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Social orienting in gaze-based interactions: Consequences of joint gaze

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## Abstract

Jointly attending to a shared referent with other people is a social attention behaviour that occurs often and has many developmental and ongoing social impacts. This thesis focused on examining the online, as well as later emerging, impacts of being the *gaze leader* of joint attention, which has until recently been under-researched. A novel social orienting response that occurs after viewing averted gaze is reported, showing that a gaze leader will rapidly orient their attention towards a face that follows their gaze: *the gaze leading effect*. In developing the paradigm necessary for this illustration a number of boundary conditions were also outlined, which suggest the social context of the interaction is paramount to the observability of the gaze leading effect. For example, it appears that the gaze leading effect works in direct opposition to other social orienting phenomenon (e.g. gaze cueing), may be specific to eye-gaze stimuli, and is associated with self-reported autism-like traits. This orienting response is suggested as evidence that humans may have an attention mechanism that promotes the more elaborate social attention state of *shared attention*. This thesis also assessed the longer term impacts of prior joint gaze interactions, finding that gaze perception can be influenced by prior interactions with gaze leaders, but not with followers, and further there is evidence presented that suggests a gaze leader's attention will respond differently, later, to those whom have or have not previously followed their gaze. Again, this latter finding is associated with autism-like traits. Thus, the current work opens up a number of interesting research avenues concerning how attention orienting during gaze leading may facilitate social learning and how this response may be disrupted in atypically developing populations.

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**Tables**

**Acknowledgements and declarations**

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The candidate has not previously submitted any of this work towards the award of a degree.

Some of the work contained within this thesis has been communicated to the scientific community via publications:

Experiments 3-8 are presented in Edwards, Stephenson, Dalmaso and Bayliss (2015), while Experiment 11 is presented in Dalmaso, Edwards and Bayliss (2016). Both publications can be found in the Appendix A and B, respectively.

Edwards, S. G., Stephenson, L., Dalmaso, M., & Bayliss, A. P. (2015). Social orienting in gaze leading: A mechanism for shared attention. *Proceedings of the Royal Society: B, 282*(1812). DOI: 10.1098/rspb.2015.1141

Dalmaso, M., Edwards, S. G. & Bayliss, A. P. (2016). Re-encountering individuals who previously engaged in joint gaze modulates subsequent gaze cueing. *Journal of Experimental Psychology: Learning, Memory & Cognition, 42(2), 271-284.*

# Chapter 1: Introduction

Through interactions with our environment we can, and do, learn a great deal. However, for social species like humans we can also learn a lot from other people. Thus, in some sense, other people are perhaps the most important ‘things’ in our environment. A particular interaction that can be seen as crucial to our social learning is jointly attending objects with other people (Corkum & Moore, 1995), as this can have a range of outcomes from language acquisition (Baldwin, 1995) to more general social development (Tomasello, 1995), which are outlined in more detail below.

For example, as is discussed in more detail below, we can learn about the valence of an object based on the gaze and facial expression of another person (Bayliss, Frischen, Fenske & Tipper, 2007). That is, we can infer that an object is likely unpleasant if someone whom gazes towards it is displaying a disgusted expression while doing so. Indeed, there has been a great deal of research regarding the impact of following others’ gaze (see Frischen, Bayliss & Tipper, 2007 for review).

The person whom looks first in such a joint gaze encounter can be seen as the instigator of the interaction, having led the gaze of someone else (Mundy & Newell, 2007, Bayliss, Murphy, Naughtin, Kritikos, Schilbach & Becker, 2013). This gaze leading can be viewed as particularly interesting given that it has been theorised that the sharing of attention, and of intentions, that are afforded by gaze leading may be uniquely human acts (Tomasello & Carpenter, 2005; Moll & Tomasello, 2007).

However, as yet we know considerably less about the gaze leader of joint gaze encounters, compared with what has been discovered regarding the person that follows gaze (see Frischen et al., 2007 for review). Therefore, the current work aimed to further our understanding of what happens during joint gaze encounters from the perspective of the instigator of the interaction, the *gaze leader* (Bayliss et al., 2013).

## Visual attention

Many species, but perhaps most notably humans, rely heavily on vison in order to process the signals in their environment. We must therefore be able to ‘filter’ the vast array of visual inputs we receive in order to make sense of our world (see Driver, 2001 for review). This is achieved via *selective attention* (Broadbent, 1958; see also Desimone & Duncan, 1998; Pashler, 1998). Such selections can be broadly split into two types; a salient feature in the environment may capture our attention (bottom-up processing), or we may select what we attend to in a goal directed manner (top-down processing; Yantis, 1993). Our attention is therefore somewhat under our control, but can also act automatically when stimuli are sufficiently salient (see, Itti, Koch & Niebur, 1998) – a consideration that is recurrent throughout this thesis. However, the present work is mostly interested in social influences on and mechanisms of visual attention, and therefore the more detailed conceptualisations of the type of attention that might be at play are, in the present thesis, ubiquitously secondary.

**Attention capture and orienting**

As mentioned, attention selection can occur in either top-down or bottom-up manners (Yantis, 1993). However, when considering how attention might be cued, or drawn to certain locations, features or objects, it is also useful to consider exogenous and endogenous cues (e.g. Theeuwes, 1991). An Exogenous cue could be a peripheral onset stimuli, like a flashing light in the periphery, which draws your attention to it. Conversely, an endogenous cue might be a conspecific to whom you are currently attending that points out something in the environment for you to look at. Each of these cue types are discussed further below. Jonides (1981) illustrated that responses to exogenous cues are reflexive (bottom-up), while endogenous cues require more effort on the part of the person being cued (top-down).

Attention can orient overtly, for example when someone turns around or shifts their eyes towards a source of intrigue, or covertly by attending to something in your periphery while not overtly looking there (see Posner, 2014 for review). Socially, this distinction could be very important as we are able to attend to things in our environment without alerting others to our source of intrigue – a point that is returned to later. Therefore, while where someone is looking is highly correlated with where they are attending, the two are not mutually inclusive.

Posner, Nissen & Ogden (1978) illustrated the human capacity to orient covert attention, while not overtly moving their eyes. Participants maintained a central fixation while responding to stimuli that appeared to the left or right of where they were looking. Thus, participants were utilizing their peripheral vision, or ‘looking out the corner of their eye’. A central cue would appear before the peripheral target. On 80% of trails this central cue would validly cue participants as to where the target is about to appear, and so did not correctly cue the location of the target on 20% of trials. Participants were able to respond to the peripheral target more quickly when it was validly cued, even though they always remained fixating the centre of the screen. Thus, attention can be seen as separate from eye-movements.

Interestingly, in a similar experiment to that outlined above, the central cue was only predictive of the peripheral target location on 20% of trials (Posner, 1980). Under these conditions, attention was shown to first move in the direction indicated by the central cue but then later attention would have shifted in the opposite direction and towards the most likely target location. Thus, there can be seen to be a clear distinction between reflexive and more controlled attention allocation.

Indeed, the distinction of reflexive and more controlled attention allocation is being seen as increasingly important. Posner (1980) noted that although attention can operate separately to eye-movements, they are also highly correlated. However, more recent work has shown that reflexive forms of attention allocation are much more tightly linked to the oculomotor system than are endogenous, controlled, attention allocations (see Klein, 2009; Smith & Schenk, 2012, for reviews).

As well as capturing attention, peripheral onset cues can also lead to inhibited attention at the cued location, a finding termed *inhibition or return* (IOR, Posner & Cohen, 1984). That is, attention is initially captured, facilitating processing near the cue, but processing of stimuli at the same location is later impaired. It has been suggested that IOR acts to increase the foveation of new information at other locations (Posner, Rafal, Choate & Vaughan, 1985). Interestingly, IOR appears only to function with reflexive attention shifts, but not with more controlled endogenous attention allocation (Klein, 2009; Smith & Schenk, 2012).

Importantly with regard to the current thesis, Posner and colleagues (Posner, 1978; Posner et al., 1978; Posner, 1980; 2014; Posner & Cohen, 1984) are seen to have pioneered the spatial cueing paradigm (but see Leonard, 1953), whereby, for example, attention shifts of participants are measured by how quickly they can respond to targets appearing across the visual field, after the onset of a cue (Posner, 1978; see Posner, 1980; 2014, for reviews). As outlined below, this paradigm has now been used, and modify, to greatly advance our understanding of attention orienting in general, and also specifically with regards to social orienting.

To summarise, the human attention system appears to be highly adaptive, allowing for salient stimuli to automatically capture attention, facilitating the serial search of the environment by inhibiting attention to items that have previously captured our attention, while also allowing top-down goal-directed allocation of attention. However, for social animals that live in groups there are many other conspecific whose attention might be drawn to interesting things, and thus is may be beneficial to be sensitive to the attention allocation of others (Emery, 2000).

## Social attention

### Eyes

While humans rely heavily on vision to perceive the environment around them, their gaze direction can also act as a signal to others (Gibson & Pick, 1963). Indeed, the human eyes have a unique morphology in that they have an unusually large proportion of visible white sclera, which contrasts with the relatively dark iris (Kobayashi & Kohshima, 1997, 2001). Higher iris-sclera contrast is costly in that others can now more easily ascertain our gaze direction (Emery, 2000; Kobayashi et al., 1997). However, precisely this ease of gaze direction discrimination may have facilitated the social fluency of our species, allowing for a range of social gaze-based interactions between conspecifics (see Emery, 2000 for review). Thus, humans appear to be adapted to sharing with others our attentional focus.

### How do we perceive and code others' attention orientation?

It appears that both luminance and geometric cues may contribute to the perception of gaze direction. Ando (2002) showed that decreasing the luminance of one side of the sclera would lead participants to perceive the gaze as being directed towards the now darker side, which suggests that our perception of others' gaze direction is at least in part based on the perception of the relative positions of the dark iris and light sclera. Further illustrating the importance of luminance cues, Ricciardelli, Baylis & Driver (2000) showed that gaze direction is disrupted, even to the extent that it is reversed, if the contrast of the dark iris and light sclera are inverted. That is, averted gaze to the left, when the colour contrast of the image is inverted, will be perceived as rightward gaze due to the now darker sclera being to the right of the now lighter iris. However, gaze can also be perceived when only outline-drawings are used so that luminance cues are not present (e.g. Ando, 2002), indicating gaze perception is more nuanced that merely comparing luminance contrasts. Indeed, luminance and geometric cues may be developmentally distinct, with very early luminance based perception followed by a later developed, explicit ability to judge gaze direction using geometric cues (Anderson & Doherty, 1999; Doherty, McIntyre & Langton, 2015).

That the eyes are important stimuli is also reflected by findings that there appears to be devoted neuro-architecture underlying gaze perception. Perrett et al., (1985) examined the responsiveness of cells in macaque monkey temporal cortex – cells which had previously been associated with responding to faces (e.g. Gross, Rocha-Miranda & Bender, 1972; Perret, Rolls & Caan, 1982) and which may be analogous to human superior temporal sulcus (STS) (see Allison, Puce & McCarthy, 2000, for review) - finding that certain populations of cells responded preferentially to certain head orientations and gaze directions. Further, Perrett, Hietenan, Oram & Benson (1992) showed that the information contained by gaze, head and body orientation are integrated, suggesting that the most parsimonious explanation for such cells is that they code for the direction of attention of an observed individual (see also Langton, Watt & Bruce, 2000, for review).

Direct evidence in humans is limited due to methodological constraints. However, recent evidence suggests that indeed humans do have gaze-direction specific cells. Jenkins, Beaver & Calder (2006) illustrated that participants habituate to averted gaze in a direction-specific manner, suggesting that different cells code for different observed gaze directions. Further, Calder et al., (2007) used this adaptation paradigm, where participants habituate to specific gaze directions, while participants were (functional magnetic resonance imaging; fMRI) scanned and found gaze direction specific responses in the anterior STS, as well as the inferior parietal lobule.

The STS has also been shown to be sensitive to whether observed gaze is directed towards an object or not (e.g. Pelphrey, Singerman, Allison & McCarthy, 2003). This may further suggest that such coding is socially sensitive (e.g. Perrett et al, 1992) and that working out *what* others are looking at is paramount. Indeed, objects can interfere with our perception of gaze direction; Lobmaier, Fischer & Schwaninger (2006) showed that observers are biased to think the gaze of others is directed towards nearby objects, possibly suggesting we expect others to look at objects. Further, eye-gaze perception that recruits STS has also been shown to activate the inter parietal sulcus, an area involved in covert orienting of attention, leading to the suggestion that a prime reason for coding the gaze of others is to then orient our own attention towards the same referent (Hoffman & Haxby, 2000); *joint attention* (Emery, 2000).

**Being looked at: direct and mutual gaze**

Humans can detect eye contact from birth (Farroni, Csibra, Simion, & Johnson, 2002) and preferentially look at the eye-region, perhaps from as early as 7 weeks old (Haith, Bergman & Moore, 1977). Thus, we are fascinated by the eyes and sensitive to the gaze of others from an early stage. As such our first gaze-based interactions likely come from *mutual gaze* with a care giver, where both agents are gazing at each other (Farroni et al., 2002; Emery, 2000).

While many species recognise being looked at, direct gaze is often interpreted in a threat-related manner (Emery, 2000). Conversely, humans may interpret direct gaze as a communicative act (see Senju & Johnson, 2009). However, the temporal dynamics of gaze that is directed towards us is critical to how it is interpreted – a prolonged stare is still likely threatening (see Kleinke, 1986 for review). Thus, humans can be seen as interpreting gaze in a social manner, while also being sensitive to its many dynamics.

The importance of mutual gaze as a communicative act is highlighted by Frith (2008). Frith summarises the importance of being looked at, and more specifically of two agents looking at each other, as an ostensive cue. That is, that mutual gaze prior to averted gaze should indicate that the gaze leader of the pair *intended* for joint attention to occur. Indeed, other work has shown that a third person will pay more attention to the gaze cues of a pair of faces if those faces look at one another prior to jointly attending an object (Böckler, Knoblich & Sebanz, 2011). The importance of mutual gaze as an ostensive cue, as it relates to this thesis, will be discussed further in later sections concerning joint attention.

Direct gaze can capture attention (Senju & Hasegawa, 2005; Conty, Tijus, Hugueville, Coelho & George, 2006), presumably due to the salience associated with such an indicator of being attended. Relatedly, direct gaze can also increase face processing efficiency (George, Driver & Dolan, 2001; Macrae, Hood, Milne, Rowe & Mason, 2002), increase arousal in the recipient of gaze (e.g. Nichols & Champness, 1970; Conty et al., 2010), and signal approach (Hietanen, Leppänen, Peltola, Linna-aho & Ruuhiala, 2008), which is all congruent with humans interpreting being looked at as an important communicative act that is likely to signal an imminent interaction.

Interestingly, it appears that humans may have an expectation that gaze is directed towards them (Mareschal, Calder & Clifford, 2013). Mareschal and colleagues manipulated the visibility of the eye-region of faces that were presented with varying gaze directions, with participants requested to identify whether or not gaze was directed at them. Under increased uncertainty, participants were more likely to identify the gaze as being directed at them. This bias for direct gaze was suggested to reflect the high potential cost of not realising you are being looked at, which may leave us unaware of an imminent interaction.

However, humans can be highly accurate at perceiving the gaze direction of others. For example, when participants have to make a categorical judgment about whether or not they are being looked at correct responses can be as high as 98% (Jenkins, Beaver & Calder, 2006). However, when the deviated gaze was reduced from 10 degrees from direct to only 5 degrees, gaze direction identification was less accurate (71%), which may reflect the human tendency to assume direct gaze when gaze direction is harder to ascertain (e.g. Mareschal et al., 2013).

There are a range of gaze directions that can be interpreted as eye contact ('cone of gaze'; Gamer & Hecht, 2007), which is in concert with the aforementioned expectation that humans have of being looked at (Mareschal et al., 2013). That is, gaze that is actually deviated away from 'direct' can be perceived by the recipient as being directed at them. Gamer and Hecht (2007) showed that the amount of deviation in gaze direction away from truly direct that would be interpreted as eye contact by a recipient (the 'width of the gaze cone') varied depending on factors such as: how far away the 'looker' is, which may have reduced the certainty of gaze direction (e.g. Mareschal et al., 2013); the presence of other agents, which may have been interpreted as likely gaze targets of the looker (e.g. Lobmaier, Fischer & Schwaninger, 2006); and the orientation of the head, which also signals direction of attention (e.g. Perrett et al., 1992; Perrett, Hietenan, Oram & Benson, 1992). More recently, the cone of gaze has been shown to vary with individual differences, such that individuals that have higher social anxiety have a larger cone of gaze – a larger expectation that they are being looked at (Gamer, Hecht, Seipp & Hiller, 2011; Schulze, Lobmaier, Arnold & Renneberg, 2013). Thus, while there may be a general prior to assume direct gaze, there are many contributing factors that influence how the gaze of others is interpreted.

### Averted gaze

Just as being looked at signals we are being attended to, so to can we eventually extrapolate that when other people are not looking at us they may still be looking at interesting objects (see Emery, 2000 and Frischen et al., 2007 for reviews). Indeed, many species follow eye gaze (e.g. Hare & Tomasello, 1999), and this following in humans appears rapid and reflexive (Driver et al., 1999). But, as is prudent to the current work, gaze following also has higher level social impacts in that we can form opinions and make judgements of other people and the looked at objects by following gaze (see Frischen et al., 2007 for review). This is discussed further below in the *gaze following* subsection. Averted gaze is considered further throughout the following sub-sections, with specific focus on how it pertains to the current thesis. Importantly, and especially so for the current work, following gaze can be seen as the first step in establishing joint attention (Emery, 2000).

## Joint attention

Joint attention has received empirical interest for decades, primarily investigating infants' development of the ability to jointly attend the same referent with another individual (e.g. Scaife & Bruner, 1975, see also Moore & Dunham, 1995). Indeed, such skills are fundamental to our language development (e.g. Baldwin, 1995; Mundy & Gomes, 1998), but also more generally to our social capacity to learn via observing others (Mundy & Newell, 2007; see also Emery, 2000 for review). Even when general intelligence is accounted for, infant language acquisition and social competencies are correlated with frequency of joint attention behaviours (Morales et al., 2000; Mundy et al., 2007), illustrating how crucial jointly attending with others is to our social development.

A prototypical joint attention episode consists of two agents and an object. The first agent notices the object and reorients towards the object. Having seen this reorientation, the second person responds by also reorienting towards the same object (Emery, 2000). Crucially this means that each of the agents has experienced something different (Mundy & Newell, 2007), and the cognitive processes involved in each are therefore likely unique for each of the two individuals (e.g. Mundy & Gomes, 1998). The *gaze leader,* also sometimes referred to as the *joint attention initiator,* who looked first, has noticed some new object in the environment, but may not have necessarily become aware that their gaze was followed. This will be further discussed later in contrast to *shared attention*, a more elaborate and reciprocal form of joint attention (Emery, 2000). However, the other individual, the *gaze follower*, also sometimes referred to as the *joint attention responder,* as well as learning about a new object in the environment, has also had the opportunity to learn about the other agent (e.g. Bayliss & Tipper, 2006) – the gaze follower now knows where the gaze leader's attentional focus is and can use this to infer mental states, and possibly predict the future actions, of the gaze leader (Baron-Cohen, 1995; Nummenmaa & Calder, 2009). In this thesis the terms *gaze leader* and *joint attention initiator* will be used interchangeably, as will *gaze follower* and *joint attention responder.*

Such sophisticated use of others' gaze is no easy feat. Baron-Cohen (1994; 1995; see Langton, et al., for review) hypothesised the existence of a 'mind reading' system, which may afford the inference of others' mental states based on their observed state (e.g. emotional expression) and attentional focus (e.g. where they are looking). Indeed, the link of eye gaze behaviour in the development and neuro-correlates of metalizing have been reviewed elsewhere (see Frith & Frith, 2003).

A cognitive system whereby metalizing related to the eye gaze of others was proposed by Baron-Cohen and included four modules (but see Perret & Emery 1994, for proposed additions to the model). The intentionality detector (ID) was suggested as a module that serves to infer intentions on to actions – to assume that the apparent goal of an observed action was the motivation of that action. Indeed, humans seem driven to infer intentions, even to the extent that we anthropomorphise basic shapes that move as 'wanting' to do so (e.g. Heider & Simmel, 1944). Next there is the eye direction detector (EDD), which acts to notice eyes, calculate their focus, and finally attributing the agent with the eye's as 'seeing' (Langton et al, 2000). The next module, the shared attention mechanism (SAM), is suggested to act as a means to combine the first two modules, which for example, would allow for the attribution that someone may like what they are looking at. However, the primary function of SAM has also been suggested as to identify instances when one is attending to the same referent as another agent, which based on the combined information from ID and EDD may suggest that yourself and another agent are also 'sharing' mental states (Langton et al, 2000). Finally, the SAM allows for the development of a theory of mind (ToM, via the ToM mechanism, ToMM), which is the developmental milestone that indicates we are able to comprehend that another mind can know things that we do not (e.g. Charman et al., 2002).

**Models of joint attention**

While it is generally accepted that joint attention behaviours and social cognition are highly related (Carpenter, Nagell, Tomasello, Butterworth & Moore, 1998; Charman, 2003; Mundy & Newell, 2007), there is some debate regarding their functional relation (see Mundy & Newell, 2007). For example, the social cognition model posits that joint attention behaviours develop as a result of social cognition developments (Carpenter et al., 1998). Conversely, the attention-system model suggests that joint attention skills are a vital building block in the formation of fully functioning social cognition (Charman, 2003; Mundy & Newell, 2007). Indeed, Brooks & Meltzoff (2005) showed that 9 month olds will follow the head turn of an adult regardless of whether that adult has their eyes open or closed, while older infants inhibit responses to head turns with closed eyes. This has been interpreted as supporting the attention-system account as it illustrates that responses to others' attention are made prior to the social cognitive consideration of whether that turning head can 'see' (Mundy & Newell, 2007). Further, the social-cognitive model suggests that the ability to initiate joint attention and responding to others gaze should develop at similar times, however it appears that abilities related to responding to joint attention develop prior to those required to initiate joint attention (Mundy & Newell, 2007).

It has been proposed that joint attention as a whole results from the interaction between too attention systems (Mundy, Card & Fox, 2000; Mundy, 2003). Specifically, the implicated attention systems are one posterior attention system and one anterior attention system (Posner & Rothbart, 2007). In brief, the posterior attention system, which is proposed to facilitate responses to others' attention, develops earlier than the anterior system, responds to biologically meaningful stimuli, and is supported by parietal and superior temporal cortices (Mundy & Newell, 2007). The anterior system is proposed to facilitate the initiation of joint attention, being related to allocating attention in goal-directed and volitional manners, and implicates regions including the frontal eye field, pre frontal association cortex, orbital frontal cortex and anterior cingulate (Mundy & Newell, 2007). This seems to suggest that whereas attention allocation during gaze following can be seen as rapid and reflexive (Driver et al., 1999), the attention reorienting of the gaze leader is, by definition – if intentional – endogenous. Thus, the two sides of joint attention can be seen as distinct, developing at different time points and being supported by separate neuro-architecture, but also highly related given the integration between these two systems.

**Gaze following: one side of joint attention**

Laboratory experiments have illustrated that attention will 'follow' the direction of others' gaze (Driver et al., 1999; Friesen & Kingstone, 1998; Hood, Willen & Driver, 1998, see Frischen, Bayliss & Tipper, 2007 for review). Such experiments have employed the *gaze cueing* paradigm, which is an extension of the aforementioned spatial cueing paradigm (Posner, 1980), where by a centrally presented onscreen face displays averted gaze to the left or right prior to the appearance of a lateral target at the looked at or non-looked at location. Responses are consistently faster when the target appears to the side of space that was cued by the onscreen gaze, reflecting attentional orienting in the direction of averted gaze; *gaze cueing*.

In order to explore the time-course of attention orienting to averted gaze, experiments often vary the time interval between the display of averted gaze and the presentation of the lateral target ('stimulus onset asynchrony', SOA). Doing so has also revealed gaze cueing to be a rapid response, being shown as early as 14ms after cue onset (Hietanen & Leppänen, 2003), while more commonly strong cueing effects emerge at SOA's of around 100-300ms (e.g., Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Marotta, Lupiañez, & Casagrande, 2012; Tipples, 2008). After approximately 1 second, cueing effects have dissipated (e.g. Frischen & Tipper, 2004; 1005 ms, Friesen & Kingstone, 1998). Notably, gaze cueing also appears to be reflexive, occurring even when participants know the onscreen gaze is non-predictive (Kingstone & Frischen, 1998), illustrating the robustness of attention orienting in the direction to which other people look.

It initially appeared that gaze cues do not produce inhibitory attention responses such as IOR (e.g. Frischen & Kingstone, 1998). However, using longer SOA's than had been previously included, Frischen and Tipper (2004) showed that gaze cues can produce IOR, but only at long SOA's (e.g. >2 seconds). It therefore appears that although gaze cues do produce similar attentional responses to other attention cues (e.g. IOR), they do so in fundamentally different manners, as evidenced by the differing time courses of orienting. Frischen, Smilek, Eastwood & Tipper (2007) further investigated IOR and gaze cues, showing that IOR was more likely to occur if the onscreen face disappeared after showing averted gaze, which also suggest that gaze cues are persistent, acting as cues while onscreen, which may have interfered with previous investigations of IOR in response to eye-gaze.

Arrows were shown to cue attention prior to illustrations involving eye gaze as a cue (e.g. Posner, 1980), and can do so in strikingly similar ways to gaze cues (Tipples, 2002). Thus, it has been suggested that a domain general mechanism may account for attention orienting to both types of cues (Frischen, Bayliss & Tipper, 2007). However, gaze cues produce a number of outcomes that arrows do not, such as affective modulations. For example, we prefer objects that are looked at by others (Bayliss, Paul, Cannon & Tipper, 2006), but we also rate as more trustworthy faces that consistently cue our attention to valid target locations, compared with invalid cuers (Bayliss & Tipper, 2006), which suggests that even the reflexive gaze cueing response is interpreted in a socially informative way. Bayliss & Tipper (2006) also found that faces that always look away from the location to which a target will appear were rated as being presented more often than they actually were, suggesting that it may be important to remember these potentially deceptive faces (Frischen et al., 2007, see also Emery, 2000). Thus, experiences of others' gaze behaviour appears to be highly socially informative.

Further, the emotional expression of the cueing face can also influence how a gaze follower will alter their affective perception of an object. Bayliss, Frischen, Fenske & Tipper (2007) showed that the object preference related to observing others' gaze at that object is larger for gazing faces with positive emotional expressions compared to faces with negative expressions. Interestingly, the emotional expression of the cueing face can also impact evaluations of that individual. Bayliss, Griffiths & Tipper (2009) illustrated that identity specific learning regarding how reliable an individual has been at providing valid or invalid gaze cues was reliant on the cueing face displaying a positive expression, as when the faces were not smiling participants could not reliably distinguish between previously valid and invalid cuers. It has been suggested that invalid cuers could be interpreted by participants as deceptive (Bayliss & Tipper, 2006; see also Emery, 2000 for comparative examples). However, Bayliss et al's (2009) findings may suggest that in humans looking away from objects per se is not sufficient to 'deceive', but that a concatenation of gaze direction and facial expression leads a participant to infer intentionality of the cueing face and may therefore be perceived as more deliberate acts by participants.

Attention orienting to gaze can also be influenced by a number of features relating to the cueing face. For example, the familiarity with (Deaner, Sheperd & Platt, 2007) or physical dominance of (Jones, et al., 2010) the cueing face can moderate the amount of attentional orienting elicited in an observer. Further, gaze cueing can be influenced by social knowledge relating to the cueing faces (see Dalmaso, Pavan, Castelli, & Galfano, 2012; Dalmaso, Galfano, Coricelli, & Castelli, 2014, see also Hudson, Nijboer, & Jellema, 2012). For example, the same face will illicit greater cueing in an observer if that observe has read a biography indicating that individual is a high, compared with low, status individual (Dalmaso et al., 2012). Therefore, both physical and experiential information about an individual can influence gaze cueing of attention in response to that individual.

**Objects in joint gaze interactions**

While aspects relating to both of the individuals in a joint gaze encounter can influence how the other person will interpret and respond to the interaction, it is of course important to consider the third aspect of the triadic interaction; the object. As introduced at the outset of this chapter, objects appear to be special cases when it comes to attention (see Chen, 2012 for review), and as is outlined below, so too does this appear to be the case when perceiving others' attention.

Butterworth (1991) showed that by approximately 12 months old infants are able to correctly follow the gaze of others to a specific object, whereas prior to this the infant would assume the gaze was directed at the first object in the line-of-sight of the gazer. Thus a potentially crucial developmental milestone is reached whereby gaze following that leads to joint attention is possible (Mundy et al., 2007). Indeed, such object based joint attention is what distinguishes mere gaze following from joint attention (Emery, 2000), and jointly attending objects with others can be seen as critical to language acquisition (Baldwin, 1995). That is, by jointly attending objects with others we are able to attribute that the vocalisation of the gazer may refer to the looked at object, and thus we are able to associate this pairing, fostering language acquisition (Baldwin, 1995).

Further, infants appear to prefer gaze that is directed towards objects, than gaze directed elsewhere (Senju, Csibra & Johnson, 2008), possibly evidencing an early preference of, and expectation that, others' will look at interesting objects. Indeed, as discussed above, affective attributions regarding objects are influenced by others' gazing at them (e.g. Bayliss, et al., 2006; Becchio, Bertone & Castiello, 2008). Thus objects can be seen as crucial for social gaze-based interactions.

It appears that generally greater gaze cueing of attention will occur for gaze directed towards images of objects, compared with gaze towards scrambled images (Bayliss & Tipper, 2005). Interestingly, individuals with an Autism Spectrum Condition (ASC) tend to orient towards such social objects less than typically developing individuals (Swettenham et al., 1998). Bayliss and Tipper's (2005) data supports this, with participants with higher AQ scores orienting less towards images of objects and more towards scrambled images, with the reverse being the case for participants with lower AQ scores.

One reason that objects might be important for joint gaze scenarios is due to the potential interactions that objects can afford (Gibson, 2013, Makris, Hadar & Yarrow, 2013). That is, we may expect that a person will interact with an object that they are attending to, if that object affords such interactions. Consequently, we can predict future actions of gazers and infer mental states regarding what a gazer may think of the object to which they are attending (Baron-Cohen et al., 1995; Nummenmaa & Calder, 2009). Conversely, this may also imply that a gaze leader, the person who has looked first in a joint gaze encounter, may expect that someone that follows their gaze towards an object may hold such expectations and make such inferences about themselves. Thus, it can be suggested as plausible that the gaze leader may benefit from being vigilant towards such instances of having their gaze followed, as they can then monitor what other people think about what they are thinking.

## Individual differences in gaze-based interactions

Just as the physical dominance of the cueing faces can impact the attention orienting of a participant (e.g. Jones et al., 2010), so too does it appear that attention orienting to conspecifics is sensitive to dominance hierarchies in monkeys (Shepherd, Deaner & Platt, 2006). Here, male monkeys appeared to only be cued by the attention orienting of conspecifics that were of equal or higher status to themselves (Shepherd et al, 2006). Thus, it can be seen that attention orienting, at least in monkeys, can be highly socially flexible and vary between individuals.

In humans, individual differences in the observer have also been shown to influence gaze cueing. For example, Bayliss di Pellegrino & Tipper (2005) found that gaze cueing magnitude correlates negatively with participants levels of self-reported autism-like traits, as measured by the Autism Quotient (AQ; Baron-Cohen et al., 2001). Thus it might be that those with more autism-like traits are less sensitive to the social cues of others. Bayliss et al (2005) also illustrated that gaze cueing is weaker in male participants than female participants, which could also be related to the higher prevalence of autism-like traits in males, compared with females (Baron-Cohen et al., 2001; Baron-Cohen, Knickmeyer & Belmonte, 2005).

Of course, much research implementing the AQ, for example, is interested in making inferences to both typically developing populations and individuals with a diagnosis of Autism. Perhaps unexpectedly, given the trend for higher AQ participants to show less gaze cueing, there is conflicting evidence regarding whether individuals with ASC show impaired social orienting, with some experiments finding that participants with ASC show gaze cueing in response to averted gaze (e.g. Kylliäinen & Hietanen, 2004; Senju, Tojo, Dairoku, & Hasegawa, 2004), while others find no significant cueing (e.g. Ristic et al., 2005). However, as reviewed by Frischen et al (2007), such conflicting reports may be due to the heterogeneity of Autism as a condition, with for example high-functioning individuals with ASC often showing gaze cueing (e.g. Leekam, Hunnisett & Moore, 1998).

Is less cueing related to ASC, a deficit? Impaired social orienting relating to ASC fits well with evidence of atypical joint attention behaviours and development in people with ASC (Charman, 2003; Mundy, 1995). However, it is noteworthy that in computer-based gaze cueing experiments using non-predictive gaze cues, it can be seen as logical to ignore the non-predictive, and therefore essentially useless, gaze cues. While impaired spontaneous orienting of attention may indeed lead to social deficits in everyday life, at least with regards to the type of cognitive tasks that are often used to examine joint attention - less cueing could also be seen as reflecting higher control over attention whereby higher AQ participants, who are likely predominantly male (Baron-Cohen et al., 2001), are better able to inhibit their gaze cueing response (e.g. Shepard et al., 2006, see Frischen et al., 2007 for review).

However, individual differences in autism-like traits can correlate with attention orienting in response to averted gaze in more subtle ways, which may suggest autism-like traits are linked to social-cognitive learning from gaze-based interactions (e.g. Bayliss & Tipper, 2005). Here, individuals with less autism-like traits showed greater gaze cueing when those cues were towards faces or tools, compared with targets appearing on scrambled versions of the same objects. However, the reverse trend was observed for participants with high levels of self-reported autism-like traits. This could indicate that it is not necessarily cueing per se that is disrupted in ASC, but that autism-like traits co-vary with the way in which the social context of an interaction is processed, such that higher AQ participants appear to be less cued in some instances due to generally less orienting towards socially valid objects (Swettenham et al., 1998).

Further, Bayliss & Tipper (2006) had participants complete a gaze cueing task where some faces would always produce valid cues to the target location, while others would always invalidly look away from the target location. Here, participants rated the previously valid cuers as more trustworthy than the invalid cuers. However, it was notable that the magnitude of the difference between the ratings of each face correlated with participants AQ score, such that higher AQ participants showed less differentiation of the two face types regarding ‘trust’. Thus, it might be that crucial information from such social encounters are not utilised by higher AQ participants in the same way as those with less autism-like traits.

Interestingly, recent evidence has illustrated that in some instances it is possible to elicit stronger gaze cueing from participants with higher, compared with lower, AQ scores (e.g. Hudson, Nijboer & Jellema, 2012). Here, participants interacted with anti- or pro-social faces. In a subsequent gaze cueing task low AQ participants showed little cueing in response to anti-social faces and more cueing in response to pro-social faces. However, participants with higher AQ scores showed strong gaze cueing in response to both face types, illustrating that more gaze cueing can occur for high vs low AQ participants. Importantly, this data suggests that the surprise finding of *more* cueing by higher AQ participants is likely due to an impaired processing for face-specific learning of prior behaviour – it might be that the key social information pertaining to the previous anti-social behaviour of certain faces was missed by higher AQ participants, thus not leading to a dampened cueing response to those faces, later.

Taken together, the above literature suggests a strong link between individual differences and attention orienting during, and affective consequences resulting from, joint gaze interactions. However, the above experimental evidence concerns the gaze follower, as the participant in such experiments is following the gaze of an onscreen cueing face. Importantly, the other side of joint attention, gaze leading, is thought to be specifically impaired in individuals with ASC (Mundy, 1995; 2003; see Mundy & Burnette, 2005 for review). Unfortunately, experimental evidence regarding the attention allocation of the gaze leader during joint attention initiation is limited, meaning that it is not clear what responses might be expected of either typical or atypical populations. However, as joint attention initiation behaviours appear to be less frequent in individuals with ASC, one would hypothesis that similar differences in orienting during gaze leading may emerge regarding participants self-reported autism-like traits, as has been the case with gaze following (see Frischen et al., 2007 for review).

