PHILOSOPHICAL TRANSACTIONS B

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Review

Cite this article: Hamilton AF de C. 2016 Gazing at me: the importance of social meaning in understanding direct-gaze cues. *Phil. Trans. R. Soc. B* **371**: 20150080. http://dx.doi.org/10.1098/rstb.2015.0080

Accepted: 17 September 2015

One contribution of 16 to a theme issue 'Understanding self and other: from origins to disorders'.

Subject Areas:
neuroscience, cognition

Keywords:
gaze, autism, theory of mind, audience effect, social cognition

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Gazing at me: the importance of social meaning in understanding direct-gaze cues

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Direct gaze is an engaging and important social cue, but the meaning of direct gaze depends heavily on the surrounding context. This paper reviews some recent studies of direct gaze, to understand more about what neural and cognitive systems are engaged by this social cue and why. The data show that gaze can act as an arousal cue and can modulate actions, and can activate brain regions linked to theory of mind and self-related processing. However, all these results are strongly modulated by the social meaning of a gaze cue and by whether participants believe that another person is really watching them. The implications of these contextual effects and audience effects for our theories of gaze are considered.

1. Introduction

A pair of eyes staring at you can be a compelling social signal, with substantial effects on behaviour. This paper reviews cognitive and neuroimaging studies of responses to direct-gaze cues in typical and autistic populations, in order to understand the varied and subtle effects of direct gaze on human behaviour. By necessity, this paper is only a brief overview of a large literature in this area, with an emphasis on recent studies and neuroimaging. Detailed reviews are provided elsewhere [1–4]. Several different facets of gaze processing can be distinguished, and provide a structure for the present paper. First, direct gaze acts rapidly to arouse and modulate responses. However, such effects are also strongly dependent upon context. Neuroimaging studies demonstrate that direct gaze engages brain regions linked to self-related processing and theory of mind. Finally, new evidence suggests that live gaze from a real person may have different effects compared with photos of gaze, with important consequences for our cognitive models. Here I review each of these areas before suggesting some future directions. In particular, I suggest that it is important to consider the social meaning of direct-gaze cues rather than studying these cues in isolation. For clarity, I use the term 'direct gaze' when a participant views a stimulus (live, photo, video or computer generated) in which eyes appear to gaze directly at the participant. Mutual gaze or eye contact refers to the situation where two people look directly at each other.

2. Effects of gaze are rapid and arousing

Direct-gaze cues have a clear effect on both social and non-social behaviour. They capture visual attention [5–9] and enhance memory [10–12]. Neonates [13] and adults [14] prefer direct to averted gaze. Direct gaze from a confederate also acts as an arousing stimulus, leading to increases in skin conductance responses (SCR) [15,16]. Photos showing direct gaze also increase the SCR but only when participants also perform a demanding cognitive task (not a simple task) [17]. These arousal changes can have cognitive consequences. For example, participants are better at reporting their emotional responses to pictures following direct-gaze primes, and also show stronger correlations between SCR and reported emotions following this priming [18]. The authors

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interpret this result in terms of an enhancement of self-focus induced by the direct-gaze cues.

More recent work comparing responses during direct gaze from a live confederate or from a photo found changes in SCR and in N170 event-related potential (ERP) amplitude only for the live direct gaze [19,20]. Further interpretation of these differences between photos and live gaze are in §6 below. Overall, these studies point to the idea that direct gaze can lead to changes in arousal, and attention. It has been suggested that an innate, subcortical mechanism is responsible for these effects [1].

In contrast with the marked, rapid impact of direct gaze on typical adults, several studies report unusual responses to direct gaze in participants with autism. Differences in responsiveness to eye contact and gaze contribute to the diagnosis of autism, and many studies have tried to pin down what drives these behavioural differences. Some show alterations in the early, basic processing of direct-gaze cues. For example, typical children find it easier to detect an oddball stimulus with direct gaze than one with averted gaze, but children with autism show no direct-gaze advantage [21]. Typical adolescents viewing faces under continuous flash suppression detect direct-gaze faces faster than averted gaze faces, but again children with autism show no direct-gaze advantage [22]. The preference for direct over averted gaze found in typical adults was absent in adults with autism [14]. ERPs to direct gaze in infants at risk of autism were related to later diagnosis [23], suggesting that unusual responses to direct gaze may be an early marker of autism.

