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Catching Eyes: Effects of Social and Nonsocial Cues on Attention Capture

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Abstract

Direct eye contact and motion onset are two powerful cues that capture attention. In the present study, we combined direct gaze with the sudden onset of motion to determine whether these cues have independent or shared influences. Participants identified targets presented randomly on one of four faces. Initially, two faces depicted direct gaze, and two faces depicted averted gaze. Simultaneously with or 900 ms before target presentation, one face with averted gaze switched to direct gaze, and one face with direct gaze switched to averted gaze. When gaze transitions and target presentation were simultaneous, the greatest response-time facilitation occurred at the location of the sudden onset of direct gaze. When target presentation was delayed, direct-gaze cues maintained a facilitatory influence, whereas motion cues induced an inhibitory influence. These findings reveal that gaze cues and motion cues at the same location influence information processing via independent and concurrently acting social and nonsocial attention channels.

Keywords
attention, cognition(s), social cognition, visual attention

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You are at a party, and someone across a crowded room suddenly looks at you. Your gaze is drawn to them, and your eyes meet. You feel an instant connection, unable to look away for a moment or two. Is this the beginning of love at first sight or just stimulus-driven attentional capture? People experience the capture of attention by the sudden onset of direct gaze in many daily interactions, and love does not emerge out of every encounter. Picture a less romantic scenario, such as delivering a lecture in front of several dozen students or administering an exam. Suddenly, one student lifts his or her head and looks straight at you. Is the student preparing to ask you a question or, perhaps, to engage in some other, less acceptable activity? What is clear is that the sudden onset of direct gaze will attract your attention. What underlies this powerful effect of sudden onset eye contact on attention was the central question of the present research.

The instance of sudden onset of direct gaze entails at least two cues occurring at the same location in space that are known to be effective in attracting and capturing attention: the social cue of direct eye contact and the nonsocial cue of sudden onset motion. The purpose of the present research was to determine whether social cues exert their influence independently of cues that are also part of the nonsocial world (e.g., motion cues) or whether the two types of cues share processing systems. Some psychologists have distinguished the processing of social information from other kinds of information by arguing that social information is particularly probabilistic, inexact, and ambiguous (Heider, 1958/1977; Mitchell, 2009) and is heavily based on implicit, prereflective processes (Frith & Frith, 2008; Vogeley & Roepstorff, 2009). In the example of the sudden direct-gaze shift of the student described previously, the communicative signal of direct gaze (social cue) and the salient exogenous

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motion (nonsocial cue) are combined in one instance in time and space. Is the motion cue “bound” to the social cue, and do they draw on a single attention system? Or are these cues combined additively?

Humans’ sensitivity to gaze cues is striking. Perceiving the gaze of others reflexively draws one’s attention in the same direction (Driver et al., 1999; Friesen & Kingstone, 1998). Similarly, faces depicting direct gaze (when the face is looking directly at the observer) capture attention; such faces are recognized faster and memorized better than faces depicting averted gaze (Hood, Macrae, Cole-Davies, & Dias, 2003; Senju & Hasegawa, 2005; Vuilleumier, George, Lister, Armony, & Driver, 2005). Gaze cues modulate subsequent attentional and cognitive processing of social information (Kleinke, 1986; see Senju & Johnson, 2009, for a review) and thereby foster communication and successful social interaction (Csibra & Gergely, 2009; Richardson & Dale, 2005).

Likewise, Abrams and Christ (2003) provided evidence that the onset of motion provides a potent exogenous cue that captures attention (see also Al-Aidroos, Guo, & Pratt, 2010). In their studies, they asked participants to identify letters that appeared at one of four placeholder locations. The innovative aspect of their method was that different placeholders were in different states of motion prior to target onset. Specifically, in the initial display, two of the placeholders were moving while the other two remained static. Prior to target onset, one static placeholder began to move, and one of the moving placeholders stopped moving. Response times (RTs) to the targets presented at the location of the motion onset were shortest when the target appeared simultaneously with the motion transition, but they were longer than in all other conditions when the target was presented 900 ms after the motion transition. This pattern of short-term facilitation and long-term inhibition at the location of motion onset is characteristic of stimulus-driven attentional capture (e.g., Posner & Cohen, 1984).