**The other side of joint attention: the gaze leader**

As reviewed above, engaging in joint attention as a responder has many behavioural and affective outcomes associated with it. However, in order to fully understand joint attention, we need to consider both conscious agents; the *follower* and the *leader* (Mundy & Newell, 2007; Schilbach, 2010; Bayliss et al., 2013). Indeed, it has been suggested that the cognitive processes involved in gaze leading could be different from those engaged in gaze following (e.g. Mundy & Gomes, 1998). Further, it has been suggested that social deficits in ASC may be more prominent in joint attention initiation than in gaze following (Mundy, 2003). For example, Mundy (1995) showed that initiating joint attention using pointing, which is a fundamental method of requesting objects, was less frequent in individuals with ASC than typically developing peers. Therefore, it can be hypothesised that investigations regarding joint attention initiation, and especially how the quality of such encounters is encoded, could be particularly informative to our conceptualisations of both typical and atypical (e.g. ASC) social attention orienting and social interactions more generally.

Although assessing the consequences of joint attention from the initiator's perspective could be crucial to our conceptualisation of joint attention as a whole, relatively little empirical work has focussed on joint attention initiation. This is likely due to practical limitations - it is technologically challenging to create controlled stimuli that are able to 'respond' to the gaze shift of a participant in an ecologically valid way (Schilbach et al., 2013). That is, in order to reverse the gaze cueing paradigm, where the participant is the responder, to simulate joint attention initiation the participant must be responded to - stimuli that can be updated based on the participant's locus of attention is therefore required. Indeed, it is becoming established that in order to truly assess social interactions, it is imperative that we look at the 'second person' (Schilbach et al., 2013). That is, rather than merely looking at how one person (a participant) interprets the social cues of another (e.g. by looking where that other person is looking), a second person approach looks to assess how that person who did the signalling interprets the response to their own behaviour (e.g. as is empirically assessed in this thesis: do you notice when someone follows your gaze, or looks at the same thing as you?). A number of recent works have utilized gaze-contingent eye-tracking in order to address this challenging design requirement of having stimuli 'respond' to participant's behaviour (e.g. Schilbach et al., 2010; Wilms et al., 2010; Redcay et al, 2010; Bayliss et al., 2013; Pfeiffer et al, 2014). Using such stimuli has allowed for the advancement of our understanding of gaze leading. Below, recent experiments concerning the neuro-correlates of joint attention, particularly from the initiator's perspective are outlined. Next, the importance of ecologically valid interactions in social cognitive gaze research is considered. Finally, a number of recent experiments regarding the behavioural and affective consequences of gaze leading are introduced.

**Neuro-correlates of joint attention**

While a number of experiments have assessed the neuro-correlates of joint attention, this has usually been done from the responder's perspective (see Frischen et al., 2007 for review). However, more recently, using interactive, gaze-contingent stimuli a number of studies have also been able to compare the relative neuro-correlates of both initiating joint attention and responding to others' joint attention initiations (e.g. Schilbach et al., 2010; Redcay, Kleiner & Saxe, 2012). Below a number of these latter studies are summarised.

In one of the first experiments to assess both initiating and responding to joint attention, Schilbach et al., (2010; see also Wilms et al., 2010 for further methodological details) set up an eye gaze interaction with a virtual avatar, which have been suggested as comparable to real world stimuli (Bente et al., 2008). Here, participants were told that the avatar represented the eye-movements of another person who was taking part in the experiment from an adjacent room. Crucially, the avatar's 'behaviour' was controlled by an algorithm that used the participant's own gaze behaviour as an input. Thus, when participants looked to particular parts of the screen (i.e. at objects) the avatar could also, subsequently, 'look' towards the same, or different, location as the participant. While following the gaze of another benefits the follower as they can learn something new about their environment, it is less clear what benefits are associated with leading the gaze of others. Therefore it is particularly interesting that this study indicated increased activity in the ventral striatum (Schilbach et al., 2010; see also Redcay et al., 2012; Gordon et al., 2013 for similar method and results), an area of the brain that is thought to be related to *reward* processing, which has been proposed as crucially involved in shared intentions previously (Mundy & Newell, 2007; Tomasello & Carpenter, 2007). Therefore, it may be that when we successfully initiate joint attention we find the experience rewarding, which would presumably increase the likelihood of engaging in such behaviours again.

Redcay et al (2012) conducted an interactive experiment where participants, lying in an fMRI scanner, would interact with a video of an experimenter. Here a number of neuro-correlates were found to be specific to joint attention initiation (e.g. bilateral middle frontal gyri, bilateral intraparietal sulci), which are related to voluntary attentional control and therefore proposed to reflect the greater social intent of initiating vs responding to joint attention, while other areas were preferentially active during responding to joint attention (e.g. posterior superior temporal sulcus, ventral medial prefrontal cortex), which were suggested as reflecting recruitment of the social-cognitive network (see Saxe, 2006). This experiment also revealed overlap between those areas that were active during both responding and initiating joint attention (e.g. dorsal medial prefrontal cortex, right posterior superior temporal sulcus), suggesting that both initiating and responding to joint attention crucially involve attention direction identification and processes related to sharing attention. Thus, this work further illustrates the proposed 'integrative attention-systems' model of joint attention, showing that responding to and initiating joint attention are distinct but overlapping social cognitive behaviours (see also Caruana, Brock & Woolgar, 2015).

**Ecological validity in social attention research**

It is important to consider that the above investigations into gaze leading during joint attention were in part only possible due to technological advancements, such as gaze contingent stimuli and interactive set-ups combined with fMRI, that have allowed for controlled but realistic interactions whereby a participant has their gaze responded to. Indeed, the validity of the social interaction is paramount to the experience of the participant, and therefore also vital to the responses and interpretation of that interaction with respect to the participant.

There is evidence that the social experience of a participant can radically alter the observable outcomes relating to an interaction. For example, while there are dozens of illustrations of gaze cueing (see Frischen et al., 2007 for review), it appears that in real life interactions we may look less towards an object that an oncoming pedestrian looks at (Gallup, Chong & Couzin, 2012). It is still likely that gaze cueing of attention occurs here, but it is notable that the overt orienting of gaze direction may be inhibited, so that only covert reorientation occurs.

Interactions can also, intuitively, differ when they are face-to-face vs facing a pre-recorded video (Freeth, Foulsham & Kingstone, 2013). Interestingly, this experiment showed that participants were influenced by a partners gaze behaviour to a greater extent if the interaction was live, compared with videoed (c.f. Gallup et al., 2012). It also appeared that individual differences in participants behaviour related to AQ was more evident for video interactions than for face-to-face. Again, this evidence likely suggests a difference in observability between different levels of social interactions. Indeed, similar video vs live interaction comparisons have also revealed greater activation of reward (ventral striatum) and other social cognition-related brain areas for live interactions, compared to video interactions (Redcay et al., 2010).

Thus it appears that participants are highly sensitive to the social validity of interactions they are engage in. Hence, the interactive paradigms that have been utilised in neuroimaging research (e.g. Wilms et al., 2010; Schilbach et al., 2010) have also been employed in behavioural experiments in order to investigate joint attention initiation further.

**Joint attention initiation: behavioural and perceptual consequences**

Pfeiffer, Timmermans, Bente, Vogeley & Schilbach (2011) used a gaze contingent display for their ‘Non-verbal Turing task’. Here, participants would look at an object and a gaze contingent response would have an onscreen face follow their gaze, or ‘look’ elsewhere. The participant’s task was to judge whether the on-screen gaze was being controlled by the computer, or by a participant in another room. Across experiments, participants were also led to believe that the other person would behave in different manners; for example the participant was led to believe that the other person was naïve to the task, or that they were trying to cooperate in helping the participant discriminate between the computer and a real person. When participants thought that the other person was naïve to the task, the strongest predictor of ‘humanness’ attributions was whether the avatar followed the participant’s gaze, suggesting that gaze following is interpreted as a human behaviour and possibly that we expect others to follow our gaze. However, illustrating how context-sensitive gaze leading encounters are, when the participant thought the other person was cooperating, the strongest ‘humanness’ predictor was the contingency of the response. That is, the on-screen avatar’s gaze was varied from always following to never following participants (with varying intermediaries) - in the cooperative condition, either always following or never following (i.e. the most consistent behaviours by an avatar in response to one’s own) were perceived as most humanlike.

Pfeiffer et al (2012) looked to further investigate the impact of having one’s eye gaze followed. In one experiment the on-screen avatar would always follow the gaze of the participant, or do nothing. Under these conditions, humanness ascriptions were highest for on-screen gaze that responded 400 ms after the participants own gaze reorientation, and declined rapidly for increasing latencies. However, when the on-screen avatar always responded, by either following the participants gaze or looking elsewhere, humanness ascriptions were highest when the gaze response was made between 800-1200 ms after the participants own reorientation. These interesting data suggest that gaze leaders are sensitive both to the latency to which their gaze is responded and to the social relevance of the gaze following response made by the other person (avatar) in a joint gaze context.

Crucially, these data taken together also suggest that the latter consideration may take longer than the former.

The above may also speak to the reward related aspect of gaze leading (e.g. Schilbach et al., 2010): Catmur & Heyes (2013) showed that when being imitated, the contingency of the imitation is more influential over how pleasurable the interaction was, compared with the similarity of the imitation behaviour. That is, we give preference to imitations that closely follow our behaviour in time, prioritising this over imitations that are more accurate. Having one's gaze followed could be interpreted as imitative (Edwards, Stephenson, Dalmaso & Bayliss, 2015, but see Pfeiffer et al., 2012), and thus it may be that the time course of gaze following will be imperative to how rewarding the gaze leader perceives the interaction.

One study has used such virtual gaze-contingent avatars, as describes above, in order to assess how recognition memory is impacted by joint attention. Kim and Mundy (2012) had participants either initiating or responding to joint attention with an onscreen face towards one of two images. After the interaction phase, participants were better at identifying whether a given image was shown during the previous interaction phase if that image had been jointly attended to by the participant looking first, as opposed to following the gaze of the onscreen face. This highlights that gaze leading and gaze following are interpreted differently to one another, and also illustrates that recognition memory for gaze leading referents is facilitated during gaze leading. Interestingly, this study presented evidence that participant's memory for images associated with joint attention initiation, but not responding, correlated with measures of spatial working memory, which can be viewed as somewhat surprising given the number of experiments linking responding to joint attention with attention reorienting (see Frischen et al, 2007 for review), while we do not yet know what are the spatial responses of attention to gaze leading. The current thesis takes great impetus from this, as one of the main aims of the current work is to assess how and if the attention of a 'gaze leader' orients once joint gaze is achieved.

Perhaps only one study has looked to use gaze contingent stimuli to assess the behavioural and affective consequences of initiating joint attention. Bayliss et al., 2013 established a gaze leading paradigm whereby participants would, for example, see an onscreen face with an object either side of it. Participants were simply asked to inspect both objects and then to choose and look at their preferred object. On some trials the onscreen face would also look at that object (responding to the participant's gaze leading, creating a state of joint attention), while on other trials the onscreen face would look at the other object. Face identities were consistently presented as either gaze-followers or not. Amongst the most clear findings, participants returned to look at the central face quicker when joint attention had been established (Experiment 1), possibly indicating a preference to reengage with those who respond appropriately to the participants joint attention initiation bids. Joint attention faces were also rated more positively by participants, compared with non-joint attention faces. However, this face preference failed to replicate in experiment 4, where particular objects were also consistently presented on joint or non-joint attention trials. The authors suggested that the preference ratings may have transferred from the faces to the objects. Thus, it may be difficult for empirical research regarding joint attention initiation to assess the initiator's perceptions of both the other person and the object of the scenario at the same time. However, successful gaze leading did lead to more consistent ratings of object preferences, which may indicate that having someone also look at the object you have decided you prefer acts as a confirmatory response (Bayliss et al., 2013).

Thus, it appears that there are many concequeces related to having one's gaze followed. Given how socially integral initiating joint attention appears to be, it would seem importat for the success of ongoing interactions that we are vigelant towards instances of sucessful joint attention initiation. However, as yet, we know very little about the attentional concequeces of gaze leading.

## Thesis purposes

As reviewed above, joint attention behaviours are crucial to our successful social development (e.g. Mundy, 1995; see also Moore & Dunham, 1995). However, probably due to methodological constraints, much less research has focussed on the joint attention initiator, than the follower. Thus, while we know a great deal about the attentional, affective, and neuro-correlates of following others' gaze (see Frischen et al., 2007 for review), we know considerably less about what happens to the person being followed. Recently, research has begun to uncover intriguing outcomes regarding the initiation of joint attention, revealing a number of outcomes for ocular-motor and choice behaviours (Bayliss et al., 2013), recognition memory (Kim & Mundy, 2012), as well as the neuro-correlates of initiating joint attention (Schilbach et al., 2010; Wilms et al., 2010; Redcay, Kleiner & Saxe, 2012). However, thus far it is unclear what, if any, influence gaze leading has on the *attention* of the 'leader'.

Therefore, the first and primary aim of this thesis was to elucidate the putative attention mechanisms that are engaged when one's joint attention initiation bids are successful. One, theoretically driven, possibility is that the gaze leader would, having had theirs gaze followed, rapidly orient their attention towards the gaze follower. Indeed, such a response may allow the gaze leader to fully utilise the emerging 'meeting of minds' (Bruner, 1995), and thus we can propose that the gaze leader would benefit from noticing the success of their gaze leading initiation attempts, so that they more appropriately guide their current and future interactions. Indeed, although gaze leading can be seen as more volitional than merely following gaze (see Mundy & Newell, 2007), there is no reason to rule out the possibility of rapid and reflexive attentional responses emerging as a result of responses by others to our initial volitional reorienting. Such monitoring of the impact our own behaviour has on others in dynamic social encounters has been highlighted elsewhere (e.g. Schilbach et al., 2013), however this specific instance regarding gaze leading may necessitate the elaboration of mere incidental joint attention into the more mentalistic encounter described as shared attention (Emery, 2000). This hypothesis is more fully developed in the following chapters where attempts to assess this possibility are made.

Thus, the current thesis presents a number of experiments that look to develop a paradigm by which attention orienting of a gaze leader during joint attention initiation can be measured (e.g. Chapters 3 and 4; Edwards et al., 2015). In each trial the participants fixated a predetermined location and subsequently one onscreen face would also look to the location to which the participant fixated, while a second face would look elsewhere. By assessing manual reaction times to targets presented on these faces, attention allocation of the gaze leader (here, the participant) once their gaze has been followed could be assessed. The latency at which the target was displayed, after the on-screen gaze was averted, was also manipulated as this could inform us about the type of attention that may be involved.

Similarly to the above, this thesis is also interested in what the offline, or longer term, impacts of gaze leading might be. In everyday life we are likely to interact with the same people multiple times. It is therefore plausible that our attention allocation in response to others should be sensitive to the quality of the previous encounters we have had with a given individual. This is tested in Experiment 11 (Experiment 2b of Dalmaso, Edwards & Bayliss, 2016), where participants interacted with face identities that would either consistently respond to their gaze by following it, or rebuff the participants joint gaze by looking elsewhere, then in a second task the roles were reversed such that participants were being cued by the onscreen faces, allowing for the assessment of how previous gaze leading encounters can influence how the people we have or have not made follow our gaze can influence our attention later. Chapter 5 also presents two experiments that assessed what impact that previous joint gaze interactions, from both the gaze leader and gaze follower perspectives, can have on gaze perception. Specifically, these experiments (9 and 10) assessed whether participants perception of being looked at was influenced by their earlier interactions with those same faces. Thus, it was possible to assess the previously untested question of whether previous gaze based interactions can directly impact gaze perception, while also comparing this from both joint attention perspectives; the leader and follower.

However, before assessing either the offline or online consequences of gaze leading, this thesis first presents experiments (1 and 2) that look to address potentially unresolved issues in previously published work. That is, data may already exist that suggests that gaze leaders orient towards faces that subsequently look where they are looking (e.g. Cañadas & Lupiáñez, 2012). However, as is discussed in the proceeding chapter, the authors offer only limited consideration of joint gaze as an explanation for their results, instead proposing the attention capture relating to direct gaze (see Senju & Hasegawa, 2005) may better explain their findings, even though the face stimuli only display averted gaze. Thus, Chapter 2 of this thesis is concerned with replicating and expanding on this previous work, with the aim of disentangling two potentially competing hypotheses.

# Chapter 2: Is there already evidence of attention capture by joint gazers?

As reviewed in the previous chapter, joint attention research has generally neglected the role of the initiator (the gaze leader). However, recent research has shown that gaze leading can produce some intriguing impacts on the gaze leader's behaviour, affective perceptions (Bayliss et al., 2013) and neural activity (e.g. Schilbach et al., 2010). While it is well established that joint attention behaviours, including leading others' gaze, are crucial for our social development (e.g. Baldwin, 1995; Mundy & Gomes, 1998; Mundy & Newell, 2007), it also appears that initiating joint attention has many impacts on our online, dynamic social interactions as adults (see Schilbach et al., 2013). The present work is therefore interested in testing the hypothesis that a behaviour as socially important as gaze leading may suggest that the gaze leader should monitor the success of their gaze leading encounters in order to continue interacting appropriately. It is proposed that the response of others to our own gaze leading initiation attempts could be important enough to become salient in that it should capture the attention of the gaze leader – put simply, it is hypothesised that it is worth noticing when and if someone looks at the same thing that you are. However, as of yet we know very little about the putative attention mechanisms that are engaged during gaze leading, much less whether or not such a hypothesised attention capture would be reflexive, and so there is limited direct empirical evidence with which to assess this suggestion.

Possibly due to the aforementioned lack of empirical interest regarding joint attention initiation, there may have been a tendency to assess 'joint attention' only from the gaze follower's perspective (e.g. gaze cueing) and attribute this as reflecting 'joint attention' as a whole. For example, some research has assessed gaze based interactions that may have involved some aspects joint attention, but did not explicitly considering the role the participant was assuming (e.g. Senju et al., 2006; Tipples et al., 2012). In such studies, participants were shown a central onscreen face with direct gaze. Next, a chequerboard stimulus would briefly appear to the left or right of the face, and subsequently the face would either display averted gaze towards, or away from, where the chequerboard had previously appeared. Event related potentials (ERPs) indicated that onscreen gaze directed away from where the stimulus was displayed was interpreted by participants as 'violating expectations' (Senju et al., 2006; Tipples et al., 2012), suggesting that participants expected the onscreen face to look towards where the stimuli had previously appeared. Notably, the sudden peripheral onset of the chequerboard *prior* to the onscreen face displaying averted gaze, would have likely drawn participants' attention towards the chequerboard (e.g. Posner, 1980). Therefore, such findings could be interpreted as participants expecting that things that capture their attention will also capture the attention of, and hence be looked at by, others. Indeed, this may be similar to the proposition that we expect other humans to follow our attention (e.g. Pfeiffer et al., 2011). But crucially the paradigms outlined above (Senju et al., 2006; Tipples et al., 2012) did not control whether the participant is leading or responding to the gaze of the onscreen face – if participants have their attention captured by the peripheral onset chequerboard they may interpret the subsequent on-screen gaze-aversion as following, or not following, their attentional reorientation. Conversely, if a participant’s attention is not drawn to the peripheral stimuli on a given trail, they may well interpret the central averted gaze as cueing them towards, or away from, the chequerboard.

A potential further consequence of neglecting gaze leading is that some previous experiments may have actually employed paradigms that could afford some insight regarding the attentional response engaged when someone else looks where we are, without fully considering the explanatory capacity of joint gaze. For example, Cañadas and Lupiáñez (2012; see also Jones, 2015) had participants fixate a central cross while a peripheral face would display averted gaze towards or away from the central cross. The participants made speeded identification of the direction of the displayed gaze (left or right), with results indicating that identification of gaze direction was faster when the onscreen gaze was directed towards the central cross.

The authors (Cañadas & Lupiáñez, 2012) describe the above findings as ‘reverse congruency effects’. That is, stimuli response compatibility (see Kornblum, Hasbroucq & Osman, 1990), would suggest that participants should be quicker to identify the direction of onscreen gaze, for example, when a face to the left of fixation looks to the left (which in this case would be away from the central fixation cross) because the left presentation and leftward gaze direction would be compatible with the response the participant was required to make, which was pressing a key with their left hand to identify leftward gaze and to indicate rightward gaze pressing another key with their right hand. Thus, Cañadas and Lupiáñez (2012) observed the *reverse* response pattern.

‘Reverse congruency’ effects have however been illustrated previously (e.g. Anstis, Mayhew &’ Morley, 1969; as cited in Ricciardelli & Driver 2008). Anstis et al had participant judge the gaze direction of faces that were displayed with varying gaze directions and head orientations, finding that participants appeared to perceive deviated gaze, for example gaze to their right, as being more extreme (e.g. further to the right) if the head was orientated in the *opposite* direction (e.g. to the left), than when both the head and gaze were orientated in a common direction. Further, Ricciardelli & Driver (2008) re-analysed some previously collected data (Ricciardelli, Baylis & Driver, 2000) and found that in some instances their data also showed ‘reverse congruence’ effects.

However, Ricciardelli & Driver (2008) noted that illustrations of reverse congruency effects appear to be related to non-speeded tasks – Antis et al (1969) did not require speeded responses and found *reverse congruency* patterns of responses, whereas Langton (2000) had participants make speeded responses and found *congruency* patterns of responses. Directly assessing the contribution of the speed-of-response task demands, Ricciardelli & Driver (2008) confirmed that reverse congruency effects appear only when participants have longer to process the stimuli (un-speeded responses), while no reverse congruency effects emerge during speeded tasks. Thus, it would appear somewhat surprising for the aforementioned findings of Cañadas and Lupiáñez (2012), where participants were required to make *speeded* gaze-direction identifications, to be a result of similar reverse congruency effects as those previously reported (see Ricciardelli & Driver, 2008 for discussion).

One possibility for the reaction time (RT) advantage reported by Cañadas and Lupiáñez (2012), is that the centrally aimed gaze is detected more quickly due to participant’s attention orienting towards the face that is ‘looking’ at the same object (the central fixation cross) that they themselves are looking. Bayliss et al (2013) illustrated that gaze leaders look back towards those that follower their gaze more quickly than towards faces that did not follow their gaze. As oculomotor movements are facilitated by pre-emptive covert shifts of attention (see Posner, 1980), Bayliss et al’s (2013) gaze data might reflect indirect evidence of attention being drawn towards faces that follow participants’ gaze.

However, possibly perpetuated by the general lack of empirical interest regarding gaze leading, Cañadas and Lupiáñez present an alternative explanation suggesting that the ‘inward’ gaze, towards the fixation cross, may be perceived by participants as direct gaze, which has previously been show to capture attention (e.g. Senju & Hasegawa, 2005). That is, even though the onscreen gaze was averted, in the same way as is used in gaze cueing research (e.g. Bayliss & Tipper, 2005, see Frischen et al., 2007 for review), the authors suggested that participants may perceive this gaze as directed towards themselves. This suggestion may have merit, as we know that direct gaze captures attention (Senju & Hasegawa, 2005) and that humans have a bias to think they are being looked at (Mareschal et al., 2013). Indeed, when participants were asked to rate how much they thought the face was looking at them, they rated the central gaze as ‘at them’ more than non-central gaze (Cañadas & Lupiáñez, 2012). However, this is far from conclusive and may simply reflect response bias to a potentially leading question. For example, if the response options had been ‘at me’, ‘leftwards’ or ‘rightwards’ participants may have indicated direct gaze to a much lesser extent.

Thus, it is not yet clear whether previously reported RT facilitation for faces that are ‘looking’ towards a central shared referent are best explained by ‘joint attention/ gaze’, or by participants perceiving central gaze as ‘direct’. The present chapter presents two experiments that look to address this issue further.

## Experiment 1: Attention capture by joint gazers?

This experiment set out to more directly assess whether previous findings of faster gaze direction discrimination for faces looking at a central fixation cross (which participants were also fixating), compared to faces looking elsewhere, could be accounted for by participants perceiving the more central gaze as being directed ‘at them’ (see Cañadas & Lupiáñez, 2012). The competing hypothesis is that such effects are due to attention orienting towards faces that look where we look, based on the theoretical advantages afforded by noticing whether our gaze leading attempts have been successful, or not. One could further argue that such active and deliberate gaze leading may not be necessary – noticing that you are coincidentally looking at the same thing as someone else could be advantageous. Indeed, while faces presented in the periphery can cue attention (e.g. Friesen & Kingstone, 2003), it is not clear what attention orienting, if any, occurs when a peripheral face is jointly gazing with us.

Here Cañadas and Lupiáñez’s design (see above) was replicated and extended. By block, the position of the fixation cross was manipulated, while all other stimuli presentations were consistent. Specifically, as well as having the fixation cross centrally, it was also positioned to the periphery of the faces, crucially meaning that the same face, in the same position, that had previously been looking at the central fixation cross and also potentially ‘at’ participants would now look ‘at’ participants while looking *away* from the shared referent.

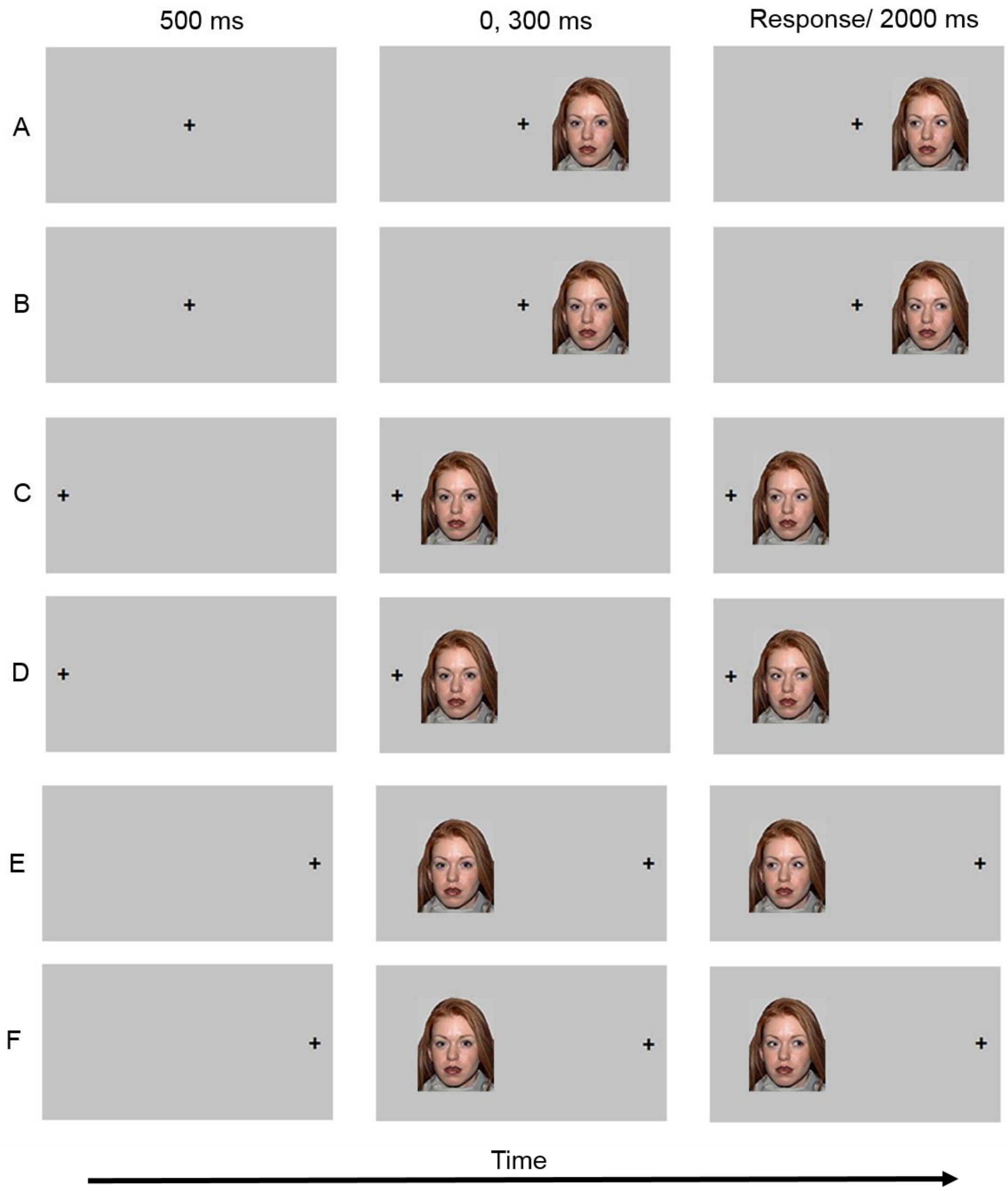


*Figure 1*. Example procedure in Experiment 1. Trails started with a fixation cross for 500 ms, which participants fixated, presented centrally (A, B) or peripherally to the left or right (C-F). Next a face was presented to the left or right of centre with direct gaze for 0 or 300 ms, depending on SOA, after which the face displayed averted gaze towards (A, C, F) or away from (B, D, E) the fixation cross. Participants made speeded identification of gaze direction, pressing the ‘Z’ key to indicate leftward gaze or the ‘M’ key to indicate rightward gaze. Note that on trials with SOA 0 ms no direct gaze was presented. Stimuli are not to scale.

If RT's are facilitated only by the perception of direct gaze, RT's to identify gaze direction should be faster when gaze is directed centrally, regardless of where the fixation cross is positioned (e.g. faster RT's on trials depicted in Figure 1, Panels A and D, than Panels B and C). However, if the RT facilitation is reliant on the shared attentional focus of the onscreen face with the participant, RT's should be faster for central-facing gaze (e.g. faster responses to the face in Panel A, but no such facilitation to the face in Panel D).

## Method

In all experiments we have reported how we determined our sample size, all data exclusions (if any), all manipulations, and all measures we have collected (see Simmons, Nelson & Simonsohn, 2012).

### Participants

Informed consent was obtained from 20 students (2 males), from the University of East Anglia (Age; *M*=21.5 years, *SD*=6.0 years) to participate in the experiment in exchange for course credit or payment. All were naïve as to the purpose of the experiment.

### Apparatus/ Stimuli

Stimuli consisted of 24 colour photographs of 8 identities (4 male, 4 female; 3 images per identity) with a neutral expression, taken from the NimStim photo set (Tottenham et al., 2009). The original image (8cm x 10.5 cm) of each identity had direct gaze, but had been edited to create 2 new images containing gaze to the far left and far right, respectively. E-Prime 2.0 software was used to create the experimental program, which allowed for automated stimuli presentation & data collection. Each participant was run on a standard Dell desktop PC with a 17" monitor running at 640× 480-pixel resolution.

### Design

A 2 (fixation position: central, lateral) × 2 (SOA: 0ms, 300ms) × 2 (gaze: joint, non-joint) within subjects design was used in order to assess the critical research question, which included trial where the fixation cross was central, as well as trials where the face appeared on the same side of the display as the peripheral fixation cross.

However, faces could also appear on the opposite side of the screen on trials where the fixation cross was peripheral (e.g. face appears to the right of centre while the fixation cross is to the far left of the display), meaning that those faces would be further away from the participants fixation than all others. Thus, these trials were analysed separately and can be considered a 2 (SOA: 0ms, 300ms) × 2 (gaze: joint, non-joint) within subjects design. Mean reaction time (RT) and error rates were measured.

**Procedure**

Participants sat approximately 60 cm from the screen and were required to make speeded discrimination of the direction (left or right) of onscreen averted gaze. Participants started each trial fixating a cross (blocked by position; left (16.5 cm from centre), centred, right (16.5 cm from centre) on a silver background for 500 ms. Block sequence was randomised. Next, a picture of a face with direct gaze was presented either to the left or to the right of the screen (7.5 cm from Centre) for 0 or 300 ms. Note: in cases of the 0 ms SOA, the face appeared with averted gaze only, whereas with SOA of 300 ms the faces ‘looked’ towards the left or right. Finally, the same picture with the eyes gazing either to the right or to the left was presented at the same location until response or 2000ms had elapsed. Speeded identification of gaze direction was made by pressing the ‘Z’ key or ‘M’ key with left and right index fingers, respectively. A practice block consisting of 48 randomly selected trials proceeded three experimental blocks of 128 trials each.

## Results

Accuracy and error rates can be found in Table 1.

**Accuracy**

Participants made correct responses on >98% of trails in each condition, as such no further analysis was conducted on these data.

**Reaction times**

Responses above or below 3SD of participants means were removed (1.5% data).

**Table 1.**

Mean and Standard Deviations (in parentheses) for reaction times (ms) in Experiments 1 & 2. Close face denotes trials where the face was presented in a position close to the fixation cross, Far face denotes trials where the face stimuli was presented to the opposite side of the display with respect to the fixation cross. JA = Joint attention trail where the onscreen face looks towards the fixation cross, nJA = trials where onscreen gaze was away from the fixation cross. Overall= collapsed by SOA.

| | | Close face | | | | Far face | |
|---|---|---|---|---|---|---|---|
| | | Central fixation | | Peripheral fixation | | Peripheral fixation | |
| | | JA | nJA | JA | nJA | JA | nJA |
| E1 RT | Overall | 505 (64) | 545 (69) | 529 (57) | 528 (69) | 597 (112) | 639 (130) |
| | 0ms SOA | 597 (92) | 654 (104) | 614 (69) | 622 (83) | 775 (196) | 817 (198) |
| | 300ms SOA | 414 (55) | 440 (59) | 444 (55) | 434 (68) | 456 (75) | 492 (90) |
| E2 RT | Overall | 482 (103) | 499 (101) | 491 (90) | 487 (96) | 555 (172) | 575 (171) |
| | 0ms SOA | 551 (80) | 578 (71) | 552 (58) | 555 (69) | 674 (157) | 674 (143) |
| | 300ms SOA | 414 (75) | 420 (54) | 429 (73) | 419 (68) | 429 (73) | 419 (68) |

**Faces comparable distance away from cross.** A 2 (fixation position; central, non-central) × 2 (SOA; 0, 300) × 2 (gaze: joint, non-joint) ANOVA on reaction times (RTs) to identifying the gaze direction presented revealed a significant effect of gaze, $F(1,19)=11.78$, $p=.003$, $\eta^2_p = .38$, indicating that RTs were faster when the face was looking towards the fixation cross (517ms), than when looking away (537ms). There was also a significant effect of SOA, $F(1,19)=222.24$, $p<.001$, $\eta^2_p = .92$, indicating that RTs were faster at the longer (433ms) than shorter (621ms) SOA. There was no main effect of fixation position, $F(1,19)=.041$, $p=.841$, $\eta^2_p = .002$. There was a significant SOA × Gaze interaction, $F(1,19)=11.97$, $p=.003$, $\eta^2_p = .38$, indicating that RT differences between joint and non-joint conditions were larger at the shorter (joint, 606ms; non-joint, 638ms) than at the longer (joint, 429ms; non-joint, 437ms) SOA. There was also a significant Fixation position × Gaze interaction, $F(1,19)=10.92$, $p=.004$, $\eta^2_p = .37$. The effect of gaze was strong when the face was looking towards a central fixation cross, $t(19)=-4.117$, $p=.001$, $dz=.92$, while no such effect emerged when the face was looking towards a peripheral fixation cross $t(19)=.066$, $p=.948$, $dz=.01$. Neither the Fixation position × SOA interaction, $F(1,19)=3.44$, $p=.079$, $\eta^2_p = .15$, or the 3-way interaction, $F(1,19)=.853$, $p=.367$, $\eta^2_p = .04$, were significant.

