
‘Gaze deflection’ reveals how gaze cueing is tuned
to extract the mind behind the eyes

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Running Head : Gaze deflection
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Abstract (149 words)

Here is a social phenomenon that almost everyone experiences occasionally, but that to our knowledge has not previously been studied: you are surreptitiously looking at someone, and then when they catch you staring at them, you immediately turn away. In such experiences — which we will call *gaze deflection* — the ‘deflected’ gaze is not directed *at* anything in particular, but simply *away* from the other person. As such, this is a rare instance where we may turn to look in a direction without intending to look there specifically. Here we show that gaze cues are markedly less effective at orienting an observer’s attention when they are seen as ‘deflected’ in this way — even controlling for low-level visual properties. We conclude that gaze cueing is a sophisticated mental phenomenon: it is not merely driven by perceived eye or head motions, but is rather well-tuned to extract the ‘mind’ behind the eyes.

Classification

Social Sciences: Psychological and Cognitive Sciences

Keywords

Attention; Gaze Cueing; Intentionality; Social Perception; Gaze Deflection

Significance Statement (119 words)

We report what may be the first scientific study of *gaze deflection* — a common experience in which you turn to look in a different direction when someone ‘catches’ you staring at them. We show that gaze cueing (the automatic orienting of attention to locations at which others are looking) is far weaker for such displays, even when the actual eye and head movements are identical to more typical intentional gazes. This demonstrates how gaze cueing is driven by the perception of *minds*, not eyes — and it serves as a case study of both how social dynamics can shape visual attention in a sophisticated manner, and how vision science can contribute to our understanding of common social phenomena.

One of the most important events we perceive in our daily lives is when a nearby agent shifts their attention — e.g. turning suddenly to look in a different direction. Indeed, our visual system is especially sensitive to where others are looking, as is demonstrated by many previous studies of gaze shifting (for a review see [1]), and these events are so salient that we have an automatic tendency to look in the direction that others are looking (e.g. [2]). This gives rise to the phenomenon of *gaze cueing*: in a display with two potential target locations flanking a face, for example, observers are faster and more accurate at identifying targets that appear where the face is looking (e.g. [3, 4]; for a review, see [5]). This sort of gaze cueing is triggered not just when viewing eyes, but also when viewing simple head turns (6; see also [7]).

Why are such gaze shifts so powerful? They might be driven simply by the salient motions of the eyes and heads themselves. But another possibility is that they are driven by the higher-level perception that an agent has shifted their attention or intentions. Exploring these possibilities requires a stimulus in which these factors diverge, which may seem unusual; after all, we usually look towards the objects that are the focus of our intentions (8). But there is one relatively common (though previously unstudied) social phenomenon in which a gaze shift may not actually signal an intention to look at the second location. This occurs in what we will call *gaze deflection* — when you are surreptitiously looking at someone but then suddenly look away (perhaps toward a second person) when the first person catches you staring at them. Here the intention is not to look *at* the second person, but only *away* from the first person.

Do such ‘deflected’ gazes still drive gaze cueing? In five experiments (including direct replications), we showed each observer an animation with three actors¹ either exhibiting gaze deflection (Deflection animations), or performing the identical movements — but now temporally reordered — such that impressions of gaze deflection were eliminated and all gaze shifts were seen as intentionally directed at their new locations (Control animations). In Experiment 1a, each animation (depicted in Figure 1 and in Supplementary Videos S1-S2, and

¹ In fact, the people in the videos were the paper’s authors — but for reasons of agreed-upon differences in photogenic fitness, one of the authors was included twice, and one was eliminated altogether.

also online at <http://perception.yale.edu/gaze-deflection/>), began with a central person (A) turning to look at the rightmost person (B; the 'First' gaze, seen as *Directed*). In Deflection animations, B turned her head to face A, who then (exhibiting gaze deflection) immediately turned to look in the other direction, thus facing a third person (C; the 'Second' gaze, seen as *Deflected*). In Control animations, shortly after turning to look at B, A instead spontaneously (i.e. without B 'catching' her staring) turned to look towards C (the 'Second' gaze, now seen as *Directed*). Only then did B turn her head toward A. To measure how observers' attention varied in response to the Deflection vs. Control animations, we presented a single target letter along the direction of A's gaze during either the First gaze (Early targets; depicted in Figure 2a) or Second gaze (Late targets; depicted in Figure 2b). This same design was then employed in Experiment 1b (a direct replication of Experiment 1a).

Next, we ruled out two classes of potential confounds, pertaining to temporal differences (Experiment 2) and spatial differences (Experiments 3a and 3b) in the animations employed in our original experiments. In Experiment 2, we explored the role of *temporal* factors: Whereas the Deflection vs. Control animations in Experiments 1a and 1b featured different numbers of head turns (and differential delays) before the Late target was presented, these temporal factors were now equated (as depicted in Supplementary Figure S1 and Supplementary Videos S3-S4). This experiment also served as a conceptual replication of Experiments 1a and 1b, since they featured different videos, now of actors facing toward the camera so that their eyes were fully visible (as in Figures 2d and 2e).

Finally, we explored the role of *spatial* factors: In Experiment 2, Deflection animations ended with both actors looking toward the target location (as in Figure 2d), while Control animations ended with one of the actors looking forward (as in Figure 2e). To ensure that these differing spatial configurations could not explain the observed differences between Deflected and Control animations, Experiment 3a (and Experiment 3b, its direct replication) retained these final tableaux from Experiment 2, but eliminated the preceding motions which led to the

perception of 'deflected' vs. 'directed' gazes in the first place (as depicted in Supplementary Figure S2).

