues towards the stimulus by nearby pedestrians increased the probability of passers-by looking as well. In contrast to cueing paradigms used for laboratory research, however, we found that individuals were more responsive to changes in the visual orientation of those walking in the same direction in front of them (i.e. viewing head direction from behind). In fact, visual attention towards the stimulus diminished when oncoming pedestrians had previously looked. Information was therefore transferred more effectively behind, rather than in front of, gaze cues. Further analyses show that neither crowding nor group interactions were driving these effects, suggesting that, within natural settings gaze-following is strongly mediated by social interaction and facilitates acquisition of environmentally relevant information.

Keywords: joint visual attention; social cognition; behavioural contagion; collective behaviour

1. INTRODUCTION

Gaze-following, or the ability to adjust visual attention to that of others (also called joint visual attention), may be a fundamental behaviour of terrestrial vertebrates [1]. Psychologists have typically employed laboratory experiments to study gaze-following in humans, using eye-tracking software to record changes in attention shifts or saccades, when presented with either faces with averted gaze direction [2] or dynamic social scenes [3]. Close behavioural coupling of visual orientation may provide a range of adaptive benefits to social species, since changes in the gaze direction of neighbours has the potential to provide important information about both the surrounding physical and social environment.

Within modern urban environments, however, the social inhibition regarding orienting towards strangers may dampen gaze-cueing effects in real-life encounters: e.g. staring at individuals in public settings, can promote avoidance strategies [4], and gaze-avoidance has also been observed for unfocused interactions [5]. Recent experimental work has identified that the potential for social interaction (e.g. eye contact or communication) reduces orienting towards others [6]. Furthermore, pedestrians may use the visual attention of neighbours to infer walking direction to avoid collisions—for example, when presented with a computer animation of an oncoming pedestrian with a distinct gaze direction, participants in the laboratory shift their attention to the opposite direction, leading to reverse gaze-following behaviour [7]. Despite these recent insights into human social attention, however, the lack of appropriate tools has limited the objective evaluation of gaze-following in natural (non-laboratory) environments.

Milgram *et al.* [8] performed the first study of gaze-following in crowds, instructing stimulus groups to stop and stare up into a building window on a crowded thoroughfare, and the response of passers-by in adopting this behaviour was measured. In this case, gaze-following was relatively unambiguous, as the confederates were looking upwards into the building. Similarly to laboratory studies, however, there was little potential for social interaction between passers-by, since the stimulus members were instructed to hold a fixed upward gaze. Using comparable methodology, this experiment was recently replicated to quantify the spatio-temporal dynamics of gaze-following in crowds [9]. When pedestrians were in the field of view of the stimulus members (walking in front of them), thus having an increased possibility for social interaction, gaze-following was less frequent.

To investigate natural instances of gaze-following between pedestrians, we displayed a visually attractive stimulus near an entranceway of a building with a hidden camera placed inside to detect direct eye contacts by passers-by. Thus, we used a comparable method of data collection to that of previous field research [8,9], but focus on more localized and naturalistic visual interactions between passers-by without manipulating gaze cues (i.e. the use of confederates).

2. MATERIAL AND METHODS

Data collection occurred during 4 days in May 2011, which included roughly 2 h per day (463 min). An apparatus (2.00 × 1.00 m) with a small Plexiglas window (0.50 × 0.50 m) covered with privacy window film (approximating a one-way mirror) was placed to one side of a bi-directional corridor (8.59 × 2.12 m) near an entranceway to a public building on a university campus (figure 1*a*). Behind the reflective viewing window, which was positioned in the upper-half of the apparatus close to eye-level for most people (figure 1*b*), we placed a running camcorder to track directed looks from passers-by. The apparatus itself was painted to match the existing décor of the environment, while the mirrored Plexiglas served as an attractive visual stimulus and allowed us to conceal the camcorder. To enhance visual attention towards our camera, we taped large red arrows around the viewing window (figure 1*b*).

The apparatus was placed on a ledge (0.25 m high) to not interfere with pedestrian traffic, and the base was triangular with the viewing window at a 30°–35° angle towards one end of the corridor (figure 1*a*). This configuration enabled pedestrians entering the building to immediately see the mirrored stimulus, whereas those approaching the exit of the building could not until they traversed half of the corridor. All pedestrian responses were recorded within 2.57 m from the edge of the triangular base to the entranceway to the building (‘recording zone’). Since recent research has shown pedestrian visual interactions occur primarily within a 2.00 m radius [9], this setting appeared conducive to gaze-following.

Following institutional guidelines, written scripts were posted on either end of the corridor notifying pedestrians that there was an ‘experiment’ taking place and that a camcorder was recording the scene. The rationale of the research was not provided, nor was the location of our camera.

