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SHORT REPORT

# Direct gaze, eye movements, and covert and overt social attention processes

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## Abstract

The present study is a replication and extension of previous research examining the effects of others' gaze direction and gaze shifts on both participants' ($N = 32$) manual responses, as an indicator of covert processes, and their visual attention, as an indicator of overt processes, within an experimental response time (RT) paradigm, under both fixed- and free-viewing instructions. Participants viewed arrays of faces displaying direct or averted gaze, which shifted or held their gaze, concurrent with the presentation of a target letter that participants had to identify overlaid on one face, all while their gaze was recorded with an eye-tracking system. Participants' RTs and eye movements both revealed faster responses when the target face displayed either direct or shifted gaze, and especially when its gaze had shifted from averted to direct, though these effects were modulated by the viewing instructions. Thus, the findings replicate and extend previous research by revealing that direct gaze and dynamic motion onset affect both covert and overt attention.


**Keywords** Direct gaze · Averted gaze · Social attention · Eyetracking · Vision

How social and nonsocial cues affect visual processes and social interactions are long-standing yet emerging areas of investigation. The physiology of the human eye makes it an effective communicative cue (Emery, 2000; Frischen, Bayliss, & Tipper, 2007), and gaze direction serves productive and receptive signal functions (Duncan, 1969; Gobel, Kim, & Richardson, 2015). Productively, we intentionally direct others' attention using our gaze (Böckler, Knoblich, & Sebanz, 2011; Conty, George, & Hietanen, 2016; Hietanen, Myllyneva, Helminen, & Lyyra, 2016; Langton, Watt, & Bruce, 2000; Nummenmaa & Calder, 2009; Otsuka, Mareschal, Calder, & Clifford, 2014; Sebanz, Bekkering, & Knoblich, 2006; Senju & Hasegawa, 2005; Senju & Johnson, 2009; Shirahama, 2012). Receptively, we infer others' attention from their gaze direction (Carrick, Thompson, Epling, & Puce, 2007; Langton et al., 2000) and reflexively look where others are looking even when doing so is uninformative (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; Kuhn & Kingstone, 2009).

Gaze direction also contributes more deeply to social interactions. Beyond following others' averted gaze, perceived direct gaze, classified as eye contact in actual social interactions, has the phenomenal effect of activating social awareness and capturing attention (Conty et al., 2016; Kendon, 1967). Faces exhibiting direct gaze quicken facial recognition (Hood, Macrae, Cole-Davies, & Dias, 2003), and amplify emotional state awareness (Baltazar et al., 2014). These effects are so exuberant that they have been theorized to represent covert processes, operating preattentively, automatically, and beyond volitional control (Laidlaw, Risko, & Kingstone, 2012; Rothkich, Madipakkam, Rehn, & Sterzer, 2015; Stein, Senju, Peelen, & Sterzer, 2011; Yokoyama, Sakai, Noguchi, & Kita, 2014).

Dynamic motion onset also automatically elicits attention (Abrams & Christ, 2003; Kawahara, Yanase, & Kitazaki, 2012), and is oftentimes coupled with direct gaze in social communication (Hayward & Ristic, 2017), though few studies have investigated how gaze and motion onset cues combine to affect attention and cognition. Böckler, van der Wel, and Welsh (2014), however, explored this with a target detection

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task. Participants fixated a cross surrounded by four face images, two each displaying direct and averted gaze, and all with a letter overlaying the forehead. After a fixed interval, two of the faces held their gaze direction while the other two shifted to the alternative gaze direction, and, simultaneously, one of the letters was replaced with one of two target letters while the other three were replaced with a distractor letter. Participants identified the target letter faster when it appeared on a face that had shifted rather than held its gaze direction, displayed a held direct gaze rather than a held averted gaze, or transitioned from averted to direct gaze rather than from direct to averted gaze, supporting the predictions that direct gaze and onset motion both attract covert social attention.

Thus, leading theories suggest that we are drawn to others' eyes and orient in their gaze direction, though how this occurs is not fully understood. It is unknown, for instance, whether others' gaze direction and gaze shifts are subject to and influence both covert and overt attention, which we explore here by replicating Böckler et al. (2014), with novel manipulation and measure extensions. We manipulate overt attention by varying participants' instructions. Böckler et al. (2014) provided instructions to fixate a centrally presented cross throughout their experiment, with the expectation that participants could and would do so, and observed effects were therefore inferred to have operated through covert processes. We will contrast participants we instruct to fixate a central cross and those not given this instruction. If effects of others' gaze are entirely covert, then no differences should emerge between instructions conditions, because covert processes should be similarly accessible across conditions. By contrast, if direct-gaze and gaze-shift effects are influenced by overt processes, then condition differences should emerge. In addition, we incorporate eye-tracking measures to analyze effects on overt attention. We will examine the effectiveness of the instruction to hold fixation, and, more importantly, will test whether participants' eye movements reflect previously documented performance differences. Thus, our goal was to illuminate the effects of others' gaze on both covert and overt attention.