Results

The average discrimination accuracy for Early and Late targets in Experiment 1a is depicted separately for Deflection and Control animations in Figure 2c. Inspection of this figure suggests two clear patterns of results: (a) In the Deflection animations, letter discrimination accuracy was higher for First gazes (seen as Directed) compared to Second gazes (seen as Deflected); but (b) this bias was not present in the Control animations (when both gazes were Directed). These impressions were confirmed by the following analyses. The proportions of correct responses for Early and Late targets were compared using a two-proportion z-test in Deflection and Control animations respectively. There was a significant difference between First and Second gazes in the Deflection animations (87.0% vs. 71.0%; $z=2.78$, $p=.005$, $h=0.40$), but not in the Control animations (74.0% vs. 80.0%; $z=1.01$, $p=.313$, $h=0.14$). And the difference between these differences (i.e. the interaction effect) was also highly reliable ($z=2.66$, $p=.008$). Thus, the gaze cueing effect is greatly reduced when the gaze is 'deflected', even when the actual head motion is identical. These effects were directly replicated in Experiment 1b: there was a significant difference between Early vs. Late targets in Deflection animations (86.0% vs. 70.0%; $z=2.73$, $p=.006$, $h=0.39$), but not in Control animations (74.0% vs. 76.0%; $z=0.33$, $p=.744$, $h=0.05$), and the difference between these differences was also significant ($z=2.12$, $p=.034$). And in Experiment 2, gaze cueing was once again greatly reduced when the gaze was 'deflected' (61.0% vs. 71.0%; $z=2.11$, $p=.035$, $h=0.21$; see Figure 2f) — despite the identical timing of head turns, and even with fully visible eyes.

Experiment 3a retained only the final tableaux from Experiment 2. Now, with the elimination of the preceding head turns (that yielded impressions of gaze deflection), there was no difference between the Deflection-Frame and Control-Frame conditions. Indeed, if anything

there was a trend in the opposite direction: accuracy was greater with final tableaus from Deflection animations compared to those from Control animations (54.0% vs. 48.0%; $z=1.20$, $p=.230$, $h=0.12$; see Figure 2f). And crucially, there was a reliable interaction with target accuracy from Experiment 2 ($z=2.32$, $p=.020$), thus demonstrating that the final spatial configurations alone cannot be responsible for the gaze deflection effect. These effects were directly replicated in Experiment 3b: accuracy was again trending in the opposite direction, with better performance for final tableaus from Deflection compared to Control animations (55.0% vs. 45.5%; $z=1.90$, $p=.057$, $h=0.19$), and the interaction again revealed that this was different from the gaze deflection effect observed in Experiment 2 ($z=2.83$, $p=.005$).

Discussion

The current study exploits the phenomenon that we have called ‘gaze deflection’, and employs it for the first time in an empirical study. Gaze deflection is a familiar (perhaps all too familiar) social phenomenon from everyday life, whereas most studies of gaze cueing use either static images of isolated faces or short video clips in which eye movements are divorced from their context (such that the agents in most such experiments aren’t actually looking at anything; see [9]). The results were clear and powerful: even when tested in only a single trial per observer, eye and head movements were much less effective at cueing attention when they were seen as ‘deflected’, and thus dissociated from the actual direction of intention.

These effects seemed to reflect the social significance of gaze deflection, rather than any lower-level properties. In particular, they did not reflect differences in the timing of head turns, since these were equated in Experiment 2. And they also can’t be explained by traditional gaze cueing mechanisms to the differing spatial configurations. When multiple people turn to look in the same direction (as in Figure 2d), gaze cueing is typically amplified (e.g. [10]), and such ‘pooling’ effects are particularly strong in the context of actual head turns as we used in the present studies (as opposed to mere eye movements; e.g. [11]). This sort of groupwide gaze

cueing remains powerful even when people are looking directly to the right or left (12), and attention is not cued in such configurations to the space between multiple people who are gazing in the same direction (13). Accordingly, we also demonstrated directly (in Experiments 3a and 3b) that such spatial configurations do not yield such differences in the absence of the head turns that give rise to the perception of gaze deflection.

The phenomenon of gaze deflection, with its dissociation between the perceived direction of *gaze* and the perceived direction of *intention*, provides unique insights into recent debates on the relative contribution of visual cues and mental states to social attention (for a recent review, see [14]). It has long been assumed that gaze cueing is driven by the visual cue of eye gaze alone (e.g., [4, 15]). Building on other recent work uncovering humans' remarkable ability to construct rich models of others' attentional states (e.g. [16]), the current results use a familiar social phenomenon to directly demonstrate that cueing of attention is especially tuned to the perceived attentional states of others, and less so to brute visual cues. Attention, in this sense, seems tuned not to follow the eyes, but rather to follow the *mind* behind the gaze.