For the present study, the methods of Abrams and Christ (2003) were adapted to investigate the combined effects of direct gaze (social cue) with sudden motion onset (nonsocial cue) on subsequent processing. Participants identified a target that was presented randomly on one of four faces. The initial display consisted of two faces with direct gaze (eye contact with the participant) and two faces with averted gaze (eyes looking toward the lower left side of the screen). Simultaneously with the presentation of the target (Experiment 1) or 900 ms prior to target presentation (Experiment 2), one of the faces with averted gaze switched to direct gaze, and one of the faces with direct gaze switched to averted gaze. The other direct- and averted-gaze faces remained static and maintained their initial gaze direction. In this way, one face showed only the social cue (direct gaze in both displays), one face showed the motion cue with nonsocial gaze (sudden switch from direct to averted gaze), one face showed no cues (averted gaze in both displays), and one face showed the motion cue with social gaze (sudden switch from averted to direct gaze).

This arrangement of conditions allowed us to determine whether direct gaze and motion cues have additive or interactive effects on target processing. If social (gaze) and nonsocial (motion) cues activate interactive or shared mechanisms and represent a unique source of attention-capturing information, then a pattern of RTs similar to that reported by Abrams and Christ (2003) should be observed—shortest RTs for targets presented at the location of the sudden-direct-gaze stimulus at the 0-ms stimulus onset asynchrony (SOA; Experiment 1) but longest RTs for that condition at the 900-ms SOA (Experiment 2). Alternatively, if gaze and motion stimuli activate independent mechanisms, a different pattern may emerge. Separate studies have shown that SOAs elicit differential effects in motion-onset cues than in social cues: Direct gaze holds attention (Frischen, Bayliss, & Tipper, 2007), whereas motion onset has been shown to demonstrate a pattern of short-term facilitation and long-term inhibition (Abrams & Christ, 2003). Thus, if the different cues activate independent mechanisms, direct-gaze cues should facilitate information processing at both SOAs, whereas motion cues should facilitate processing at the 0-ms SOA but hinder it at the 900-ms SOA.

Experiment 1

Method

Participants. Sixteen right-handed students (11 women, 5 men) with a mean age of 21.4 years (*SD* = 2.1) participated in the experiment and were compensated with €10. Participants completed an informed consent form and provided background information. The procedures complied with the ethical standards of the 1964 Declaration of Helsinki regarding the treatment of human participants in research.

Experimental setup and procedure. Participants placed their head on a chin rest positioned 80 cm away and directly in front of a 17-in. thin-film-transistor monitor (screen resolution of 1,680 by 1,050 pixels). In each trial, participants saw two displays (see Fig. 1 for the general layout of the displays). The first display (cue display) contained four placeholder locations, each showing the number “8” overlaid on an image of a face. Each image was 200 by 250 pixels (3.8 × 4.7° of visual angle) and presented on a white background. The images appeared in each of the cardinal directions relative to a central fixation cross and at a distance of 50 pixels (0.9° of visual angle) away from it. All the faces for the first and second