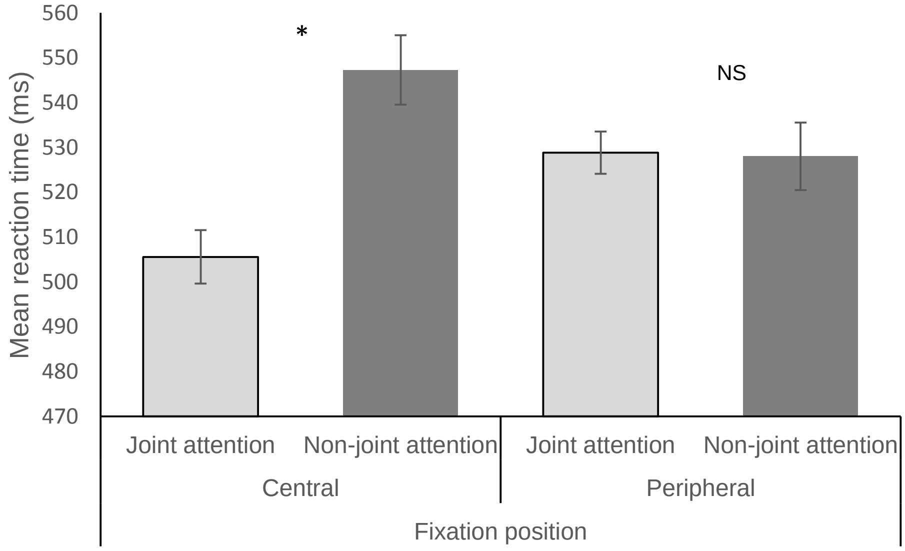


*Figure 2.* Mean reaction times (RT) for correctly identifying displayed gaze direction in Experiment 1, for conditions where the face was presented proximally to the fixation cross, divided by fixation position and type of gaze. Error bars represent within-subjects standard error of the mean (Loftus & Masson, 1994). Asterisk denotes p=.001. NS= non-significant.

**Faces further away from cross.** A second, separate, 2 (SOA) × 2 (gaze) ANOVA was conducted on responses from trials where the face appeared on the opposite side of the screen to the fixation cross. There was a significant effect of SOA, $F(1,19)=116.84$, $p<.001$, $\eta^2_p = .86$, owing to faster responses at the longer (474ms), than shorter (796ms), SOA. The main effect of Gaze was also significant, $F(1,19)=12.93$, $p=.002$, $\eta^2_p = .41$, as RTs were faster on joint (616ms), than non-joint (655ms), trials. The SOA × gaze interaction was not significant, $F(1,19)=.190$, $p=.668$, $\eta^2_p = .01$.

## Discussion

Participants were faster to identify the direction of gaze of the onscreen face when that gaze was directed towards a central fixation cross, thereby replicating the effect shown by Cañadas and Lupiáñez (2012). However, crucially this RT facilitation was not replicated when the fixation cross was not central, but instead presented to the far left or right of the display, where there was no reliable RT benefit for gaze in any direction. Thus, it appears that the RT facilitation of a face looking centrally is dependent on the participant also looking centrally, and is evidence against the interpretation that gaze that it ‘towards’ the participant is capturing their attention.

Given that having the participant look at the same location as the onscreen face appears to be crucial to the RT facilitation regarding central gaze, it is surprising that jointly attending the peripheral fixation crosses did not also lead to RT facilitation. It may be the case, therefore, that in this particular stimuli-setup, both joint gaze and perceiving gaze as being more direct are both contributing to the RT facilitation for discriminating gaze direction, but clearly these data illustrate that attention capture of ‘direct gaze’ alone is an insufficient explanation.

The time-course of the current effects are also noteworthy. The original work included 4 SOA’s (0ms, 75ms, 150ms, 250ms), and in the experiment most similar to the current Experiment 1 (also their Experiment 1) they found gaze-based RT facilitation only at the 0ms and 75ms SOAs, but not at the others. In the current work, a 0ms SOA was included due to this being where the strongest effects had previously been found, while 300ms was included as it is closer to the times that are common in gaze-based orienting research (see Frischen et al., 2007 for review). In the current work we too found stronger effects at the 0ms SOA, compared with the 300ms SOA. This may suggest the mechanism behind the current attentional response is reflexive. However, this is difficult to assess when taken together with the unusual pattern of responses found by Cañadas and Lupiáñez.

It is notable, but not informative to our main hypothesis, that when faces were presented at the opposite side of the display to the fixation cross, RTs were facilitated when the gaze was directed towards the fixation cross (but note that in this condition gaze that is directed towards the cross was also across the participant’s central loci, making this condition unable to contribute to assessing our main research question). It therefore appears that this RT facilitation, whatever its mechanism, occurs over different eccentricities.

Given the inconclusive findings in the non-central fixation conditions, it may be necessary to develop a new paradigm with which to fully investigate the attentional response to having someone look at the same referent to which you are fixating. However, first, in order to have more confidence in the current findings we decided to replicate our procedure with different face stimuli.

## Experiment 2: Replication with schematic faces

Social attention responses to the eye-gaze of others (e.g. gaze cueing) are not limited to the use of (images of) real faces. Indeed, perceiving the gaze direction of others is initially based on low level luminance differences between the iris/ pupil and sclera (Doherty, McIntyre & Langton, 2015). Further, some of the first laboratory illustrations of gaze cueing used schematic faces (e.g. Friesen & Kingstone, 1998). Furthermore, children can attribute mental states and desires to schematic faces (e.g. Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker, 1995).

Cañadas and Lupiáñez's (2012) finding, of faster identification of gaze when it is directed towards a central referent, replicated when only the eyeballs were shown (even though they described them to participants as marbles). However, no such replication occurred when highly impoverished representations of eyes were used, which consisted of two opaque triangles (pupils) inside square brackets (eyes). This may suggest such effects are only observable when images of real, biologically relevant, stimuli are used. However, neither of these follow ups are common stimuli choices for assessing the social specificity of gaze-based attentional effects.

Here, we used schematic faces (see Figure 3), akin to those used by Friesen and Kingstone (1998), in order to further assess the extent to which biologically relevant stimuli are required to produce the RT facilitation afforded by jointly gazing a central referent (see Experiment 1).

### Method

#### Participants

Informed consent was obtained from 18 students (2 males), from the University of East Anglia (Age; *M*=22.1 years, *SD*=6.7 years) to participate in the experiment in exchange for course credit or payment. All were naïve as to the purpose of the experiment.

#### Apparatus/ Stimuli

The set-up was identical to Experiment 1, except that the images of faces were replaced by schematic faces (see Figure 3), which subtended approximately the same area as the faces used in Experiment 1.

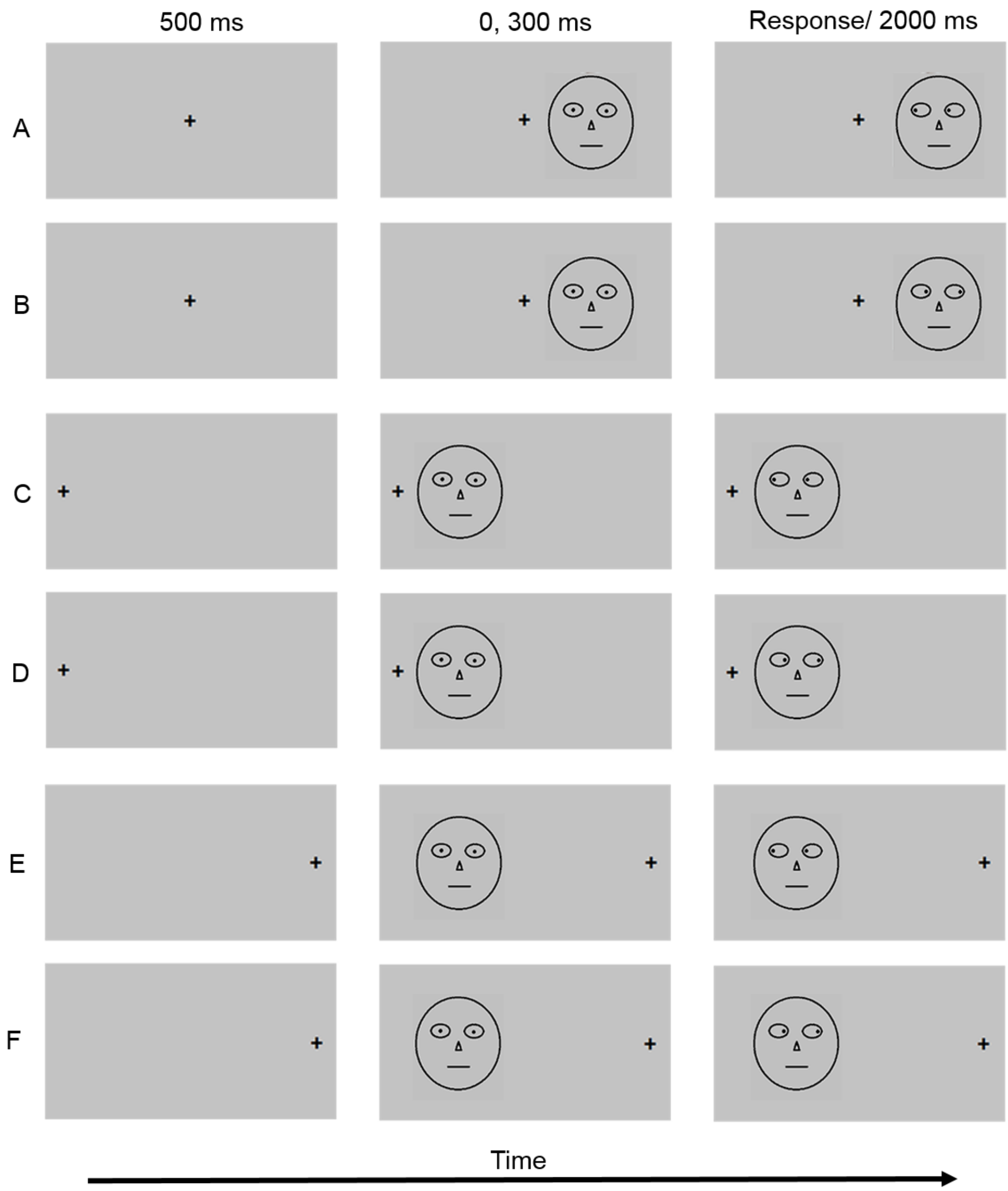


*Figure 3.* Example procedure in Experiment 2. Trails started with a fixation cross for 500 ms, which participants fixated, presented centrally (A, B) or peripherally to the left or right (C-F). Next a face was presented to the left or right of centre with direct gaze for 0 or 300 ms, depending on SOA, after which the face displayed averted gaze towards (A, C, E) or away from (B, D, F) the fixation cross, to which participants made speeded identification pressing the ‘Z’ key to indicate leftward gaze or the ‘M’ key to indicate rightward gaze. Note that on trials with SOA 0 ms no direct gaze was presented. Stimuli are not to scale.

**Design & Procedure**

Identical to Experiment 1.

**Results**

Analyses were conducted as in Experiment 1. 1.4% of data were removed as outliers. See also Table 1.

### Accuracy

Participants made correct responses on >99% of trails in each condition, as such no further analysis was conducted on these data.

### Reaction times

**Faces comparable distance away from cross.** The 2 (fixation position; central, non-central) × 2 (SOA; 0, 300) × 2 (gaze: joint, non-joint) ANOVA revealed no significant main effects of gaze, $F(1,17)=1.74$, $p=.205$, $\eta^2_p = .09$, or of fixation position, $F(1,17)=1.07$, $p=.747$, $\eta^2_p < .01$, but the main effect of SOA did reach significance, $F(1,17)=651.78$, $p<.001$, $\eta^2_p = .98$, indicating quicker responses at the longer (420ms), than shorter (559ms), SOA. No interactions reached significance.

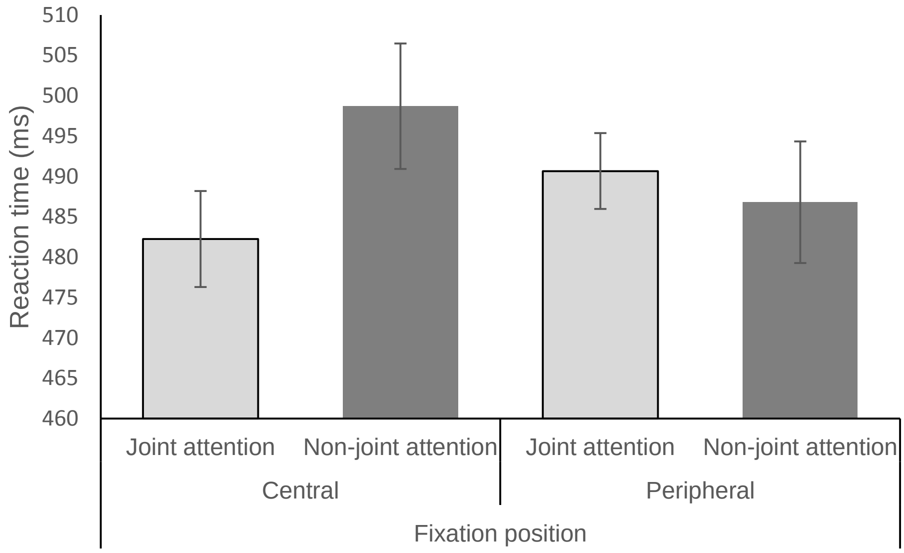


*Figure 4.* Mean reaction times (RT) for correctly identifying displayed gaze direction in Experiment 2, divided by fixation position and type of gaze. Error bars represent within-subjects standard error of the mean (Loftus & Masson, 1994). NS= non-significant.

**Faces further away from cross.** A second, separate, 2 (SOA; 0, 300) × 2 (gaze: joint, non-joint) ANOVA was conducted on responses from trials where the face appeared on the opposite side of the screen to the fixation cross (e.g. when the fixation cross is presented to the left of the screen and the face appears right-of-centre). There was a significant effect of SOA, $F(1,17)=206.65$, $p<.001$, $\eta^2_p = .92$, owing to faster responses at the longer (456ms) than shorter (674ms) SOA. There was no significant difference between RTs for joint (555ms) vs non-joint (575ms) trials, $F(1,17)=2.44$, $p=.137$, $\eta^2_p = .13$. The interaction was not significant, $F(1,17)=2.89$, $p=.107$, $\eta^2_p = .15$.

## Discussion

Participants' RTs to identify the displayed gaze direction of schematic faces was not influenced by whether the gaze was directed towards or away from the participant's fixation position, or whether that fixation was positioned centrally or peripherally. These results therefore do not replicate those of Experiment 1. Thus, this experiment does not add to the differentiation of whether attention is drawn to faces due to jointly attending the same referent, or because participants perceive more central facing gaze at directed at them.

Although the current data did produce the standard preparatory effect of faster responses at longer SOA's, no interactions involving SOA were observed. Thus, the current experiment can offer no further insight into the complicated issue of the time-course of the effects currently of interest, as mentioned in the discussion of Experiment 1.

This failed replication is presumably due to the change in stimuli. In Experiment 1 images of real faces were used, whereas here only schematic drawings of faces were presented. Cañadas & Lupiáñez (2012) showed that their effects replicated when only eyeballs were shown, but not when impoverished representations of eyes were used. Taken together, it would appear that response time facilitation for gaze directed at a central shared referent only occurs when images of real eyes are included, indicative of a highly social orienting response. Although schematic faces can cue attention (Friesen & Kingston, 1998), and are perceived as having minds (Baron-Cohen et al., 1995), it may be the case that more socially rich stimuli are required when manipulating joint gaze interactions where the participant is not simply being cued.

While informative regarding the social specificity of the RT facilitation of gaze direction discrimination when jointly attending a central referent, due to the null findings this experiment cannot contribute to the differentiation of the mechanistic basis of the previously reported RT facilitation (Experiment 1; Cañadas & Lupiáñez, 2012; Jones, 2015).

## General discussion

The experiments presented in this chapter further our understanding regarding previous observations that participants are able to identify gaze direction more quickly when that gaze is directed at a central referent to which the participant is also looking. While previous research (Cañadas & Lupiáñez, 2012; Jones, 2015) had suggested that this response facilitation was due to participants perceiving the central-facing gaze as direct gaze, which can capture attention (e.g. Senju & Hasegawa, 2005), there remained a competing hypothesis related to joint attention – it could be that participants are quicker at identifying the gaze direction of faces looking at the same referent that they are looking at because their attention is drawn towards faces that jointly attend with them.

Here, Experiment 1 showed that the facilitation of gaze direction discrimination is reliant on the participant also gazing at the central referent. When participants looked at a fixation cross in the periphery, so that the onscreen face would look centrally ('at them') while *not* looking at the same referent as the participant, the RT facilitation was diminished. Therefore, it appears that the attentional capture of direct gaze cannot sufficiently account for the previously reported RT advantage for gaze direction discrimination.

Experiment 2 attempted to replicate these findings using comparable, but less social, stimuli. Using schematic faces produced no reliable RT advantage for gaze direction discrimination, regardless of whether the gaze was directed centrally or not, or at or away from the participant's fixation. This is in line with the data of previous work that showed that impoverished representations of eyes do not produce this RT advantage (Cañadas & Lupiáñez, 2012) but is somewhat surprising given that schematic faces have been shown to produce gaze cueing, even when presented peripherally (Friesen & Kingstone, 1998; 2003). Thus, it appears that whatever mechanism is driving the RT advantage found in Experiment 1 (and previously by Cañadas & Lupiáñez, 2012; Jones, 2015) is highly dependent of the social context of the 'interaction' and may be reliant on biologically valid stimuli (e.g. eyes).

While the attentional capture of direct gaze is an insufficient explanation for the findings of Experiment 1, the data are also not directly supportive of the suggestion that this effect may be based on joint attention. If the RT facilitation was due to attention orienting towards faces that 'look' at the same thing that participants are looking at, responses should have been faster when the onscreen gaze was directed towards the fixation cross, regardless of whether the fixation cross was presented centrally or peripherally. As RTs were not facilitated for joint gaze of peripheral crosses, these results do not fully support the proposition of attention capture by faces that jointly attend with participants. It therefore appears that with the current stimuli setup it is necessary that gaze orientation is shared and that this shared referent is central, in order to produce the RT facilitation.

There are a number of methodological considerations that might have influenced the current experiments. Firstly, only one face was presented at any given time. While the presentation of a single peripheral schematic face has previously been shown to produce gaze cueing of attention (Friesen & Kingstone, 2003), other research appears to indicate that images of real faces presented in the periphery do not produce gaze cueing (Palanica & Itier, 2015). Palanica and Itier (2015) had participants fixate a central cross, which then had a face appear to its immediate left or right. The face would display either direct or averted gaze, with either a centred or off-centred head orientation. Participants then made speeded responses to detect a target appearing on the face, or on the opposite side of the screen. Palanica and Itier indicate that their preliminary analysis revealed no systematic cueing effects based on the head orientation or gaze direction of the faces. However, as this was not their primary interest no statistics are presented. It is therefore difficult to assess the strength of this surprise finding of no cueing being elicited by these non-central faces (c.f. Friesen & Kingstone, 2003). However, such a finding may suggest, for example, that assessing attention orienting in response to non-central averted gaze is made difficult when only one face is presented –a single face may always capture attention, as would be expected with a peripheral on-set stimuli (Posner, 1980), and therefore limit the observable impact of the social attention cues of that face on participants.

In the current experiments, where only one face is displayed, the participant's task could be viewed as relatively easy, as reflected in very high accuracy scores – their task is to make a judgement about the gaze direction of the face and therefore they necessarily have to attend to the face. Thus it may be that a ceiling effect is masking any differences in gaze discrimination in Experiment 2, as well as in conditions where the fixation cross was peripheral in Experiment 1. That is, as the task was so easy for participants, any differences in responses due to stimuli manipulations may have been masked – it may only be the case that the RT advantage of a face that is jointly gazing with a participant is only observable when attention is more dispersed, either by a more difficult perceptual task, or by increasing the number of potential target locations. Potentially, therefore, making the task more difficult may allow for more accurate assessment of how attention orients when perceiving another face 'look' where you are also looking. Why then, would the same ceiling effect not have masked the difference that emerged when the cross was central (Experiment 1)? One contributing factor could be that in blocks where the fixation cross was central, the face, which was the imperative stimuli regarding the task asked of participants, could appear to either the left or right of where participants were attending. However, in blocks where the fixation cross was peripheral, although the face still appeared in the same two locations, the face would always appear to the same side of space relative to the fixation cross. Thus, potential differences in attention orienting strategies of participant between blocks could limit comparisons between fixation positions.

A further methodological consideration, related to the above, regards the control imposed over participants. While participants were instructed to look only at the fixation cross, it is possible that they would instead make saccades towards the faces in order to facilitate their responses. Future work may account for this by introducing a measure of eye-movements during trials. Indeed, participants may have been particularly likely to not follow instructions on peripheral blocks; in all blocks looking centrally offers the most convenient means of being equally able to respond to the face wherever it appears.

To conclude, previous illustrations of facilitated gaze direction discrimination are not sufficiently accounted for by participants perceiving the gaze as being 'direct'. The present experiments do however suggest that only biologically valid stimuli produce such RT facilitations. The current data do also not fully concur with the hypothesised attention capture of faces that look at the same thing as a participant. The current paradigm may be somewhat limited, and it is therefore suggested that future work should look to specifically develop a paradigm that will allow for the assessment of attention orienting in response to others following our gaze.

# Chapter 3: Introducing a new paradigm to assess gaze leading

Although recent findings have illustrated joint attention initiation can lead to a number of outcomes regarding neuro-correlates (Schilbach et al., 2010; Wilms et al., 2010; Redcay, Kleiner & Saxe, 2012), ocular-motor and choice behaviours (Bayliss et al., 2013), and recognition memory of objects (Kim & Mundy, 2012), it is still unclear whether leading the gaze of another person has any measurable attentional response in the 'leader'.

The previous chapter was inconclusive regarding whether attention orients towards faces that look at the same referent as a participant. In Experiment's 1 and 2 (Chapter 1) there was only 1 face onscreen at a time, and the face (or at least the gaze direction displayed by that face) was always the participant's target. As such, it is likely that a participant would necessarily have their attention captured by the face in a task relevant manner, which may have limited the observability in differences between conditions. Below there is a recap of the theoretical impetuous of this current line of work, before introducing the extensions of the previous chapter that the current chapter presents.

When considering a joint gaze episode, it is reasonable to suggest that the leader, once followed, would benefit from shifting their attention towards the follower – being vigilant towards who has followed our gaze would allow us to react more fluently and appropriately to the interactions that may be instigated from this initial 'meeting of minds' (Bruner, 1995). Indeed, the 'leader' of a joint attention episode has caused another individual (the gaze follower) the reorient their attention. It is important that we monitor what effects our own behaviour has on others in dynamic social encounters (Schilbach et al., 2013). Thus, a theoretically driven hypothesis regarding joint attention initiation is that the gaze leader who initiates the interaction may, once the other person has responded, reorient their attention from the shared referent to which they first looked, towards the person that 'followed' their gaze.

Further than merely monitoring how our behaviour impacts others, having one's gaze followed could be interpreted by the leader as a form of imitation: the gaze follower has oriented towards the same referent as the gaze leader, mimicking their attentional state. Imitation is important in social cognitive development (Meltzoff & Decety, 2003) and many primate species appear to recognise being imitated (Haun & Call, 2008; Paukner, Anderson, Borelli, Visalberghi, & Ferrari, 2005; see also Nadel, 2002), which might suggest imitation is salient. Thus, noticing a conspecific has imitated our attentional focus may be similarly salient.

Importantly, this hypothesised social orienting response of ‘noticing’ when our gaze is followed could propel joint attention encounters into more socially elaborate shared attention interactions (Emery, 2000). According to Emery, joint attention requires only that the gaze follower is aware that they are jointly attending the same referent as the person they followed, whereas the gaze leader my not necessarily become aware that their gaze is followed. However, shared attention relies on both parties being aware of their shared attentional focus, which may foster continued and elaborating interactions.

Again, due to the less-than-conclusive findings in Chapter 1, here, we developed a novel paradigm, aiming to illustrate the putative mechanism that is hypothesised to respond to the detection of having one’s eye-gaze followed. In the experiments presented in this chapter we assessed attentional orienting in response to peripherally presented onscreen averted gaze: In each experimental trial, one face looked to where the participant is looking, while another face looked in the opposite direction. Therefore, by assessing RTs to manually discriminate targets appearing on these faces, which were now task irrelevant, we assessed how observing another face look at the same thing as a participant influenced their attentional distribution. Notably, while the SOA’s used in Chapter 2 were chosen to allow direct comparison with the work the experiments were based on (Cañadas & Lupiáñez, 2012) and the field more generally (see Frischen et al., 2007), here we revert to SOA’s that will aid in comparison with the general literature on gaze-based attentional orienting. Specifically, we employ an SOA that is generally too early to find gaze cueing (100 ms), and another at which gaze cueing is normally strongly illustrated (400 ms; see Frischen et al, 2007).

## Experiment 3: Introducing a new paradigm

In the first experiment, participants fixated a central cross. Subsequently, four faces were presented across the horizontal midline with two located to the left and two to the right or fixation (see Figure 5). On each trial, the two innermost faces would simultaneously open their eyes and look in a common direction (left or right). A target letter would then appear on the bridge of the nose of one of the four faces, allowing us to assess how attention is distributed across the display.

The two innermost faces were the critical target loci for evaluating our hypotheses. One of the innermost faces would look towards the fixation cross that participants were fixating, while the other would look away from the cross. Our hypothesis was that participants will orient towards a face that suddenly looks at the location to which they are currently looking (in the example in Figure 5, the face to the left of fixation, looking to the right), and respond to targets appearing there more quickly than at any other location. However, a strong competing hypothesis suggests that gaze *following* would dominate, causing participants to orient towards, and respond faster to targets appearing in the direction of observed gaze (i.e. gaze cueing). We included the outermost target locations to assess whether such a stimuli display also influences responses at further eccentricities, which while being potentially informative were not critical to the evaluation of our hypothesis.

### Method

In all experiments we have reported how we determined our sample size, all data exclusions (if any), all manipulations, and all measures we have collected (see Simmons, Nelson & Simonsohn, 2012).

**Participants.** Eighteen participants (four men) at UEA (Age; $M$=22.6 years, $SD$=2.8 years) completed the experiment in return for course credit or payment (in this experiment and in all others). Participants in all experiments reported normal or corrected-to-normal vision. We aimed to collect data from approximately 20 participants and stopped at $n$=18, for convenience, at the end of a block of booked testing sessions.

**Apparatus and Stimuli.** Face stimuli consisted of greyscale photographs taken from a stimulus set created by (Bayliss, Bartlett, Naughtin & Kritikos, 2011). Eight identities with a calm facial expression were used (four female). For each face identity, three images were used such that each identity could be displayed with closed-eyes, leftward gaze, or rightward gaze. Each face image measured 50mm × 64mm. Two faces appeared on each side of the central cross; the centre-point of the inner-most faces was 33mm away from the centre, the centre-point of the outer-most faces was 84mm away from the centre. Face identities were randomly assigned to each position on each trial, with the constraint that a given identity could only appear in one location per trial. Target letters (N or H) were size 18 bold Arial text (4mm × 4mm), presented in purple on a white background (6mm × 6mm). Stimulus presentation was controlled by a standard desktop computer with an 18” screen (pixel resolution 1024 × 768) and manual responses were made on a standard keyboard.

**Design.** A 4 (Target Location; ‘Null face’, ‘Joint Attention face’, ‘Single-cued face’, ‘Double-cued face’; see Figure 5) × 2 (stimulus onset asynchrony – ‘SOA’; 100ms, 400ms) within-subjects design was used. Although we used four target locations, the two critical target locations are the innermost ones (‘Joint Attention face’ and ‘Single-cued face’). We used the additional target locations to assess how attention was distributed beyond these two locations. Reaction times (RTs) and accuracy rates were measured.

**Procedure.** Participants sat approximately 70cm away from the display. Each trial started with a white fixation cross presented in the centre of a black background for 500ms. Next, four pictures of faces with closed eyes were added to the display. 1200ms later, the central cross then enlarged. After 300ms the innermost faces were then both displayed with averted gaze in a common direction (left or right) for either a 100 ms or 400ms SOA (see Figure 5). Next, a letter target was presented on the bridge of the nose of one of the four faces until a response was made, or until 5000ms elapsed, whichever came first. Participants made speeded identification responses to the target by pressing the ‘H’ key with the index finger of their preferred hand when an H was displayed, and pressing the spacebar with the thumb of the same hand when an N was displayed. Finally, a feedback screen was displayed for 1500ms – this was a black screen after a correct response, but showed a red central cross after an incorrect response. Participants completed the experiment alone in a dimly-lit room. After 6 practice trials, the experiment comprised a total of 256 trials over four blocks and the session took approximately 60 minutes.

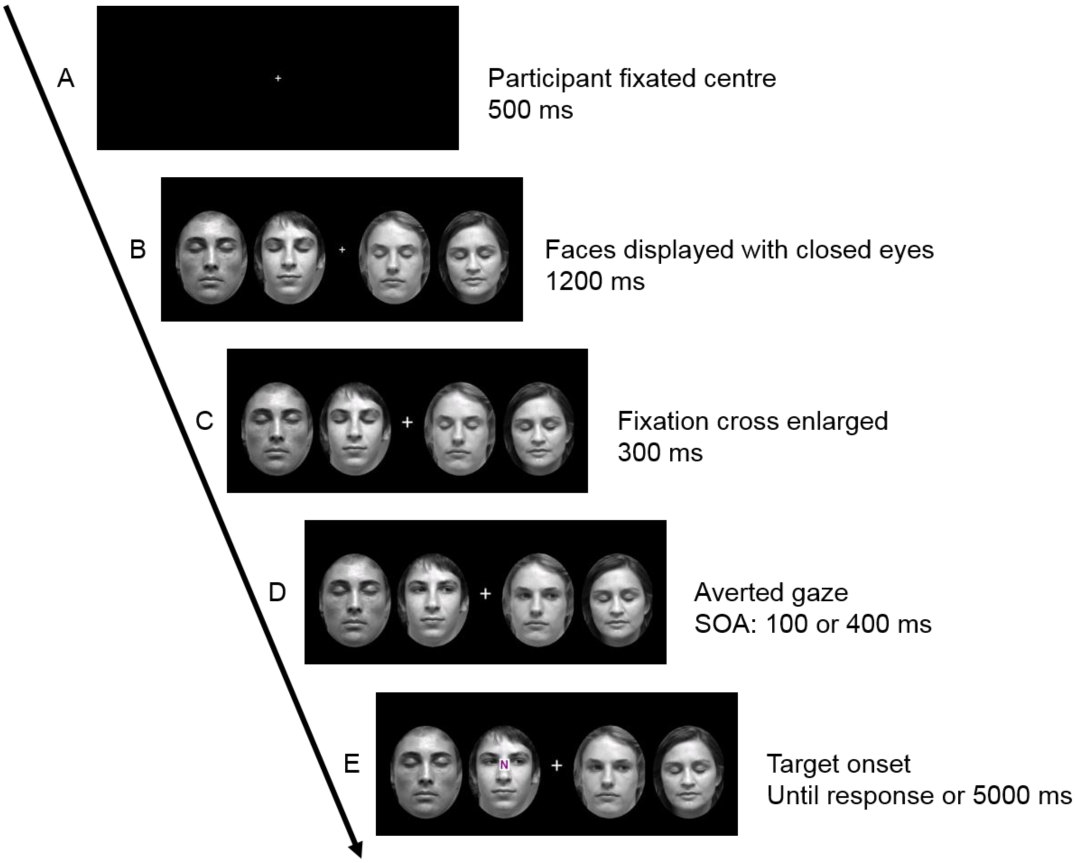


*Figure 5*. Example trial from Experiment 3. Participants first fixated the central cross (A). After the faces were presented (B) the central cross enlarged (C). Next, the two centremost faces were displayed with averted gaze in a common direction to the left or right (D). Finally, a target letter appeared on one of the four faces (e.g. the Joint attention face, E) to which participants made speeded manual identification pressing the 'H' or space bar keys to indicate the presence of the letter 'H' or 'N', respectively. In this example (Panel E) the four faces, from left to right, are termed as: Null face (not looked at), Joint attention face (looks at central shared referent), Single-cued face (in line of site of the Joint attention face), and Double-cued face (in line of site of both the Joint attention and Single-cued faces).

**Results**

Mean and standard deviations for accuracy rates and reaction times for each condition (and all Experiments in this chapter) are found in Table 2. 'Condition' refers to the location of the target on a given trail, as this could be on one of the 4 faces. Trials with correct reaction times 3*SD*s above or below the participant's mean were removed (1.5%) before the means for each condition were calculated. Percentage accuracy for each condition was also calculated. The same criteria were used in each experiment in this chapter.

**Accuracy.** On average correct responses were made on 91.80% of trials (*SD* = 5.36%), see Table 2. A 4 (Target Location) × 2 (SOA) repeated measures ANOVA showed a significant main effect of Target Location, $F(3,51)=3.34$, $p=.026$, $\eta^2_p=.16$. The main effect of SOA was not significant, $F(1,17)<1$, nor was the Condition × SOA interaction $F(3,51)<1$. To explore the main effect of Target Location, we looked at performance at the peripheral locations and the more critical innermost locations separately. Thus, a 2 (Inner Target Locations) × 2 (SOA) repeated measures ANOVA showed there was a trend for lower accuracy to targets appearing on the 'Joint Attention face' than on the 'Single-cued face', $F(1,17)=4.43$, $p=.050$, $\eta^2_p = .21$. The same analysis on the peripheral target locations revealed no difference in performance, $F(1,17)=1.15$, $p=.298$, $\eta^2_p = .06$. No other main effects or interactions were significant, *F*'s<1.

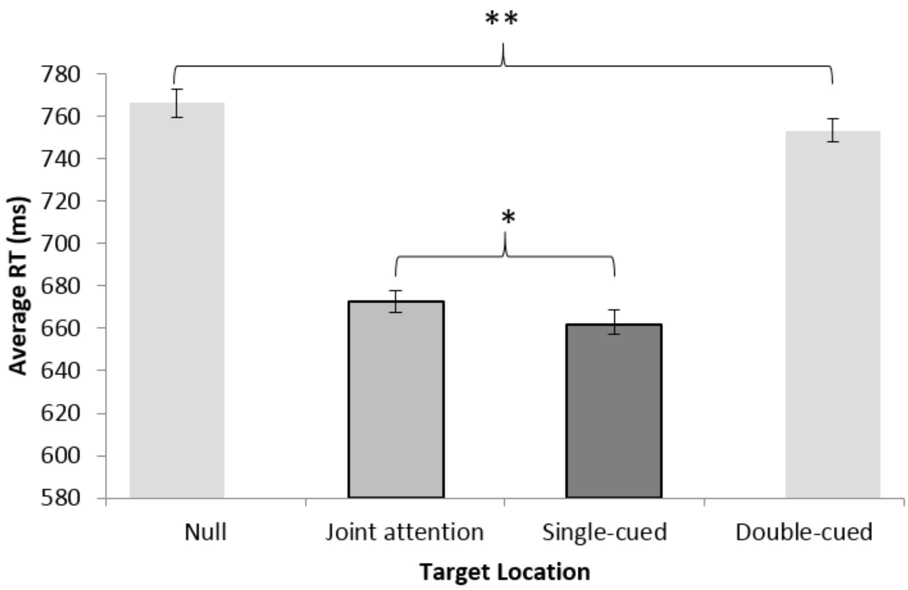


*Figure 6.* Mean reaction times (RT) for correctly identified targets in Experiment 3, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Masson, 1994). Asterisk denotes p=.016, double asterisk denotes $p<.001$, from respective 2x2 ANOVA's.

**Reaction times.** A 4 × 2 ANOVA revealed a significant main effect of Target Location, $F(3,51)=75.2$, $p<.001$, $\eta^2_p=.82$. The main effect of SOA was also significant,

$F$(1,17)=43.5, $p$<.001, $\eta^2_p$=.72 (see Table 2). The Target Location × SOA interaction was significant, $F$(3,51)=5.12, $p$=.004, $\eta^2_p$=.23. To interpret these effects, follow-up 2 × 2 ANOVAs on performance at inner and outer target locations were conducted separately. For innermost targets, in line with the accuracy data above, but contrary to our experimental hypothesis, RTs at the Single-cued location (662ms) were significantly faster than at the Joint Attention location (673ms), $F$(1,17)=7.18, $p$=.016, $\eta^2_p$ =.30 (see Table 2, Figure 6). The effect of SOA and the interaction were both significant, $F$(1,17)=11.15, $p$=.004, $\eta^2_p$ =.40, $F$(1,17)=5.79, $p$=.028, $\eta^2_p$ =.25, respectively. The interaction was significant because the RT advantage at the Single-cued face was present only at the 400ms SOA, $t$(17)=3.14, $p$=.006, $dz$=.74, and not at the 100ms SOA, $t$(17)=-.991, $p$=.335, $dz$=.23. The same 2 × 2 ANOVA for the outermost target locations revealed faster responses at the ‘Double-cued’ face, than at the ‘Null’ face, $F$(1,17)=70.87, $p$<.001, $\eta^2_p$=.81. There was no effect of SOA, $F$(1,17)=1.82, $p$=.193, $\eta^2_p$=.10, while the interaction was marginal, $F$(1,17)=4.35, $p$=.053, $\eta^2_p$=.20. The interaction approached significance because RTs between the outermost faces did not differ at the 100ms SOA, $t$(17)=.183, $p$=.857, $dz$=.04, but revealed a trend at the 400ms SOA, $t$(17)=2.040, $p$=.057, $dz$=.48.