Methods and Materials

Participants

For each experiment, 400 observers were recruited through Amazon Mechanical-Turk (MTurk; Expt 1a: 244 females, $M_{\text{age}}=36.96$; Expt 1b: 242 females, $M_{\text{age}}=35.77$; Expt 2: 203 females, $M_{\text{age}}=34.40$; Expt 3a: 187 females, $M_{\text{age}}=36.21$; Expt 3b: 194 females, $M_{\text{age}}=34.67$), and each completed a single trial in a 3-5 min session in exchange for monetary compensation. (For a discussion of this pool's nature and reliability, see [17]. All observers were in the U.S., had an MTurk task approval rate of at least 80%, and had previously completed at least 50 MTurk tasks.) This sample size was determined arbitrarily before data collection began, and was fixed to be identical in each of the three experiments reported here. All experimental methods and procedures were approved by the Yale University Institutional Review Board, and all observers

confirmed that they had read and understood a consent form outlining their risks, benefits, compensation, and confidentiality, and that they agreed to participate in the experiment.

Apparatus

After agreeing to participate, observers were redirected to a website where stimulus presentation and data collection were controlled via custom software written in HTML, CSS, JavaScript, and PHP. (Since the experiment was rendered on observers' own web browsers, viewing distance, screen size, and display resolutions could vary dramatically, and so we report stimulus dimensions below using pixel [px] values.)

Stimuli and Design

Experiments 1a and 1b. As depicted in the sample screenshots in Figure 1, observers viewed an animation (1196×290px) centered in their browser window and surrounded by a gray (#605D5D) 3px frame on a dark gray (#404040) background. Three people were viewed from behind, on a background wall (approximately #CFCBC4). The three people were sitting in front of laptops, and typing sounds played throughout the animation. The people initially looked straight ahead, with the timings of the movements described below reported with respect to the beginning of the animation.

In the 'Deflection' animations, the central person turned her head (at 3.5s) towards the rightmost person (the 'First' gaze, seen as *Directed*), and then seemed to stare at her. At 7.2s, the rightmost person turned her head to face the middle person, who then (exhibiting gaze deflection) immediately (at 7.5s) turned to look in the other direction, thus facing the leftmost person (the 'Second' gaze, seen as *Deflected*). (The leftmost person looked straight ahead throughout the animation.) The final tableau was then visible for an additional 1.1s (i.e. until 8.6s), at which point it disappeared. In the 'Control' animations, the central person again turned her head (at 3.5s) toward the rightmost person (the 'First' gaze, again seen as *Directed*), and then seemed to stare at her. At 7.5s (without having been 'caught'), the central person then turned to look in the other direction, thus facing the leftmost person (the 'Second' gaze, also now seen as *Directed*). Only after this (at 8.8s) did the rightmost person turn her head toward

the central person. The final tableau was then visible for an additional 1.5s (i.e. until 10.3s) at which point it disappeared. (Once again, the leftmost person looked straight ahead throughout the animation.)

Each observer viewed a target letter presented for 0.13s on the background between the people (roughly in line with their eyes) while the animation was playing. This target was a gray (#9C9892) "T" or an "L" (presented in Helvetica, roughly 20x30px). Targets presented during First gazes (Early targets; depicted in Figure 2a) were presented between the middle and rightmost people (centered at 788px from the image's left border) along the direction of gaze (centered at 143px from the image's top border), 0.1s after the middle person finished turning her head towards the rightmost person (at 4.4s). Targets presented during Second gazes (Late targets; depicted in Figure 2b) were presented between the middle and leftmost people (centered at 408px from the image's left border) along the direction of gaze (centered at 143px from the image's top border), 0.1 s after the middle person finished turning her head towards the leftmost person (at 8.4s).

In the actual animations that observers viewed, the identities of the leftmost and rightmost people were counterbalanced, using the identical stimuli. In fact, since the leftmost person never turned her head, only two initial movies were filmed, but the leftmost person in each movie was the first static frame of the rightmost person from the other movie. (Given the uniformly-lit wall in the background, this frame was added into the animation without any obvious segmentation cue, such that it appeared to be an animation of three separate people — as depicted in Figure 1.) The two resulting animations were qualitatively identical, but because they were constructed from two separately filmed movies, their timing was slightly different. In particular, compared to the timing of the first pair of animations (as described above), the second movie's key events occurred at the following timestamps: (a) the middle person turned to the right at 3.7s; (b) in the Deflection animations, the rightmost person then turned to the left at 7.2s; (c) in the Deflection animations, the middle person turned to the left at 7.6s; (d) in the Control animations, the middle person turned to the left at 7.6s; (e) in the Control animations,

the rightmost person looked to the left at 9.0s; (f) targets presented during First gazes appeared at 5.4s; and (g) targets presented during Second gazes appeared at 8.4s.

The design described above resulted in a total of 16 animations: 2 target timings (Early/Late) × 2 target identities (“L”/“T”) × 2 orders of head movements (Deflection/Control) × 2 identities for the rightmost vs. leftmost people — and each was viewed by 25 unique observers.

Experiment 2. Observers viewed a silent animation (1000×298px) surrounded by a gray (#5F5D5B) 6px frame and featuring two people viewed from the front, on a background wall (approximately #DFDFD7).

In the Deflection animation, the left person turned her head (at 2.0s) towards the right person, and then seemed to stare at her. At 4.0s, the right (i.e. stared-at) person turned her head to face the left person, who then (exhibiting gaze deflection) immediately (at 4.8s) turned to look in the other direction. The final tableau was then visible for an additional 0.7s (i.e. until 6.0s), at which point it disappeared. In the Control animation, the right person was facing to her left in the beginning, and at 2.0s she turned to face straight ahead. At 4.0s, the left person turned her head towards the right person to stare at her, and then immediately (at 4.8s) turned to look in the other direction. (Since the right person was facing her laptop during these movements, this shift now appeared to be intentional rather than deflected.) The final tableau was then visible for an additional 0.7s (i.e. until 6.0s), at which point it disappeared.