However, in some cases typical and autistic behaviour following direct-gaze cues is similar. Both typical and autistic children are faster to detect upright faces with direct gaze than averted gaze [24]. Both groups also showed equal performance on a task requiring them to adjust the eyes of a virtual character until it 'looks at you' [25]. SCRs to direct-gaze photos or avatar faces can be similar in typical and autistic participants [26,27]. These studies suggest that abnormal responses to direct gaze are not inevitable in autism, and it will be interesting to determine exactly when and why typical and autistic participants diverge in their response to gaze.

3. Direct gaze modulates actions

Direct gaze not only leads to arousal and attentional effects, but can also have rapid and specific consequences for actions. Several studies have examined if and how direct gaze might affect mimicry responses, because mimicry is an affiliate social behaviour which is typically not consciously controlled. In a careful real-life study, eye contact from an actor who appeared to be injured caused an increase in facial mimicry from a participant, compared with a matched condition where the actor did not make eye contact [28]. Cognitive studies also show that videos with gaze cues can rapidly modulate mimicry responses [29], and that medial prefrontal cortex (mPFC) has a critical role in this process [30]. A person requesting assistance and making eye contact influences the kinematics of a reach and grasp action, compared with a person making the same gesture without eye contact [31]. The gaze of a second person can influence kinematics even when the potential for direct gaze is present, that is, when the face is visible and eye movements are permitted [32]. In infants, direct-gaze cues also enhance imitation learning [33], which has been taken as evidence for natural pedagogy. It is worth noting that the mimicry or imitation responses modulated in these studies are not arbitrary behaviours, but are socially meaningful and linked to affiliation and prosocial behaviour. This provides an initial cue that direct gaze does not necessarily modulate all responses (e.g. the responses on incongruent trials in Wang *et al*. [29]), but acts specifically on the prosocial mimicry response. This implies that even rapid effects of direct gaze are socially meaningful.

Several studies have examined whether the modulatory effects of gaze on action differ in people with an autism diagnosis. For example, typical children who observe a model reach for an object show kinematic contagion, copying the action features, only if the model is able to gaze freely at the scene, but children with autism spectrum disorder do not show any such contagion [34]. Typically developing toddlers watching videos of actions with or without direct gaze will look at the actor's face more and imitate more when direct gaze is present, while toddlers with autism look less to the face and imitate less [35]. However, participants with autism are not always unresponsive to gaze cues—both typical and autistic participants show more contagious yawning following an instruction to look at the eyes of the person in the video [36]. All these studies suggest that direct gaze acts as an important prompt to imitation and other motor responses in typical participants, but may not always have this effect in autism.

Together, these studies highlight the rapid and compelling nature of a direct-gaze cue which can change attention, arousal and motor responses in a meaningful fashion. Responses to this cue may differ in people with autism. A model based on subcortical alerting mechanism combined with slower cortical systems has been put forward to account for many of these results [1]. In this model, a fast-track modulator acting via the amygdala produces a rapid arousal response to direct gaze, while slower cortical networks including areas of the social brain process information about social context. This model is powerful, but there is increasing evidence that the impact of context on gaze processing is more than just an after-thought. Here I highlight more social aspects of gaze processing which have not been considered in so much detail.

4. Gaze has a context-dependent social function

The primary reason that processing of direct gaze is complex is that this cue cannot be interpreted in isolation. Film-makers and advertisers know this, using direct gaze to signal threat (e.g. the 'Kubrick Stare' in 'A Clockwork Orange') and to attract social interest (e.g. underwear advertisements) in different contexts. Decades of research into the use of gaze in natural interactions (reviewed in Kleinke [2]) shows how gaze can signal attentiveness, competence and social dominance. This means that gaze can be a positive, neutral or negative cue, depending on the context. Direct gaze can be used to regulate conversation shifts [37] and to signal social interest [38]. Prolonged gaze or staring leads to avoidance behaviours [39], but in other contexts prolonged mutual gaze can be a sign of love and attraction [40]. These early studies demonstrate how the social meaning of a gaze cue changes radically depending on the context.