# Method

## Participants

Thirty-two undergraduate students participated (11 males, 21 females; see the supplement, Participants section, for a power analysis). All participants had normal or corrected-to-normal vision, were ≥ 18 years old ($M_{\text{Age}}$ = 19.9 years), and earned course credit for participating. One additional participant was tested but excluded as an outlier (mean RT > + 4 *SD*s from the sample mean). The study was approved by the Georgia Southern University Institutional Review Board.

## Apparatus

Participants completed the study on a Tobii TX-300 eye-tracking system with a 512 × 285 mm (1,920 × 1,080 pixels) LCD monitor, at a distance of $M$ = 63.1 cm, with binocular gaze recorded at 60 Hz. Participants responded on a wireless keyboard held on their laps. E-Prime 2.0 (Psychology Software Tools Inc., Pittsburgh, PA, USA) managed the stimulus presentation, eye-tracker functionality, and response measurement. We processed the eye-tracking data with customized Matlab scripts (MathWorks Inc., R2016a), which extracted gaze sequences as a function of tracking quality and clustered gaze sequences into discrete fixations (see the supplement, Eye-Tracking Procedure section).

## Stimuli and procedure

The stimuli were adapted directly from those of Böckler et al. (2014). On each trial, participants viewed an array of four face images, two each displaying direct and averted gaze, all with an "8" overlaid on the forehead (see Fig. 1, left frame), each in 200 × 250 pixel resolution (4.7° × 5.8° visual angle), in a diamond pattern around a central cross. After 1,500 ms, a stimulus shift to another array of faces, two with unchanged gaze, and one each shifted from direct to averted and from averted to direct gaze (see Fig. 1, right frame), co-occurred with a change of three of the "8s" to a distractor letter (either "E" or "U") and one to a target letter (either "S" or "H"), which participants identified as quickly as possible. Thus, gaze direction was determined by whether the target face displayed direct or averted gaze, and gaze shift by whether the target face was shifted or unchanged across arrays. The response screen appeared until participants had provided a manual response, and it was followed by a 1,000-ms blank screen intertrial interval.

Participants were assigned, in alternation, to a fixed-viewing condition, in which their instructions included (see the Instructions in the supplement), "Please try to hold your eyes on the cross that appears at the center of the screen throughout the trials," or a free-viewing condition, which omitted this instruction (though the cross was present for all participants). Participants completed 96 trials of each combination of direct versus averted gaze by shifted versus unchanged target face, using each possible unique combination of target and distractor face and letter position, for 384 total trials. Participants took a break, with a self-determined duration, every 50 trials.

# Results

## Response times

Response times (RTs) were calculated as the differences between the stimulus shift and the key-press response.

**Fig. 1** (Left) Initial stimulus screen. (Right) Response screen: The upper face has shifted from direct to averted gaze and displays the "S" target, the lower face has shifted from averted to direct gaze, and the faces on the left and right hold their averted and direct gazes, respectively.

Following Böckler et al. (2014), incorrect-response trials ($M$ = 2.7%) and those with RTs ± 2 $SD$s beyond the group mean ($M$ = 2.8%) were excluded (see Table S1 for inclusion rates per condition). We conducted a 2 × 2 × 2 mixed model analysis of variance (ANOVA), with instructions examined between groups, gaze direction and gaze shift as repeated measures, and mean RTs as the dependent variable (DV). This revealed effects of gaze direction, $F(1, 30) = 6.56$, $p = .016$, $\eta_p^2 = .179$, with faster responses for direct ($M$ = 879.2 ms, $SEM$ = 19.1) than for averted ($M$ = 889.7, $SEM$ = 19.8) gazes; and gaze shift, $F(1, 30) = 96.63$, $p < .001$, $\eta_p^2 = .763$, with faster responses on shifted ($M$ = 849.6, $SEM$ = 16.8) than on unchanged ($M$ = 919.3, $SEM$ = 22.2) gazes. Instruction condition was nonsignificant, $F(1, 30) = 1.46$, $p = .237$, $\eta_p^2 = .046$, though instructions and gaze shift did interact, $F(1, 30) = 6.43$, $p = .017$, $\eta_p^2 = .177$. Simple effects analyses indicate a greater gaze-shift effect in the fixed-viewing, $F(1, 30) = 76.46$, $p < .001$, $\eta_p^2 = .718$, than in the free-viewing, $F(1, 30) = 26.60$, $p < .001$, $\eta_p^2 = .470$, condition (see Fig. 2). All other interactions were nonsignificant ($p \geq .125$). An analogous ANOVA on response accuracy revealed no effects (all $F$s ≤ 2.09, all $p$s ≥ .159), indicating no speed–accuracy trade-off.