(a) *Analysis*

Two independent reviewers scored the time entering the scene, walking direction (towards/away from stimulus), looking behaviour (yes/no), sex (male/female) and group status (walking alone/with others)

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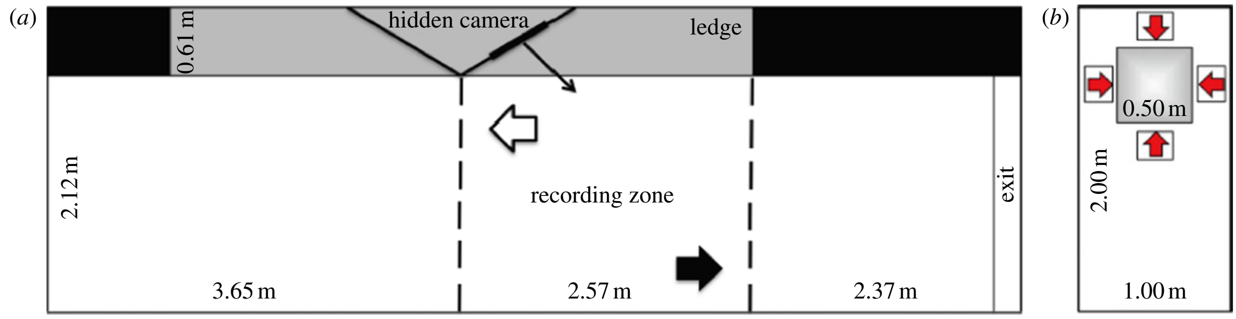

Figure 1. (*a*) Overhead view of the corridor, apparatus and bi-directional pedestrian traffic. Looks towards our stimulus (bold line of triangle) were recorded within the 'recording zone.' The white arrow represents a walking path towards the stimulus, whereas the black arrow represents one away from it. (*b*) Ground view of the visual stimulus.

from all passers-by. Groups were identified as walking together with clear social interaction (talking, gesticulation). Both reviewers scored more than 10 per cent of the same videos, obtaining high inter-rater reliabilities for looks ($\alpha = 0.909$) and group status ($\alpha = 0.916$). Intra-rater reliability was also high (one reviewer: looks, $\alpha = 0.963$; group status, $\alpha = 0.969$). Gaze-following was defined by multiple pedestrians looking within a 3-s window, with the subsequent glances considered to be socially mediated.

3. RESULTS

(a) *Gaze-following*

Over the testing period, 2882 pedestrians traversed the corridor (6.225 min^{-1}). The baseline rate of gazing at the stimulus (without previous gaze cues) was 28.4 per cent, but this significantly increased when another pedestrian looked within the previous 3 s (49.4%) ($\chi^2_1 = 82.460$, $p < 0.001$). Gaze-following significantly dropped when extending the cueing window to 10 s (42.1%) ($\chi^2_1 = 6.885$, $p = 0.009$), suggesting that this response is indeed socially mediated. Females were slightly more likely to look at the stimulus without any visual cues (30.4 versus 26.7%) ($\chi^2_1 = 3.988$, $p = 0.046$), but there was no difference it terms of gaze-following ($\chi^2_1 = 1.515$, $p = 0.218$). Thus, the results below refer to data from both sexes.

(b) *Directional flow*

We then investigated whether gaze-following varied as a function of the direction of travel and locality of the visual cues. When walking towards the stimulus, the baseline rate of looking at it was 39.9 per cent. This increased to 57.1 per cent when another pedestrian looked within the previous 3 s ($\chi^2_1 = 31.021$, $p < 0.001$). When comparing the gaze-following response as a function of the locality of the gaze cues, just 16.7 per cent of passers-by walking towards the stimulus glanced when an oncoming pedestrian (travelling away from the stimulus) previously looked, while this is true for 58.7 per cent of passers-by when cues came from distancing pedestrians walking in the same direction (figure 2: $\chi^2_1 = 8.346$, $p = 0.004$).

Similar results were obtained from pedestrians exiting the building (walking away from the stimulus). The baseline rate of looking at the stimulus when walking in this direction was just 13.9 per cent, but increased to 30.8 per cent when another pedestrian previously looked ($\chi^2_1 = 26.797$, $p < 0.001$). When separating the locality of the visual cues, just 20.2 per cent of passers-by looked when they came from oncoming pedestrians (walking towards the stimulus), while this was true for 48.1 per cent of passers-by when cues came from distancing pedestrians walking in the same direction (figure 2: $\chi^2_1 = 12.302$, $p < 0.001$).

Gaze-following was thus much more prevalent when pedestrians were cued by someone walking in the same direction in front of them (57.1%), as opposed to when someone was approaching from the opposite direction (19.8%) ($\chi^2_1 = 92.912$, $p < 0.001$). Visual information was transferred more effectively from behind, rather than in front of, gaze cues. In fact, the presence of gaze cues from oncoming pedestrians diminished looks from passers-by (19.8 versus 28.4%) ($\chi^2_1 = 3.575$, $p = 0.059$).