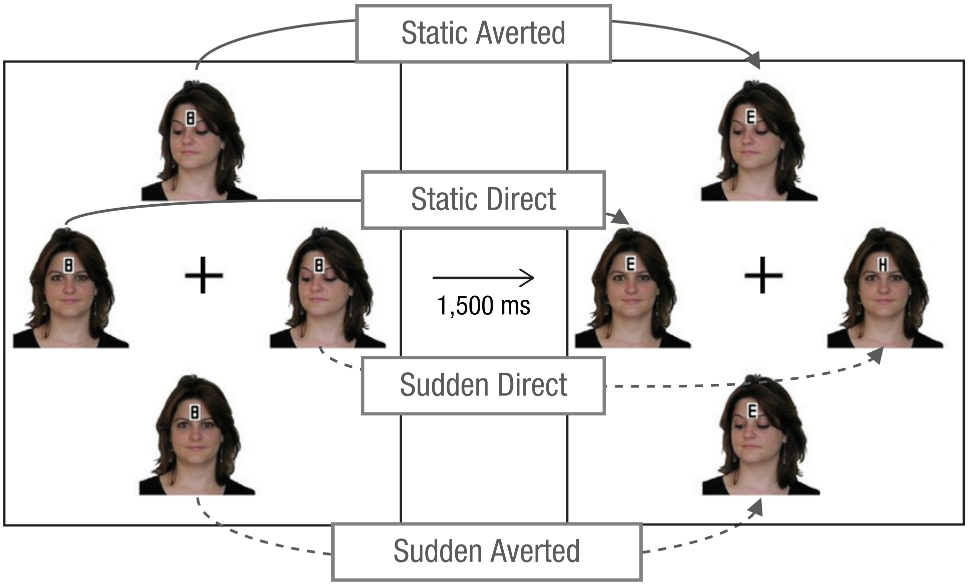

Fig. 1. Example trial sequence. In each trial in Experiment 1, participants saw two displays. The cue display (left) contained four face images, each with the number "8" overlaid on it, surrounding a central fixation cross. Two faces gazed directly at the participant, and the gaze of the other two was averted toward the bottom left of the screen. After 1,500 ms, the cue display transitioned to the target-distractor display (right). One of the faces changed from direct to averted gaze (the sudden-averted condition), and one changed from averted to direct gaze (the sudden-direct condition). The faces at the other two locations remained unchanged (static-averted and static-direct conditions). Simultaneously, one of the figure-8 placeholders was replaced by a target letter ("H" or "S"), and the other three placeholders were replaced with the same distractor ("E" or "U"). Participants' task was to report the target letter as quickly as possible. Trials in Experiment 2 were the same as in Experiment 1, except that there was a 900-ms delay between the onset of the second display and the appearance of the target and distractor letters.

displays were images of the same woman, but her gaze direction varied. In each display, two faces had direct gaze, and two had averted gaze toward the bottom left of the screen (from the participants' perspective).

The cue display transitioned to the target-distractor display after 1,500 ms, at which point two important changes took place. First, one of the faces changed from direct to averted gaze (the sudden-averted condition), and one changed from averted to direct gaze (the sudden-direct condition). The faces at the other two locations remained unchanged, with one showing direct gaze (the static-direct condition) and one showing averted gaze (the static-averted condition) throughout the trial. The images of the faces themselves were irrelevant for the actual task participants performed. Second, one of the figure-8 placeholders was replaced by a target letter ("H" or "S"), and the other three placeholders were replaced with distractors ("E" or "U"). Participants were instructed to maintain fixation on the central cross. The participants' task was to identify the target letter from among the distractor letters as quickly as possible and press either the "S" or the "H" key with their left or right index fingers, respectively, on a standard keyboard. On a given trial, the distractors were all the same letter. Target and distractor letters were all presented on the woman's forehead, with the bottom part of the symbol falling between the eyebrows, and were aligned with one of the axes of the fixation cross.

In total, there were 384 possible combinations of the factors gaze direction, image position, and target-distractor combination. Each participant completed each combination once, and the trial order of these combinations was assigned through a random permutation. Before beginning the experimental trials, participants completed a set of 10 practice trials to ensure that they understood the task. Participants had a chance to take a short break after 192 trials.

Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997) for MATLAB (The MathWorks, Natick, MA) were used for stimulus presentation and response recording. A customized MATLAB script was used to compile and format the data, which was then exported to SPSS for further analysis.

Results and discussion

RT was identified as the interval from the onset of the target-distractor display until the first key was pressed.

Trials on which the incorrect key was pressed were classified as errors, and the RTs associated with those trials were eliminated from the data set (3.0% of the data; range = 0.5%–6.77% across participants). The remaining RTs were grouped according to condition (i.e., the data were collapsed across the location and identity of the target and distractors). RTs that were more than 2 standard deviations from the mean in each condition were eliminated from the data set as outliers (4.1% of the data; range = 2.3%–5.7%). Mean RTs and the total number of execution errors were submitted to separate 2 (gaze direction: direct, averted) × 2 (motion: sudden, static) repeated measures analyses of variance (ANOVAs). Note that gaze direction refers to the orientation of the face when the target-distractor display was presented, not to the original orientation at the beginning of the trial.