To directly replicate Böckler et al. (2014), we ran a 2 × 2 repeated measures ANOVA for gaze direction and gaze shift in only the fixed-viewing condition. This revealed effects of gaze direction, $F(1, 15) = 8.86$, $p = .009$, $\eta_p^2 = .371$, and gaze shift, $F(1, 15) = 54.57$, $p < .001$, $\eta_p^2 = .784$, and no interaction, $F(1, 15) = 0.75$, $p = .40$, $\eta_p^2 = .048$. Although notably larger than the effect obtained in the preceding analysis with both conditions, this gaze direction effect size was nearly identical to that found by Böckler et al. (2014), and our gaze shift effect size was markedly larger than theirs, essentially providing direct replication.

## Eye-tracking data

First, we tested whether participants looked away from the central cross. We ran a 2 × 2 × 2 mixed model ANOVA, as

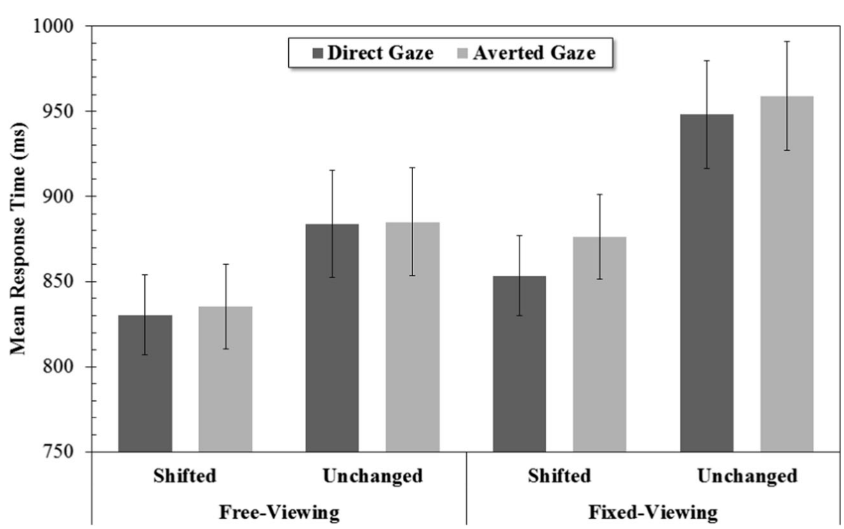


**Fig. 2** Mean response times per instruction, gaze shift, and gaze direction condition. Error bars represent ± $SEM$s.

with RTs, with the number of fixations per trial ≥ 1.5° from the central cross as the DV.[1] Most importantly, this revealed an instructions effect, $F(1, 30) = 11.99$, $p = .002$, $\eta_p^2 = .286$, with fewer fixations away from the cross for the fixed-viewing ($M = 3.68$, $SEM = 0.33$) than for the free-viewing ($M = 5.17$, $SEM = 0.27$) condition. Gaze shift was also significant, $F(1, 30) = 22.29$, $p < .001$, $\eta_p^2 = .426$, with more fixations for unchanged ($M = 4.55$, $SEM = 0.26$) than for shifted ($M = 4.30$, $SEM = 0.25$) gazes. Gaze direction and instructions interacted, $F(1, 30) = 7.22$, $p = .012$, $\eta_p^2 = .194$, and simple effects analyses indicated a gaze direction effect in the free-viewing condition, $F(1, 30) = 7.56$, $p = .010$, $\eta_p^2 = .201$ (direct: $M = 5.24$, $SEM = 0.31$; averted: $M = 5.10$, $SEM = 0.30$), but not in the fixed-viewing condition, $F(1, 30) = 1.10$, $p = .302$, $\eta_p^2 = .035$ (direct: $M = 3.66$, $SEM = 0.31$; averted: $M = 3.70$, $SEM = 0.30$). Despite these effects, one-sample *t* tests indicated that both groups looked away from the cross greater than zero times per trial, on average, both $ts(15) \geq 11.07$, both $ps < .001$. Thus, the fixed-viewing instructions likely reduced participants' eye movements, though they tended to look away from the cross.