A target letter was presented to the left of the left person (centered at 130px from the image’s left border), 0.1 s after the left person finished turning her head towards her right (and the observer’s left), along the direction of gaze (centered at 283px from the image’s top border). This target (a gray #B1B0A7 “T”, presented in Helvetica, roughly 38x46px) gradually faded in over the course of 0.20s, remained visible 0.10s, and gradually faded out for another 0.20s.

There were thus 2 animations corresponding to 2 orders of eye/head motions (Deflection/Control) — and each was viewed by 200 unique observers.

Experiments 3a and 3b. These experiments were identical to Experiment 2, except as noted here. Observers viewed the final 0.7s of the animations (which consisted of only static frames) from Experiment 2 (cropped to hide the laptop logos, 1000×268px). In Deflection frames, both people were thus facing to the left (as in Figure 2d); and in Control frames, the left person was facing to the left, while the right person was facing ahead (as in Figure 2e). The target letter (#000000) was again presented to the left of the left person and began fading in as the animation began. The animation ended 0.2s after the target faded out, at 0.7s. There were thus 2 animations corresponding to 2 head directions (Deflection/Control frames), and for half of the observers (counterbalanced across conditions), the videos were horizontally flipped, for a total of 4 animations — each viewed by 100 unique observers.

Procedure

Each observer was instructed to watch a single animation as closely as possible, as it would be displayed only once. Observers viewed the animation (which started playing automatically after 0.5s in Expts 1a and 1b, upon a keypress in Expt 2, and upon a keypress and after a 1s “Get Ready” message in Expts 3a and 3b). In Expts 1a and 1b, immediately after the animation ended (and disappeared), observers were asked three questions (only one of which was visible at a time): (a) whether they had seen a letter appear during the animation; (b) whether it was a “T” or an “L” (and to guess if they did not know); and (c) how confident they were in their response (on a scale of 1-7, with 1 labeled “Not at all”, and 7 labeled “Entirely”). In Expt 2, observers were asked two questions (only one of which was visible at a time): (a) whether they had seen a letter appear during the animation; (b) which letter they saw (A-Z; and to guess if they did not know). In Expts 3a and 3b, observers were asked only one question: which letter they saw (A-Z; and to guess if they did not know). In all experiments, they then also answered questions that allowed us to exclude (with replacement) observers who guessed the purpose of the experiment (e.g. mentioning gaze following; $n=27$, 10, 25, 15, and 7, in Expt 1a, 1b, 2, 3a, and 3b respectively); who interrupted the experiment ($n=16$, 9, 21, 55, 54); who didn’t view the video “in full view” ($n=95$, 49, 9, 11, 11); who reported past participation in a

similar study ($n=4, 8, 24, 46, 45$); who encountered any problems ($n=19, 7, 4, 3, 2$); or who failed to answer our questions sensibly ($n=7, 2, 24, 49, 32$; e.g. responding to our question about the experiment's purpose by writing "i cant see"). In Expts 2, 3a, and 3b, we also removed observers who entered anything other than a single letter in response to the letter identification question (e.g. "jjhhgkjk"; $n=2, 17, 9$). The resulting unique excluded observers (some of whom triggered multiple criteria; $n=142, 70, 79, 101, 96$) were replaced without ever analyzing their data. (The relatively high exclusion rate for observers who reported not watching the video "in full view" in Expts 1a and 1b may be due to observers misunderstanding our poorly-worded question as involving whether the *people* in the videos — and not the videos themselves — were "in full view". In fact, the video depicted only the upper bodies of the people, as in Figure 1. When this question was replaced by directly measuring the size of observers' browser windows in Expts 2, 3a, and 3b and comparing it to the size of the animation, only 9, 11, and 11 observers were excluded.)

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Data Availability

All raw data are available in the Supporting Information file associated with this submission.

Author Contributions

C. Colombatto, Y.-C. Chen, and B. J. Scholl designed the research and wrote the manuscript. C. Colombatto and Y.-C. Chen conducted the experiments and analyzed the data with input from B. J. Scholl. This project was funded by ONR MURI #N00014-16-1-2007 awarded to BJS. The preregistration for Experiment 2 can be viewed at <http://aspredicted.org/blind.php?x=8af5id>, and that for Experiments 3a and 3b can be viewed at <https://aspredicted.org/blind.php?x=af8ey2>.

Author Note

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Figure Captions

Figure 1. A schematic depiction of the animations observers viewed in Expts 1a and 1b.

Figure 2. (a) and (b) Examples of the stimuli used in the letter discrimination task from Expts 1a and 1b, including the Early target (a) and Late target (b). (c) Average accuracy in the letter discrimination task for Early vs. Late targets in Expt 1a. Accuracy was impaired for Late targets (relative to Early targets) in Deflection animations, but not in Control animations (where both gazes were seen as Directed, since there was no gaze deflection). (d) and (e) Examples of the stimuli used in the letter identification task from Expt 2, in both the Deflection animation (d) and the Control animation (e). (f) Average accuracy in the letter identification task for Deflection vs. Control animations in Expt 2, and for Deflection vs. Control configurations in Expt 3a. Accuracy was impaired for targets (relative to Control animations) in Deflection animations, but only when presented as dynamic animations (Expt. 2), and not when presented as static frames (thus eliminating impressions of gaze deflection; Expt. 3a). Error bars indicate 95% confidence intervals.