Recent experimental studies lead to similar conclusions. The duration of gaze from a virtual character influences a participant's judgements of liking, with increases in liking as gaze duration increases up to 4 s [41]. Engagement of medial and orbital prefrontal brain regions also correlated with gaze duration in the same study, and contrasting results have been found for participants with autism [42]. Thus, changes in gaze duration alone can dramatically change the social meaning of a gaze cue and our neurocognitive response to it. This work is reviewed in more detail in Schilbach [43].

There are also clear interactions between gaze and other social cues. Attractive faces paired with direct gaze engage brain systems linked to reward [44], but participants judged smiling faces with direct gaze or neutral faces with averted gaze as more attractive that smiling/averted or neutral/direct faces [45]. Gaze from an avatar interacts with facial expression (angry/neutral) and action (pointing or not) to influence early EEG responses [46]. Direct gaze in a video must be paired with a slight smile to induce an enhancement of mimicry (Y Wang & A Hamilton 2013, unpublished data). These studies suggest that the rapid responses to a gaze cue depend strongly on the emotions on the face. Experimental studies are not available, but real-world experience also suggests that the identity of the person providing direct gaze is likely to be a modulator—responses to direct gaze from a rival or from a potential partner would be very different. Altogether, direct gaze cannot be understood as a signal in isolation, but must be considered in relation to the rest of the social context.

5. Neurocognitive responses to direct gaze

These context-dependent effects suggest that direct gaze is more than a rapid arousal cue, but must engage more elaborate social-cognitive processes. Examining fMRI studies of responses to direct gaze is one way to determine whether neural processing of direct gaze shares substrates with other cognitive mechanisms, and if so, which mechanisms. Key brain regions that could potentially be activated by direct gaze include: mPFC linked to self-related processing and theory of mind [47]; temporoparietal junction (TPJ) linked to theory of mind and self–other distinction [48]; superior temporal sulcus (STS) linked to processing of averted gaze and gaze shifts [49]; amygdala linked to processing of threatening and ambiguous stimuli [50].

Neuroimaging studies of direct gaze report activation in all these areas. In an early study, both direct gaze and speech directed to the participant activated mPFC [51]. ERPs recorded when participants viewed direct or averted gaze showed that direct-gaze cues engage medial prefrontal and superior temporal regions just 200 ms after stimulus onset [52]. Seeing an avatar make dynamic gaze shifts towards the participant engages posterior STS [53]. Taking part in joint attention tasks with an avatar, where the avatar looks at the participant and then follows the participants gaze to a peripheral cue, also engages mPFC [54] and right TPJ [55]. Viewing a live confederate outside the scanner who engages in mutual gaze with a participant activates mPFC [56]. In a recent study using hyperscanning, where two participants in two scanners could see live video of each other's faces simultaneously and could interact via gaze, right TPJ showed coupling between participants. These results all suggest that the core social regions of mPFC and TPJ are engaged by direct gaze.

Several other studies have compared communicative actions directed at a participant with those directed away. For example, typical and autistic participants viewed an avatar who walked past them, looking either towards or away from the participant. The typical participants engaged right TPJ and anterior insula substantially more than the participants with autism, when viewing the direct gaze condition [57]. When typical participants view videos of ostensive gestures directed towards/away from them, right posterior STS is engaged more for the ostensive condition only and mPFC less for the same condition, but activation of TPJ does not change [58]. mPFC is also engaged when participants feel addressed by a gesturing speaker [59], though eye contact was not directly controlled here. In six-month-old infants, direct gaze combined with infant-directed speech led to greater engagement of superior temporal and inferior frontal cortex than either cue alone [60]. Note that the method used here, near infrared spectroscopy, did not allow recording from mPFC or TPJ. In another study where participants saw movies of an actor speaking towards/away from the participant with or without gestures, posterior cingulate differentiated conditions including both cues from those lacking one or other communicative cue [61]. These studies of communicative actions accompanied by direct gaze to the participant all show engagement of brain regions linked to social cognition and mentalizing (mPFC, TPJ, posterior STS, posterior cingulate), but are not consistent in their localizations. This is probably due to the different paradigms and stimuli used in each study, and possibly to the subtle effects of contextual cues as described earlier. Despite this variability, it is likely that communicative cues including direct gaze can engage brain systems linked to theory of mind and self-related processing.