Second, we examined eye movements to the faces before the stimulus shift and whether participants looked at the direct-gaze faces faster and longer. We calculated the preshift gaze latencies as the time from the start of each trial until the first look at, and the preshift gaze durations as the cumulative time looking at, either the direct- or the averted-gaze faces. We conducted two 2 × 2 mixed model ANOVAs, with instruction condition examined between groups and gaze direction as a repeated measure, with gaze latencies and gaze durations as DVs. All preshift gaze latency effects were nonsignificant (see the supplement, Preshift, Gaze Latencies section). For preshift gaze durations, however, there were effects of gaze direction, $F(1, 30) = 9.91$, $p = .004$, $\eta_p^2 = .248$, and instructions, $F(1, 30) = 24.36$, $p < .001$, $\eta_p^2 = .448$, as well as their interaction, $F(1, 30) = 9.07$, $p = .005$, $\eta_p^2 = .232$. Fixed-viewing participants looked at the faces less and did not differ between direct ($M = 261.0$, $SEM = 45.3$) and averted ($M = 260.3$, $SEM = 43.5$) gazes, $F(1, 30) = 0.009$, $p = .924$, $\eta_p^2 < .001$, whereas free-viewing participants looked at the faces longer overall, and at direct gazes longer ($M = 553.0$, $SEM = 34.2$) than averted gazes ($M = 517.5$, $SEM = 33.8$), $F(1, 30) = 18.97$, $p < .001$, $\eta_p^2 = .387$. Thus, before the stimulus shift, participants' eye movement speeds did not vary by stimulus gaze or instructions, but free-viewing participants tended to look at the faces, especially those with direct gaze, longer.

Finally, we calculated postshift gaze latencies as the time from the stimulus shift to the first look at the target face (i.e., a visual–motor analogue to the RT measure). We excluded trials with no look at the target face ($M = 4.1\%$), with incorrect responses ($M = 2.2\%$), and with postshift gaze latencies ± 2 *SD*s beyond the group mean ($M = 2.1\%$; see Table S3 for the inclusion rates per condition).[2] We conducted a 2 × 2 × 2 mixed-model ANOVA, as in the RT analysis, with mean postshift gaze latencies as the DV. As Fig. 3 illustrates, we found main effects of gaze direction, $F(1, 30) = 12.22$, $p = .016$, $\eta_p^2 = .289$, with shorter latencies when gazes were direct ($M = 386.0$ ms, $SEM = 7.3$) rather than averted ($M = 398.7$, $SEM = 7.5$); gaze shift, $F(1, 30) = 98.28$, $p < .001$, $\eta_p^2 = .766$, with shorter latencies on shifted ($M = 356.6$, $SEM = 7.0$) than on unchanged ($M = 428.0$, $SEM = 9.0$) gazes; and instructions, $F(1, 30) = 24.06$, $p < .001$, $\eta_p^2 = .445$, with shorter latencies for free ($M = 357.0$, $SEM = 10.2$) than for fixed ($M = 427.7$, $SEM = 10.2$) viewing. Gaze shift and instructions interacted, $F(1, 30) = 9.50$, $p = .004$, $\eta_p^2 = .240$, and simple-effect analyses indicated a greater shifted–unchanged difference in fixed viewing, $F(1, 30) = 84.44$, $p < .001$, $\eta_p^2 = .738$, than in free viewing, $F(1, 30) = 23.34$, $p < .001$, $\eta_p^2 = .438$. All other interactions were nonsignificant ($p \geq .178$). Thus, these findings replicate and extend the RT analyses and indicate that both direct gaze and gaze shifts, as compared to averted and stable gazes, draw overt attention.

## Discussion

This study replicates and extends previous research on how both gaze direction and gaze shifts affect social attention. As in Böckler et al. (2014), participants responded faster when a target appeared on a face that exhibited direct rather than averted gaze and when gaze shifted rather than was held. Using the same sample size, stimuli, procedure, data inclusion criteria, and analyses, these findings mirrored those of Böckler et al. (2014), which contributes to this area of research at a time when replications are highly valued (Nelson, Simmons, & Simonsohn, 2018; Open Science Collaboration, 2015).