The analysis of RTs revealed main effects of gaze direction, $F(1, 15) = 8.88$, $p < .01$, $\eta^2 = .372$, and motion, $F(1, 15) = 5.67$, $p < .05$, $\eta^2 = .274$ (Fig. 2a). Consistent with previous research, results showed that RTs to targets presented on faces with direct gaze were shorter (813 ms, $SD = 114$ ms) than RTs to targets on faces that looked away (838 ms, $SD = 114$ ms). Likewise, RTs to targets on the sudden-motion-onset faces (those that changed gaze orientation) were shorter (811 ms, $SD = 114$ ms) than to targets on the static faces (841 ms, $SD = 118$ ms). The interaction between motion and gaze direction was not significant, $F(1, 15) < 1$, $\eta^2 = .021$, which suggests that the magnitudes of the differences across the conditions did not differ. The analysis of response errors did not reveal any significant effects (*p*s > .1), which indicates that the pattern of RTs was not associated with a speed/accuracy trade-off (Fig. 2b).

The results of Experiment 1 indicate that the target was processed most efficiently when it was presented at the location of the sudden onset of direct gaze (the sudden-direct condition). This finding is consistent with the hypothesis that the onset of direct gaze captures attention to a greater degree than any other cue stimulus. The absence of an interaction between motion and gaze direction provides initial evidence that the sudden-direct-gaze effect may be the result of independent effects of direct-gaze cues and of motion cues. That is, the advantage of direct over averted gaze (main effect of gaze direction) and the advantage of dynamic over static stimuli (main effect of motion) may have been combined additively to yield the greatest overall advantage for the location that had both cues. It is not entirely certain, however, whether this sudden-direct-gaze advantage reflects a unique case in which the "special" nature of the sudden onset of direct gaze is processed by a single subsystem (i.e., a single attentional channel or mechanism) or whether the effect is driven by the addition of separate attentional mechanisms that process the social gaze cue and the motion cue independently. Experiment 2 was designed to distinguish between these possibilities.

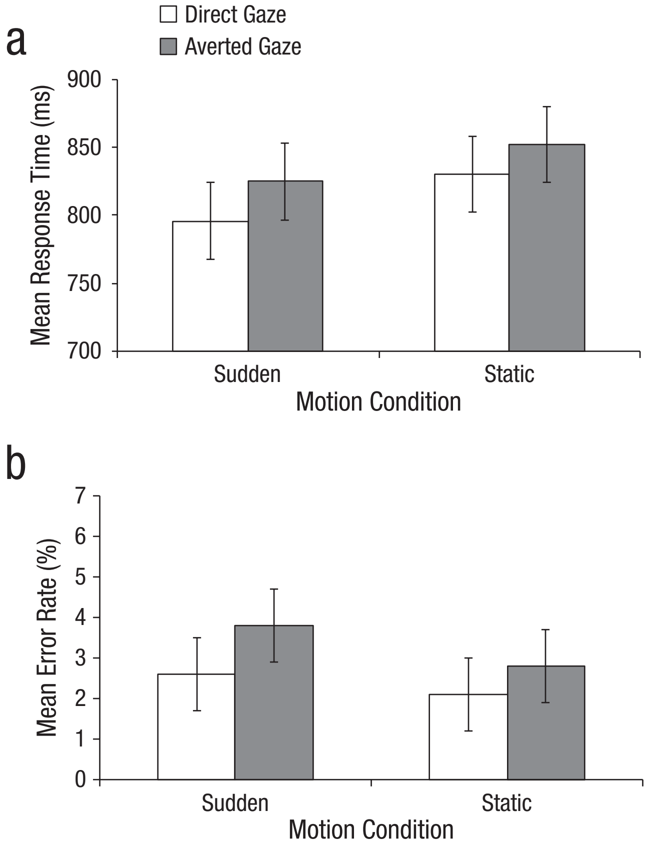

Fig. 2. Mean response time (a) and error rate (b) as a function of motion condition and gaze direction in Experiment 1. Error bars display within-subjects confidence intervals (following Loftus & Masson, 1994).