**Table 2.**

Mean RT (ms) and Accuracy (%) in all conditions presented in Experiments 3-5. Note: positive numbers indicate a bias towards the Joint Attention face. Standard deviations in parentheses. N = Null, JA = Joint Attention, S = Single-cued, D = Double-cued.

| | | SOA 100 ms | | | | SOA 400 ms | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | JA | S | D | N | JA | S | D |
| E3 | Accuracy | 91.0 (7.9) | 91.8 (5.7) | 94.3 (5.4) | 90.3 (6.3) | 91.5 (8.8) | 92.7 (5.4) | 93.6 (5.0) | 89.2 (8.0) |
| | RT | 775 (184) | 672 (154) | 680 (172) | 774 (181) | 757 (186) | 673 (170) | 644 (151) | 733 (171) |
| E4 | Accuracy | 97.3 (4.5) | 97.3 (4.0) | 96.8 (6.6) | 96.3 (4.2) | 97.4 (4.0) | 97.5 (2.9) | 98.7 (2.2) | 97.6 (3.4) |
| | RT | 734 (141) | 689 (130) | 695 (133) | 753 (145) | 703 (146) | 652 (149) | 656 (144) | 713 (136) |
| E5 | Accuracy | 95.4 (5.0) | 95.2 (4.6) | 96.2 (3.9) | 96.1 (3.5) | 96.7 (3.5) | 96.5 (4.6) | 95.6 (4.2) | 96.7 (4.2) |
| | RT | 666 (121) | 612 (110) | 631 (123) | 676 (119) | 616 (177) | 582 (118) | 601 (125) | 643 (125) |

**Discussion**

This experiment tested whether faces that looked at the participant's fixation location captured attention. Contrary to our hypothesis, RT's were fastest to targets appearing on the innermost face in the looked at direction. Thus, observed averted gaze, presented peripherally, cued attention in the direction of averted gaze. Reaction times were faster to targets appearing in the direction of averted gaze; i.e. the Single-cued face appears in the line of sight of one face (the Joint attention face) and the Double-cued face appears in the line of sight of two faces.  Although these data are counter to our hypothesis, these results are nevertheless in line with reports of gaze cueing (Frischen et al, 2007), and add to a growing literature regarding how non-centrally averted gaze affects attention, (e.g. Friesen & Kingstone, 2003).

The time-course of the current gaze-cueing effects are as expected. No reliable cuing emerged at the early 100ms SOA, but did so at the 400ms SOA – a delay that usually produces such effects (see Frischen et al., 2007). Thus, the present results are certainly in line with previous illustration of gaze cueing.

The findings of Chapter 2 suggest that the location of the fixation cross may be important for the way the gazing face is processed by a participant. However, in this experiment, and those to follow, the fixation cross is held to a constant central location. This is because the current experiment includes a visually busy display that is not conducive to the manipulation of fixation cross location. As will be seen, later versions of the current paradigm may be more appropriate to test this interesting possibility. However, this was beyond the scope of the current thesis.

It therefore appears that the current stimuli set up produced no evidence of attention orienting towards those that jointly gaze with a participant. However, as will be discussed in the following experiments, there are potentially a number of theoretically driven reasons that the current paradigm may have failed to elicit evidence for the hypothesised orienting response relating to gaze leading. For our present purposes, this experiment shows that our stimulus layout can produce measureable attentional effects, but that evidence of a shared attention mechanism may require a different approach.

### Experiment 4: Paradigm refinement - gaze contingency

We considered that in Experiment 3 participants may not have interpreted the face that followed their gaze (the 'Joint Attention face') as an interactive partner because the participant did not actively move their eyes to the fixation location, which negates the possibility of being 'followed'; instead the participant passively maintained fixation at the centre of screen. Indeed, the importance of contingency on gaze following has already been illustrated (e.g. Pfeiffer et al., 2012; 2012). Pfeiffer and colleagues showed that under certain conditions the time interval between a participant looking somewhere and an onscreen face 'following' their gaze was a crucial contributor to how 'contingent' the interaction was rated as by the participant (Pfeiffer et al., 2012), while it also appears that contingent responses influence the 'humanness' of the interaction (Pfeiffer et al., 2011). In our previous experiment (Experiment 3), participants did not make an initiation eye-movement, which may raise two issues: 1) participants may not perceive the on-screen face as following their gaze, as they have not reoriented their own attention, 2) as the participants did not make an eye-movement it may have not been possible for them to assess the contingency of the on-screen face's response, as they do not have an appropriate time point to anchor the beginning of the interaction to.

Indeed, the 'leader' of a joint attention episode, has affected change on their social environment: they have caused another agent to reorient their attention. In dynamic interactions, it is important to detect the effects that our own behaviour has on others (Schilbach et al., 2013). Therefore from a theoretical perspective it is intuitive that our paradigm may require active initiation by the participant in order for the participant to subjectively experience the interaction as 'gaze leading'.

In this experiment, participants also complete a self-reported measure of autism-like traits (AQ; Baron-Cohen et al., 2001). Such individual differences have previously been informative regarding gaze following (e.g. Bayliss & Tipper, 2005) and spontaneous joint attention initiation has been suggested as a particular impairment in ASC (Mundy, 2003). Here, we were interested in whether participant's level of autism-like traits might also relate to how their attention orients when having their gaze followed. Participants completed this measure in a number of experiments that are presented in this thesis and the results are most informative when considered together. Thus all data regarding AQ can be found in Chapter 4.

Thus, in Experiment 4 we used a gaze contingent display. Participants were eye-tracked and their own gaze behaviour would, in real time, trigger the onscreen stimuli display. Participants moved their eyes from the bottom of the screen to the centre to initiate the trial, with correct fixation of the central fixation cross causing the faces to display averted gaze (see Bayliss et al., 2013; Wilms et al., 2010). We anticipated this more active gaze behaviour would potentiate the hypothesised *gaze leading effect*.

**Method**

**Participants.** Thirty-three adults (Age; *M*=22.8 years, *SD*=4.4 years, five were men) participated. Due to calibration and tracking difficulties three participants completed only three of the four blocks; the collected data were retained and analysed. Because the data from Experiment 1 showed a pattern that was counter to our *a priori* hypotheses, we decided to increase our target sample size for further experiments to 32 in order to facilitate the detection of what we expected could be a small effect. We terminated testing for convenience at the end of a block of laboratory bookings.

**Apparatus and Stimuli.** The stimuli were the same as in Experiment 1 except for the addition of a second cross 65mm directly below the central cross. Additionally, a chin-rest was used and right eye position was tracked (Eyelink 1000, SR Research, Ontario, Canada; spatial resolution $0.1^{\circ}$, 500 Hz). Finally, in this and subsequent experiments, the Autism Spectrum Quotient (AQ) questionnaire was used to measure autistic-like traits of participants (Baron-Cohen et al., 2001), which has previously been shown to share a relationship with social orienting of attention (Bayliss & Tipper, 2005; Bayliss, di Pellegrino & Tipper, 2005; Bayliss & Tipper 2006).

**Design & Procedure.** The experimental design was the same as Experiment 3. The procedure differed from Experiment 3 in the following ways. On each trial, the participant first had to fixate the lower cross for 500 ms, which would trigger the enlargement of the central cross, which was the cue to saccade to the central cross. After fixating the central cross for 300ms, each trial continued to its conclusion in the same way as in Experiment 3. There was a 500 ms inter-trial-interval (blank screen). The experimenter was present for the duration of the session. Finally, participants completed the AQ.

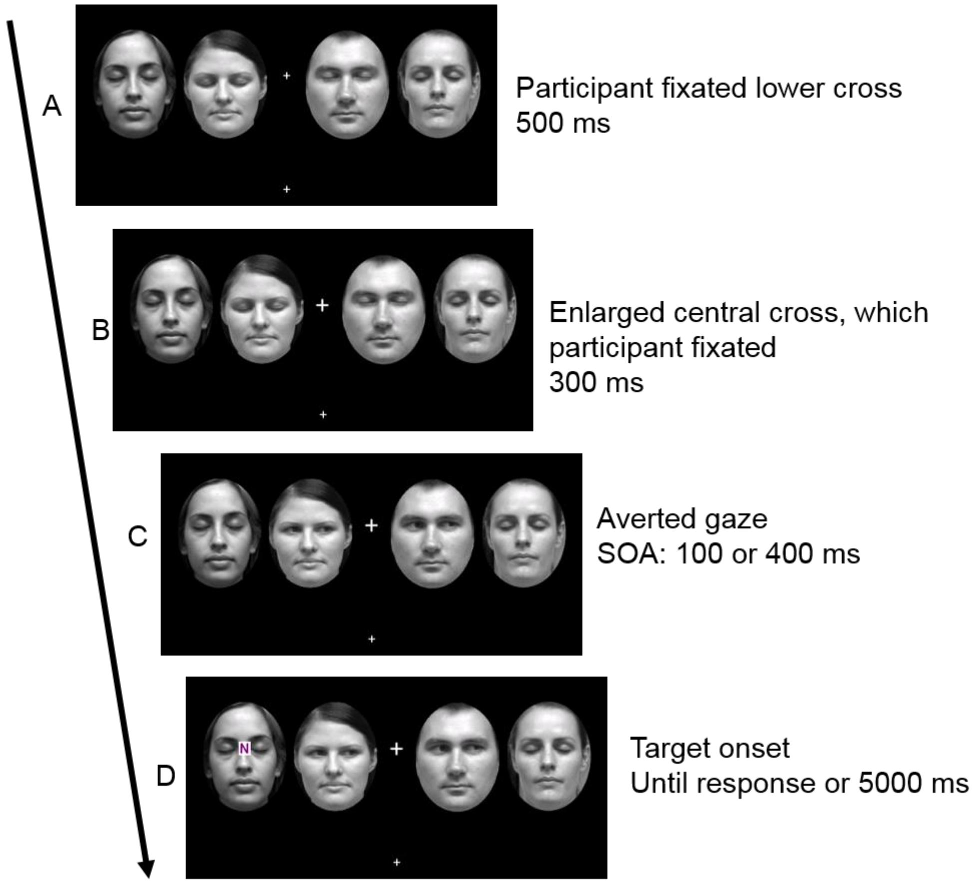


*Figure 7.* Example trial from Experiment 4. Participants first fixated the lower cross (A), which triggered the central cross to enlarge. Participants then fixated the central cross (B), which triggered the display of averted gaze (C). Finally, a target letter appeared on one of the four faces (e.g. the Null face, D) to which participants made speeded manual identification pressing the 'H' or space bar keys to indicate the presence of the letter 'H' or 'N', respectively.

**Results**

**Accuracy.** Analysis was identical to Experiment 3. On average correct responses were made on 97.36% of trials ($SD$ = 3.45%). There was no significant main effect of Target Location, $F(3,96)<1$, and no significant interaction, $F(3,96)=1.22$, $p=.31$, $\eta^2_p=.037$. The main effect of SOA approached significance, $F(1,32)=4.06$, $p=.052$, $\eta^2_p=.113$ (see Table 2).

**Reaction times.** Analysis was again identical to Experiment 3. 1.7% of trials were discarded as outliers. The main effect of Target Location was significant $F(3,96)=42.5$, $p<.001$, $\eta^2_p=.57$. There was a significant main effect of SOA, $F(1,32)=32.53$, $p<.001$,

$\eta^2_p$=.50. The interaction was non-significant *F*(3,96)<1. A 2 × 2 ANOVA on performance at the innermost target locations revealed a no effect of target location, *F*(1,32)<1, the effect of SOA was significant, *F*(1,32)=18.58, *p*<.001, $\eta^2_p$=.37, and there was no significant interaction *F*(1,32)<1. For completeness, we also report that differences between the Joint Attention and Single-cued face target locations were non-significant at the 100ms and 400ms SOAs, *t*(32)=-.79, *p*=.44, *dz*=.14, *t*(32)=-.51, *p*=.62, *dz* = .09, respectively. The 2 × 2 ANOVA performed on the outermost target locations revealed a main effect of target location due to significantly faster responses at the 'Null' face compared with the 'Double-cued' face, *F*(1,32)=5.66, *p*=.023, $\eta^2_p$=.15. The main effect of SOA was significant, *F*(1,32)=39.20, *p*<.001, $\eta^2_p$=.55, and the interaction was non-significant, *F*(1,32)<1.

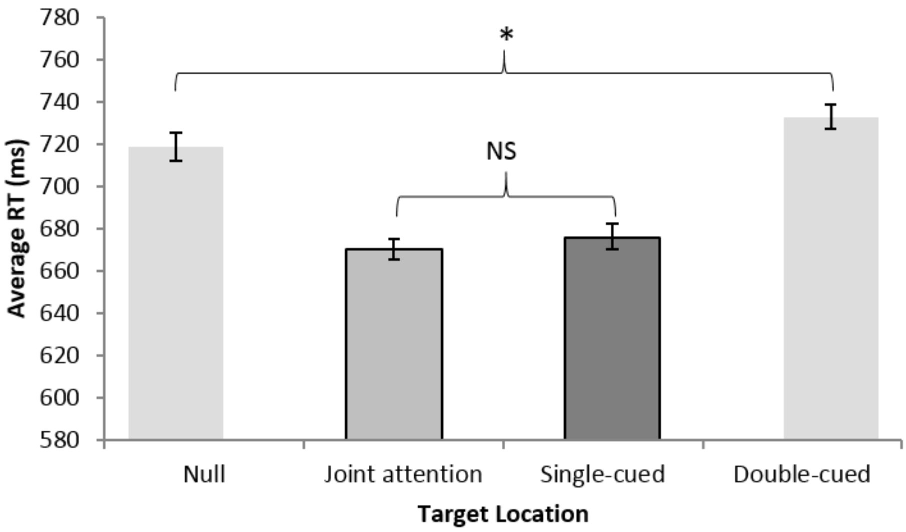


*Figure 8.* Mean reaction times (RT) for correctly identified targets in Experiment 4, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Masson, 1994). Asterisk denotes p=.023, NS= non-significant, from respective 2x2 ANOVA's.

**Discussion**

Here, there was no difference in reaction times to targets appearing on either the Joint attention or Single-cued faces, again not supporting our hypothesis. However, it is noteworthy that this active task does not replicate the gaze cueing effect observed in Experiment 3, despite the use of an identical target display (see Figure 7). It is possible that the gaze cueing effect from Experiment 3 has been abolished in the present experiment by the partial engagement of a directly competing process (i.e. the gaze leading effect). That is, perhaps now that participants are actively initiating the joint attention encounter, their attention is shifting towards faces that ‘follow’ their gaze, but not enough to be statistically reliable due to gaze cueing still orienting participants’ attention towards the opposite direction. In Experiment 5 we aim to explore this possibility further.

## Experiment 5: Paradigm refinement - object specificity

Encouraged that increasing the ecological validity of the gaze leading interaction from having participants passively fixate (Experiment 3) to actively initiating the interaction (Experiment 4) may have led to increased attention orienting towards the Joint attention face, we sought to further examine how increasing the validity of the gaze leading interaction may further elucidate the hypothesised gaze leading effect.

By definition joint attention involves two people attending to the same object (Emery, 2000). In the previous experiments the ‘object’ to which participants have jointly attended with an onscreen face has been a fixation cross. We therefore considered that, as fixation crosses are not usual everyday items to look at, participants may not have perceived the fixation cross as a valid referent to which attention could be shared. Potentially, participants may perceive the onscreen gaze as looking past the fixation cross (compare Figure 7, 9). Indeed, this may have contributed to the finding of *gaze cueing* in Experiment 3.

Not only are objects central to joint attention by definition, but further it is well documented that attending with others to objects is a key milestone in human social development (Mundy et al., 2007). Further, we may expect others to look at objects (Senju, Csibra & Johnson, 2008; Lobmaier, Fischer & Schwaninger, 2006), and seeing other people look at objects can influence our own affective processing of those objects (Bayliss et al., 2006; Becchio, Bertone & Castiello, 2008). Furthermore, there is accumulating evidence illustrating the object-based specificity of attention (e.g. Lavie & Driver,1996; Wannig, Stanisor & Roelfsema, 2011). Thus, there are a number of reasons to hypothesise that including a more realistic object may be crucial to the participants interpretation of a gaze leading encounter.

Therefore, in the current experiment the central fixation cross was replaced by an image of a real-world object, with the expectation that this addition would increase the ecological validity of the current design to an extent that the expected ‘gaze leading’ effect would emerge.

### Method

Thirty-two adults (Age; *M*=19.2 years, *SD*=1.6 years; eight males) took part. Due to calibration and tracking difficulties three participants completed only three blocks of the four. The same stimuli as Experiment 4 were used with the addition of sixteen not-to-scale images of kitchen objects (Bayliss et al., 2006; see Figure 9). The design was identical to Experiment 4. The procedure was identical to Experiment 4, except that crucially the fixation of the lower cross now triggered the central cross to be replaced by a randomly selected image of an object. Participants again completed the AQ.

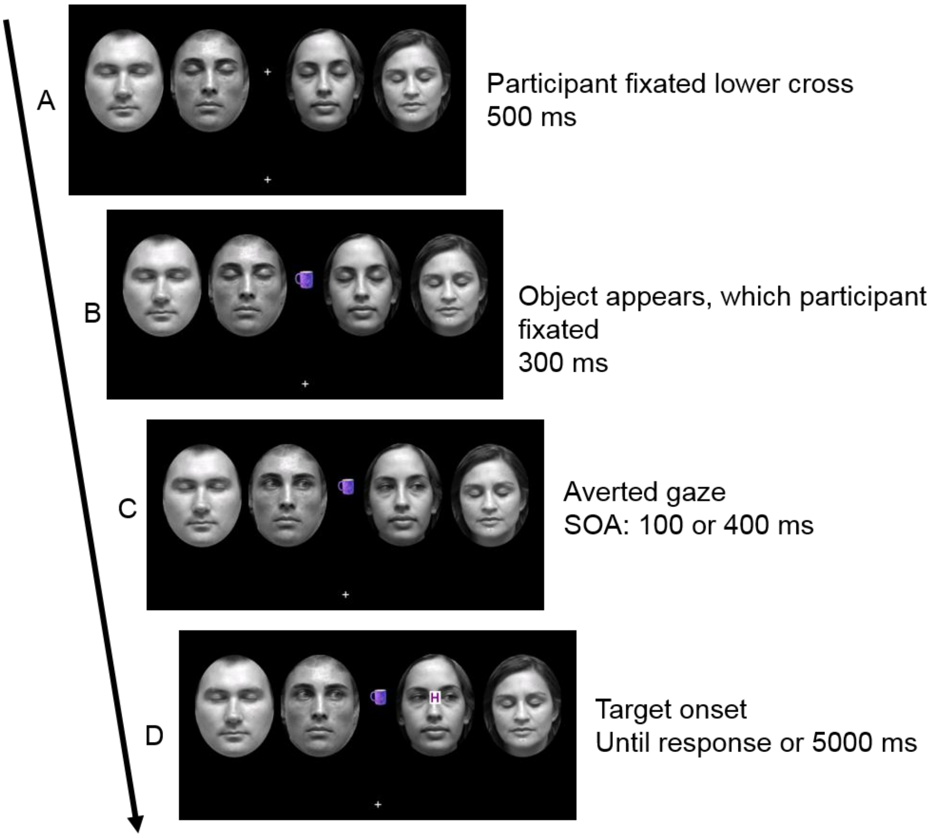


*Figure 9.* Example trial from Experiment 5. Participants first fixated the lower cross (A), which triggered the central cross to be replaced by an image of an object (B). Participants then fixated the object, which triggered the display of averted gaze (C). Finally, a target letter appeared on one of the four faces (e.g. the Single-cued face, D) to which participants made speeded manual identification pressing the 'H' or space bar keys to indicate the presence of the letter 'H' or 'N', respectively.

**Results**

**Accuracy.** The same analyses as above were performed. Participants made correct responses on 96.0% of trials ($SD$ = 3.51%). There was no significant main effect of Target Location, $F(3,93)<1$, SOA, $F(1,31)=3.62$, $p=.066$, $\eta^2_p=.105$, and no significant interaction $F(3,93)=1.033$, $p=.382$, $\eta^2_p = .032$.

**Reaction times.** Again, the same analyses as above were performed. 1.7% of trials were discarded as outliers. The main effect of Target Location was significant, $F(3,93)=49.6$, $p<.001$, $\eta^2_p=.62$. There was a significant main effect of SOA, $F(1,31)=52.0$, $p<.001$, $\eta^2_p=.63$. The interaction was not significant, $F(3,93)=1.86$, $p=.141$, $\eta^2_p=.057$. To determine the source of the Target Location main effect, a 2 × 2 ANOVA showed that RTs at the Joint Attention face (597ms) target location were faster than at the Single-cued face (616ms), $F(1,31)=18.98$, $p<.001$,$\eta^2_p=.38$, with follow up contrasts showing that this effect was reliable at the 100ms, $t(31)=-3.45$, $p=.002$, $dz=.61$, and 400ms SOAs, $t(31)=-2.60$, $p=.014$, $dz=.46$. The effect of SOA was also significant, $F(1,31)=17.37$, $p<.001$, $\eta^2_p=.36$, and the interaction was non-significant, $F(1,31)<1$. The 2 × 2 ANOVA on RTs to the peripheral locations revealed faster RTs at the 'Null' face, than at the 'Double-cued' face, $F(1,31)=9.02$, $p=.005$, $\eta^2_p=.23$. The SOA main effect was significant, $F(1,31)=72.76$, $p<.001$, $\eta^2_p=.70$, and the interaction was not, $F(1,31)=3.60$, $p=.067$, $\eta^2_p=.10$.

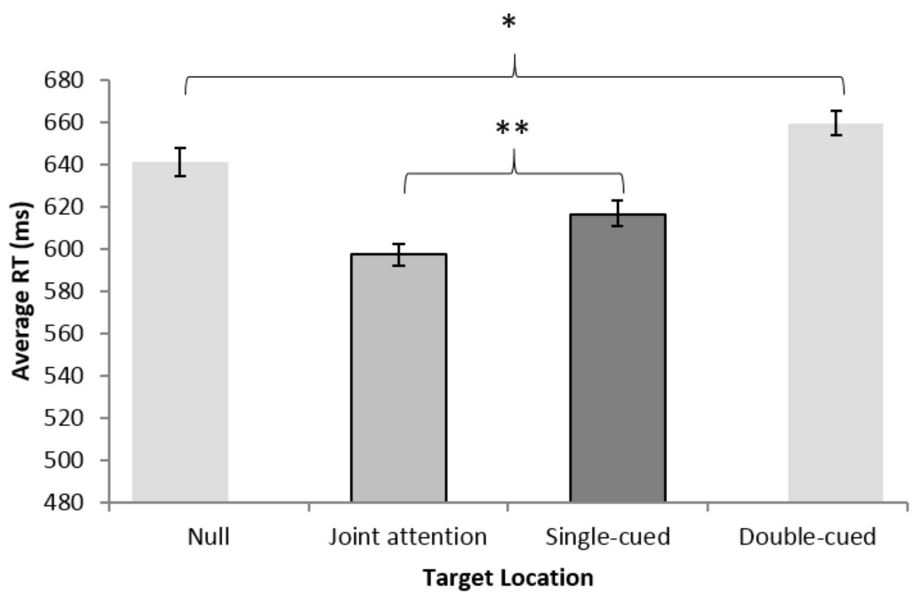


*Figure 10.* Mean reaction times (RT) for correctly identified targets in Experiment 5, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Masson, 1994). Asterisk denotes p=.005, double asterisk denotes $p<.001$, from respective 2 x 2 ANOVA's.

## Discussion

Here, RTs were fastest to targets appearing on the Joint attention face than at any other location (see Figure 10). Thus, this is the first evidence that a joint attention initiator will preferentially shift their attention towards the face of an individual that has responded to their gaze reorientation and looked at the same object. It appears that during gaze leading, the attention of the initiator will be captured by those that follow one's gaze. We term this response *the gaze leading effect*.

The result is strikingly converse to that of Experiment 3, in which with an identical target display produced a standard gaze cueing effect. It therefore appears that the subjective experience of the participant can be seen as crucial to how their attention will respond to such encounters. Further, this suggests that engaging in active, object-oriented joint attention initiation overrides gaze cueing and instead potentiates an attention shift towards the face of an individual who has followed one's gaze. Initiating and responding to joint attention have been proposed as distinct in a number of ways (e.g. Mundy and Newell, 2007), and here we present evidence that each is accompanied by separate, competing, attention reorienting responses.

It may be interesting to note the time-course of the gaze leading effect in the present study. Attention allocation appeared at both the 100ms and 400ms SOA. This can be seen as somewhat surprising as gaze-based attention orienting (gaze cueing) does not normally occur as early as 100ms (c.f. Experiment 3). However, the potentially related findings of Experiment 1, where facilitation towards faces jointly gazing with participants towards a central fixation cross occurred at a 0ms SOA, may suggest that the gaze leading effect response is rapid. However, further work is needed to confirm this, and to assess the reflexivity of the gaze leading effect.

The gaze leading effect is a novel finding regarding social attention, but is also intuitive given how important social eye-gaze encounters are for humans. When someone follows our eyes, they will come to know what we are looking at and can use this information to infer our mental state regarding the referent to which we are gazing (e.g. Nummenmaa, & Calder, 2009). Therefore, it may be beneficial to remain vigilant towards having your eye-gaze followed – being able to track who knows, and what they are thinking about, what we are thinking about is likely crucial in order to successfully manage impressions and for continuing iterative social interactions successfully.

## General Discussion

The experiments in this chapter illustrate, for the first time, that faces that follow gaze capture attention. When participant's shifted their overt attention to a newly appeared object (Experiment 5), they then shifted their attention preferentially towards faces that also subsequently looked towards this object. Thus, it may be the case that humans have an attentional mechanism that prioritises those that engage with us by following our gaze. Indeed, should this effect prove to be replicable, it could be suggested that this orienting response implies a mechanism in the human attention system that acts to elaborate mere joint gaze into the more socially sophisticated interaction of shared attention (Emery, 2000).

It is notable that this 'gaze leading' effect only emerged in one of the three experiments presented in this chapter, which suggests that this effect is highly context dependant with regards to the subjective experience of the participant. Where the gaze leading effect did not emerge (Experiment 3, 4) it is possible that the interaction was not perceived by participants as fully constituting gaze leading. That is, only Experiment 5 included active reorienting towards a socially valid object on the part of the participant. Thus, it may be that both of these conditions are crucial for the illustration of the gaze leading effect. However, it is worth noting that in casual debrief participants appeared generally unaware of the hypothesis of the experiment, or of the consistency of any manipulations.

While the current series of three experiments suggest that the gaze leading effect is fairly difficult to illustrate, appearing reliably only in one of the three experiments, there are strong theoretical rationales for why this might be. For example, comparing across the experiments presented in this chapter, it appears that the gaze leading effect is a social orienting response that does indeed operate in direct opposition to the gaze cueing effect (see Frischen et al., 2007, for review). Congruent with this interpretation, Experiment 4 fits well as an intermediary between the gaze cueing effect observed in Experiment 3 and the gaze leading effect of Experiment 5. That is, the procedure of Experiment 4 had active initiation but no object present, and was thus half way between the paradigms of Experiments 3 and 5. Reassuringly then, perhaps, the null result in Experiment 4, where RT's did not differ between the critical target location, could suggest that the two competing orienting responses of gaze cueing and gaze leading were having equitable impacts on the participants attention allocation.

Future work may wish to further investigate the relative contributions of the manner of the interaction (passive vs active) and the nature of the shared referent (fixation cross vs object image) to the gaze leading effect. The experiments presented in this chapter suggest that both are important. However, future work should also examine, for example, whether the gaze leading effect is observable in object based, non-active tasks. It may also be interesting to assess whether having a face as the shared referent also produces a gaze leading effect, which would allow for the examination of potentially more socially complex interactions, and could be achievably tested using an altered version of Experiment 3 wherein the participant fixates one of the centre-most faces and the nearest outermost face also looks at the participant's gaze target. Further, the relative contribution of each (objects and active initiation) could also help elucidate the mechanism behind the gaze leading effect, for example whether this is a special case of object based attention (e.g. Pelphrey et al., 2003) or related to the contingent response to our own behaviour (e.g. Pfeiffer et al., 2012), or both.

To conclude, we have the first evidence that the visual system prioritises faces that follow one's gaze, jointly attending with us. This effect appears reliant on a scenario where the participant has actively initiated joint attention towards an ecologically valid shard referent. While this effect fits predictions based on social orienting in gaze leading, it is necessary to replicate this novel finding before any strong claims can be made.

# Chapter 4: Extending on the gaze-leading paradigm

The previous chapter presented the first evidence to suggest that there could be a mechanism in the human attention system that prioritises individuals who follow our gaze: the gaze leading effect. However, this novel phenomenon has thus far only been reliable in one experiment. Therefore it is important that before any strong conclusions are made regarding this orienting response, the gaze leading effect is shown to be replicable. Furthermore, the paradigm which was developed in Chapter 3 is somewhat novel and therefore further experiments using this paradigm will allow for its validation.

A direct replication of Experiment 5 (Chapter 3) would suffice in evidencing the replicability of the gaze leading effect and would offer validation of our paradigm. However, the gaze leading effect potentially opens a number of interesting lines of inquiry. Therefore, the experiments presented in this chapter do not only aim to replicate the gaze leading effect, but also to further our understanding of this social orienting response.

Should the gaze leading effect prove to be reliable, future work may look to assess how a number of aspects relating to the identity of the gaze following face can modulate the gaze leading effect. For example, the magnitude of gaze cueing a given face can elicit has been shown to be modulated by the physical characteristics of the face (e.g. masculinity/dominance, Jones et al., 2010; Ohlsen, van Zoest, & van Vugt, 2013), but also by non-visual information regarding the identities of these faces (Deaner, Shepherd, & Platt, 2007; see also Frischen & Tipper, 2006). Therefore, it would be beneficial for future work if the current paradigm, which has this far consisted of a visually busy display containing an object, fixation cross, and four faces, could be simplified to facilitate future investigations relating to identity-specific consequences of gaze leading.

Another aspect of the gaze leading effect that may prove insightful is the object which acts as the shared referent of the joint attention interaction. The way in which objects are perceived can be influenced by joint attention gaze-based interactions. For example, we generally prefer objects that other people cue our attention towards (Bayliss et al., 2006). But more recently Bayliss et al (2013) showed that gaze leading can also impact how we perceive objects, finding that having another person follow our gaze to an object may make us more consistent in our evaluation of that object, as though successful gaze leading can act in a confirmatory capacity. Given the importance of looking at objects, or seeing others look at objects, the present chapter includes one experiment that aimed to assess whether the gaze leading effect can be accounted for by the salience of seeing a face gaze towards an object per se, as opposed to being an orienting response that truly relies of sharing attention.

Early gaze cueing work looked to assess its social specificity by comparing orienting to gaze cues with orienting to arrow cues (e.g. Driver et al, 1999; Friesen & Kingstone, 1998; Hood, Willen & Driver, 1998). Arrows and gaze have been shown to influence attention is strikingly similar ways (see Frischen et al., 2007 for review), and it has therefore been suggested that both result from a domain general mechanism (Böckler, van der Wel & Welsh, 2014). Conversely, thus far the gaze leading effect appears to be highly sensitive to the social context of the interaction, with strikingly different orienting responses emerging based on relatively minor visual changes (e.g. Experiment 3 vs Experiment 5). It will therefore be interesting to assess whether orienting responses related to gaze leading can also be produced by arrow stimuli, or whether the gaze leading effect is an orienting response that is specific to gaze.

Thus, the present chapter presents three experiments that aim to further our understanding of the gaze leading effect. While aiming to replicate this novel effect, this work is also interested in outlining further boundary conditions, ruling out possible confounding factors, while also providing a proof-of-concept for the current paradigm to be expanded upon in the future.

## Experiment 6: Gaze leading effect replication with fewer target loci

This experiment aimed to replicate the novel finding of the gaze leading effect, while also simplifying the stimuli display. The two outer-most faces have been informative thus far, providing results consistent with our hypothesis, while also not being critical in the evaluation of whether gaze following faces capture the attention of the gaze leader. Thus, the peripheral faces were removed, providing only two target locations (the innermost locations).

Having only 2 target locations may make the task easier (e.g. Beck & Ambler, 1973) as attention is not needed to be distributed as widely. It could also reduce the need for saccade preparation (Posner & Cohen, 1980, see also Posner & Cohen, 1984), as both targets were relatively close to fixation. Thus, this experiment may provide converging evidence in support of the gaze leading effect using a comparable, but slightly different, stimuli arrangement.

There are also more practical benefits to simplifying the stimuli display. As future work may look to assess how the gaze leading effect varies depending of factors relating to characteristics of the gaze follower, much in the same way the research interests of gaze cueing research developed, simplifying the display so that only two faces are present – one being the gaze follower and the other not following gaze – may facilitate such enquires. That is, both onscreen faces will be 'behaving' by displaying averted gaze towards or away from where the participant looks, and with only two face displayed participants may be more able to encode identity-specific information relating to these faces.

We predicted that the gaze leading effect of faster RTs to identifying targets appearing on the face that had looked at the same referent as the participant, compared with those appearing on a face that looks elsewhere, would replicate under these conditions.

### Method

In all experiments we have reported how we determined our sample size, all data exclusions (if any), all manipulations, and all measures we have collected (see Simmons, Nelson & Simonsohn, 2012).

**Participants.** Thirty-two students (five men) at UEA (Age; *M*=19.6 years, *SD*=1.5 years) completed the experiment in return for course credit or payment (in this experiment and in all others). Due to technical difficulties three participants completed only three of the four blocks. Participants in all experiments reported normal or corrected-to-normal vision. We aimed to collect data from approximately 30 participants and stopped at $n$=32, for convenience, at the end of a block of booked testing sessions.

**Apparatus and Stimuli.** Face stimuli consisted of greyscale photographs taken from a stimulus set created by (Bayliss, Bartlett, Naughtin & Kritikos, 2011). Eight identities with a calm facial expression were used (four female). For each face identity, three images were used such that each identity could be displayed with closed-eyes, leftward gaze, or rightward gaze. Each face image measured 50mm × 64mm. One face appeared on each side of the central cross; the centre-point of the face was 33mm away from the centre. Face identities were randomly assigned to each position on each trial, with the constraint that a given identity could only appear in one location per trial. Target letters (N or H) were size 18 bold Arial text (4mm × 4mm), presented in purple on a white background (6mm × 6mm). Stimulus presentation was controlled by a standard desktop computer with an 18" screen (pixel resolution 1024 × 768) and manual responses were made on a standard keyboard.

**Design.** A 2 (Target Location; 'Joint attention face', 'Single-cued face') × 2 (stimulus onset asynchrony – 'SOA'; 100ms, 400ms) within-subjects design was used. Reaction times (RTs) and accuracy rates were measured.