We also extended this previous research to examining the role of overt attention, by manipulating participants' instructions and tracking their gaze. Participants received fixed- or free-viewing instructions. Some have posited that faces exhibiting direct gaze preattentively draw attention, in a way that is reflexive and beyond volitional control (Laidlaw et al., 2012; Rothkich et al., 2015; Senju & Hasegawa, 2005; Stein et al., 2011; Yokoyama et al., 2014). We reasoned that, if others' gaze direction and gaze shifts affect only covert processes, then the conditions should not differ, because covert processes should be similarly accessible across conditions. If, however, overt processes are involved, then the effects of gaze direction and gaze shifts should be modulated by instruction

[1] This included all trials, though excluding trials as above produced the same qualitative findings. Also, the analysis of fixation durations provides converging evidence (see the supplement, Fixation Durations section and Table S2).

[2] The rates further indicated that the fixed-viewing participants looked at the faces less, yet did so on most trials.

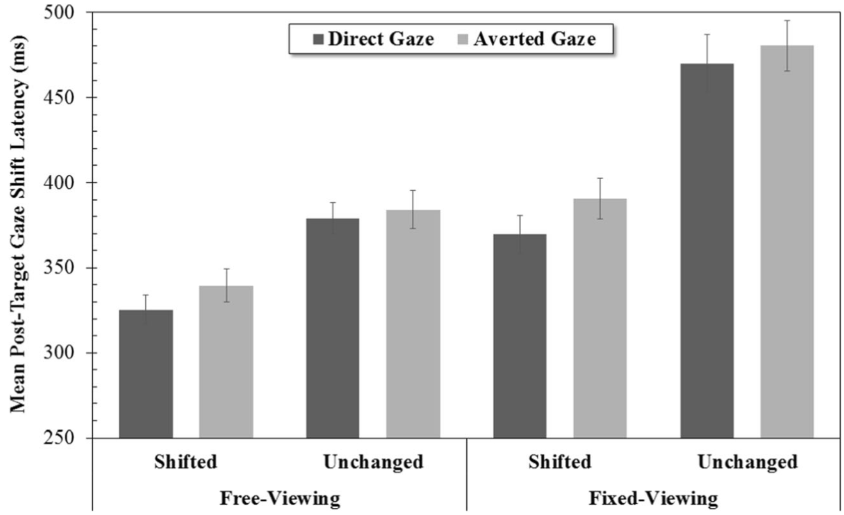


**Fig. 3** Mean gaze shift latencies per instruction, gaze shift, and gaze direction condition. Error bars represent ± *SEM*s.

condition. The participants in both conditions were faster to respond to and look at faces that shifted their gaze, which is consistent with the proposal that covert processes are at play; however, these effects were larger in the fixed- than in the free-viewing condition, suggesting that the free-viewing participants' freedom to engage overt attention may have reduced the covert motion onset effect (Abrams & Christ, 2003; Hayward & Ristic, 2017; Kawahara et al., 2012). The directionality of this effect is particularly intriguing, as it suggests that constraining participants to fixate the cross amplified the relative advantage for processing the gaze-shift motion information, and in turn that this, more so than gaze direction, is especially likely to capture covert attention. Furthermore, this suggests that gaze shift, onset motion, and direct gaze capture covert and overt attention in different ways, which must be explored further in future research.

The eye-tracking measures revealed faster looks to a target face when it displayed direct rather than averted gaze and shifted rather than unchanged gaze, suggesting that direct gaze and gaze shifts activate overt receptive social attention (Carrick et al., 2007; Conty et al., 2016; Langton et al., 2000). Examining the intersection of the instructions manipulation and eye-tracking measures, the fixed-viewing participants looked away from the cross less than did free-viewing participants, although they too looked at the faces on most trials. This suggests that they were cooperative and invested in performing the task as instructed, but also that there may have been some inability to inhibit overt attention to others' faces. Before the stimulus shift, the participants in the free-viewing condition looked at direct-gaze faces longer, even though the faces were nonpredictive of where the target letter would appear. This suggests some underlying preference for the direct-gaze stimuli and is consistent with social attention facilitation (Baltazar et al., 2014; Hood et al., 2003; Kendon, 1967), even though the stimuli were mere two-dimensional photographs, which some have argued contribute minimally to self-referential mentalizing processes, and therefore constrain observable effects that may be amplified with genuine social–interactive eye contact (Conty et al., 2016; Hietanen et al., 2016).

In conclusion, our results indicate that free versus fixed viewing modulated the effects of others' gazes on both participants' responses and their eye movements. The participants instructed to maintain fixation showed a stronger stimulus gaze shift effect. Our findings, however, reveal that direct and shifting gaze most likely affect not only covert attention processes, as assessed by RTs, but, also, as indicated by eye-tracking measures that revealed highly similar findings, overt attention processes.

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