To this end, an SOA of 900 ms was introduced between the change in gaze orientation and the onset of the targets and distractors. Previous studies have found contrasting effects of SOAs on exogenous motion cues and on social cues. Specifically, it has been shown that motion-onset stimuli elicit an inhibitory effect (longer RTs) at the location of the cue for SOAs larger than 300 ms—this is known as *inhibition of return* (IOR; e.g., Abrams & Christ, 2003). This pattern reflects the facilitatory and inhibitory mechanisms that result from the capture of attention (Posner & Cohen, 1984). By contrast, gaze cues are known to capture and hold attention (Frischen et al., 2007) and to elicit IOR at much longer SOAs (> 1,400 ms) or none at all. Previous work suggests that the mechanisms underlying reflexive gaze following IOR may be independent (Friesen & Kingstone, 2003).

If the sudden-direct-gaze cue is processed by a single attentional channel that is also used for the processing of exogenous motion cues, a larger inhibitory effect (i.e., longer RTs) should emerge for the sudden-direct condition than for all other conditions (a mirror image of the findings of Experiment 1). In contrast, if sudden direct gaze draws on a single attentional channel that is also used for the processing of social gaze cues (likely endogenous; see Frischen et al., 2007), the SOA may have no effect on the sudden-direct-gaze cues but some effect on the sudden-averted-gaze cues. This should be reflected in particularly short RTs at the location of the sudden-direct-gaze cue and particularly long RTs at the location of the sudden-averted-gaze cue. Finally, if the sudden-direct-gaze effect emerged via the addition of independent gaze- and motion-processing channels with different mechanisms, then a facilitation effect at the location of both direct-gaze stimuli should be observed together with inhibitory effects at the location of the motion stimuli. This pattern would be reflected in longer RTs for motion-onset stimuli and shorter RTs for direct-gaze cues (i.e., two main effects with no interaction).

Experiment 2

Method

Participants. A different cohort of 16 right-handed participants (10 women, 6 men) with a mean age of 21.0 years (*SD* = 2.3) completed Experiment 2. All individuals signed informed consent forms prior to participation.

Experimental setup and procedure. The same method and general procedure as in Experiment 1 was employed in Experiment 2, except for one important change: The target-distractor display was not presented until 900 ms after the gaze direction of two faces changed. Thus, the gaze transition still occurred 1,500 ms after the initial display, but the target-distractor display appeared another 900 ms later.

Results and discussion

RTs associated with trials on which errors occurred (3.3% of the data; range = 0.8%–8.6%) and RTs that were more than 2 standard deviations from the mean in each condition (5.0% of the data; range = 3.4%–8.3%) were eliminated from the data set. Mean RTs and the total number of execution errors were submitted to separate 2 (gaze direction: direct, averted) × 2 (motion: sudden, static) repeated measures ANOVAs.

The analysis of RTs revealed main effects of gaze direction, $F(1, 15) = 9.68$, $p < .01$, $\eta^2 = .392$, and motion, $F(1, 15) = 25.14$, $p < .001$, $\eta^2 = .626$ (Fig. 3a). As in Experiment 1, RTs to targets presented on faces with direct gaze were shorter (934 ms, *SD* = 127 ms) than RTs to targets on faces with averted gaze (957 ms, *SD* = 137 ms). However, RTs to targets on sudden-motion-onset faces were longer (974 ms, *SD* = 129 ms) than to targets on static faces (918 ms, *SD* = 138 ms). The interaction between gaze direction and motion was not significant, $F(1, 15) < 1$, $\eta^2 = .013$, which suggests that the magnitudes of the differences across conditions did not differ. The analysis of response errors did not reveal any significant effects (*p*s > .1; see Fig. 3b), which suggests that the pattern of RTs was not associated with a speed/accuracy trade-off.