Supplementary Video Information

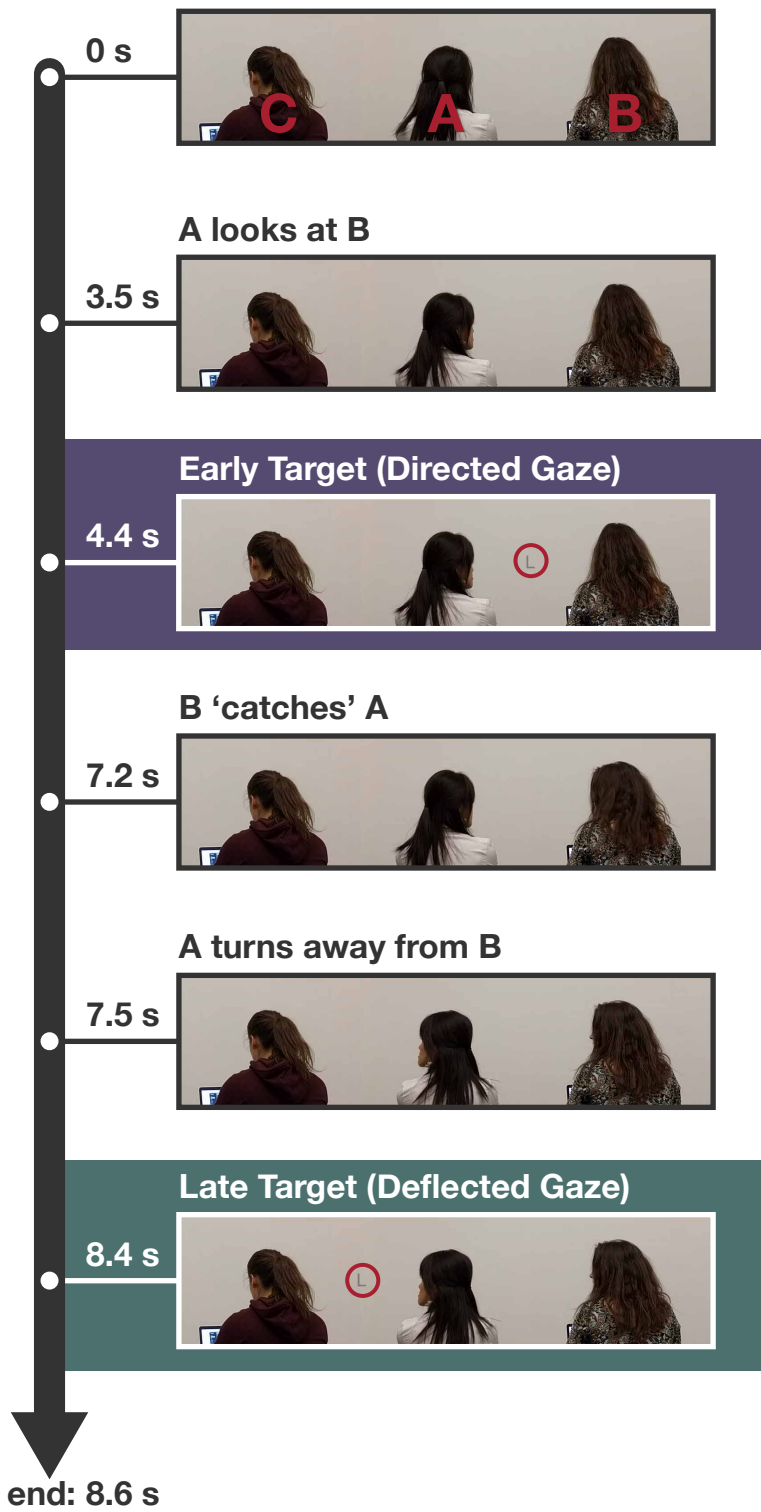
Supplementary Video S1. Sample 'Deflection' animation used in Experiments 1a and 1b. After the central person (A) turns to look towards the rightmost person (B), B turns her head to face A (i.e. 'catching her' staring). A then immediately turns to look in the other direction (towards another person, C), thus exhibiting gaze deflection. The letter target appears shortly afterwards along the direction of this second (deflected) gaze.

Supplementary Video S2. Sample 'Control' animation used in Experiments 1a and 1b. After the central person (A) turns to look towards the rightmost person (B), she then turns again to look in the other direction (towards another person, C). The letter target appears shortly afterwards along the direction of this second (directed) gaze. Only then does B turn her head to face A.