(c) *Crowding and group effects*

Since multiple pedestrians walking in the same direction could slow traffic and alter attention and/or trajectory, it is possible that crowding could contribute to the directional results by increasing glances towards the stimulus in the absence of visual cues. We tested this possibility, and found, in contrast, that gaze towards the stimulus actually fell when other pedestrians were in close proximity (i.e. passed by within last 3 s) and not looking as compared to when others were not present (24.3 versus 30.3%) ($\chi^2_1 = 9.001$, $p = 0.003$). Crowding thus inhibited, rather than potentiated, independent looks towards the stimulus.

Of the 2882 pedestrians recorded, 824 (28.6%) were walking with at least one other person. Since pedestrians travelling together may be more likely to follow the cues of in-group members, it is also possible that groups could be driving the observed effects. Gaze-following was indeed more prevalent among group members than between individual pedestrians (59.1 versus 39.7%) ($\chi^2_1 = 18.659$, $p < 0.001$). However, the principal findings do not change when excluding groups from the analysis. The tendency to look at the stimulus when walking alone increased when someone previously looked (39.7 versus 28.3%) ($\chi^2_1 = 13.412$, $p < 0.001$): furthermore, gaze-following remained more prevalent among individuals walking in congruent directions (50.3 versus 17.8%) ($\chi^2_1 = 21.944$, $p < 0.001$), and gaze cues from oncoming pedestrians reduced the tendency to look (17.8 versus 28.3%) ($\chi^2_1 = 3.858$, $p = 0.049$).

4. DISCUSSION

During naturalistic gaze-following behaviour between pedestrians, individuals are shown to be more

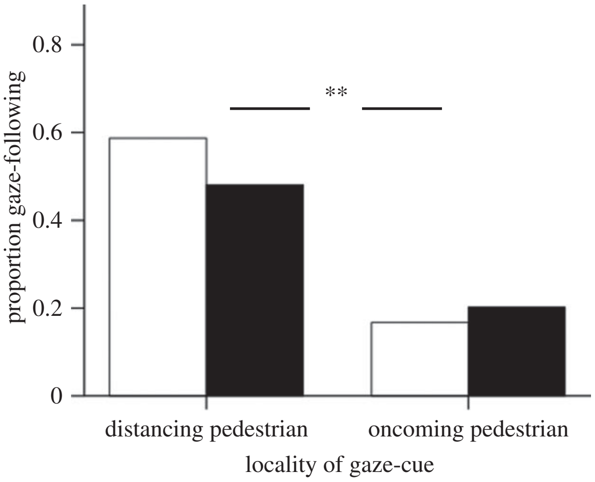

Figure 2. Pedestrians were more likely to follow gaze cues of passers-by walking in congruent directions, independently of the approach to the stimulus (**p's < 0.01). Filled bars represent walking away from the stimulus and unfilled bars represent walking towards the stimulus.

responsive to changes in the visual orientation of those walking in the same direction in front of them than to the averted face and eye direction of passers-by walking towards them, independent of how the stimulus was approached (figure 2). In other words, pedestrians aligned their visual attention with those walking in similar directions and were reluctant to follow gaze cues of oncoming pedestrians. Unlike previous laboratory research simulating pedestrian encounters [7], passers-by who directed their visual attention towards the stimulus did not hold a fixed gaze direction as they approached, and thus it is unlikely that these glances was interpreted as an indicator of one's navigational path. Furthermore, we show that these effects are not a product of crowding or due solely to group interactions.

The rearwards transfer of visual attention refines recent research using stationary stimulus groups within large crowds [9], but contrasts with typical laboratory cueing paradigms. Despite the uniqueness of the human sclera for enhancing gaze cues [10], we show that pedestrians also continually monitor changes in visual orientation from behind. A number of potential explanations emerge from these results. The first lies within the social interactions of oncoming pedestrians, e.g. it is possible that the tendency for strangers to avoid eye contact reduces the likelihood to even perceive oncoming visual cues. However, since the propensity to look at the stimulus diminished in the presence of oncoming glances, it appears that pedestrians do observe these cues but choose either not to use this information to direct their own gaze since this may enhance the possibility of social interaction [6], or do so in a more covert manner. In contrast, social interaction becomes less likely when copying the attention of pedestrians from behind. Furthermore, the environmental relevance of visual cues may play a role in the decision to follow another pedestrian's gaze. That is, individuals walking in the same direction ahead of you are interacting in an environment that you will shortly experience, and thus cues relating to this context may be more important than those coming from oncoming pedestrians. For instance, the behaviours of pedestrians walking in a congruent path have been shown to influence the road-crossing decisions of others [11].

Experimental and theoretical research suggests that the use of gaze cues varies with social context [12], and thus it is likely that the physical properties of spatial environments, and the nature of interactions of the people within them, will also influence the strength of this response and information transferred. Work of this type will better allow us to understand human social interactions within the context and spatial nature of crowded civic locations.

The university ethics board approved this research.

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