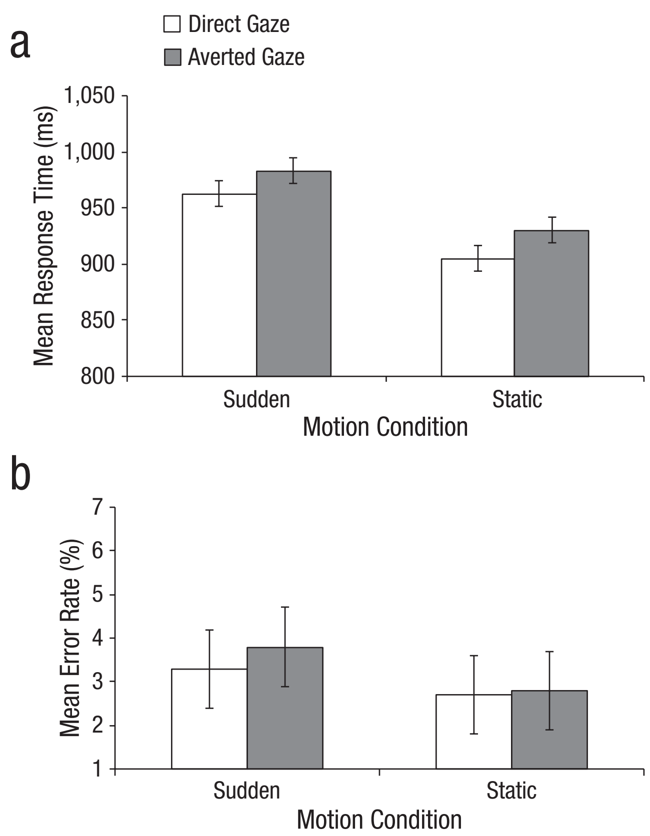

Fig. 3. Mean response time (a) and error rate (b) as a function of motion condition and gaze direction in Experiment 2. Error bars display within-subjects confidence intervals (following Loftus & Masson, 1994).

To further test for possible differences between Experiments 1 and 2, we performed a subsequent ANOVA that included the between-subjects factor experiment (Experiment 1, Experiment 2) and the within-subjects factors motion (sudden, static) and gaze direction (direct, averted). Results revealed a significant interaction of motion and experiment, $F(1, 30) = 26.0$, $p < .001$, $\eta^2 = .464$, because motion cues reduced RTs in Experiment 1 but increased RTs in Experiment 2. The main effect of gaze direction was significant, $F(1, 30) = 18.4$, $p < .001$, $\eta^2 = .380$, whereas the interaction of gaze direction and experiment was not, $F(1, 30) < 1.0$, which suggests that gaze cues reduced RTs in a similar manner in both experiments. The three-way interaction of experiment, motion, and gaze direction was not significant, $F(1, 30) < 1.0$. This subsequent analysis confirms that the pattern of effects in the two experiments were reliably different—the direct-gaze stimulus had a facilitatory effect in both experiments, whereas the motion stimulus had a facilitatory effect in Experiment 1 (0-ms SOA) but an inhibitory effect in Experiment 2 (900-ms SOA).

The results of Experiment 2 suggest that the sudden-direct-gaze effect observed in Experiment 1 was the additive result of independent attentional mechanisms concurrently acting at the same location. The motion information was processed separately from the gaze information, with the motion information demonstrating the pattern of brief facilitatory and later inhibitory effects expected with stimulus-driven attentional capture (e.g., Abrams & Christ, 2003; Posner & Cohen, 1984) and the gaze information demonstrating a pattern consistent with the capture and holding of attention associated with social gaze cues (e.g., Frischen et al., 2007; Frischen & Tipper, 2004).

Participants in both experiments were instructed to maintain fixation at the center of the screen, but they might have performed overt eye movements in addition to covert shifts of attention when faces and letters changed. Although the execution of eye movements does not preclude our interpretations, future studies could aim to disentangle the effects of the two processes.

General Discussion

In the present study, we investigated the relation between social gaze cues and nonsocial motion cues co-occurring in time and space by assessing their effect on subsequent attention processes. Experiment 1 showed that both motion cues and social gaze cues capture attention. Consistent with the subjective experience of suddenly established eye contact, the largest effect on subsequent attentional processing was induced by the combination of both types of cues. Effects of motion and gaze cues did not interact. Experiment 2 addressed whether sudden-direct-gaze cues draw on a single attentional mechanism or whether the effect of sudden direct gaze is supported by the mechanisms of motion cues and direct-gaze cues working independently. Though subjective experience denotes the unique quality of sudden direct gaze, results suggest that two independent mechanisms contribute to the processing benefit in the sudden-direct condition: an exogenous attentional mechanism that drives effects of motion cues and a different attentional mechanism that drives effects of social gaze cues. Although direct-gaze cues displayed properties that are similar to the processing of directional gaze cues (i.e., no IOR; see Frischen et al., 2007), which suggests that the underlying attentional mechanism is endogenous in nature, additional research is necessary to further clarify the nature of direct-gaze cuing effects.