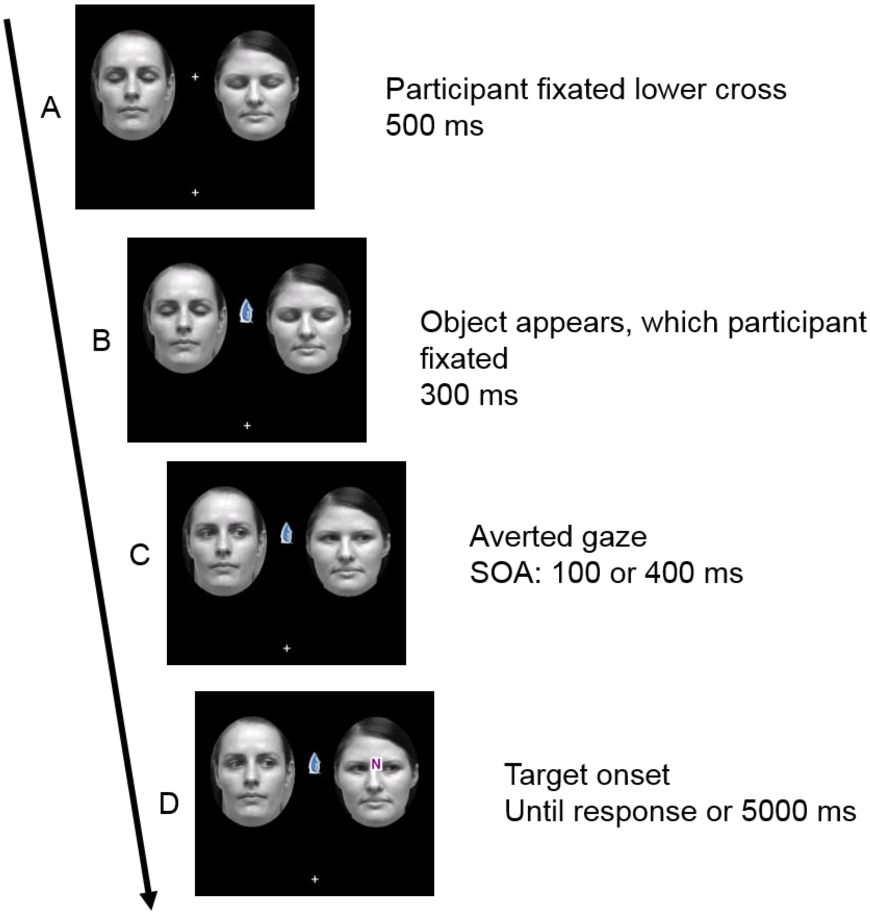


*Figure 11.* Example trial from Experiment 6. Participants first fixated the lower cross (A), which triggered the central cross to be replaced by an image of an object (B). Participants then fixated the object, which triggered the display of averted gaze (C). Finally, a target letter appeared on one of the two faces (e.g. the Single-cued face, D) to which participants made speeded manual identification pressing the ‘H’ or space bar keys to indicate the presence of the letter ‘H’ or ‘N’, respectively. In this example the face to the left is the Joint attention face and the face to the right is the Single-cued face. Stimuli are not to scale.

**Procedure.** Participants sat approximately 70cm away from the display. Each trial started with a white fixation cross presented in the centre of a black background, with a second cross 65 mm below, and one face either side of the central cross. Participants had to fixate the bottom cross for 500 ms, which triggered the replacement of the central cross with an image of an object (see Figure 11). After 300ms fixation of centrally presented object, the faces were both displayed with averted gaze in a common direction (left or right) for either a 100 ms or 400ms SOA. Next, a letter target was presented on the bridge of the nose of one of the faces until a response was made, or until 5000ms elapsed, whichever came first. Participants made speeded identification responses to the target by pressing the ‘H’ key with the index finger of their preferred hand when an H was displayed, and pressing the spacebar with the thumb of the same hand when an N was displayed. Finally, a feedback screen was displayed for 1500ms – this was a black screen after a correct response, but showed a red central cross after an incorrect response. The experimenter was present throughout the session. After 6 practice trials, the experiment comprised a total of 128 trials over four blocks. Finally, participants completed the Autism Quotient (AQ; Baron-Cohen et al., 2001) questionnaire. The session took approximately 35 minutes.

**Results**

Mean and standard deviations for accuracy rates and reaction times for each condition (and all Experiments in this chapter) are found in Table 3. Trials with correct reaction times 3*SD*s above or below the participant’s mean were removed (1.5%) before the means for each condition were calculated. Percentage accuracy for each condition was also calculated. The same criteria were used in each experiment in this chapter.

**Table 3.**

Mean RT (ms) and Accuracy (%) in all conditions presented in Experiments 6-8. Note: positive numbers indicate a bias towards the Joint Attention face. Standard deviations in parentheses. N = Null, JA = Joint Attention, S = Single-cued, D = Double-cued.

| | | SOA 100 ms | | | | SOA 400 ms | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | JA | S | D | N | JA | S | D |
| E6 | Accuracy | | 97.1<br>(2.5) | 96.2<br>(4.2) | | | 98.2<br>(2.9) | 97.3<br>(2.7) | |
| | RT | | 642<br>(146) | 653<br>(146) | | | 589<br>(133) | 605<br>(126) | |
| E7 | Accuracy | | 95.1<br>(4.3) | 97.0<br>(4.3) | | | 96.6<br>(4.2) | 96.0<br>(4.1) | |
| | RT | | 613<br>(126) | 623<br>(129) | | | 566<br>(124) | 576<br>(131) | |
| E8 | Accuracy | 96.6<br>(4.1) | 98.2<br>(2.1) | 98.5<br>(2.2) | 97.4<br>(4.0) | 96.9<br>(4.1) | 98.1<br>(2.9) | 98.1<br>(2.1) | 97.3<br>(3.4) |
| | RT | 749<br>(153) | 686<br>(133) | 689<br>(132) | 753<br>(134) | 720<br>(128) | 645<br>(155) | 664<br>(155) | 737<br>(145) |

**Accuracy.** A 2 (Target location; Joint attention, Single-cued) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA was carried out on the accuracy rates of participants (97.2% of trials, *SD*=2.69%). The effect of Target Location was non-significant, $F(1,31)=3.81$, $p=.060$, $\eta^2_p=.110$; the trend is in the same direction as the RT effect (see below). The main effect of SOA was significant, $F(1,31)=12.04$, $p=.002$, $\eta^2_p=.280$. The interaction was not significant $F(1,31)<1$.

**Reaction times.** 1.5% of trials were discarded as outliers. A 2 (Target location; Joint attention, Single-cued) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA revealed a significant main effect of Target Location, $F(1,31)=8.03$, $p = .008$, $\eta^2_p = .206$, due to faster responses at the Joint attention (616ms), versus Single-cued (630ms) location. There was a significant main effect of SOA, $F(1,31)=59.04$, $p<.001$, $\eta^2_p=.66$. The interaction was not significant, $F(1,31)<1$. The effect of Target Location was not significant at the 100ms SOA, $t(31)=-1.66$, $p=.11$, $dz = .29$), but was significant at the 400ms SOA, $t(31)=-2.102$, $p=.044$, $dz=.37$. Therefore, we replicated the gaze leading effect, again showing that attention shifts preferentially towards the face of an individual that has followed the participant’s gaze.

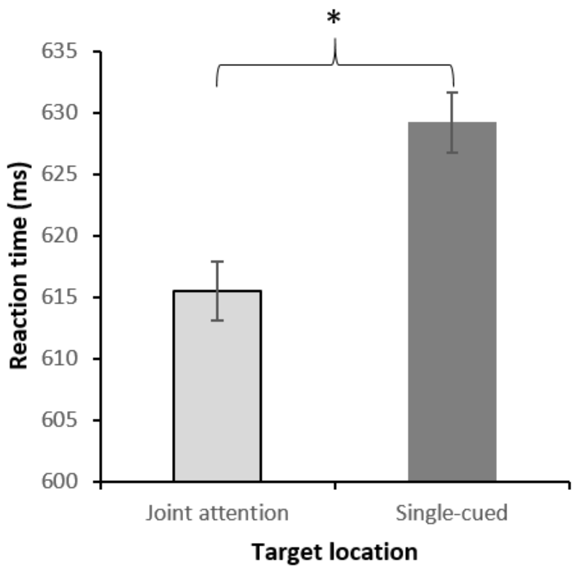


*Figure 12.* Mean reaction times (RT) for correctly identified targets in Experiment 6, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Mason, 1994). Asterisk denotes p=.008.

**Discussion**

Here, RTs to discriminate targets were faster when the target appeared on a face that had followed the participant’s gaze, as opposed to a face looking elsewhere, thereby replicating the gaze leading effect. In this Experiment, in contrast to those of Chapter 3, there were only two possible target locations and each of these were relatively close to the central object which participants fixated. Thus the gaze leading effect has replicated under ‘easier’ conditions.

Interestingly, this new two-face set up could facilitate future work in assessing face-specific features of the gaze leading effect – assessing, for example, what the long term impacts of repeated success (or failure) in gaze leading with specific identities might be. This set up may also allow future work to assess how facial features, that have been shown to impact social gaze orienting (e.g. masculinity /dominance, Jones et al., 2010; familiarity, Deaner et al., 2007; facial expression, Kuhn & Tipples, 2011; Mathews, Fox, Yiend, & Calder, 2003; social status, Dalmaso et al., 2012) influence the gaze leading effect.

Comparisons of the gaze leading effect at each SOA revealed that in this experiment the gaze leading effect was not reliable at the early (100 ms) SOA, but was at the later (400 ms) SOA. However, Experiment 5 (Chapter 3) showed the gaze leading effect to be reliable at both SOA's and so the time course of the gaze leading effect response of reorienting attention towards those that follow our gaze is not yet clear. Further replications of the current paradigm using SOA's of 100 and 400 ms may provide further insight regarding the reliability of the gaze leading effect at these timings.

Indeed, when the gaze cueing effect was first illustrated cueing was evident at SOA's of around 400 ms, but not at the early SOA of 100 ms (Driver et al., 1999). Thus, it may be logical that the 100 ms SOA is simply too early for eye-gaze related attention orienting to reliably emerge (but see Hietanen & Leppänen, 2003, for example of gaze cueing at earlier SOA's). However, as initiating and responding to joint attention are distinct (e.g. Mundy & Newell, 2007), it is also possible that the time course of attention orienting in response to having ones gaze followed will differ from that of gaze cueing. Thus, future work may also benefit from further examining how varying the SOA between the onscreen gaze aversion and the target appearing influences the observability of the gaze leading effect.

## Experiment 7: Gaze leading effect and objects

Although it is encouraging that the gaze leading effect has now been replicated, there remains a potential confound in the paradigm thus far. In the two experiments that have illustrated the gaze leading effect so far, only the joint attention face looks towards an object, while the other faces either do not display averted gaze (e.g. peripheral faces in Experiments 3-5) or look away from the object (Experiment 6). As objects are integral to social gaze-based interactions (e.g. Baron-Cohen et al., 1995; Swettenham et al., 1998; see Emery, 2000; Frischen et al., 2007 for reviews), one could postulate that the gaze leading effect, rather than representing a reorienting of attention towards a follower of gaze, instead evidences attention capture related to seeing a face gaze towards an object. That is, perhaps participants have so far simply been allocating attention towards faces that are more obviously interacting with their environment.

To directly address this issue, here the two-face paradigm of Experiment 6 was replicated, with the addition that the same object that appeared centrally also appeared to the far left and right of the faces (see Figure 13). Thus the stimuli display prior to target onset on every trial consisted of two faces looking in the same direction (left or right) and towards an identical object image. However, only one face would be looking towards the object that the participant was also fixating. If the gaze leading effect is due solely to the attentional capture of a face looking at an object, the gaze leading effect should be abolished here. However, we predicted that the gaze leading effect will replicate under these conditions.

### Method

Thirty-two adults took part (Age; *M*=19.8 years, *SD*=1.5 years, 11 males). Due to technical difficulties two participants completed only three of the four blocks. The stimulus display was identical to that of Experiment 6 except that the same object image that appeared at the central location also appeared to the left and right of the central faces, positioned so that each object was equidistant from the faces (see Figure 13). The design was identical to Experiment 6. The procedure was the same as that of Experiment 6, except that fixation of the central lower cross now caused three identical images of objects to appear (centre, far left, far right). This meant that crucially both faces looked in the same direction and at an equivalent object – the only difference being whether it was the same object to which the participant had fixated.

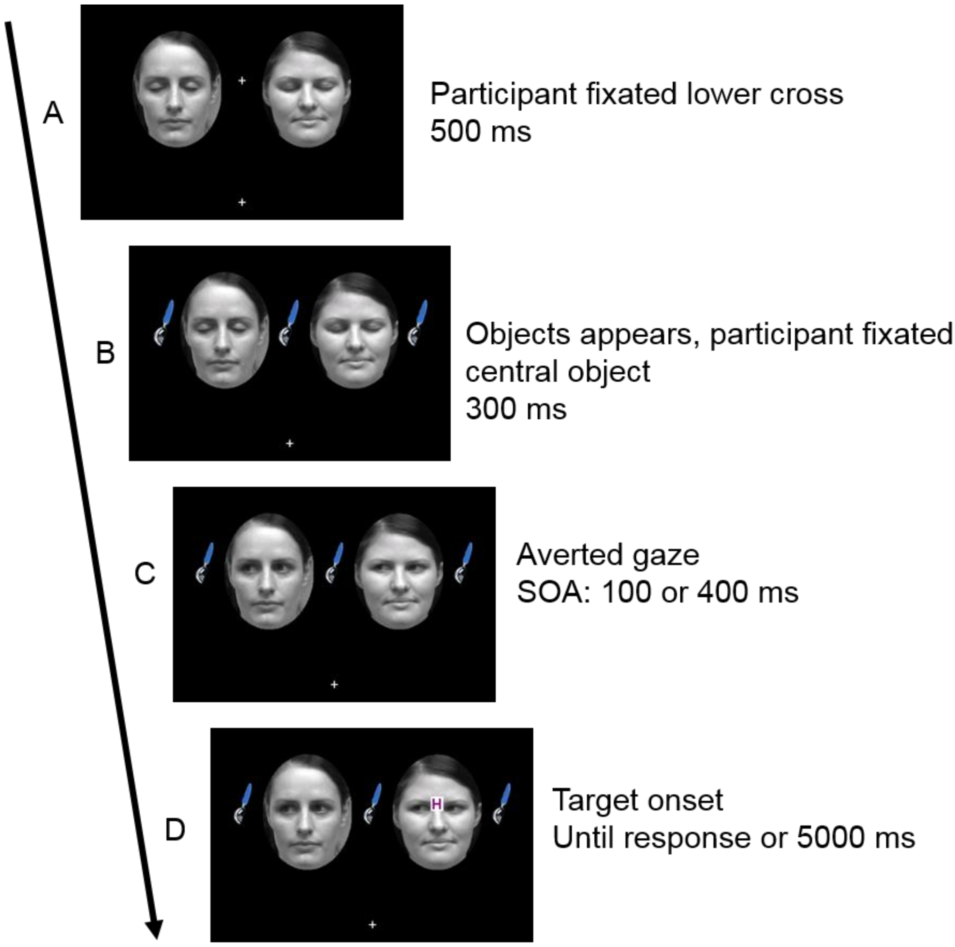


*Figure 13.* Example trial from Experiment 7. Participants first fixated the lower cross (A), which triggered the appearance of three identical images of objects (B). Participants then fixated the central object, which triggered the display of averted gaze (C). Finally, a target letter appeared on one of the two faces (e.g. the Joint attention face, D) to which participants made speeded manual identification pressing the 'H' or space bar keys to indicate the presence of the letter 'H' or 'N', respectively. In this example, the Joint attention face is to the right of centre. Stimuli are not to scale.

**Results**

**Accuracy.** Analyses were identical to Experiment 6. Participants responded correctly on 96.17% of trials ($SD$ = 3.58%). There was no main effect of Target Location or SOA, $Fs(1,31)<1$, but there was a significant interaction, $F(1,31)=6.48$, $p=.016$, $\eta^2_p$ = .173, due to slightly lower accuracy for the shorter SOA at the Joint Attention location ($M$=

95.1%) than at the Single-cued location (*M*=97.0%), whereas the reverse was the case at the longer SOA (Single-cued; *M*=96.0%, Joint attention; *M*=96.6%).

**Reaction times.** Again, the same analyses as Experiment 6 were applied. 1.4% of trials were discarded as outliers. The main effect of Target Location was significant, $F(1,31)=4.45$, $p=.043$, $\eta^2_p=.13$, due to significantly faster responses at the Joint attention (589ms), versus Single-cued face (599ms) location. There was a significant main effect of SOA, $F(1,31)=114$, $p<.001$, $\eta^2_p=.79$. The interaction was not significant, $F(1,31)<1$. Like Experiment 4, responses were not significantly faster towards the Joint Attention face at the 100ms SOA, $t(31)=-1.398$, $p=.172$, $dz=.25$, but did reach significance at the 400ms SOA, $t(31)=-2.058$, $p=.048$, $dz = .36$.

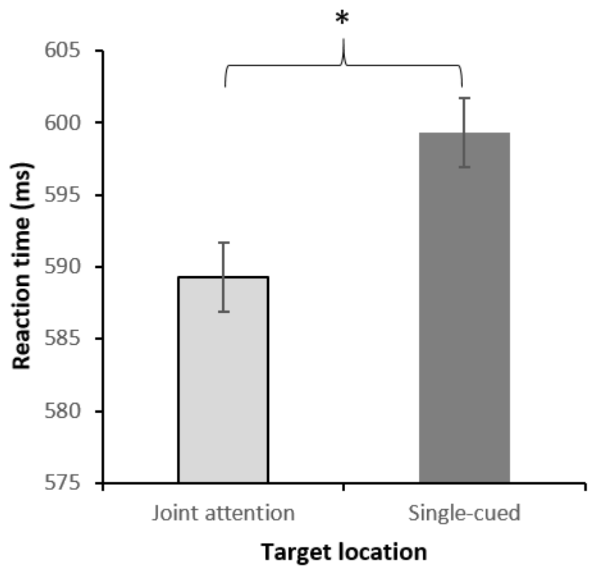


*Figure 14.* Mean reaction times (RT) for correctly identified targets in Experiment 7, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Mason, 1994). Asterisk denotes p=.043.

**Relationship between gaze leading effect (RTs) and autism-like traits.**

In this experiment, as well as Experiments 4-6, participants completed a self-reported measure of autism-like traits (AQ; Baron-Cohen et al., 2001). Prevalence of autism-like traits has previously been associated with the magnitude of gaze cueing an individual will display in response to observing averted gaze (e.g. Bayliss & Tipper, 2005). Here, we were similarly interested in assessing whether attention orienting during gaze leading would correlate with participant’s self-reported autism-like traits.

None of the individual experiments revealed significant correlations between AQ and attentional orienting towards faces that follow participant's gaze: Experiment 4, *r*=-.07, *n*=33, *p*=.69, two-tailed; Experiment 5, *r*=-.21, *n*=32, *p*=.25, two-tailed; Experiment 6, *r*=-.21, *n*=32, *p*=.25, two-tailed, Experiment 7, *r*=-.21, *n*=32, *p*=.26, two-tailed.

However, it is noteworthy that in all 3 experiments that have reliably illustrated the gaze leading effect (Experiments 5-7), the direction of the correlation, while not being statistically reliable, has been consistent. Further, the sample sizes that we used here (N=~30), which were chosen to detect a behavioural effect at the group level, may be insufficient to appropriately conclude on such correlational analyses (see VanVoorhis & Morgan, 2007). Thus, we collapsed the data across experiments 5-7, which each showed the gaze leading effect reliably at the group level, in order to increase our power for the correlational analysis. We note with caution, given the exploratory nature of this analysis, that combining the data of Experiments 5-7 revealed a significant negative relationship, *r* =-.22, *n*=96, *p*=.03, two-tailed, such that participants with more self-reported autism-like traits showed less orienting of attention towards faces that follow their gaze.

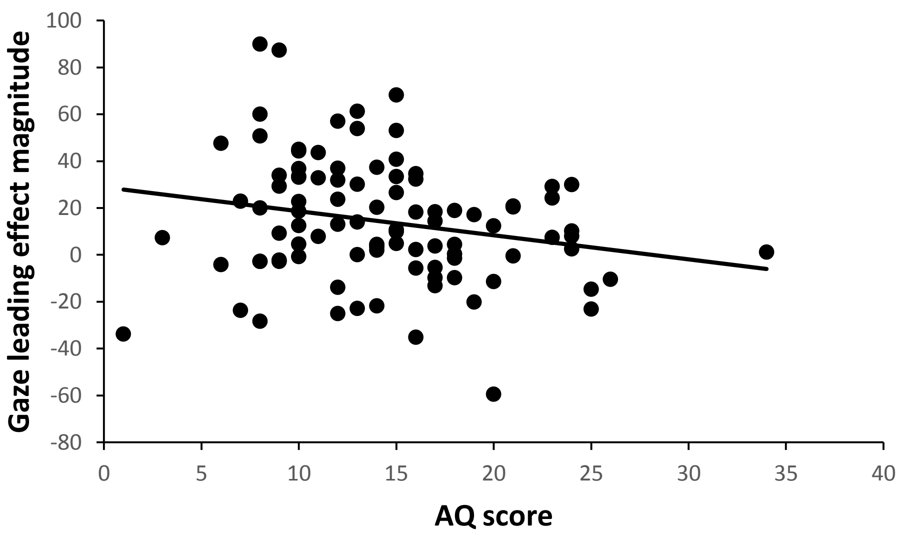


*Figure 15.* Correlation between gaze leading effect magnitude (RT to single-cued targets minus RT to Joint attention targets) and AQ score.

**Discussion**

Responses to identify targets were again fastest when those targets appeared on the Joint attention face, thereby again replicating the gaze leading effect. In this experiment, both onscreen faces looked in the same direction and towards a visually identical image of an object. However, only the Joint attention face looked at the same object that the participants had first fixated. Therefore, it appears that the response time facilitation for identifying targets that appear on faces that follow participants' gaze, the gaze leading effect, is not due to the attentional capture of seeing an onscreen face look towards an object per se, but rather reflects the attention system prioritising faces that follow gaze.

As this paradigm now includes 3 visually identical objects, future research could look to vary which object participants fixate. Indeed, the results of Chapter 2 suggest that the eccentricity of the fixation position may be important to how the surrounding stimuli are perceived. Therefore it will be of interest to assess whether the gaze leading effect occurs towards a face that is looking at the same object as the participant, regardless of which object (central or not) the participant fixates.

Interestingly, just as in Experiment 6, the gaze leading effect was not reliable at the early (100 ms) SOA, but was at the longer (400 ms) SOA. It is still unclear as to why this pattern would differ to that of Experiment 5, where the gaze leading effect was reliable at both SOA's, but future work may consider whether the number of potential target locations influences the observability of the gaze leading effect at various SOA's. However, it is noteworthy that the difference between SOA's in both experiments are small, and not qualified by an interaction. Therefore, it is perhaps more appropriate to view the currently accumulating evidence (Experiments 5-7) as being potentially interesting but highly inconclusive regarding the time course of the gaze leading effect.

Employing three iterations of the same paradigm, the gaze leading effect has now been shown to replicate. Therefore, it is possible to be more confident in suggesting what an effect might imply. Given the social and developmental importance of joint attention (Mundy et al., 2007; Emery, 2000 for review), we had predicted that it could be beneficial for individuals to be vigilant towards the success of their joint attention initiation attempts. Thus, the present results may imply the existence of an attentional mechanism present in humans that prioritises orienting towards those that have followed our gaze. Orienting in this manner would promote the elaboration of joint attention, where only the follower knows that both agents are gazing at the same referent, into shared attention, where the gaze leader also becomes aware of the shared attentional focus.

If someone does not efficiently detect that another agent has attempted to engage with them, by following their gaze, they may be less likely to appropriately continue with the developing, iterative, interaction. Thus, it is particularly interesting that when the 3 experiments that each showed a reliable gaze leading effect at the group level (Experiments 5-7) are collapsed, a statistically reliable correlation emerges between the gaze leading effect and AQ. This indicates that participants with higher AQ scores showed weaker attentional orienting towards the joint attention face, than those with lower scores. Such a relationship has been noted before between gaze *cueing* and the AQ (Bayliss & Tipper, 2005), but social attention deficits in ASC may be more pronounced in *initiating* joint attention than gaze following (Mundy, 2003) and so further examination of the gaze leading effect with regards to autism-like traits, as well as importantly also looking at clinical populations, may prove particularly informative.

Correlating the gaze leading effect with the subscales of the AQ reveals only one significant correlation: Attention switching correlates with the joint attention effect ($r=-.31$, $n=96$, $p<.001$), whereby participants scoring higher on ‘attention switching’, which denotes problematic behaviours, oriented less towards the joint attention face. None of the other subscales showed a significant correlation (Attention to detail, $r=-.06$, $n=96$, $p=.561$; Communication, $r=-.12$, $n=96$, $p=.244$; Imagination, $r=.02$, $n=96$, $p=.850$; Social skills, $r=-.19$, $n=96$, $p=.064$). Taken together, this points to the gaze leading effect relating most strongly to an attention effect, but the approaching trend of the social skills subscale may also suggest that future work should consider the social aspects of gaze leading too.

It is also notable that the average AQ score was quite low ($M=14.34$, $SD=5.65$). Therefore, it is important that future work replicates the current finding with high AQ samples before making strong claims about the link between self-reported autism-like traits and the gaze leading effect, especially as findings relating to typical populations using the AQ are often suggested as likely related to behaviours associated with ASC. Thus, we would expect to see the general pattern continue in a higher AQ group whereby they would on average show a weaker gaze leading effect. Finally, given that the current correlation reaches significance with effectively a low-AQ sample could suggest that this association will prove to be robust.

While the gaze leading effect appears to genuinely reflect attention orienting towards those that follow our gaze, there remains questions about how social this reported effect is. The gaze leading effect has only been produced during tasks requiring participants to engage in actively initiated, object centred interactions, which may suggest this is an effect that is highly sensitive to the social context of the interaction. However, it would also be interesting to assess whether or not this effect is a specific response to gaze.

### Experiment 8: Gaze leading effect and arrows

Arrows are often used as analogous, less social, cues with which to compare gaze based social orienting (e.g. Bayliss & Tipper, 2005). Indeed, gaze and arrows may be interpreted in a domain general manner (Böckler et al., 2014; Tipples, 2002; Tipples, Johnston & Mayes, 2012), both producing strikingly similar cueing of attention (see Frischen et al., 2007 for review). Such illustrations have relied on presenting the cueing stimuli, gaze cueing faces or arrows, centrally (e.g. Bayliss & Tipper, 2005). There appears to be only a couple of investigations that have used non-central arrows (Ristic et al., 2002; Tipples, 2002). Ristic and colleagues presented arrows to the left and right of fixation that would both point upwards or downwards, finding that responses were faster to targets appearing in cued, verses uncued, locations. Thus, arrow cues that are non-central were shown to cue attention, but notably these cues were positioned in a less-than-usual manner.

However, one experiment has illustrated that non-central arrows that are presented to the left or right of fixation can cue attention to the left and right of space (Tipples, 2002). Indeed, across two experiments Tipples (2002) varied a number of stimuli features in order to shown that such arrows do cue attention and that his findings cannot be accounted for by any low-level stimuli features or sudden onset capture of attention. Thus, it appears that non-central arrows can cue attention, but research showing such is limited.

Given the similarity in cueing elicited by arrows and gaze, it may be plausible that replacing the faces in our gaze leading paradigm with arrows would lead to similar results whereby attention would shift towards an arrow that points towards where the participant is fixating. Conversely, the gaze leading effect could be a special case of attention orienting that is specific to eye-gaze. Indeed, the experiments in Chapter 3 showed that the gaze leading effect is reliant on participants perceiving the interaction as gaze leading – attention did not preferentially orient towards followers if, for example, there was not an ecologically valid shared referent available. It may therefore not be surprising if participants do not experience an arrow that points to where they are looking as ‘gaze leading’.

In order to assess how attention operated in a gaze leading episode in which arrow stimuli ‘responded’ to participants gaze, we replicated the gaze leading paradigm but replaced the faces with horizontal lines positioned approximately comparable to the eye region of the faces (see Figure 16). This experiment was conducted chronologically prior to Experiment 6, thus four possible target locations were retained. Thus, participants would make a saccade towards and fixate a central object and subsequently the 2 centremost lines were presented as arrows pointing in the same direction, leftwards or rightwards, such that one arrow would point towards the central object, while another would point away from the object that the participant was fixating.

**Method**

Thirty-one adults (Age; *M*=19.6 years, *SD*=3.8 years; eight males) took part. The same stimuli set-up as Experiment 5 were used with the alteration that the face images were replaced by horizontal lines that at each end were bisected by a shorter vertical line (see Figure 16), which were positioned to be comparable to the position of the eyes on the on-screen faces in previous experiments. This experiment was conducted chronologically prior to the other experiments in this chapter, directly after experiment 5 was conducted. Thus, 4 target locations are retained in this experiment. In place of on-screen averted gaze triggered by the participant's fixation of the central object, the two vertical lines at each end of the horizontal line, at each of the two centre-most locations, were replaced by arrow-heads, thus making the on-screen line appear as an arrow (see Figure 16). The design and procedure were identical to Experiment 5, except that the on-screen gaze was now replaced by pointing arrows. Thus, comparable to the joint attention face in previous experiments was an arrow pointing towards the object that the participant was fixating, while the Single-cued face was represented by an arrow pointing away from the central object.

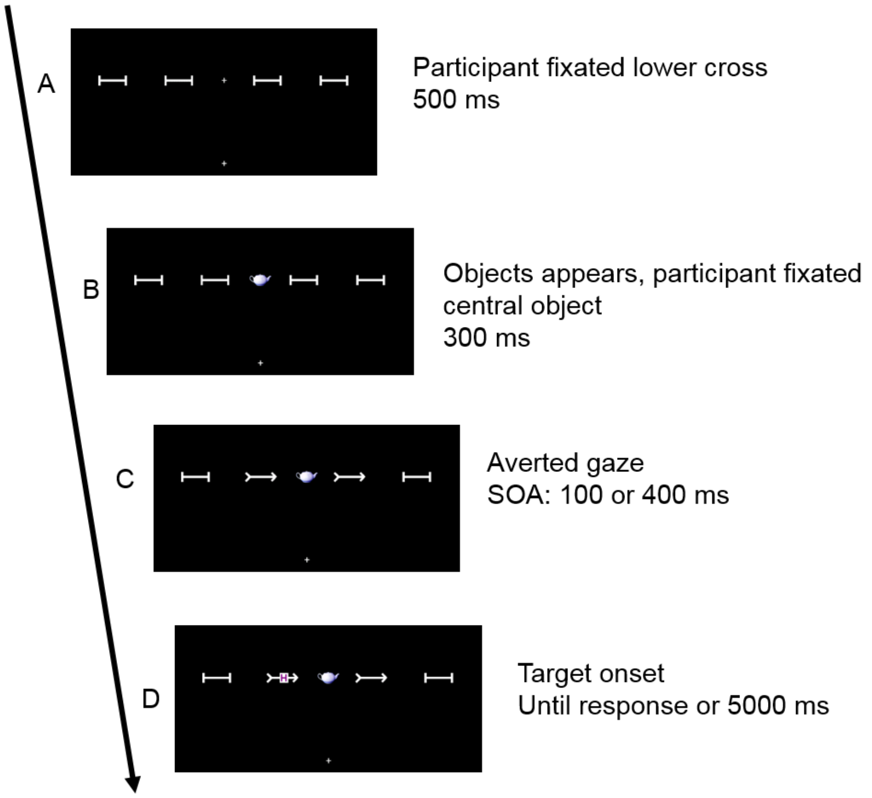


*Figure 16.* Example trial from Experiment 8. Participants first fixated the lower cross (A), which triggered the appearance of the image of the object (B). Participants then fixated the object, which triggered the display of pointing arrows (C). Finally, a target letter appeared on one of the four arrows (e.g. the Joint attention arrow, D) to which participants made speeded manual identification pressing the 'H' or space bar keys to indicate the presence of the letter 'H' or 'N', respectively.

## Results

**Accuracy.** On average correct responses were made on 97.64% of trials (*SD* = 0.68%), see Table 3. A 4 (Target Location) × 2 (SOA) repeated measures ANOVA showed no significant effects of SOA, $F(1,30)=.108$, $p=.745$, $\eta^2_p=.004$. There was a significant effect of Target location, $F(3,90)=6.40$, $p=.001$, $\eta^2_p=.18$. The target location × SOA interaction was not significant, $F(3,90)=.353$, $p=.787$, $\eta^2_p=.01$. Follow-up 2 × 2 ANOVAs were conducted as so to be comparable with the RT analysis. For the inner-most locations there were no significant effects (F's<.8, p's>.36). For the outer two locations there was also no effect of SOA or interaction (F's<.22, p's>.64). The main effect of condition also did not reach significance, $F(1,30)=3.18$, $p=.085$, $\eta^2_p=.10$.

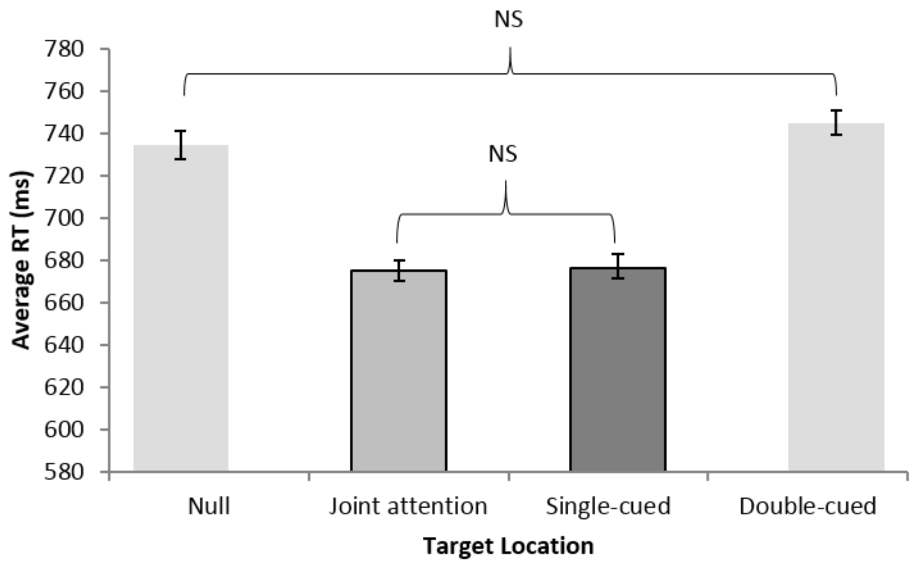


*Figure 17.* Mean reaction times (RT) for correctly identified targets in Experiment 8, by target location. Error bars represent within-subjects standard error of the mean (Loftus & Mason, 1994). NS= non-significant.

**Reaction times.** A 4 × 2 ANOVA revealed a significant main effect of Target Location, $F(3,90)=64.5$, $p<.001$, $\eta^2_p=.68$. The main effect of SOA was also significant, $F(1,30)=24.5$, $p<.001$, $\eta^2_p=.45$ (see Table 3). The Target Location × SOA interaction was not significant, $F(3,90)=.435$, $p=.728$, $\eta^2_p=.01$. To interpret these effects, follow-up 2 × 2 ANOVAs on performance at inner and outer target locations were conducted separately. For innermost targets, RTs at the Single-cued location and Joint attention location were not significantly different, $F(1,30)=.069$, $p=.795$, $\eta^2_p=.002$ (see Table 3). RTs were significantly faster at the longer (664ms) than shorter (687ms) SOA, $F(1,30)=9.53$, $p=.004$, $\eta^2_p=.24$. There was no significant interaction, $F(1,30)=.132$, $p=.719$, $\eta^2_p=.002$. The same 2 × 2 ANOVA for the outermost target locations revealed the same pattern of results: SOA, $F(1,30)=15.34$, $p<.001$, $\eta^2_p=.34$; target location, $F(1,30)=3.05$, $p=.091$, $\eta^2_p=.09$; interaction, $F(1,30)=1.09$, $p=.304$, $\eta^2_p=.04$.

**Relationship between orienting of attention to arrows and AQ.**

Participants magnitude of orienting in response to peripheral arrows showed no correlation with their AQ score, $r=.078$, $n=31$, $p=.68$, two-tailed.