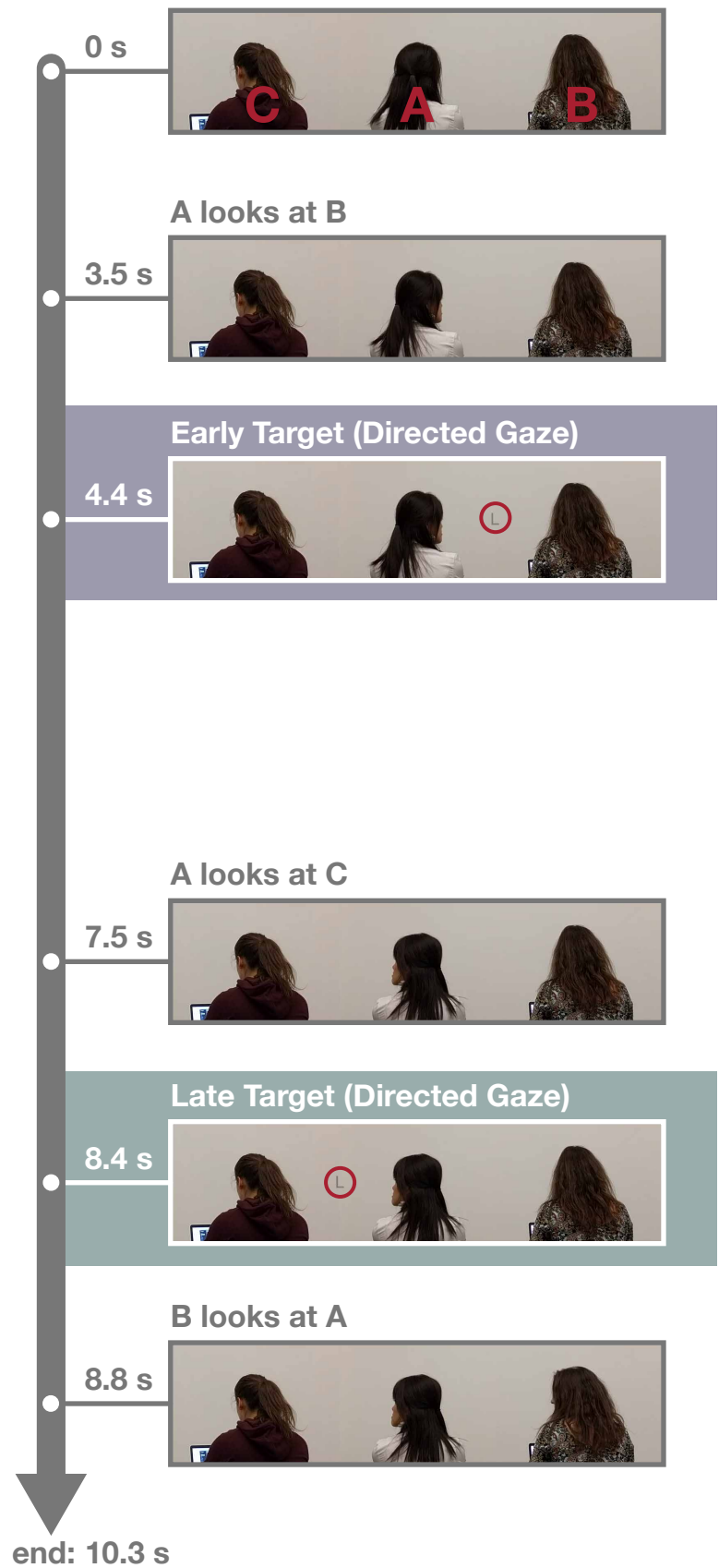
Supplementary Video S3. Sample 'Deflection' animation used in Experiment 2. The left person turns to look towards the right person, who then turns her head to face the left person (i.e. 'catching' her staring). The left person then immediately turns to look in the other direction, thus exhibiting gaze deflection. The letter target appears shortly afterwards along the direction of this second (deflected) gaze.

Supplementary Video S4. Sample 'Control' animation used in Experiment 2. The right person turns to look straight ahead; only then does the left person turn to look towards the right person, and then turns again to look in the other direction. The letter target appears shortly afterwards along the direction of this second (directed) gaze.

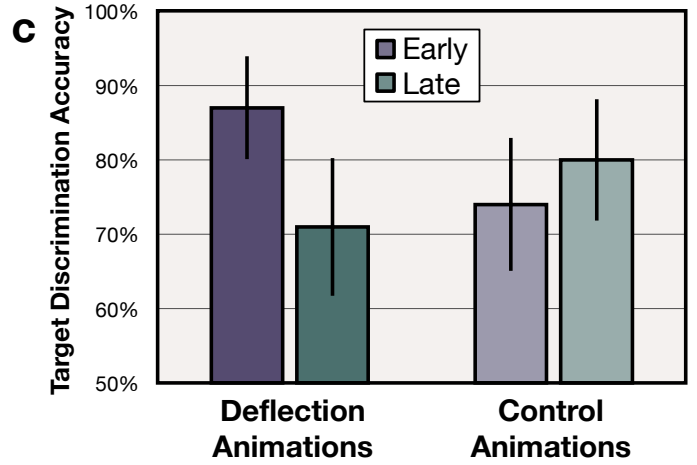
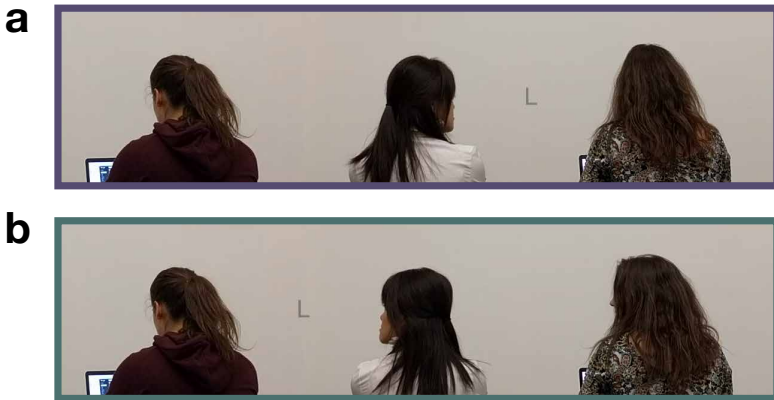
Deflection Animations