The present findings extend the literature on direct-gaze effects by showing an additional advantage in attention capture for sudden direct gaze versus static direct gaze. The influence of direct gaze appears to take effect immediately on presentation and wanes as soon as gaze is averted or direct gaze is established by another face. The rapid nature of engagement and disengagement of direct-gaze processing is revealed via consideration of the sudden-direct and sudden-averted conditions. Until the moment of target presentation, the faces depicted averted and direct gaze, respectively. The moment that averted gaze turned into direct gaze and direct gaze became averted gaze, the facilitatory effect emerged and disappeared, respectively. Hence, the influence of direct eye contact is engaged and disengaged extremely rapidly.

Previous studies have shown that other people's sudden gaze to a new location reflexively draws attention to that new location (Driver et al., 1999; Friesen & Kingstone, 1998) and that this effect can co-occur with other behavioral effects associated with the reflexive capture of attention, such as IOR (Friesen & Kingstone, 2003). The contribution of the present study lies in specifying the relation of (social) gaze cues and (nonsocial) motion cues occurring simultaneously in time and space, and our results disentangle the unique and common effects of gaze and motion cues on the time course of subsequent attentional processing. The present experiments complement and uniquely extend this research on effects of social gaze cues by providing the first evidence for a processing benefit also for targets appearing at the location of sudden-onset direct gaze. This advantage may occur because direct gaze is central to many social cognitive processes. Social cues such as direct gaze play a crucial role in communication (Tomasello & Carpenter, 2007; Tomasello, Carpenter, Call, Behne, & Moll, 2005), action coordination (Clark & Krych, 2004; Sebanz, Bekkering, & Knoblich, 2006), and the regulation of social relations (Ham & Tronick, 2006). In ongoing interactions, direct gaze often functions as an ostensive signal, communicating (a) that the person who is looked at is the one who is being addressed and (b) that the subsequent action or information is going to be meaningful. As such, direct eye contact can enhance imitation, gaze following, and learning (Csibra & Gergely, 2009; Senju & Csibra, 2008; Wang, Newport, & Hamilton, 2011). The present findings show that the combination of a social with a nonsocial cue is more powerful in capturing attention than either of the cues alone. This raises the question whether the effect of ostensive direct gaze on social cognitive processes is enhanced by combining it with nonsocial cues such as motion (as observed in the present study). Can social learning, for instance, be augmented by instantiating sudden direct as compared with static direct gaze?

Taken together, the present experiments provide the first evidence that social gaze cues exert their influence independently of other (exogenous) cues appearing simultaneously at the same location. This finding may further point to a specialized system dedicated to the processing of (implicit) social signals. Sudden direct gaze additively combines the capture attention of both the motion-onset cue and of the communicative signal of direct gaze. This finding provides some explanation for the processes that underlie the subjective experience of the impact of sudden looks, as outlined in the opening social scenarios. It seems that the best thing good students can do to signal to the lecturer that they are paying attention is to occasionally direct their gaze at him or her. By contrast, the worst thing potential cheaters during an exam can do is to lift their eyes and look at the exam administrator just before peaking over to see what their neighbors have written. Finally, that momentary connection you might feel with another person who looks at you at a party may not be love at first sight, but just the by-product of nonspecific attentional capture. The connection that is developed, however, may be an important precursor for social engagement.

Author Contributions

All authors developed the study concept and contributed to the study design. R. P. van der Wel programmed the experiment. A. Böckler collected the data. A. Böckler and T. N. Welsh analyzed the data. All authors contributed to the interpretation of the results. All authors contributed to the writing of the manuscript and approved the final version for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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