A small number of studies report activation of the amygdala in response to direct gaze. These include tasks where participants viewed hostile faces making direct gaze [62] and angry faces making direct gaze [63]. An intracranial EEG study also demonstrated a role for the amygdala in the rapid detect of direct gaze in conjunction with a negative emotion [64]. Together, these results suggest that direct gaze can activate the amygdala if it is presented in conjunction with a hostile or negatively valenced face.

Overall, the fMRI results highlight the idea that direct gaze can engage mPFC and TPJ, which are brain regions strongly linked to theory of mind and self/other processing. There are two possible cognitive interpretations of this effect. One is that direct gaze engages the participant's sense of self, making them more self-aware or self-focused [18,51]. Another is that direct gaze induces participants to engage in reputation management, considering how the other person sees them and how to control that impression [65]. These two models are not mutually exclusive, but the latter implies a stronger mentalizing requirement to consider the other as well as the self. In addition to these results, it is clear that direct gaze can activate the amygdala, but this effect is found primarily in the context of negative emotions. Overall, the data demonstrate that processing of direct gaze is strongly context-dependent, even at early stages. Variability in the engagement of mPFC and TPJ could be due to subtle contextual changes that are not easy to identify. One possible factor is the participant's belief or feeling that they are being watched by the other. There is increasing evidence that this feeling of having an audience is an important consequence of at least some direct-gaze cues, and can have substantial cognitive effects, as discussed below.

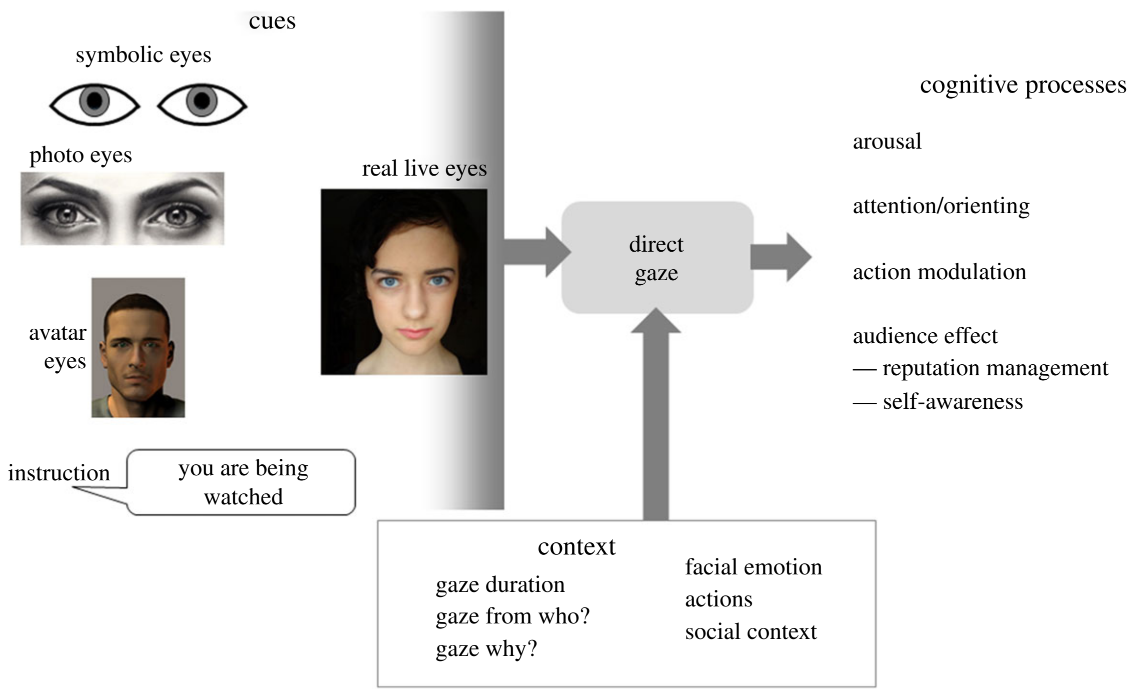

Figure 1. A summary of the cues which lead to the experience of direct gaze, some of the contextual modulation factors and the cognitive processes which can be activated by direct gaze. (Online version in colour.)