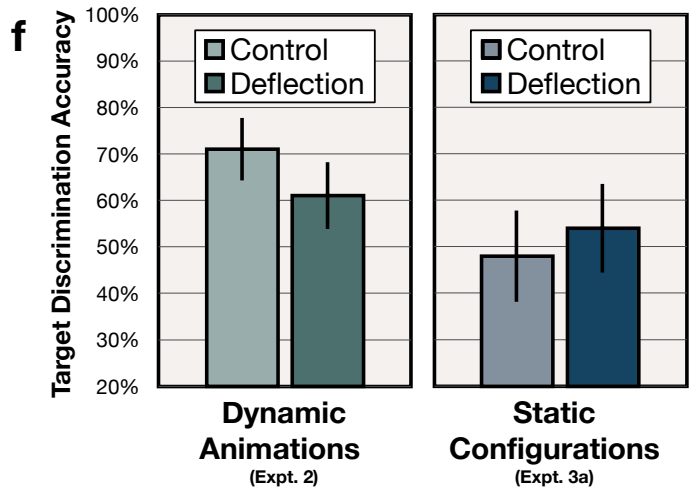
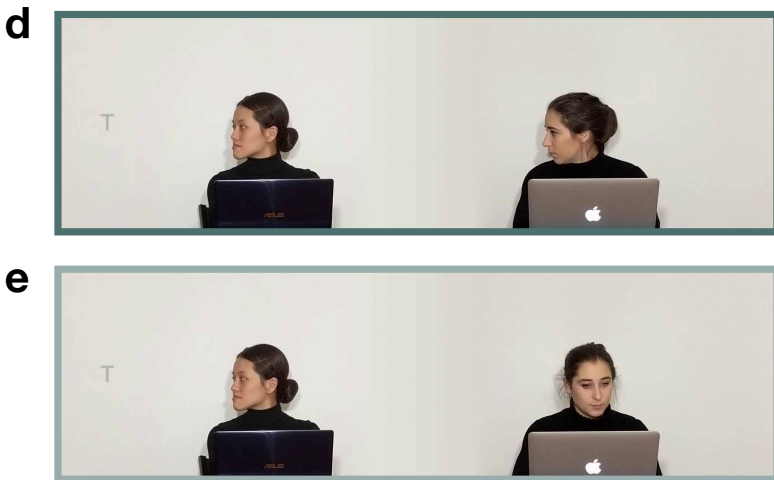
Control Animations