**Discussion**

Here, the arrow cues appeared to have no systematic influence on participants' attention. Thus, the gaze leading effect was not replicated with arrow stimuli. Having an arrow point towards an object to which you have reoriented did not capture attention. This suggests that the arrow stimuli were not being processed in the same way as the face stimuli of Experiment 5, 6 and 7. This may indicate that unlike standard gaze cueing effects, to which arrows appear to be able to produce comparable responses (see Frischen et al., 2007 for review), the gaze leading effect may be a social orienting phenomenon specific to eye-gaze.

It could be interpreted as surprising that the current stimuli did not produce cueing of attention in the direction that arrows were pointing (e.g. Posner, 1980; Tipples, 2002). However, it could be argued that the attentional response to non-central arrows is not well established, given the paucity of related research (but see Ristic et al., 2002; Tipples et al., 2002). Thus, as there is only limited evidence with which to compare the present findings any conclusions regarding the current experiment are made with caution.

Regarding the present use of arrows, it is notable that the stimuli used in the current work may have produced the perception of apparent motion in the reverse direction to which they pointed. As the vertical lines that bookended the centremost horizontal lines were replaced by arrow heads (see Figure 16), participants may have perceived motion in the opposite direction to which the arrows pointed. Therefore, as well as generally further investigating attention orienting in response to peripheral arrows, future work should also look to assess the possible influence of different arrow stimuli in both cueing and gaze leading paradigms.

While the current data may suggest that the gaze leading effect is an orienting response that only eyes can elicit, future work may wish to further investigate its social specificity. For example, is this phenomenon restricted to eye-gaze stimuli, or does it extends to other biologically relevant cues? Pointing gestures are used to indicate desired objects (see Emery, 2000) and are linked to early social communication and joint attention behaviours (Carpenter et al., 1998). Further, pointing hands can influence attention allocation (Langton & Bruce, 2000) and participants also appear to respond to the intent of the gesture, paying attention to objects that are pointed at but paying less attention to objects that look like they are going to be grasped by another person (Fischer &

Szymkowiak, 2004). However, pointing hands are visually dissimilar to eye-gaze cues. Thus, pointing hands may offer an appropriate means by which to assess whether the gaze leading effect is specific to social information related to joint attention, or more specifically to eye-gaze.

## General discussion

The experiments presented in this chapter add to our understanding of the newly illustrated gaze leading effect, which was first presented in the previous chapter (Experiment 5). Firstly, and perhaps most importantly, Experiments 6 and 7 both replicated the gaze leading effect. Therefore, we can be much more confident in making claims about the existence, and potential importance of, this novel gaze-based orienting phenomenon.

Participants rapidly oriented attention towards faces that followed their gaze. These results can be interpreted as suggesting that there is a mechanism in the human attention system that prioritises the allocation of attention towards individuals that successfully respond to our joint attention initiations. Importantly, orienting in this manner would promote the elaboration of joint attention, where only the follower knows that both agents are gazing at the same referent, into shared attention, where the gaze leader also becomes aware of the shared attentional focus (Emery, 2000). Just as shared attention may be uniquely human (Moll & Tomasello, 2007), so too may the gaze leading effect be an orienting response that only humans produce. However, this is a proposition for future comparative researchers to consider.

Experiment 6 showed that the gaze leading effect replicates when there are only two onscreen faces (as opposed to four in Experiment 5). Importantly, this validation of our paradigm will allow for future research to assess a number of possible contributing factors regarding the faces that do or do not gaze follow. Now that there are only two faces displayed, the paradigm is more suitable to vary facial features or identity specific information regarding the faces that participants interact with. For example, it may be interesting to assess how the perceived dominance of the follower, and the self-perception of the gaze leader, is influenced by successful or unsuccessful gaze leading – speculatively; subordinates follow the gaze of more dominant conspecifics (Chance, 1967; Shepherd et al, 2006), and thus it may be possible that the gaze leader would feel empowered based on consistently having their gaze followed.

Previous research has illustrated that both the congruency (whether or not one's gaze is followed) and contingency (the latency of the response after one's own gaze reorienting) can be crucial to how that interaction is interpreted (Pfeiffer et al., 2011, 2012). Indeed, the contingency of a response can be crucial to how the gaze leader interprets a response of another agent irrespective of whether joint attention occurs or not

(Pfeiffer et al., 2012). It is therefore interesting to consider whether the gaze leading effect can be viewed as an attention bias towards someone whose behaviour we have influenced. Indeed, in justifying the inclusion on gaze-contingent initiation into the paradigm, this thesis suggests that the contingency of the gaze following response is likely crucial to the gaze leading effect, as evidenced by the lack of a gaze leading response in non-contingent scenarios (Experiment 3). However, in the gaze leading paradigm used here both the Joint attention face and the Single-cued face make gaze-contingent responses to participant's gaze, and do so with the same latency. Thus, while the gaze leading effect of attention orienting towards an agent that follows gaze is likely in part due to a response being contingent to one's own behaviour, it also appears that contingency alone is insufficient in accounting for the gaze leading effect, suggesting that we preferentially orient towards those whose behaviour we have influenced in a socially conducive way.

As the gaze leading effect may be related to the contingency of others' responses to our own (re)orienting of attention, future work may benefit from directly examining gaze leading in terms of social influence. Schilbach et al (2010) showed that having your gaze followed may be rewarding, and while it is possible that this reward is based on joint attention as social approach (Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008), it may also be that we find the causation of our actions rewarding (Aarts et al., 2012). Indeed, this can likely be achieved by varying the latency between a participant's attention reorientation and of the onscreen response in the current paradigm (e.g. Pfeiffer et al., 2012). Pfeiffer et al (2014) showed that the neuro-correlates of joint attention behaviours vary when a participant thinks they have effected change on another human, verses a computer algorithm has responded to their gaze (see also Pönkänen et al., 2010; Wykowska, Wiese, Prosser & Mueller, 2014 for similar findings with ERPs). Thus it will be an important avenue of future work to assess how the contingency of the response impacts the gaze leading effect, with particular emphasis on sense of agency.

Further than monitoring instances when one's behaviour has impacted their social environment, having one's gaze followed could be interpreted as having someone mimic their attentional state. Indeed imitation is important for social cognitive development (Meltzoff & Decety, 2003), and being imitated could be salient, given that a number of species recognise such instances (Haun & Call, 2008; Paukner, Anderson, Borelli, Visalberghi, & Ferrari, 2005; see also Nadel, 2002), and that being imitated necessarily implies we have been attended. However, Pfeiffer et al (2011) argue against such an interpretation due to the reward related response proposed to accompany joint attention initiation (e.g. Schilbach et al., 2010), noting that once one notices they are being mimicked any associated reward will diminish (Thelen, Frautschi, Roberts, Kirkland & Dollinger, 1981). The role of imitation within the gaze leading effect may therefore be seen as an interesting avenue for future work. It may, for example, be interesting to assess the relative salience of agents that mimic participant's overt orientation verses mimicking the intent of that reorientation.

If the effects that we have on our social environment are not appropriately detected, we may be less able to maintain, or modify, our behaviour appropriately. For example, the gaze leading effect may be important for communication and cooperation (Moll & Tomasello, 2007) in that it allows one to realise that an attempt to interact has occurred. It is therefore interesting that the collapsed data of the three experiments that each showed a gaze leading effect at the group level (Experiment 5-7) revealed a negative correlation with AQ (and specifically the Attention switching sub-scale), such that those with more self-reported autism-like traits showed less orienting towards faces that followed their gaze. Therefore, an important task for future work is to assess how this gaze leading effect operates within clinical populations that are known to have disrupted spontaneous social orienting (e.g. ASC, Jones & Klin, 2013, and neuropsychological patients, Adolphs, 2005; Wolf, Philippi, Motzkin, Baskaya, & Koenigs, 2014). If noticing successful gaze leading is indeed impaired within such clinical populations, it will then be a challenge for future work to assess whether cognitive bias modification tasks (see Hertel & Matthews, 2011 for review) can 'teach' this orienting response by repeatedly drawing attention towards the gaze following face.

To conclude, it appears that the gaze leading effect reflects an attentional mechanism that propagates the establishment of shared attention. This effect appears to be rooted in the attentional capture of others responding to our own reorienting of attention, and is possibly specific to social stimuli. Such a social orienting responses could be critical for monitoring how we have impacted our social environment and thus our ability to successfully engage in iterative interactions.

# Chapter 5: Consequences of joint gaze interactions

Thus far this thesis has focused on online attentional orienting during gaze leading. However, every-day social encounters are likely to be reciprocal and iterative – we often interact with the same people multiple times, likely taking on different social roles from one interaction to the next. For example, while we may use the gaze of a friend to anticipate their actions or intentions, in a future interaction we may also expect that friend to make the same inferences based on our own current gaze direction. The importance of the latter has been reflected in a recently increased research interest in to how we interpret the impact our own social attention cues have on others (Schilbach et al., 2013). This 'second person' approach looks to assess what consequences emerge from influencing others' social attention. While there are now a number of intriguing findings regarding how we interpret having our eye-gaze followed during social interactions (e.g. Schilbach et al., 2010; Pfeiffer et al., 2011; 2012; Bayliss et al., 2013; Edwards et al., 2015), we know very little about how the quality of previous encounters may be used to inform future interactions.

The gaze leading effect, introduced in the preceding two chapters, is proposed to facilitate the detection of successful gaze leading. While noticing the success of joint attention initiation attempts could certainly be beneficial, as one could respond more quickly and appropriately an emerging interaction, it would also be of greater utility if the orienting of attention towards those that follow gaze also led to affective and behavioural changes when re-encountering individuals with whom we have previously interacted with. That is, we may benefit when interacting with a given individual if that interaction is informed by the quality of our previous interactions with that individual. For example, it may be worth giving less weight to the behaviour of someone we have previously found to be distrustful, so that we are less likely to be fooled again. Thus, it will be interesting to assess whether the gaze leading effect could potentiate learning about the individuals with whom we have interacted. For example, if we are aware that a particular individual often engages with us by following our gaze, and are therefore also aware that this gaze follower is benefiting from the information that our gaze conveys (Emery, 2000; Frischen et al., 2007), we may expect those individuals to be more likely to reciprocate in the future (Schilbach et al., 2013).

Joint gaze interactions appear to potentiate affective changes in how we perceive the other agents and objects that we have interacted with. For example, we rate as more trustworthy faces that validly cue our attention towards objects, than faces that look elsewhere (e.g. Bayliss et al., 2006, Bayliss, Griffiths & Tipper, 2009) and prefer objects that our attention has been drawn to by another agent (Bayliss et al., 2006). However, preference ratings of objects also appear to be confirmed, being more consistent, when another agent follows our gaze towards that object (Bayliss et al., 2013). However, it is not clear how or why these evaluative differences emerge. Objects are preferred if we have been able to interact with them in a fluent manner (Hayes, Paul, Beuger & Tipper, 2009), and gaze cueing allows for fluent detection of stimuli (e.g. Driver et al., 1999; Friesen & Kingstone, 1998; Hood, Willen & Driver, 1998, see Frischen, Bayliss & Tipper, 2007 for review), which may suggest a fluency based mechanism. However, there appears to be positive valence associated with initiating joint attention (Schilbach et al., 2010), while avoidance behaviours such as averted gaze are associated with negative valence (Hietanen et al., 2008; Harmon-Jones, Gable & Peterson, 2010; see also Pfeiffer et al., 2011 for discussion). Thus, it may be that the positive valence of approach behaviours of another agent and the fluent object-based interactions that this can afford contribute to the aforementioned socio-evaluative learning during joint gaze encounters.

While it appears that previous interactions with individuals can lead to learning in a socio-evaluative manner, such as developing trust rating differences, there is no evidence that the social attention system is impacted by these individuals' prior behaviours. However, it does appear that prior exposure to gazing faces can impact subsequent gaze cueing in a manner that suggest a direct link between gaze perception and social attention (see Bayliss, Bartlett, Naughtin, & Kritikos, 2011). Further, previous exposures to faces can lead to identity-specific responses later; Frischen and Tipper (2006) showed famous faces with averted gaze, which when re-shown with direct gaze appeared to elicit attentional orienting in the direction originally displayed. While this suggests identity-specific gaze information can be retrieved, it remains relatively unexplored whether social attentional orienting, and gaze perception more generally, in response to specific identities can be influenced by the quality of our previous encounters with those faces.

While joint gaze scenarios crucially involve two individuals averting their gaze towards a common referent, references towards each other are also vital (Carpenter et al., 1998). In order to follow the gaze of another the follower has by definition, at some level, 'noticed' the gaze of the person they are following (Emery, 2000). Similarly, the gaze leading effect suggests that the gaze leader will have their attention drawn towards a follower of their gaze (Edwards et al., 2015), which may facilitate looking towards that follower (e.g. Bayliss et al., 2013). Such 'checking back' behaviours are likely to assess the ongoing quality of the interaction (Carpenter et al., 1998). However, looking at someone can also signal approach (Kleinke, 1986) and capture attention of the recipient of gaze (Senju & Hasegawa, 2005), and so can be used to signal an imminent interaction (Hietenan et al., 2008). Thus, mutual gaze can been seen as an important behaviour relating to joint gaze interactions (see Emery, 2000 for review).

Both sides of the triadic interaction of joint attention have been shown to be relate to individual differences. For example, participants with more self-reported autism-like traits are cued towards objects by other agents in a different manner to those participants with lower AQ scores (Bayliss et al., 2005). Further, while a gaze leader will have their attention captured by an agent that follows their gaze, participants with higher AQ scores appear to do so less (Edwards et al., 2015). Thus, the present work implement such individual differences measures as it is highly expected that such differences in online attention orienting would be critical to how those interactions impact longer term processes.

This chapter presents three experiments that look to assess the long term impacts of interacting with reliable or unreliable joint gaze partners. Experiment 11 examines how social orienting in response to agents with whom a gaze leader has interacted with influences how those agents are able to later cue attention of the participant. First however, Experiments 9 and 10 assess how the gaze perception of faces are influenced by whether those faces have previously been reliable or unreliable gaze followers, or leaders, respectively.

## Experiment 9: Gaze leading and eye-gaze direction perception

Humans are highly adept at perceiving the gaze direction of others (e.g. Gibson & Pick, 1963; Anderson, Risko & Kingstone, 2011). Anderson et al (2011) showed that people can correctly detect and identify changes in gaze direction of as little as $1^0$ visual angle, and are highly accurate at assessing gaze direction with deviations of $3^0$ (e.g. 90% accuracy). Further, Gibson and Pick (1963) had participants judge if they were being looked at while an experimenter sat opposite them looking in a number of pre-specified directions, finding that ratings of 'being looked at' increased, as expected, as gaze was directed closer to the participant. However, while participants were capable of detecting gaze direction, the distribution of participant's responses also shifted when the looker's head was deviated, indicating that the attention cue of head orientation may be concatenated with gaze direction when assessing whether we are the recipient of gaze (Anderson et al., 2011).

Humans have a bias to think that the gaze of others is directed towards them (Mareschal et al., 2013). However, this bias to assume direct gaze is also subject to other influences. For example, individual differences in the observer (e.g. social phobia, Gamer et al., 2011; social anxiety, Schilze, Lobmaier, Arnold & Renneberg, 2013), but also by features of the faces that are being judged (e.g. attractiveness, Kloth, Altmann & Schweinberger, 2011) appear to influence the extent to which a participant will show a direct gaze bias. Kloth et al showed that participants perceive gaze as directed at themselves to a greater extent for attractive, compared with less attractive, faces, which could reflect an expectation that attractive people will approach us (George, Driver & Dolan, 2011).

It appears that no research has yet assessed whether the perception of direct gaze is influenced by the quality of our previous interactions with the individual whose gaze we are judging. We generally prefer those that engage in joint gaze with us (Bayliss & Tipper, 2006; Bayliss et al., 2013), and there appears to be specific positive connotations related to leading the gaze of others (Schilbach et al., 2010). It may therefore be plausible that such positive outcomes may lead to a greater expectation of direct gaze from specific individuals that have previously followed our gaze (e.g. Kloth et al., 2011). Further, direct gaze can be interpreted as a communicative act (Senju & Johnson, 2009), as can jointly attending with others (see Emery, 2000). Therefore one might propose that experiencing repeated engagement of one type (e.g. joint gaze) might translate to an expectation of engagement in the other (e.g. mutual gaze).

In order to assess whether the previous quality of gaze leading encounters has an impact on how the gaze leader's gaze perception system later responds to those individuals that they have previously encountered, participants completed two main experimental tasks. In the first task participants would either make a saccade towards a green peripheral cue, or an antisaccade away from a red peripheral cue. After successfully completing the required saccade, a centrally presented task-irrelevant face would 'look' towards the instruction cue. Some face identities would always appear on saccade trials, while others would always appear on antisaccade trials. Thus, the faces that appeared on saccade trials always looked towards the same referent as the participant (the green instruction cue) simulating joint gaze, while faces appearing on antisaccade trials always looked towards the red instruction cue that participants had looked away from. Then, in a second task participants made speeded identification of displayed gaze direction of the faces that they had previously encountered. We expected to find more erroneous identifications of direct gaze (reporting direct gaze when it is actually averted) for faces that had previously followed participant's gaze, compared with those that never followed.

## Methods

### Participants.

Twenty volunteers (mean age 19 years, SD 1.4, 2 men) participated for course credit or payment. All reported corrected or corrected-to-normal vision. The AQ (Baron-Cohen et al., 2001) was completed by all but one of the participants, and 18 completed the Social Phobia Inventory (SPIN, Connor et al., 2000).

### Stimuli, materials and apparatus.

Four neutral grayscale photographs (two males and two females; 9.6cm x 12.8cm) were taken from Bayliss, Bartlett, Naughtin and Kritikos (2011). Counterbalanced across participants, two of the identities (one of each gender) were designated as 'joint gaze faces', appearing only on saccade trials, with the other 2 faces appearing only on antisaccade trials. Task 2 presented the same faces with either direct gaze ($0^{o}$ aversion), averted 5 degrees to the right or left, or 10 degrees to the right or left. Note: a participant cannot *incorrectly* report a faces with $0^{o}$ averted gaze as having direct gaze, so these trials are not included in the analysis of an ‘at-me’ bias, but were included in the task so that there were in some cases the opportunity to correctly report direct gaze.

Participants completed the AQ questionnaire (Baron-Cohen et al., 2001), as in previous experiments, but here also completed a measure of social phobia (SPIN, Connor et al., 2000; see Appendix D), which consists of 17 items to which participants indicate on a 5 point scale how true each statement is to themselves.

The Eyelink 1000 (SR research) was again used to record eye movements, as in previous experiments.

**Design and Procedure.**

**Task 1.** A 2 (SOA; 1700ms, 2700ms) x 2 (Trial type; saccade, antisaccade) design was employed, with the speed and accuracy of participants eye-movements (sRT) measured. Each trial began with a central grey fixation cross (0.8° height × 0.8° width) on a black background flanked by two white square placeholders (0.8° height × 0.8° width ) placed 9.8° rightwards and leftwards from the cross. Participants were asked to fixate on the cross and press the space bar once they had achieved fixation, which performed a drift correction and ensured correct fixation. After six hundred milliseconds, the fixation cross was replaced by a central face with direct gaze (11° height × 8° width) for either 1700 ms or 2700 ms (SOA). Next, one of the placeholders would change colour (red on antisaccade trials, green on saccade trials) and participants had to fixate the correct placeholder for 500 ms, which triggered the on-screen faces to be presented with averted gaze (500 ms) towards the coloured placeholder. Thus, on saccade trials, the onscreen face has gaze-followed the participant, whereas on antisaccade trials gaze-following did not occur. There were 2 blocks of 80 trials, with each trial type being presented an equal number of times, in a random order, per block. Participants were instructed to move their eyes as quickly and as accurately as possible and to ignore the faces.

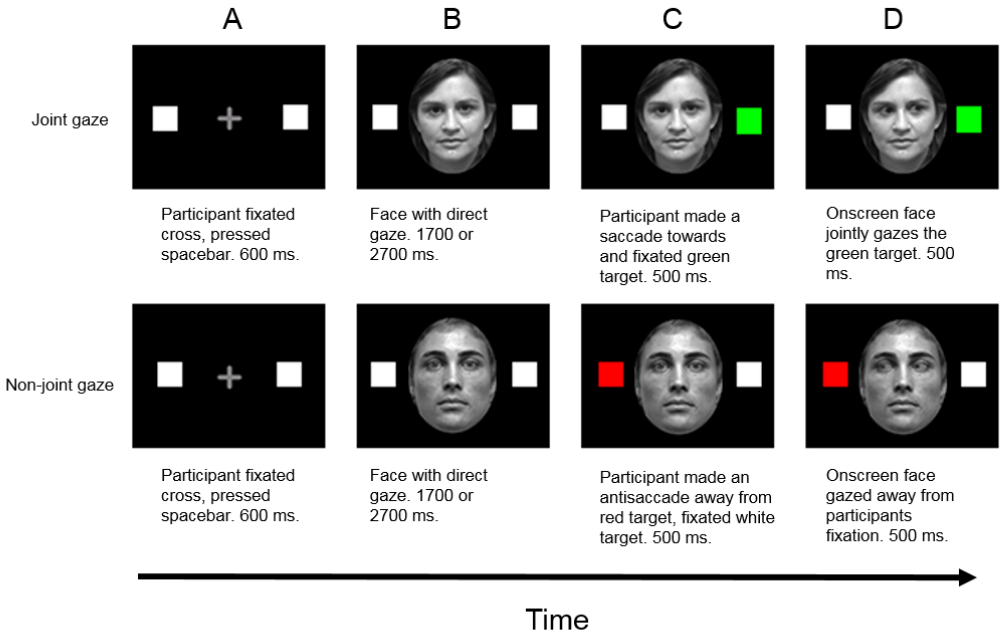


*Figure 18.* Example trials from Experiment 9, task 1. Participants first fixated the cross and pressed the spacebar (A). 600 ms later, a face was displayed for 1700 or 2700 ms (SOA) with direct gaze (B). On joint gaze trials one of the placeholders turned green (upper panel), to which participants saccaded and fixated the green target for 500 ms, which triggered the onscreen face to display averted gaze also towards the green target (D). For non-joint gaze trials the sequence was identical (e.g. A, B) except that the target was red, to which participants made an antisaccade away from, fixating the opposite place holder for 500 ms (C), which triggered the onscreen gaze to 'look' away from the participant's fixation and towards the red target. Stimuli are not to scale.

**Task 2.** A 2 (face type; joint gaze, non-joint gaze) x 2 (degree of averted gaze; $5^o$, $10^o$) design was used, with the percentage of trials in which participants incorrectly indicated they thought the gaze direction was directed 'at them' of interest. Each trial started with a central grey fixation cross, presented on a black background for 500 ms. Next, one of the faces from task 1 was shown for 500 ms with either direct gaze, averted by 5 degrees or averted by 10 degrees. Each of the 4 face identities were shown with each of the 5 gaze directions and equal number of times in a randomised order, across 280 trials. Participants were told to respond as quickly and accurately as they can by indicating the gaze-direction of the face pressing the '1', '2' or '3' key's, to indicate leftward, direct, or rightward gaze, respectively, with their index, middle and third finger of their preferred hand.

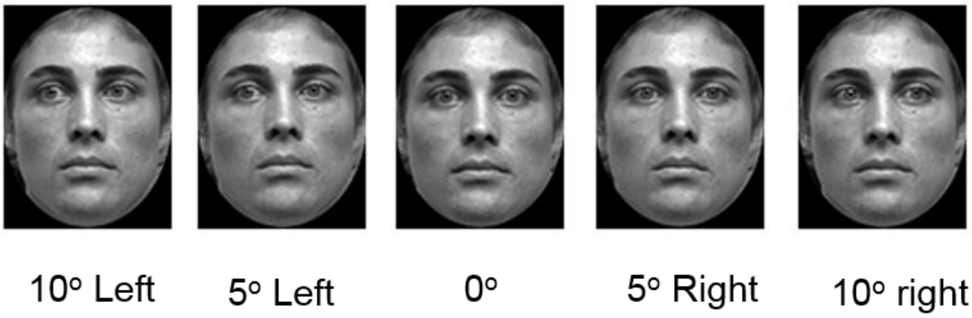


*Figure 19.* Example stimuli from Experiment 10, task 2. One face was displayed centrally, displaying one of five gaze direction; direct at participants (zero degrees deviation), deviated by five degrees to the left or right, or deviated by ten degrees to the left or right. Each face was displayed for 500 ms, during which time participants made speeded identification of gaze direction pressing the '1', '2' or '3' key to indicate leftward, direct or rightward gaze, respectively.

**Results**

**Task 1.** The task 2 data is of primary interest. However, it is first important to inspect the task 1 data to ensure that the saccade/ antisaccade task was successfully manipulating the participants' eye-gaze fluency. Eye movement onset latency was defined as the time that elapsed from the instruction cue (colour change of the placeholder) to the initiation of the first saccade/antisaccade. The first saccade/antisaccade was defined as the first eye movement with a velocity exceeding 35°/sec and an acceleration exceeding 9500°/sec$^2$. Only saccades/antisaccades with a minimum amplitude of 1° were analysed (for a similar procedure, see Kuhn & Tipples, 2011). Trials containing blinks (2.18 % of trials) were removed. Errors, namely trials in which the first saccade/antisaccade was in the opposite direction according to the instruction cue (12 % of trials), were excluded from RT analysis and analysed separately. Outliers, defined as trials in which sRT were 3 standard deviations above or below participant's mean (2.37 % of trials), were discarded from analysis.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 1700 ms vs. 2700 ms) as within-subjects factors. The main effect of task was significant, $F(1,19) = 10.83$, $p = .004$ , $\eta^2_p = .363$, with more errors on antisaccade trials ($M$ = 7.91 %, $SD$ = 7.19 %) than on saccade trials ($M$ = 3.50 %, $SD$ = 4.05 %). Neither the main effect of

SOA nor the Task × SOA interaction approached statistical significance (*F*s < 1.49, *p*s > .238).

The equivalent ANOVA on the sRT data revealed a significant effect of trial type, $F(1,19) = 35.90$, $p < .001$, $\eta^2_p = .654$, with faster eye movements on saccade (307 ms), than antisaccade (343 ms) trials. There was also a significant effect of SOA, $F(1,19) = 24.41$, $p < .001$, $\eta^2_p = .562$, due to faster eye movements when the SOA was longer (312 ms) than shorter (339 ms). The trial type x SOA interaction was also significant, $F(1,19) = 6.484$, $p = .020$, $\eta^2_p = .254$, due to sRT advantage of saccade trials being larger at the shorter, than longer, SOA.

**Task 2.** A 2 (trial type; saccade, antisaccade) x 2 (Degree of averted gaze; 5 degrees, 10 degrees) ANOVA was conducted on the proportion of trials in which participants incorrectly indicated that the on-screen gaze was directed at them – pressing ‘2’ to indicate ‘direct gaze’ – when in fact the on-screen gaze was averted. There was not a reliable difference in the number of errors made to each type of face (23% of trials for Joint gaze faces, 24% of trials for non-joint faces), $F(1,19) = 1.815$, $p = .194$, $\eta^2_p = .087$. There was, as expected, significantly more errors when the on-screen gaze was averted by 5 degrees (38%) than by 10 degrees (10%), $F(1,19) = 144.6$, $p < .001$, $\eta^2_p = .884$. there was no interaction, $F(1,19) = .075$, $p = .787$, $\eta^2_p = .004$.

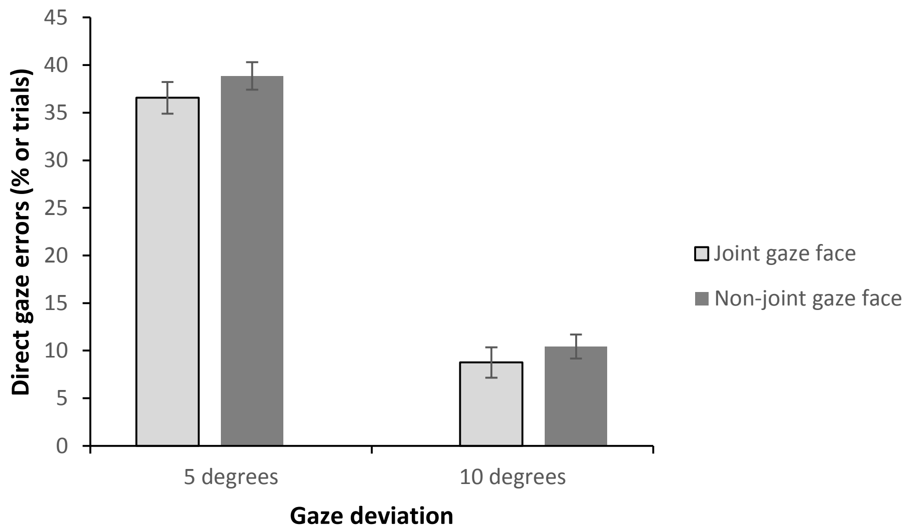


*Figure 20.* Experiment 9: percentage of trials in which participants incorrectly identified the displayed averted gaze as being directed at themselves, divided by gaze deviation and face type.

**Questionnaires.** Participants completed two questionnaires; the AQ and the SPIN. Here, neither participants self-reported autism-like traits, measured by the AQ, $r(19)=-.30$, $p=.22$, nor their self-reported social phobia level, as measured by the SPIN, $r(18)=-.10$, $p=.70$, correlated with participants sensitivity to the type of face they were judging the gaze of (antisaccade face 'at-me' errors minus saccade face 'at-me' errors).

## Discussion

There was no difference in direct gaze responses between faces that had and faces that had not previously followed participant's gaze. Further, neither of the individual differences measures (SPIN, AQ) revealed an association with participant's sensitivity to the type of face they were encountering. Thus this data suggests that the perceptual system that modulates our expectation of being looked at is not sensitive to whether or not an individual has previously been a reliable gaze follower.

There are a number of associated outcomes related with successful, verses unsuccessful, gaze leading. For example, successfully leading gaze leads to better recognition of the looked at objects (Kim & Mundy, 2012), can capture the participants' attention (Edwards et al., 2015) and also has been associated with a more rewarding experience (Schilbach et al., 2010). Therefore it can be seen as somewhat surprising that here there was no differentiation of whether an agent had or had not previously followed gaze by participants.

However, it is as yet unclear whether direct gaze perception can be modulated by previous encounters or identity-specific information. Thus, the present null findings could either reflect that gaze leading is a behaviour that does not influence the gaze perception of those we have previously encounters, or that the gaze perception system is generally insensitive to information regarding specific individuals.

There may be methodological constraints contributing to the current null finding. For example, the face stimuli (see Figure 19) were primarily chosen for convenience as the set included faces displaying the gaze directions that were necessary for this study. However, these faces displayed neutral expressions, which may have limited the learning associated with them (Bayliss et al., 2009). Therefore, future work may wish to assess whether faces with a more positive emotional expression can lead to a reliable difference in direct gaze perception based on prior gaze leading encounters. However, Kloth et al., (2011) showed that participants generally rate faces with positive emotional expressions, compared with faces with less positive expressions, as looking at them, which any such future work should also consider.

When considering joint gaze encounters, it can be informative to compare the processes of both gaze leading and gaze following (Mundy & Newell, 2007; Redcay et al., 2012; Schilbach et al., 2010). As the current experiment manipulated gaze leading, it may therefore be appropriate to compare this to the gaze perception consequences, if any, that relate to gaze following.

## Experiment 10: Gaze cueing and eye-gaze direction perception

It is not clear whether measuring participants perceptions of direct gaze can be used to illustrate impacts of previous encounters. In the previous experiment (Experiment 9) no reliable differences in direct gaze perception emerged based on prior gaze leading interactions with individuals that always had, or had not, followed participants gaze. In order to assess whether direct gaze perception is genuinely unaffected by previous social encounters, or whether other interactions can influence the gaze perception system, here we had participants take part in a gaze following task prior to judging the gaze direction of the faces they had followed. That is, rather than leading gaze in task 1, participants were following the gaze of faces that would be consistently valid or invalid cuers. Thus, compared with Experiment 9, this experiment was interested in the other side of joint attention, placing participants as the *responder*.

While the experiences of both the gaze leader and gaze follower of a joint gaze interaction are necessarily distinct (Emery, 2000; Mundy & Newell, 2007) which is reflected by different neural responses to each role (Schilbach et al., 2010), they are two sides of the same interaction and can both lead to affective and attention related modulations (Driver et al., 1998; Frischen et al., 2007; Bayliss et al., 2013, Edwards et al., 2015) and share some neuro-correlates (see Mundy & Newell, 2007; Redcay & Saxe, 2013; Caruana et al., 2015). Further, although recent findings regarding gaze leading (e.g. Schilbach et al., 2010; Bayliss et al., 2013; Edwards et al., 2015) are directly informative, they are especially so in the context of what we already know regarding joint gaze from work on gaze cueing (see Frischen et al., 2007 for review): being able to compare outcomes of gaze leading and gaze following allows us to further establish how distinct these two experiences are.

Thus, we replicated Experiment 9, with the alteration that in task 1 participants would make their eye-movement *after* the on-screen face. Participants were therefore experiencing two identities who would always 'look' to where they needed to saccade, while the other two would always 'look' away from the participant's subsequent saccade target. Then, participants identified the gaze direction of each face as in the previous experiment. This allowed us to assess whether the perception of direct gaze in the gaze follower of a joint gaze scenario is influenced by the quality of their previous gaze-based encounters.

## Methods

### Participants.

Twenty volunteers (mean age 21 year, SD 6.7, 4 men) took participated for course credit or payment. All reported corrected or corrected-to-normal vision. The AQ was completed by all participants, with 15 also completing the SPIN.

### Design.

**Task 1.** The design of task 1 was identical to that of task 1 from Experiment 9, except that now the on-screen gaze would be displayed as averted prior to the participant's cue being shown. Therefore the SOA's were adjusted so that the faces were shown for a comparable time to that of Experiment 9. Thus, there was a 2 (SOA; 200ms, 1200ms) x 2 (Trial type; saccade, antisaccade) design, again with the speed and accuracy of participants eye-movements (sRT) being of interest.

**Task 2.** Task 2 was identical to that of Experiment 9: A 2 (face type; joint gaze, non-joint gaze) x 2 (degree of averted gaze; $5^o$, $10^o$) design was used, with the percentage of trials in which participants incorrectly indicated they thought the gaze direction was directed 'at them' of interest.

**Stimuli and materials.**

Identical to experiment 9.

### Procedure.

**Task 1.** Each trial began with a central grey fixation cross (0.8° height × 0.8° width) on a black background flanked by two white square placeholders (0.8° height × 0.8° width ) placed 9.8° rightwards and leftwards from the cross. Participants fixated on the cross and press the space bar, which ensured correct fixation and preformed drift correction. After six hundred milliseconds, the fixation cross was replaced by a central face with direct gaze (11° height × 8° width) for 1500 ms. Next, the face would display averted gaze to the left or right for either 200 ms or 1200 ms (SOA). Then, the placeholder that was 'looked' at by the on-screen face would change colour (red on antisaccade trials, green on saccade trials). Participants then made speeded saccades towards the green placeholder (saccade trials) or away from the red placeholder (antisaccade trials). 500 ms fixation of the correct placeholder ended the trial. There were 2 blocks of 80 trials, with each trial type being presented an equal number of times, in a random order, per block. Participants were instructed to move their eyes as quickly and as accurately as possible and to ignore the faces and gaze direction.