6. Direct gaze can activate an audience effect

Direct gaze is not just a visual cue, but has a particular social meaning—it means 'someone is watching me'. The impact of an audience on human performance is one of the most well-studied effects in psychology [66–68] but is still not entirely understood. In the context of direct-gaze studies, it is helpful to consider whether direct-gaze cues can and do activate an audience effect. The studies reviewed above use a variety of visual cues, including photographs of an isolated pair of eyes, eyes in a face, video of a person making direct gaze, avatars which dynamically respond to a participant's gaze, live confederates who engage in mutual gaze and live video-feeds of confederates. Each of these different types of stimulus has different levels of ecological validity, social richness and potential to engage an audience effect. However, it is not always easy to predict which will induce in the participant the genuine belief that they are being watched, especially in studies where this factor is not explicitly controlled.

There are some cases where simple photos of a pair of eyes seem to induce socially relevant changes in behaviour. For example, photos of eyes induced people to pay more for coffee in a university tea-room [69] and to give more in a dictator game [70]. In each of these contexts, participants would presumably deny that the photo could see them if they were asked, but still showed some changes in their behaviour. However, in many other cases, photos of eyes do not have the same effect as direct gaze from a live person. For example, SCRs are enhanced only to live gaze [19,20].

When a participant's belief about being watched is controlled, quite different effects are seen in conditions with and without this belief. In a recent paper, participants viewed another person's face (live) and believed they saw the other either through regular glass (so the other could see back) or through a semi-silvered mirror (so the other could not see back). SCR was bigger when participants believed they were being watched. The same was true when participants believed they were being watched by a person wearing sunglasses [71]. This suggests that effects of direct gaze on SCR and arousal are mediated by an audience effect, and not just by the visual cue of a pair of eyes.

A full review of audience effects is beyond the scope of this paper (see [68,72]), but a few studies are worth highlighting. Participants who believe they cannot be seen gaze at the eyes of a high-ranking person, while participants who believe they can be seen do not [73]. Adolescent participants engaged mPFC more at times when they believed that their face could be seen by others of the same age (as cued by a simple red light) than at times when they believed their face could not be seen (red light off) [74]. All these effects suggest that the belief that one is being gazed at can engage an audience effect even without direct-gaze cues.

To summarize, it seems that the feeling of being watched has a strong effect upon behaviour, and that such a feeling can sometimes be induced by a visible cue of direct gaze (but not always) and can also be induced without such cues. It is possible that even photographs of direct gaze can implicitly engage the feeling of being watched, but that this feeling could then be suppressed in the context where participants know the stimulus is a photo, or enhanced in contexts where participants believe they are watched even without the direct-gaze cue. Such subtle and context-based modulation of how participants treat direct-gaze cues may help account for some of the variability in past results, but further study will be required to test this fully.

7. Conclusion

Figure 1 provides a summary of some of the concepts reviewed in the present paper. It illustrates how different types of visual cue (symbols, photos, avatars and instructions) may tap into the mechanisms evoked by real live mutual gaze. Responses to such mutual gaze are heavily modulated by social context including gaze duration, facial emotions and actions. Processing of gaze and context together can lead to activation of a variety of cognitive mechanisms, including changes in arousal, changes in attention and action, and engagement of reputation management processes or self-awareness. Computational modelling approaches could provide a way to distinguish the engagement of theory of mind processes from other mechanisms (e.g. [75]). The review here builds on earlier suggestions that it is critical to study interactive social behaviour [76] and gaze following as an interactive social exchange [43], but focuses specifically on the meaning of direct gaze and the potential link between direct-gaze and audience effects, which is more prominent here than in other social interactions.

To conclude, the brief review presented above demonstrates that direct-gaze cues can act at many levels, from arousal and response modulation to self-engagement and reputation management. These cues are also highly context-dependent, because slight changes in the facial expression linked to a gaze cue can entirely change the social meaning of that cue and thus its cognitive effect. Increasing data also show that live gaze, or mutual gaze, may be processed differently to static photos of direct gaze. All these factors make gaze a fascinating and challenging topic for future research. It is important to distinguish different cognitive consequences of gaze, to control appropriately for context and to use more interactive ecologically valid stimuli which allow participants to genuinely believe that the other can see them. When we can achieve these steps, it may be possible to build a theory of how a seemingly simple signal, a pair of eyes, has such profound cognitive and social consequences.

Competing interests. We have no competing interests.
Funding. A.H. is funded by an ERC grant no. INTERACT 313398.

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