Experiment 1a



Experiments 2 and 3a



Supplemental Figure S1

Deflection Animation

Control Animation

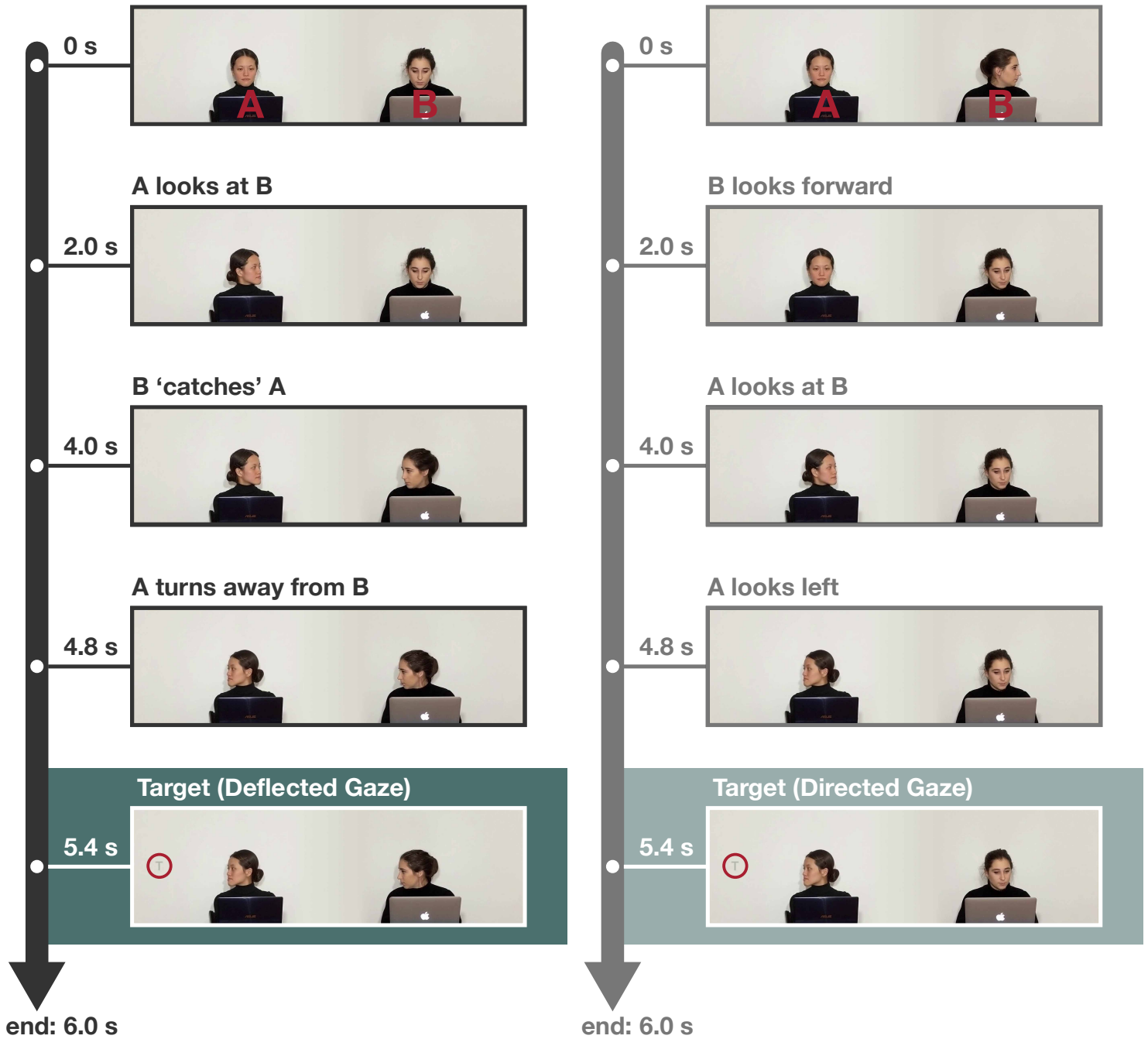
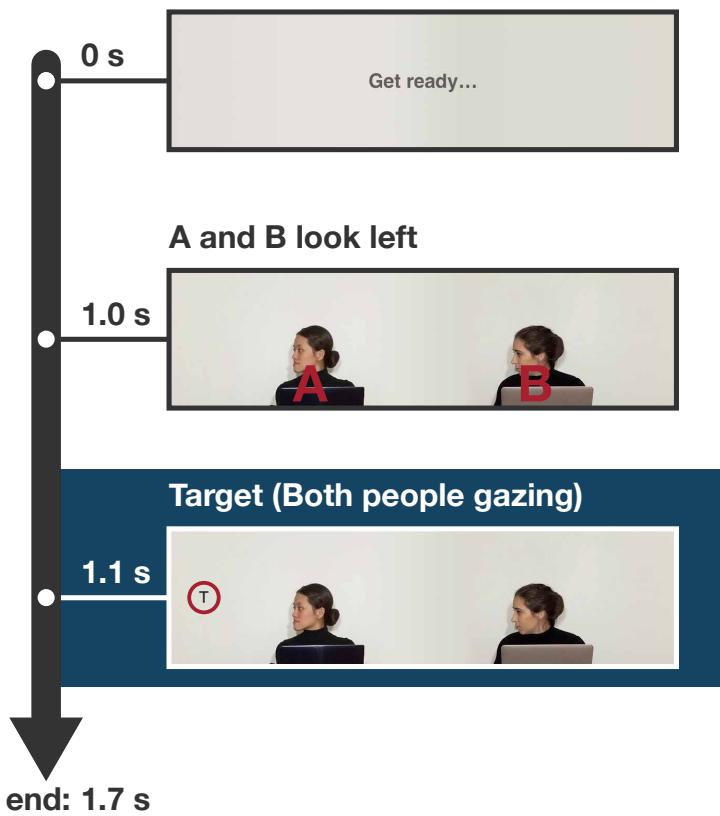


Figure S1. A schematic depiction of the animations observers viewed in Experiment 2.

Supplemental Figure S2

Deflection Frame



Control Frame

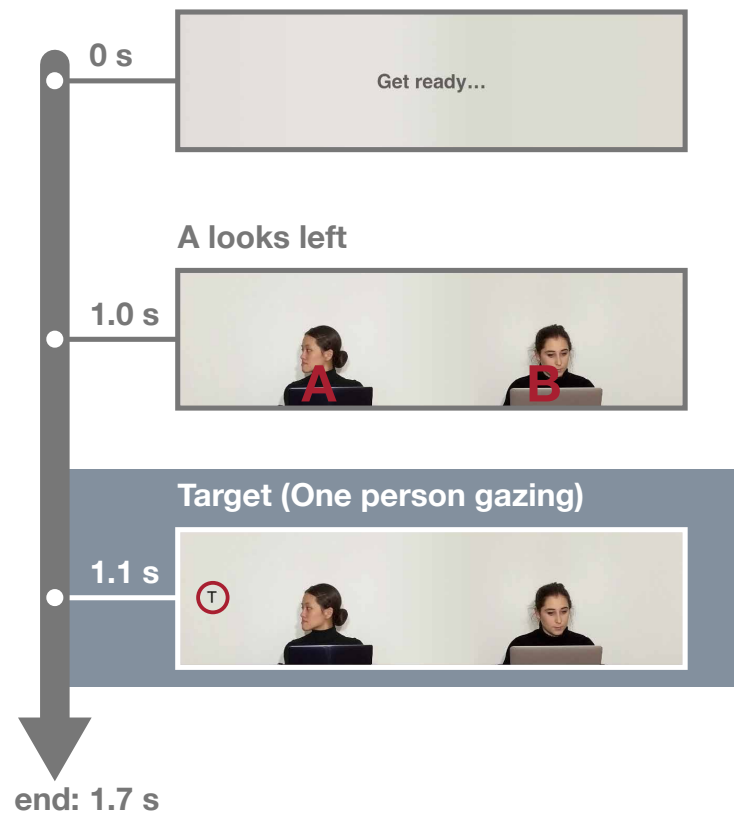


Figure S2. A schematic depiction of the frames observers viewed in Experiments 3a and 3b.