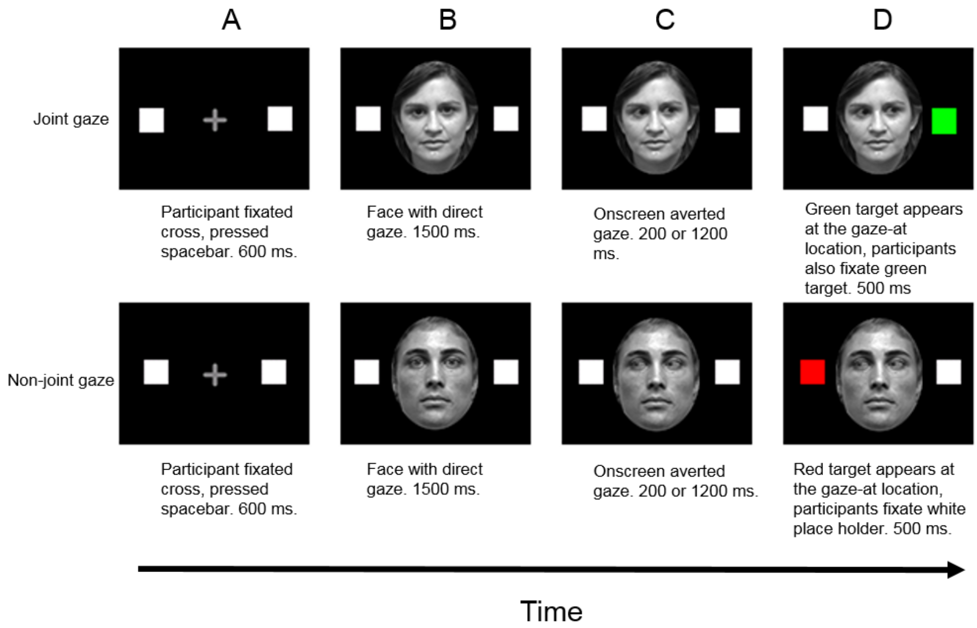


*Figure 21.* Example trials from Experiment 10, task 1. Participants first fixated the cross and pressed the spacebar (A). 600 ms later, a face was displayed for 1500 ms with direct gaze (B). Next, the same face displayed averted gaze to the left or right for either 200 or 1200 ms (SOA; C). Finally, on joint gaze trials one of the placeholders turned green (upper panel), to which participants saccaded and fixated for 500 ms (D). For non-joint gaze trials the gazed-at place holder turned red, indicating that participants should saccade to and fixate the opposite placeholder. Stimuli are not to scale.

**Task 2.** This was identical to Experiment 9: Each trial started with a central grey fixation cross, presented on a black background for 500 ms. Next, one of the faces from task 1 was shown for 500 ms with either direct gaze, averted by 5 degrees or averted by 10 degrees. Each of the 4 face identities were shown with each of the 5 gaze directions an equal number of times in a randomised order, across 280 trials. Participants were told to respond was quickly and accurately as they can by indicating the gaze-direction of the face pressing the ‘1’, ‘2’ or ‘3’ key’s, to indicate leftward, direct, or rightward gaze, respectively, with their index, middle and third finger of their preferred hand.

**Results**

Analyses of eye data were performed as in experiment 9.

**Task 1.** Trials containing blinks (5.5 % of trials) were removed. Errors, namely trials in which the first saccade/antisaccade was in the opposite direction according to the instruction cue (11 % of trials), were excluded from sRT analysis and analysed separately. Outliers, defined as trials in which sRT were 3 standard deviations above or below participant's mean (1.5% of trials), were discarded from analysis.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 200 ms vs. 1200 ms) as within-subjects factors. The main effect of task was significant, $F(1,19) = 12.82$, $p = .002$ , $\eta^2_p = .403$, with more errors on antisaccade trials ($M = 6.56$ %, $SD = 7.08$ %) than on saccade trials ($M = 3.09$ %, $SD = 3.37$ %). The main effect of SOA was also significant, $F(1,19) = 15.71$, $p = .001$ , $\eta^2_p = .453$, with more errors on trials with the shorter SOA ($M = 6.13$ %, $SD = 6.63$ %), than those with the longer SOA ($M = 3.53$ %, $SD = 4.50$ %). The Task × SOA interaction was also significant, $F(1,19) = 16.21$, $p = .001$ , $\eta^2_p = .460$, due to a bigger difference in errors between trial types at the shorter (5.63%) than longer (1.31%) SOA.

The equivalent ANOVA on the sRT data revealed a significant effect of trial type, $F(1,19) = 12.33$, $p = .002$ , $\eta^2_p = .394$, with faster eye movements on saccade (315 ms), than antisaccade (351 ms) trials. The effect of SOA was not significant, $F(1,19) = .759$, $p = .394$ , $\eta^2_p = .038$. The trial type x SOA interaction was significant, $F(1,19) = 7.93$, $p = .011$ , $\eta^2_p = .294$, due to sRT advantage of saccade trials being larger at the shorter, than longer, SOA.

**Task 2.** A 2 (trial type; saccade, antisaccade) x 2(Degree of averted gaze; 5 degrees, 10 degrees) ANOVA was conducted on the proportion of trials in which participants incorrectly indicated that the on-screen gaze was directed at them – pressing '2' to indicate 'direct gaze' – when in fact the on-screen gaze was averted. Here, there was a reliable difference in the number of errors made to each type of face (22% of trials for Joint gaze faces, 19% of trials for non-joint faces), $F(1,19) = 5.46$, $p = .031$ , $\eta^2_p = .223$. There was, as expected, significantly more errors when the on-screen gaze was averted by 5 degrees (35%) than by 10 degrees (6%), $F(1,19) = 197.0$, $p < .001$ , $\eta^2_p = .912$. there was no interaction, $F(1,19) = .761$, $p = .394$ , $\eta^2_p = .038$.

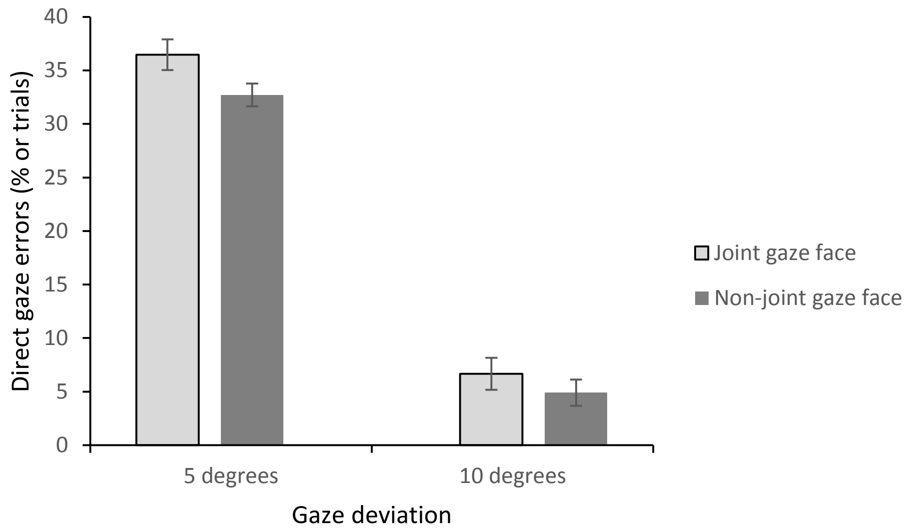


*Figure 22.* Experiment 10: percentage of trials in which participants incorrectly identified the displayed averted gaze as being directed at themselves, divided by gaze deviation and face type.

**Questionnaires.** Participants completed two questionnaires; the AQ and the SPIN. Here, neither participants self-reported autism-like traits, measured by the AQ, $r(19)=-.034$, $p=.89$, nor their self-reported social phobia level, measured by the SPIN, $r(15)=-.28$, $p=.32$, correlated with participants sensitivity to the type of face they were judging the gaze of (antisaccade face ‘at-me’ errors minus saccade face ‘at-me’ errors).

## Discussion

After encountering faces that consistently did, or did not, provide valid gaze cues towards the participant’s saccade goal, participants reencountered the same faces and had to identify the direction in which these faces were looking. Faces that had, in task 1, always led participants to a state of joint gaze were more erroneously identified as displaying direct gaze towards participants, compared with faces that had never engaged in joint gaze with participants. This indicates that participants had a larger bias to think that faces that had previously engaged in joint gaze with them, by cueing their gaze, were looking at them.

Thus, this experiment presents the first evidence that the human gaze direction perception system is sensitive to previous interactions with specific individuals. That is, the quality of our prior experiences with an individual – in this case whether they had reliably cued our attention or not – impacts the extent to which we think we are being looked at by those identities.

Participants have been shown to prefer cue-providers and the looked at objects that are associated with validly cued trials, compared with invalid gaze cues (e.g. Bayliss & Tipper, 2006, Bayliss, et al., 2006). Thus it may be that the positive interactions with valid cuer's leads participants to expect further interactions later, which direct gaze could signal (Senju & Johnson, 2009). It might also be that the positive association related to previously valid gaze cuers increases our expectation of direct gaze in a similar way to that of attractive faces (Kloth et al., 2011), potentially reflecting a self-referential bias for positive stimuli. However, it remains for future work to assess the extent to which the present findings can be accounted for by the valence of each face type, especially given that gaze leading did not lead to such differences in Experiment 9 (cf. Schilbach et al., 2010).

There are a number of methodological constraints that future work should consider. Firstly, even the faces on antisaccade trials may have been facilitative. These faces would have cued participant's covert attention towards the antisaccade cue, which may have made the cue easier to process (e.g. Koval, Thomas, & Everling, 2005). Thus, although the non-joint faces never led to a state of joint gaze with participants, they may have 'shared' attention towards the antisaccade cue with participants. Future manipulations may find stronger differences between face types if the non-joint faces do not gaze towards anything, which is indeed common in gaze cueing research (see Frischen et al., 2007).

Further, as in Experiment 9, here the faces displayed emotionally neutral expressions. Identity specific learning is increased when faces display positive emotions (Bayliss et al., 2009), and it is therefore somewhat surprising that we found differences at all. Future research may therefore look to manipulate the emotional expression of the faces, with the expectation of greater sensitivity to the previous behaviour of faces when those faces are displaying positive expressions (but see Kloth et al., 2011).

A lower level, alternative explanation for the bias to think previous gaze cuers are looking at us could be that we are less able to ascertain their gaze direction: under increase uncertainty we are more likely to report direct gaze (Mareschal et al., 2013). However, this may be unlikely here given that in a similar experiment that used the same first task as this experiment, those face that had previously provided valid cues were able later to continue to cue attention in an expected manner (Experiment 1, Dalmaso et al., 2016). Further, to see if our data could lend to this argument, exploratory analysis was performed on how quickly (RTs) participants identified the gaze of the two face types as either direct or non-direct. We decided to only explore the data for when gaze was averted by 5 degrees, as this is where gaze is more ambiguous. This analysis revealed no effect of face type, response type, or interaction (F's $< .523$, p's $> .478$), suggesting that the efficiency of processing the gaze direction of each type of face did not differ and was therefore unlikely to be influencing responses regarding gaze direction.

To conclude, it appears that we have a heightened expectation that we will be looked at by people who have previously proved to be useful during gaze based interactions, potentially reflecting that we expect to reengage with them. This is, to our knowledge, the first illustration that the quality of previous gaze-based encounters lead to identity-specific impacts in gaze perception.

## Experiment 11: Previous gaze interactions influence those subsequent

While the above experiments indicate that the quality of previous gaze based interactions can, in some contexts, lead to differences in the way we process the gaze of the individuals with whom we have interacted, it is not yet clear how previous interactions actually impact the way we interact with people with whom we have previously interacted. Thus, this experiment aimed to assess how prior joint gaze interactions impact the way in which those same individuals that were interacted with can latter influence one's social attention.

Here, participants first completed the same saccade/ antisaccade task as, in Experiments 9, such that participants were leading gaze. However, in the second task, the same faces from task one that had or had not previously followed participant's gaze were employed in a standard gaze cueing paradigm. Further, we included 2 SOA's (200 ms, 1200 ms) in order to assess the time course of the cueing response from each type of face. Generally, attention shifts in the direction of others' averted gaze in a rapid (e.g., Friesen & Kingstone, 1998) and reflexive (e.g., Driver et al., 1999; Galfano et al., 2012) manner, with SOA's of 100-300 ms commonly illustrating gaze cueing (e.g., Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Marotta, Lupiañez, & Casagrande, 2012; Tipples, 2008, see also Hietanen & Leppänen, 2003 for an example using an SOA of 14ms). The facilitation provided by averted gaze will diminish after around 1 second (e.g., 1200 ms, Frischen & Tipper, 2004; 1005 ms, Friesen & Kingstone, 1998). So, 'normally' one would expect gaze cueing at our early SOA, but not our later SOA.

The gaze cueing effect, the magnitude of which will be the variable of interest in this experiment, is a robust phenomenon (see Frischen et al., 2007 for review) even when only schematic faces are used  (e.g., Dalmaso, Galfano, Tarqui, Forti, & Castelli, 2013; Kuhn & Kingstone, 2009; Marotta et al., 2012; Ristic, Friesen, & Kingstone, 2002). However, this seemingly robust and reflexive orienting response has also been shown to be modulated in subtle ways. For example, varying visual features of the cueing faces (e.g., masculinity/dominance, Jones et al., 2010; Ohlsen, van Zoest, & van Vugt, 2013; ethnicity, Pavan, Dalmaso, Galfano, & Castelli, 2011; or age, Ciardo, Marino, Actis-Grosso, Rossetti, & Ricciardelli, 2014; Slessor, Laird, Phillips, Bull, & Filippou, 2010) can modulate the gaze cueing response that a face will elicit in a participant. Further, more changeable aspects can also influence the gaze cueing response (e.g. facial expression, Kuhn & Tipples, 2011; Mathews, Fox, Yiend, & Calder, 2003).

Social knowledge regarding the agents who are cueing attention can also modulate the magnitude of cueing an observer will show. For example, faces of familiar individuals (Deaner, Shepherd, & Platt, 2007; see also Frischen & Tipper, 2006) and of those in one's own political group (Liuzza et al., 2011) can elicit stronger cueing. Gaze cueing has also been shown to relate to 'person knowledge' , which would incorporate representations of personal traits, biographical information, but also knowledge relating to previous behavioural interactions (see Gobbini & Haxby, 2007; see also Bayliss, Naughtin, Lipp, Kritikos, & Dux, 2012; Todorov, Gobbini, Evans, & Haxby, 2007), such that faces associated with high social status bibliographies, compared with lower status, produce stronger gaze cueing (Dalmaso, Galfano, Coricelli, & Castelli, 2014, Dalmaso, Pavan, Castelli, & Galfano, 2012). Frischen and Tipper (2006) showed subsequent gaze cueing can be influenced by previous exposure to gazing faces of famous individuals, showing that such prior experiences can be encoded and retrieved. However, there is as of yet no direct evidence that the quality of previous interactions is encoded and retrieved to inform subsequent interactions.

The current experiment is experiment 2b from Dalmaso et al., (2016), which was a replication and extension of Experiment 2a in that paper. Therefore there were strong predications regarding the data. Specifically, we expected to replicate the somewhat surprising findings that gaze cueing in response to faces that did not previously follow participant's gaze would later be prolonged (e.g. gaze cueing at both SOA's), while faces that had previously always jointly gazed with participants would not produce reliable gaze cueing at either SOA. Further, although Experiment 9 of this thesis did not result in any measurable difference related to the quality of previous gaze leading encounters, Dalmaso et al's (2016) Experiment 2a was completed prior to the work presented in this chapter, and thus we had confidence that a difference could emerge based on such interactions.

Further, we aimed to gain an insight into why such surprising effects emerged. Joint gaze encounters can modulate perceptions of trust, such that gaze followers trust valid cuers more (e.g., Bayliss et al., 2009; Bayliss & Tipper, 2006). We asked participants to rate how trustworthy the faces they had encountered were in order to see if increased trust is reflected in the gaze leader as well. More speculatively, as lower-dominant individuals more strongly follow the gaze of higher-dominant conspecifics, which has been illustrated in both humans (e.g., Dalmaso et al., 2012; Jones et al., 2010) and in non-human primates (e.g., Shepherd, Deaner, & Platt, 2006), we asked participants to rate how dominant they thought each face was to assess whether validity of gaze following modulated the gaze leaders perception of the followers dominance – participants might attribute not being followed as a signal that the non-follower is ‘dominant’. Finally, it is well established that within non-clinical populations, variations in autism-like traits are related to social-attentional responses (e.g. Bayliss, di Pellegrino, & Tipper, 2005), which can also be context specific (Bayliss & Tipper, 2005). Therefore we had participants complete the AQ so that we can assess how learning related to previous encounters may be related to autism-like traits.

## Method

**Participants.** Thirty-eight students at the University of East Anglia (*Mean age* = 19 years, *SD* = 1.1 years; 4 men) participated in return for payment (£8.5) or course credit. All reported correct or corrected-to-normal vision and were naïve to the purpose of the experiment. We aimed for a sample size of 40 people and stopped at the end of a run of booked testing slots for convenience; hence n=38. Technical failure led to one participant not completing task 1, while data from another participant for task 1 was not recorded. Additionally, one participant was excluded due to having difficulty with task instructions. Therefore $n$ = 35 for the saccade/antisaccade task, and $n$ = 36 for the gaze cueing task.

**Apparatus and stimuli.** A PC running E-Prime 2.0 (Psychology Software Tools, Pittsburgh, USA) handled stimulus presentation. Participant’s right eye was tracked (Eyelink 1000, SR Research, Ontario, Canada, spatial resolution of 0.1°, 500 Hz), while their head was placed on a chin rest 65 cm away from a 46 cm monitor (1024 × 768 px, 75 Hz). Manual responses were made on a standard keyboard.

Four smiling faces of white adults (2 males) were taken from the NimStim face set (Tottenham et al., 2009), matched for age and attractiveness (see Bayliss et al., 2009; Bayliss et al., 2012). Smiling faces were chosen because of the positive context they create appears to encourage social learning processes (e.g., Bayliss et al., 2009). One face of each gender was randomly allocated to appear only on saccade trials (Face Group A), and the others to Face Group B (antisaccade trials). An additional smiling face of a white adult male was used in the practice block only.

**Design and Procedure.**

***Task 1: Saccade/antisaccade task.*** Each trial began with a central black fixation cross (0.8° height × 0.8° width) on a dark grey background flanked by two white square placeholders (1° height × 1° width ) with black contours (0.2° width) placed 9.8° rightwards and leftwards from the cross. Participants were asked to fixate on the cross and press the space bar once they had achieved fixation, allowing us to perform a drift correction and ensuring the participant was fixating the correct location. Six hundred milliseconds after the key press, the fixation cross was replaced by a central face with direct gaze (11° height × 8° width) for 1700 ms or 2700 ms, depending on SOA. Next, the instruction cue appeared (green or red placeholder) and participants were asked to saccade towards the green cue or away from the red. After 300 ms of fixating the correct placeholder the on-screen gaze was averted towards the instruction cue. After a further 500 ms fixation of the correct place holder (assessed by a gaze-contingent trigger) the trial ended

As the on-screen gaze was always directed towards the instruction cue, saccade trials resulted in both the participant and on-screen face ‘looking’ towards the green cue, whereas on antisaccade trials the on-screen face ‘looked’ towards the red cue but participants looked in the opposite direction. Half the faces (counter balanced across participants) would always appear on saccade trials and lead to a state of joint gaze with participants, while the other faces appeared on antisaccade trials and did not lead to joint gaze with participants.

Participants were instructed to move their eyes as quickly and as accurately as possible and to ignore the faces (and their gaze direction). There were 16 practice trials followed by 240 experimental trials divided into three blocks of 80 trials each. Each block was comprised an equal number of trials of each experimental condition, presented in a random order. A 5-point calibration was conducted at the beginning of each block.

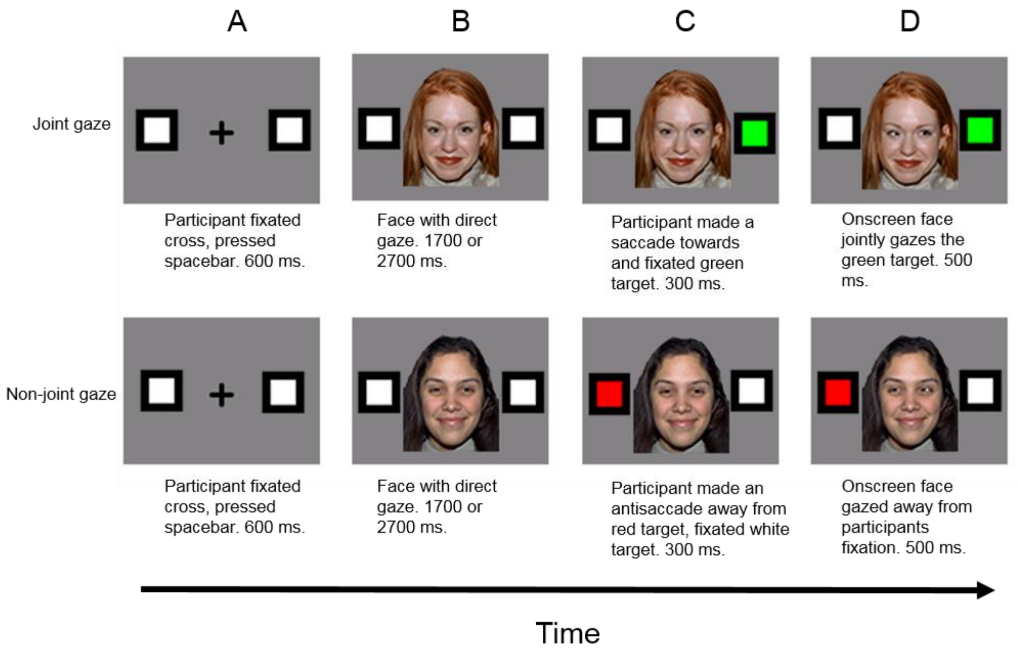


*Figure 23.* Example trials from Experiment 11, task 1. Participants first fixated the cross and pressed the spacebar (A). 600 ms later, a face was displayed for 1700 or 2700 ms (SOA) with direct gaze (B). On joint gaze trials one of the placeholders turned green (upper panel), to which participants saccaded and fixated the green target for 300 ms, which triggered the onscreen face to display averted gaze also towards the green target (D). For non-joint gaze trials the sequence was identical (e.g A, B) except that the target was red, to which participants made an antisaccade away from, fixating the opposite place holder for 500 ms (C), which triggered the onscreen gaze to 'look' away from the participant's fixation and towards the red target. Stimuli are not to scale. The experimental stimulus set comprised NimStim model numbers 2, 5, 24, and 25. These models are not depicted to comply with conditions of use of the NimStim database. *Source:* Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set.

***Task 2: Gaze cueing task.*** Each trial began with a central black fixation cross (0.8° height × 0.8° width) on a dark grey background flanked by two white square placeholders (1° square) with black contours (0.2° width) placed 9.8° rightwards and leftwards from the cross. After 600 ms, the fixation cross was replaced by a central face (from task 1) with direct gaze for 1500 ms, followed by the same face with averted gaze rightwards or leftwards. After 200 ms or 1200 ms, depending on SOA, a black target line, either vertical or horizontal (1° height × 0.2° width) appeared centrally placed inside one of the placeholders (see Figure 23) and was displayed until response or 3000 ms had elapsed. Participants made speeded identification of line orientation pressing the 'H' key with the middle finger of their dominant hand or the space bar with the index finger of the same hand, with the mapping between key and line orientation counterbalanced across participants. The centrally placed red words 'ERROR' or 'NO RESPONSE' replaced the central face for 500 ms in the case of an incorrect or a missing response, respectively.

Participants were required to maintain fixation at the centre of the screen. Unlike in task 1, where a given face identity would respond consistently, in task 2 each face was equally non-predictive of target location. Speed and accuracy of response was emphasised to participants and they were instructed that they could ignore the faces. The experiment comprised 10 practice trials, followed by 256 experimental trials. A 5-point calibration was conducted at the beginning of the practice block.

After task 2, participants rated how dominant and trustworthy they thought each face was (7-point Likert-type scale, from 1 = "low" to 7 = "high") and then completed the AQ questionnaire. The whole Experiment (Task 1, Task 2 and questionnaires) lasted about 75 minutes.

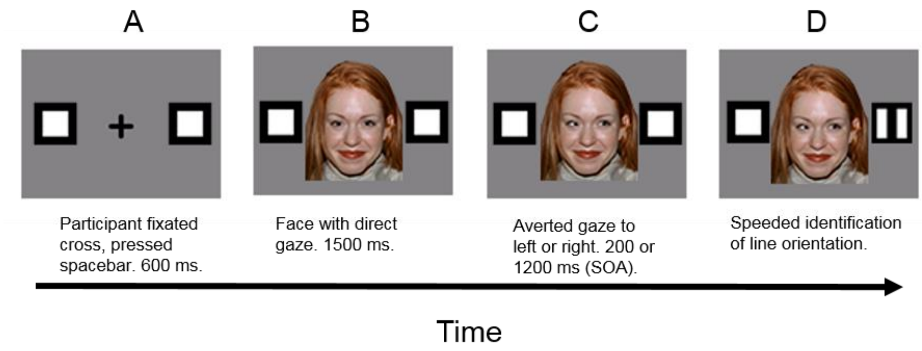


*Figure 24.* Example trial from Experiment 11, task 2. Participants first fixated the cross and pressed the spacebar (A). 600 ms later, a face was displayed for 1500 ms with direct gaze (B). Next the face displayed averted gaze to the left or right for 200 or 1200 ms (SOA, C). Finally, a line, either vertical or horizontal, appeared in one of the place holders, to which participants made speeded identification regarding orientation. In this example the vertical line target has appeared in a congruent position with respect to onscreen gaze. Stimuli are not to scale.

**Results**

***Task 1: Saccade/antisaccade task.*** The behaviour of participants in the gaze cueing task (Task 2) was of primary interest, however as a manipulation check it was important to ensure that our task 1 produced the  standard decrement of performance on antisaccade trials, showing that participants were appropriately engaged (e.g., Hallet, 1978; Wolohan & Crawford, 2012). Data was treated as is Experiment 9.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 1700 ms vs. 2700 ms) as within-subjects factors. There was a significant main effect of task, $F(1,34) = 44.786$, $p < .001$ , $\eta^2_p = .568$, with less errors for the saccade movements ($M = 4.57$ %, $SD = 3.68$ %) than for the antisaccade movements ($M = 19.79$ %, $SD = 12.9$ %), as well as the main effect of SOA, $F(1,34) = 4.866$, $p = .034$ , $\eta^2_p = .125$, as less errors were made at the longer SOA ($M = 11.22$ %, $SD = 6.82$ %) than at the shorter SOA ($M = 13.14$ %, $SD = 7.49$ %). The Task × SOA interaction was not significant ($F = 2.710$, $p = .109$).

A second ANOVA was conducted on mean Saccadic Reaction Time (sRT) with the same factors as above. The main effect of Task was significant, $F(1,34) = 41.569$, $p < .001$,

$\eta^2_p = .550$, with faster saccade movements ($M = 306$ ms, $SD = 49.9$ ms) than antisaccade movements ($M = 348$ ms, $SD = 58.5$ ms), as well as the main effect of SOA, $F(1,34) = 89.556$, $p < .001$, $\eta^2_p = .725$, due to smaller sRT at the longer SOA ($M = 315$ ms, $SD = 52.8$ ms) than at the shorter SOA ($M = 340$ ms, $SD = 49.9$ ms). The Task × SOA interaction was also significant, $F(1,16) = 9.422$, $p = .004$, $\eta^2_p = .217$. Paired comparison between antisaccade and saccade movements for each SOA revealed that sRT were smaller for the saccade, than for the antisaccade movements, at both SOA's (1700 ms SOA, $t(34)= 6.592$, $p < .001$, $d_z = .91$; 2700 SOA, $t(34)= 5.333$, $p < .001$, $d_z = 0.59$), but this difference was larger at the shorter SOA (50 ms vs. 34 ms).

Taken together, these results confirm that a saccade was easier to perform than an antisaccade, as expected.

***Task 2: Gaze cueing task.*** Errors (4.68 % of trials) and outliers, defined as trials in which RT were 3 *SD* above or below participant's mean (2.05 % of trials), were discarded from RT analysis. The percentages of errors for each participant in each condition were submitted to a 2 (Cue-target spatial congruency: congruent; incongruent) × 2 (SOA: 200 ms; 1200 ms) × 2 (Face type: Joint; non-joint) repeated-measures ANOVA. There were no significant interactions or main effects ($F$s < 2.52, $p$s > .121).

A second ANOVA was conducted on mean RT with the same factors as above. The main effect of Congruency was significant, $F(1,35) = 13.890$, $p = .001$, $\eta^2_p = .284$, with faster RT on congruent trials ($M = 673$ ms, $SD = 100$ ms) than on incongruent trials ($M = 687$ ms, $SD = 103$ ms), as well as the main effect of SOA, $F(1,35) = 6.956$, $p = .012$, $\eta^2_p = .166$, due to faster RT at the longer SOA ($M = 671$ ms, $SD = 104.3$ ms) than at the shorter SOA ($M = 690$ ms, $SD = 99.2$ ms). There was also a significant effect of Face type, $F(1, 35) = 4.936$, $p = .033$, $\eta^2_p = .124$, showing that RT were faster with non-joint gaze faces ($M = 677$ ms, $SD = 99.4$ ms) than joint gaze faces ($M = 684$ ms, $SD = 104$ ms). No interactions reached significance ($F$s < 1). However, as this is a methodological replication with strong apriori predictions, our planned comparisons will be informative. These revealed the same pattern of data as expected; participants showed reliable cueing of attention only in response to non-joint gaze faces, both at the shorter SOA, $t(35) = 2.33$, $p = .026$, $d_z = .39$ (16 ms), and at the longer SOA, $t(35) = 2.46$, $p = .020$, $d_z = .40$ (15 ms). On the contrary, no gaze cueing emerged in response to joint gaze faces, both at the shorter

SOA, $t(35) = 1.61$, $p = .116$, $d_z = .27$ (14 ms), and at the longer SOA, $t(35) = 1.58$, $p = .123$, $d_z = .26$ (12 ms).

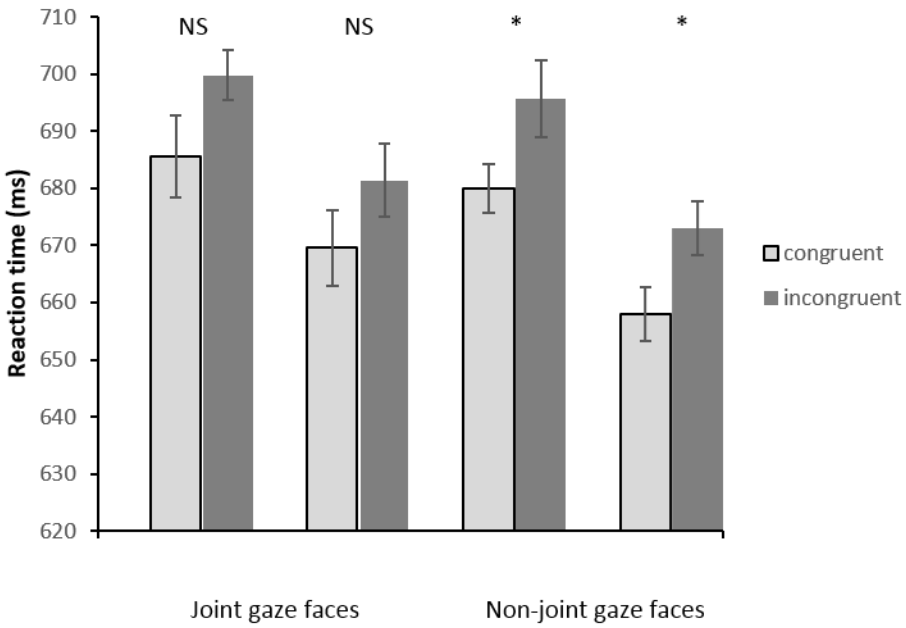


*Figure 25.* Experiment 11, task 2: Reaction times in ms to correctly identify target line orientation, divided by face type and SOA. Error bars represent within-subject standard error (Loftus & Mason, 1994).

**Face ratings.** Mean ratings of the faces on *dominance* and *trustworthiness* can been seen in Table 4. There was no difference in ratings of dominance between the two face types, $t(35) = -.699$, $p = .489$, $d_z = .12$. However, faces that had, in Task 1, always followed the gaze of the participant were rated as more trustworthy than faces that always looked elsewhere, $t(35) = 2.203$, $p = .034$, $d_z = .37$.

**Table 4.**

Mean (and standard deviation) ratings of dominance and trustworthiness for joint gaze and non-joint gaze faces in Experiment 11.

| | Dominance | | Trustworthiness | |
|---|---|---|---|---|
| | Joint gaze | Non-joint gaze | Joint gaze | Non-joint gaze |
| M | 3.60 | 3.74 | 5.08 | 4.54 |
| SD | (1.31) | (1.45) | (1.06) | (1.19) |

**Autism Spectrum Quotient.** AQ score was correlated against the cueing effect magnitude (i.e., RT on incongruent trials – RT on congruent trials) of each type of face.

AQ did not correlate with the cueing effect elicited by non-joint gaze faces, $r(34) = –.028$, $p = .87$, two-tailed. However, there was a significant positive correlation between AQ and the cueing effect elicited by joint gaze faces, $r(34) = .37$, $p = .03$, two-tailed, indicating that participants with more self-reported autistic-like traits were cued by the joint gaze faces more than those with lower AQ scores (see Figure 26).

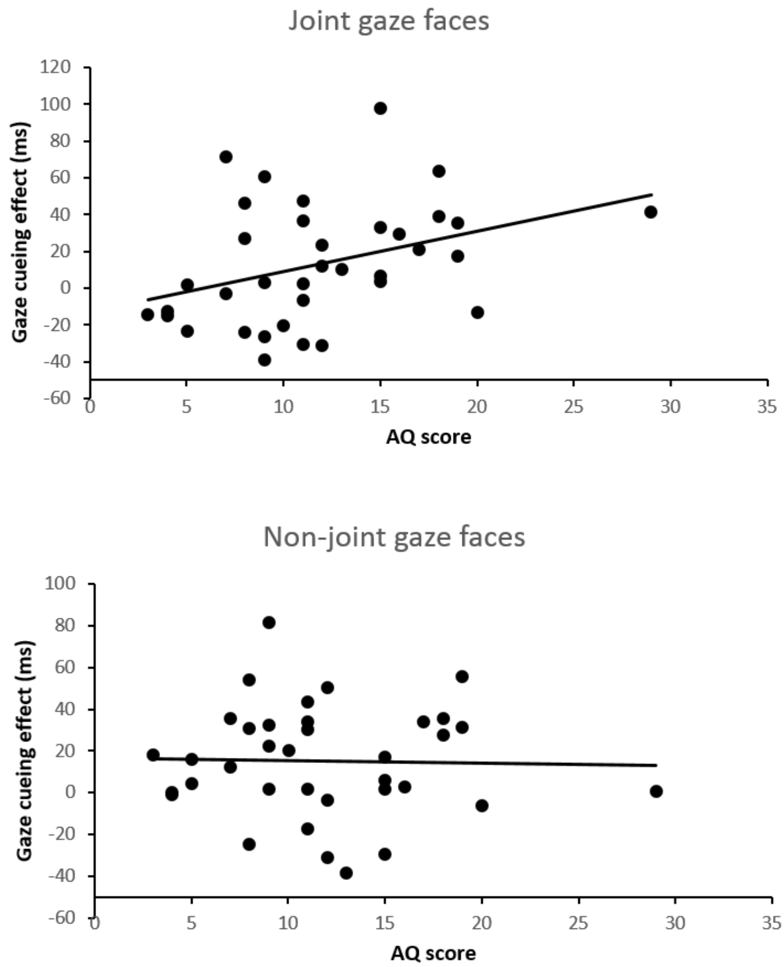


*Figure 26.* Correlation between gaze cueing effect magnitude, in response to joint gaze faces (upper panel) and non-joint gaze faces (lower panel), and AQ score for each participant in Experiment 11.

**Discussion**

Although the critical interaction did not reach significance, meaning these contrasts can only be interpreted in a limited fashion, planned comparisons revealed the expected pattern of data: faces that had previously always followed participants gaze did not produce reliable gaze cueing at either SOA, while the faces that had never engaged in joint gaze with participants in task 1 produced reliable gaze cueing at both SOAs. As introduced earlier, standard gaze cueing effects would be expected at the early SOA, but not at the later SOA (Friesen & Kingstone, 1998). Therefore, it appears that both types of faces in this experiment produced unusual orienting responses in participants, suggesting that whether someone has reliably followed our eye-gaze, or not, leads to somewhat robust changes in how our social attention system will interact with him/her later.

Firstly, the joint gaze faces did not produce gaze cueing at either the early or later SOA. This is particularly surprising given our sample of n=36, when standard gaze cueing effects have been illustrated with samples as small as n=8 (e.g. Driver et al., 1999). These faces that had in task one always followed participant's gaze are now less able to influence the participant's attention than would be expected. As participants have consistently affected change on the joint gaze faces, it could be that participants felt a degree of dominance over them (Shepherd, Deaner, & Platt, 2006). Indeed, participants perceiving joint gaze faces as being low dominant and non-joint faces as highly dominant would fit with both the lack of gaze cueing in response to joint gaze faces and accentuated cueing in response to non-joint faces (e.g. Dalmaso et al., 2012; Jones et al., 2010; Shepherd, Deaner, & Platt, 2006). However, participants showed not explicit rating differences in terms of dominance between faces that had or had not followed their gaze.

The non-joint gaze faces that had, in task 1, always looked away from the participant's saccade location later induced gaze cueing of participant's attention at both SOA's. Prolonged gaze cueing (at our longer SOA) is surprising (c.f. Friesen & Kingstone, 1998). One possibility is that we attempt to ingratiate ourselves with those face that previously ignored our joint gaze bids by orienting to their attention to a greater extent, so that we can take control of the interaction (e.g. Warburton, Williams & Cairns, 2006), or 'close the loop' (Amodio & Frith, 2006). Indeed, being ostracised can profoundly impact on gaze behaviour (e.g., Böckler, Hömke, & Sebanz, 2013; Wilkowski, Robinson, & Friesen, 2009) and people who are ostracised tend to (re)establish contact with individuals who are the source of such exclusion (e.g., Wirth, Sacco, Hugenberg, & Williams, 2010), which may suggest that our participants viewed non-followers as attempting to ostracise them.

Joint gaze faces were reliably rated as more trustworthy than non-joint faces, which is consistent with previous findings regarding gaze cueing (e.g., Bayliss et al., 2009; Bayliss & Tipper, 2006), but is the first evidence that successful or unsuccessful gaze leading leads to such differences. It appears that only one other study has reported a trustworthiness modulation of gaze cueing in young adults (Süßenbach & Schönbrodt, 2014; see also Petrican et al., 2013, for a similar results in older adults). Manipulating trust explicitly, Süßenbach and Schönbrodt (2014) showed stronger gaze cueing in response to trustworthy faces – the opposite of our data. However, in our study trust was a resultant of implicit associations formed during interactions. Therefore, it may be that we respond differently to first-hand experiences than to second-hand information. Future investigations should consider whether 'trust' genuinely reflects a difference in how much participants *trust* those that have previous followed their gaze verses whether here 'trust' merely represents an analogue for positive valence (Pfeiffer et al., 2011).

Relatedly, while invalid gaze cuers may be interpreted as deceptive, as by failing to cue attention to a valid location we may hide interesting objects (Emery, 2000; Bayliss & Tipper, 2006), it is less clear why a non-follower of gaze would be seen as such. That is, when someone does not follow gaze they are not necessarily acting in a deceptive way, but possible just reflecting a disinterest. It may therefore be interpreted as surprising that such trust rating differences emerged here. Future work may wish to consider whether such socio-evaluative judgements, such as trust, are the 'vehicle' by which we remember individual's previous behaviours.

Individual differences in self-reported autism-like traits within normal populations have proved insightful regarding social orienting processes (e.g., Bayliss, di Pellegrino, & Tipper, 2005; Bayliss & Tipper, 2005). Here, participant's AQ scores (Baron-Cohen et al., 2001) correlated with the magnitude of cueing in response to joint gaze faces, but not non-joint faces. Whereas it appears that participants learn (in task 1) to be less cued by faces that follow their gaze, participants with higher AQ scores do not appear to learn this. Stronger cueing in higher AQ participants could be viewed as surprising (c.f. Bayliss & Tipper, 2005). However, Bayliss and Tipper (2005) note that such associations can be highly context dependant, and similar associations have been reported elsewhere (e.g. Hudson, Nijboer & Jellema 2012).

Methodologically, it is noteworthy that, as in Experiment 9, in antisaccade trials participants, by definition, had to covertly attend to the red instruction cue in order to prepare a saccade in the opposite direction. Thus, although the non-joint faces do not look to the same location that the participant is looking, they do look towards the instruction cue that participants had previously attended. It is therefore possible that participants do not interpret this response as a rejection of joint gaze, but instead perceive them as making a perfectly valid response to a new stimuli. Future work may therefore look to replicate the current findings using a different gaze leading paradigm that does not involve saccade/ antisaccade trials (see Bayliss et al., 2013).

To conclude, this experiment illustrates that the social attention system is sensitive to the quality of previous gaze leading encounters. Whether or not we have successfully led the gaze of another later influences that individual's ability to cue our own social attention, as well as leading to differences in explicitly rated 'trustworthiness'. Interestingly, it also appears that the implicit learning regarding previous gaze leading encounters may be disrupted in participants with more autism-like traits.

## General discussion

The experiments presented in this chapter examined whether we are sensitive to the quality of the gaze-based interactions we have previously had with particular individuals. It appears that both our attention and gaze perception systems are impacted by whether or not a specific individual has engaged in joint gaze with us previously. However, the current work also highlights how the role that we take in a joint gaze interaction – whether we are the leader or follower of gaze – can be crucial to how that interaction impacts us later.

Experiments 11 showed that when we reencounter an individual that has previously always followed our gaze, that individual will be less able to influence our attention than would be expected by standard accounts of gaze cueing (see Frischen et al., 2007 for review). Interestingly, the opposite is the case for individuals that always rebuffed our joint gaze initiations – our attention responds to the cues of these individuals over a longer time course than is usual. Thus the human social attention system appears highly sensitive to the quality of previous gaze leading encounters.

However, whether or not a given individual had followed participant's gaze appeared inconsequential with regards to gaze direction perception. When participants had to identify the gaze direction of agents they had previously interacted with, there was no difference related to whether a given face was previously a gaze follower or not (Experiment 9). Contrasting with the above then, although gaze leading can influence subsequent attention orienting, gaze perception appears insensitive to prior gaze leading encounters.

Although previous gaze leading encounters did not influence gaze perception (Experiment 9), previous encounters of gaze following did (Experiment 10). That is, participants appeared to have a larger bias to think that faces that had always led their gaze would be displaying direct gaze when they reencountered them, as compared to the other faces that never led the participants gaze. This suggests that gaze perception can be sensitive to the previous behaviour of individuals, possibly reflecting a bias to think more positive faces are trying to engage with us. It therefore appears that whether we were the gaze follower or gaze leader in a joint attention bid is of crucial importance regarding how our gaze perception will be influenced. Indeed, when the data from both Experiments 9 and 10 are analysed together, with 'Experiment' as a between subject variable, the critical Face type x Experiment interaction is significant, $F(1,38) = 6.322$, $p < .016$ , $\eta^2_p = .143$.

This is consistent with the idea that there are unique processes underlying the initiation of, and response to, joint attention (Mundy & Newell, 2007) and further illustrates the different experiences of each participant in a joint gaze encounter.

It is interesting to consider why the role of the participant in the joint gaze interaction would have such a striking impact on how that interaction impacts later gaze perception. A low-level contribution could be that when we lead gaze we likely process the response of the participant in the periphery, as we are looking at the intended shared referent. Conversely, when we follow the gaze of another we can foveate the individual whose gaze we are about to follow. Thus, although our attention is drawn towards those that follow our gaze (gaze leading effect, Edwards et al., 2015), it is possible that we may be better able to process the behaviour of individuals that we follow, compared with those that follow us.

There might also be a higher-level difference in the way we interpret the validity of gaze following and gaze leading. Gaze cues can be used to deceive others by, for example, cueing others' attention away from interesting objects (Emery, 2000; Bayliss & Tipper, 2006). However, it is less clear, and to our knowledge as yet untested, whether non-followers of gaze would be similarly considered deceptive: although successful gaze leading is preferred to unsuccessful gaze leading (Bayliss et al., 2013), an individual who does not follow our gaze might simply do so because they are not interested in interacting with us, rather than necessarily trying to deceive us. Thus, while we trust partners that jointly gaze objects with us, more than those that don't engage in joint gaze, both when they are the gaze follower (e.g. Bayliss & Tipper, 2006) or the leader (e.g. Experiment 11; Dalmaso et al., 2016), such socio-evaluations could be based on different mechanisms for each role of joint gaze encounters.

As motivation and reward appear to be more strongly associated with initiating, as opposed to  responding to, joint attention (e.g. Mundy & Newell, 2007; Schilbach et al., 2013), one would expect to find greater feelings of ostracism when ones gaze is not-followed, than when someone avoids validly cueing you. That is, it might be perceived as more negative when our effortful attempt to initiate joint gaze is rebuffed compared with when someone else fails to cue us to something interesting. It could therefore be hypothesised that interpretations of ostracism between unsuccessful gaze leading and unsuccessful gaze following could account for the different impacts each have on attention and perception when reencountering interactive partners (Experiments 9-11; see also Dalmaso et al., 2016). However, the findings of Experiment 11 indicate that how successful gaze leading is interpreted in relation to self-reported autism-like traits is specific to successful, rather than unsuccessful, gaze leading encounters. This may therefore suggest that rather than the negative outcomes akin to ostracism relating to having one's joint gaze rebuffed, it is the positive connotations of successful joint gaze initiation that are most crucial to ongoing interactions.

To conclude, both gaze processing and attention orienting can be influenced by the quality of previous joint gaze encounters with specific individuals. Moreover, our role as either the leader or follower in those previous interactions may be crucial to how respond when reencountering individuals with whom we have previously interacted.

# Chapter 6: Discussion

Research regarding joint attention has until recently neglected one half of the interaction, failing to consider this fundamental social behaviour from the perspective of the gaze leader. Recent research has revealed some intriguing modulations relating to gaze leading including behavioural, affective (Bayliss et al., 2013) and neuro-correlate (e.g. Schilbach et al., 2010) outcomes. It therefore follows that this apparently important response to our own behaviour – someone has responded to our gaze by following it – should theoretically be important enough to become salient, or even impact future interactions. However, research that can speak to this hypothesis is lacking. Thus, this thesis was primarily interested in furthering our knowledge regarding the putative attention mechanisms engaged when one successfully leads the gaze of another, as well as the impacts this might have on future interactions with a given individual.

## Results overview

To investigate whether the attention of a gaze leader will orient towards those that follow their gaze, Chapter 2 presented two experiments that looked to directly assess two competing hypotheses relating to previous findings of RT facilitation for gaze discrimination of faces that look towards a central, shared referent (e.g. Cañadas & Lupiáñez, 2012). Cañadas and Lupiáñez suggested that the central facing gaze could be capturing attention due to being perceived as direct gaze, towards participants (Senju & Hasegawa, 2005). However, it is also possible that the RT facilitation reflected attention orienting towards faces that look at the same referent to which a participant is fixating. Experiment 1, this thesis, illustrated that the RT facilitation for faces that look towards a central shared referent could not be accounted for solely due to ‘direct gaze’ perception as no such facilitation emerged for centrally aimed gaze that was *not* towards a shared referent. However, RT facilitation did also not occur for gaze directed at non-central shared referents, which suggests that attention capture of gaze following faces is also not necessarily able to account for the attentional distribution in this paradigm. Experiment 2 replicated the procedure of Experiment 1 but replaced the face images with schematic representations of faces. Here, no RT facilitation emerged at all. Thus, whatever mechanism was driving the RT facilitation in Experiment 1 could be highly socially context dependant.

In the first two experiments only one face was displayed on the screen at any given time and no control was placed over where participants looked, which raises the possibility that participants would simply always attend towards the face, thus occluding any differences based on the face's 'behaviour'. Indeed, previous research has found no gaze cueing resulting from a single onscreen non-central face (e.g. Palanica & Itier, 2015), while others using multiple potential cueing locations, such that participants cannot guess the location of the cue, have shown non-central faces can cue attention (e.g. Frischen & Kingstone, 2003). Therefore, in Chapter 3 we developed a novel paradigm with which we aimed to further explore the attention orienting response to having one's eyes followed. In Experiment 3 we presented four possible target locations, one on each of four horizontally aligned faces. With participants gazing centrally, with 2 faces to each side of their fixation location, the two centre most faces would 'look' in the same direction such that one face looked at the shared central referent (joint attention), while the other face looked away from it. Here we had expected faster target identification for targets appearing on the 'joint attention' face, reflecting attention prioritisation of this gaze follower. However, to our surprise, the results reflected gaze cueing – participants were fastest to identify targets that appeared on the faces that looked away from the centre.

Having considered that Experiment 3 lacked a crucial aspect of real-life joint attention initiation – the participant was not making an initiation- in Experiment 4 we increased the ecological validity of the procedure by having participants make an initiation eye-movement to the centre of the screen, which gaze-contingently triggered the onscreen gaze aversion. Here, no gaze-based facilitation emerged; reaction times to identify targets on either the joint attention or non-joint attention face did not differ. This could suggest that, compared with Experiment 3, gaze cueing was less dominant due to a competing orienting response of attention shifting towards a face that follows gaze.

Given that increasing the validity of the interaction, by adding an initiation on the part of the participant, led to a different orienting response pattern – gaze cueing was no longer evident – we sought to further increase the ecological validity of the interaction. In Experiment 5 we replaced the central cross with an image of a real-world object, which finally revealed reliably faster responses to targets appearing on the face of a gaze follower: the gaze leading effect. It therefore appears that this effect is highly context dependant, illustratable only when interactions are actively initiated and object based. We looked to further explore this newly discovered social orienting response in Chapter 4.

The gaze leading effect replicated with only two targets locations (Experiment 6) and again when both onscreen faces looked at visually identical objects (Experiment 7). Thus, it appears that the gaze leading effect reflects attention orienting towards those that follow our gaze, rather than merely orienting towards faces that look at objects. Finally, the gaze leading effect did not replicate with arrow stimuli (Experiment 8). More work is necessary to fully understand the attention responses to peripheral arrow cues, as there is much less evidence related to this, than to how central arrows influence attention (but see Ristic et al., 2002; Tipples, 2002). However, this may suggest that the gaze leading effect is a social orienting response that only eyes can elicit, which would be particularly interesting given the often reported similarity arrows and gaze can have on attention (see Frischen et al., 2007 for review).

Having established the existence of a novel orienting response, and illustrating a number of boundary conditions associated with it (the gaze leading effect, Chapters 3 & 4; Edwards et al., 2015), Chapter 5 looked to assess whether there were longer term impacts of gaze leading encounters. Of interest was whether people encode the previous gaze behaviour of others and then use this to inform their future interactions with those same individuals. In all three experiments (Experiments 9-11) participants first completed a saccade/ antisaccade task where a to-be-ignored central face would either engage in joint gaze with a participant or would look elsewhere. Certain identities would always lead to a state of joint gaze, while other faces never would. Then, a second task assessed how those previous encounters impacted later interactions with those same individuals.

Experiment 9 placed the participant as the gaze leader in task 1, with some onscreen faces always following participants' gaze and others always looking elsewhere. In task 2, where participants made speeded gaze direction identification of the faces that they had previously engaged with, participants showed no reliable difference if their expectation of direct gaze between the two face types. This may indicate direct gaze perception is uninfluenced by prior interactions, but it could also be that specifically *gaze leading* does not impact later gaze perception. In order to assess whether direct gaze perception can be influenced by other prior interactions, Experiment 10 replicated Experiment 9 with the alteration that in task 1 participants were following the gaze of faces that were either consistently valid or invalid gaze cuers. Here, in task 2, participants had a larger bias to assume direct gaze from the faces of valid cuers, compared with invalid cuers. Thus, previous interactions can influence direct gaze perception, and gaze leading and gaze following influence gaze perception in different manners.

Finally, Experiment 11 again placed participants as the gaze leader in task 1, but had participants then engage in joint gaze again in task 2 whereby participants were then responding to the faces that they had previously interacted with, allowing for the assessment of how participant's attention is cued by those faces that had previously always, or never, followed their gaze. Somewhat surprisingly given the robustness of the gaze cueing effect (Frischen et al., 2007 for review), faces that had always followed participants gaze no longer produced reliable gaze cueing of participant's attention. Equally striking, the faces that never gaze followed participants now produced temporally elongated gaze cueing, such that gaze cueing emerged at SOA's far beyond the norm (see Frischen & Tipper, 2004; Friesen & Kingstone, 1998). Thus, the quality of previous responses to our own gaze behaviour appears to be crucial to how we interpret the attention signals of others when we reencounter them. This experiment also provides the first evidence that gaze leading also leads to increased trust ratings for those that follow gaze, verses those that do not follow gaze.

As noted in the discussion section of Chapter 5, there is always some form of joint attention as even the non-joint gaze faces look towards the anti-saccade stimuli which participants had to at least covertly attend to in order to prepare the correct eye-movement. Particularly because the gaze leading effect relates to an attentional cue (e.g. the AQ subscale in Chapter 4), it could be argued that there are not really separate conditions here – the onscreen face always looks at the imperative stimulus, and the participant must always attend to this stimulus (at least covertly) in order to prepare the correct eye-movement. However, notably, the gaze leading effect experiments always had the participant initially overtly attend (fixate) the referent to which the on-screen face looked. Therefore, future work should consider whether a gaze leading effect response can occur when a participant only covertly attends to something in their environment, and how this might be interpreted differently to overtly sharing attention (as is evident in Chapter 5).

Indeed, it may still be useful to notice when someone overtly attends to something that has interested you, even if you did not overtly attend to it. For example, this might reaffirm that what captured your attention is indeed interesting (e.g. Bayliss et al., 2013). However, whether the attentional response to such instances is equivocal to that of overtly sharing attention remains to be seen. Future work should also consider whether the present findings suggest that the overt shift of attention by the participant overwrites their previous covert shift of attention on antisaccade trials (e.g. Experiments 9-11), or whether there is an additive effect of both covertly and overtly jointly attending (on saccade trials), or a combination of both, that leads to the different impacts from either experiencing joint or non-joint gaze.

Comparing across the experiments of Chapter 3 and 4 it appears that the gaze leading effect only emerges when the gaze leading encounter has an image of an object as the shared referent. However, Experiment 1 (Chapter 2) showed RT facilitation for gaze direction identification of faces gazing towards a centrally shared referent, which might be suggestive of a gaze leading-like effect, but such response patterns were not apparent when the shared referent was non-central. If the RT facilitation relating to centrally shared gaze in Experiment 1 is related to the gaze leading effect, it is reasonable to suggest that this RT facilitation would be increased if the fixation cross was replaced by an image of a real world object, and it would therefore also be interesting to assess whether a gaze leading effect-like response would also occur when gaze is directed towards non-central object images.

The gaze leading effect appears highly sensitive to the social specificity of the ‘interaction’ (Chapters 3 & 4). Not only is the shared referent crucial, but the gaze leading effect did not replicate with arrow stimuli. This can be seen as somewhat surprising given how similar gaze and arrow cues are usually shown to impact attention (e.g. Bayliss & Tipper, 2005). Interestingly, taken together with previous research (Cañadas & Lupiáñez, 2012) the paradigm used in Chapter 2 of this thesis only appears to produce impacts on attention that might be related to the gaze leading effect when the face stimuli are biologically relevant. Therefore, it seems highly likely that the mechanism driving the RT facilitation in Experiment 1 is related to the gaze leading effect.

Experiment 11 showed that our attention will be cued in different ways by individuals based on whether those individuals have previously followed, or not followed, our gaze to engage in joint attention. It is interesting to consider whether this differentiation is based on the gaze leading effect. That is, the gaze leading effect may be the mechanism by which successful gaze leading is encoded, which then leads to different orienting responses later. Indeed, both the attentional response to those we have previously led the gaze of (Experiment 11), and the gaze leading effect (Experiments 5-7), have been shown to correlate with participants prevalence of autism-like traits – a point that is returned to below. It may therefore be interesting for future research to consider whether individuals that show less of a gaze leading effect also are less sensitive to the quality of their own previous gaze leading encounters.

It is necessary to note that it could be argued that within the current thesis true gaze leading, and therefore potentially shared attention, only occurred in a sub-set of experiments. Specifically, mutual gaze was not present prior to joint gaze in any of the experiments in Chapter 3 and 4. As such the participants should not truly perceive their gaze to have been 'followed' as the on-screen faces had closed eyes and thus could not 'see' the participants reorientation. However, mutual gaze prior to joint gaze was present in Chapter 5, and in half the trials of both Experiments 1 and 2 (Chapter 2). Future work may therefore wish to consider the importance of mutual gaze as an ostensive cue in future investigations of the gaze leading effect.

## Implications

While a range of relevant literature regarding joint attention and gaze leading have been considered thus far, there are also a number of previous experiments, which may be initially considered less directly relevant, which may be interpreted differently in light of the findings of the current thesis. For example, Böckler et al (2011; 2014) showed that the magnitude of gaze cueing elicited by two non-central faces, presented with one either side of a central fixation cross to which participants fixated, was larger if those faces looked inwards 'at each other' (both faces could also be perceived as looking at the fixation cross and thus jointly attending with the participant) immediately prior to the gaze cue of 'looking' upwards or downwards. The authors attributed these findings as reflecting increased orienting in response to faces that one has observed engaging in mutual gaze (the two onscreen faces 'looking' at each other). However, it may also be the case that participants were having their attention captured by one or both of the faces, which may have been perceived by participants as 'following' their gaze. This is of course highly speculative given that the procedure of Böckler et al (2011; 2014) had neither active reorientation by participants or images of objects as the shared referent. However, the gaze leading effect has yet to be assessed in instances where more than one agent looks towards the same referent as a participant.

This thesis presents evidence that the attention orienting response to having ones gaze followed is in direct opposition to that of following others gaze (e.g. Experiment 3 vs Experiment 5). Further, both gaze following and gaze leading can lead to different impacts on subsequent gaze processing (Experiment 9 vs Experiment 10), and also have different impacts of the subsequent interactions we have with given individuals (Dalmaso et al., 2016). Thus, it seems highly important that research is explicit in placing the participant as either the gaze leader or gaze follower in an interaction, as potentially subtle changes regarding who (the participant or an onscreen face, for example) looks somewhere first could lead to drastically different outcomes.

Related to the above, Senju et al (2006) presented participants with an onscreen face that would either look towards or away from the location of a briefly presented peripheral chequerboard stimulus. ERP responses to gaze away from, verses towards, the chequerboard were interpreted as reflecting a violation of expectation, suggesting that we may expect others to look at objects (Senju et al., 2006). However, crucially the chequerboard was displayed prior to the onscreen gaze aversion. Given that such peripheral onset stimuli capture attention (e.g. Posner, 1980), it may actually be that participants were ‘expecting’ that the onscreen face will ‘look’ towards the same referent that had captured their attention. Indeed, we may expect that others will follow our gaze (e.g. Pfeiffer et al., 2011). Future work may look to assess whether non-gaze followers are interpreted as norm-violators in gaze leading paradigms.

**Joint and shared attention**

The definition of *joint attention* is changeable (Kingstone, Friesen & Gazzinga, 2000). For example, some contend that joint attention can require that both agents are aware of their joint focus (e.g. Redcay & Saxe, 2013) while perhaps more commonly this would be interpreted as shared attention, with joint attention only requiring the gaze follower to be aware of the shared state of attention, with the gaze leader potentially unaware that their gaze has been followed (Bayliss et al., 2013; Emery, 2000; Pfeiffer et al., 2012). As the present work suggests that a gaze leader will rapidly reorient their attention towards a gaze follower (Chapters 3 & 4; Edwards et al., 2015), it is likely that many instances of joint attention are likely to progress into shared attention. It may therefore be necessary to develop more nuanced definitions of joint and shared attention that take into consideration the apparent human propensity to ‘notice’ when their gaze is followed.

Tomasello et al (2005) suggested that being aware of sharing attentional focus with another agent, or sharing a goal, may be inherently rewarding and motivate social interactions. Kim & Mundy (2012) suggested that this reward could be a contributor to the finding that gaze leading leads to better memory than gaze following by participants. Indeed, joint attention initiation has been suggested as producing neuro-correlates suggestive of reward processing (e.g. Schilbach et al., 2010). Taken together with the current work, it might well be that the reward associated with initiating joint attention reflects the anticipated benefits that might emerge from the developing shared attention with the gaze follower.

It may be interesting for theorists to consider to what extent the gaze leading effect, which is here suggested as implying a mechanism for promoting shared attention, can account for the previously hypothesised Shared Attention Mechanism (SAM, Baron-Cohen et al., 1995). Indeed, in order to fully comprehend how the SAM might function, which was proposed to assess instances in which you and another agent are sharing attention, one must necessarily consider that the SAM would have an input *both* when gaze following and when gaze leading occurs. Observing someone else look at an object is interpreted in a unique manner (e.g. Pelphrey et al., 2000), while here it also appears that the gaze leading effect is not just sensitive to others looking at objects, but crucially to others looking at the object to which we are looking (e.g. Experiment 7). Thus we might propose that the mechanisms underpinning both the vigilance towards others looking at objects, and also the vigilance towards others looking at the same object that we are, function to allow interactions based on jointly attending the same object. Further, the SAM is proposed as a prerequisite for the development of a theory of mind (ToM, Baron-Cohen et al., 1995), which fits well with the current observation of the gaze leading effect co-varying with autism-like traits.

**Ecological validity in social attention research**

As outlined in Chapter 1 of the current thesis, the social context of an interaction can lead to strikingly different responses in a participant (e.g. Pfeiffer et al., 2011; Redcay et al., 2010). The present work is also congruent with this notion, illustrating that the social context of the interaction is also crucial to how gaze leading encounters are interpreted by the gaze leader. For example, Chapter 2 showed that images of real faces (Experiment 1) produce response biases in participants that schematic faces do not (Experiment 2), which taken together with previous research (Cañadas & Lupiáñez, 2012) could suggest that gaze leading encounters are only perceived differently by the gaze leader based on whether or not biologically relevant stimuli are responding to the participant.

Further, the gaze leading paradigm that was developed across Chapters 3 and 4 further illustrates the importance of the participant's subjective experience of the interaction. The gaze leading effect of attention orienting towards those that follow gaze was only evident in interactions that involved active, object-centred gaze leading (Experiments 5-7). However, the gaze leading effect was not shown when the shared referent was a mere fixation cross (Experiment 4) and was reversed in Experiment 3 such that the response patterns suggested that participants were actually following the on-screen gaze and thus presumably not perceiving the 'interaction' as gaze leading at all. Thus, subtle alterations to the ecological validity of the interaction drastically altered the response of participants.

Given that the observable responses made by participants can differ between face-to-face interactions and video-based interactions (e.g. Freeth et al., 2013), it will be a challenge for future work to develop paradigms that allow for the assessment of attention orienting during gaze leading in 'real' face-to-face interactions (see Schilbach et al., 2015 for review).

### Gaze leading associations with autism-like traits

As suggested above, the differentiation of those that we are interacting with based on the quality of our gaze leading interactions with those individuals (e.g. Experiment 11) could relate to the gaze leading effect (Chapters 3 & 4; Edwards et al., 2015). Interestingly, while participants generally appeared to 'learn' not to be cued later by those that had previous followed their gaze, participants with higher AQ scores appeared to learn this to a lesser extent (Experiment 11; see Dalmaso et al., 2016 for further evidence of this being a learning effect). That is, participants with higher AQ scores showed *more* cueing in response to faces that had previously followed their gaze, than lower AQ participants. It therefore appears that higher AQ participants may be missing out on valuable information during gaze leading encounters. Importantly, participants with higher AQ scores appeared to orient their attention towards faces that follow their gaze to a lesser extent than those with lower AQ scores (across Experiments 5-7; Edwards et al., 2015). This could suggest that it is the disrupted gaze leading effect response, which has been shown to relate to AQ, which leads to the disrupted learning of prior responses of others during gaze leading encounters. Thus, gaze leading appears to have a number of intriguing associations with individual differences measures of autism-like traits within typically developing groups, which opens up a number of interesting avenues for future work to consider how such findings would translate to clinical populations, some of which are outlined below.

## Future directions

The current work was not directly interested in assessing the relative contributions of covert and overt attention. For example, the experiments concerning the gaze leading effect did not impose limits on participants fixation behaviour once the onscreen face had 'responded' to their gaze. Bayliss et al (2013) showed that participants were faster to return to look at faces that had followed, verses not followed, gaze. Such overt reorienting can be facilitated by covert shifts of attention in the same direction (e.g. Posner, 1980), which may indicate that covert attention is drawn towards gaze followers. However, future work is required to assess the relative contributions of covert and overt orienting responses during gaze leading, for example by imposing strict gaze-based instructions on participants during the interaction.

As mentioned above, it appears that the gaze leading effect may be specific to biologically relevant stimuli. Future work may further assess this by comparing attention orienting in response to gaze following faces with pointing hands that 'respond' to participant's gaze by pointing at, or away from, the shared referent. Indeed, pointing is an integral part of naturalistic joint attention, a behaviour that is used to initiate joint attention (Desrochers, Morissette & Ricard, 1995), and a pointing had offers the advantage, compared to non-social stimuli such as arrows, of being both visually dissimilar to eye-gaze while still being biologically relevant.

A further avenue for future investigations is to uncover the underlying mechanisms relating to the gaze leading effect. As proposed by Edwards et al (2015), it is likely that the orienting of attention by gaze leaders towards those that follow their gaze first relies of the peripheral detection of the other persons gaze, a process that could be supported by the amygdala (e.g. Adolphs, Gosselin, Buchanan, Tranel, Schyns & Damasio, 2005). Importantly, the gaze leader must then encode the gaze direction of the other agent in order to work out if joint gaze is occurring, which likely occurs in the aSTS (Calder et al., 2007). Finally, the gaze leader must reorient their attention towards the gaze follower, for example via the inferior parietal lobule (Calder et al., 2007). Thus, future work can look to employ neuroimaging techniques (e.g. EEG) during gaze leading in order to assess the underlying neuro-architecture related to orienting one's attention towards those that follow gaze to establish joint attention.

Leading the gaze of another might be processed in a rewarding manner (Schilbach et al., 2010). The gaze leading, as opposed to following, side of joint attention has also been suggested as a key deficit relating to ASC (Mundy, 2003). This thesis presents evidence that the gaze leading effect, which might relate to the registering of successful joint attention initiation, varies with sub-clinical autism-like traits. It may therefore be interesting for future work to assess whether participants that orient less towards those that follow their gaze (i.e. show a smaller gaze leading effect) also show less reward processing during those interactions. Should this be the case, there might be an insightful link between the gaze leading effect and joint attention initiation behaviours in ASC – if one does not register the success of a gaze leading encounter the possibility of finding that encounter rewarding may be compromised, which in turn may make one less encouraged to engage in such behaviours in the future. Therefore, a particularly important avenue of future enquiry also concerns the magnitude of the gaze leading effect that is observable in clinical populations such as individuals with ASC. More speculatively, measuring such an orienting response may also prove useful with the diagnosis of atypical social attention.

Relatedly, it will be important for future work to uncover the mechanism behind how gaze leading encounters lead to altered attention orienting later. While the results of Experiment 11 are most informative when considered in the context of the other experiments we have employed to assess later attention orienting when reencountering agents (see Dalmaso et al., 2016), it is not yet clear how or why previous gaze leading encounters influence attention in the way observed in Experiment 11. Thus, comparing this 'learning' based on prior gaze leading experience with the magnitude of the gaze leading effect during those interactions may be potentially insightful.

**Summary**

This thesis has investigated the behavioural outcomes related to initiating joint attention by leading the gaze of others. Evidence of a novel social orienting effect in response to averted gaze is reported; the gaze leading effect (Chapters 3 & 4; Edwards et al., 2015). The gaze leading effect suggests that once you have reoriented your own attention to look at an object, you will rapidly reorient attention towards a faces that follows your gaze. This effect appears to be inherently linked to jointly attending the same object as another person. This orienting response is suggested as implying a mechanism in the human attention system that acts to promote shared attention, by making a gaze leader aware that their gaze has been followed. This response may be crucial for appropriately interpreting and responding to the responses that others make to our own behaviour. As the gaze leading effect was also associated with autism-like traits (Experiments 5-7), a particularly interesting avenue for future work will be to assess whether a disrupted gaze leading effect response can account for the atypical joint attention initiation behaviours associated with ASC.

This thesis also illustrated that prior experiences of joint gaze with particular individuals can impact subsequent interactions. While gaze perception of faces appeared unaffected by whether a given face had or had not previously followed participants gaze, participant did appear to have a larger expectation of being looked at in response to faces that had previously validly cued participant’s attention, compared to invalid cuers. Crucially, this further highlights the distinct processes associated with initiating or responding to joint gaze. Finally, leading the gaze of others can impact how those gaze followers can later influence our own attention. Thus, for the first time we can suggest that our attention system is sensitive to identity-specific information that is learned through prior experiences. This work also provides evidence that gaze followers may be interpreted as trustworthy by gaze leaders.

Thus, this thesis increases our understanding of the online and later emerging impacts of engaging in joint gaze, particularly with regards to the previously under-researched perspective of the gaze leader in a joint attention encounter. This work also opens up a number of interesting avenues for future investigations regarding gaze leading, from continuing to delve into the underlying mechanisms related to shared/ joint attention, as well as potentially fruitful investigations into the relation of joint attention initiation deficits in atypically developing populations.

**References**


Aarts, H., Bijleveld, E., Custers, R., Dogge, M., Deelder, M., Schutter, D., & van Haren, N. E. (2012). Positive priming and intentional binding: Eye-blink rate predicts reward information effects on the sense of agency. *Social neuroscience*, *7*(1), 105-112.

Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature*, *433*, 68-72. doi:10.1038/nature03086.

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. *Trends in cognitive sciences*, *4* (7), 267-278.

Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: the medial frontal cortex and social cognition. *Nature Reviews Neuroscience*, *7*(4), 268-277.

Anderson, J. R., & Doherty, M. J. (1997). Preschoolers' perception of other people's looking: Photographs and drawings. Perception, 26, 333–344.

Anderson, N. C., Risko, E. F., & Kingstone, A. (2011). Exploiting human sensitivity to gaze for tracking the eyes. *Behavior research methods*, *43*(3), 843-852.

Ando, S. (2002). Luminance-induced shift in the apparent direction of gaze. Perception, *31*(6), 657-674.

Baldwin, D.A. (1995). Understanding the link between joint attention and language. In C. Moore and P.J Dunham (Eds). *Joint attention: Its origins and role in development* (131-158). New York: Psychology Press.

Baron-Cohen, S. (1994) How to build a baby that can read minds: cognitive mechanisms in mindreading. *Cahiers de Psychologie Cognitive* 13, 513–552.

Baron-Cohen, S. (1995). The eye direction detector (EDD) and the shared attention mechanism (SAM): Two cases for evolutionary psychology. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 41–59). Hillsdale, NJ: Erlbaum.

Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology*, *13*(4), 379-398.

Baron-Cohen, S., Knickmeyer, R. C., & Belmonte, M. K. (2005). Sex differences in the brain: implications for explaining autism. *Science, 310*(5749), 819-823.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5-17.

Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism-spectrum as a function of target context. *British Journal of Psychology, 96*(1), 95-114.

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgements: Should eye trust you? *Psychological Science*, *17*, 514-520.

Bayliss, A. P., Bartlett, J., Naughtin, C. K., & Kritikos, A. (2011). A direct link between gaze perception and social attention. *Journal of Experimental Psychology: Human Perception and Performance, 37*(4), 634-644.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology, 58A*(4), 631-650.

Bayliss, A. P., Frischen, A., Fenske, M. J., & Tipper, S. P. (2007). Affective evaluations of objects are influenced by observed gaze direction and emotional expression. *Cognition*, *104*(3), 644-653.

Bayliss, A. P., Griffiths, D., & Tipper, S. P. (2009). Predictive gaze cues affect face evaluations: The effect of facial emotion. *European Journal of Cognitive Psychology*, *21*, 1072-1084.

Bayliss, A. P., Murphy, E., Naughtin, C. K., Kritikos, A., Schilbach, L., & Becker, S. I. (2013). 'Gaze leading': Initiating simulated joint attention influences eye movements and choice behavior. *Journal of Experimental Psychology: General*, *142*(1), 76-92. doi: 76.10.1037/a0029286.

Bayliss, A. P., Naughtin, C. K., Lipp, O. V., Kritikos, A., & Dux, P. E. (2012). Make a lasting impression: The neural consequences of re-encountering people who emote inappropriately. *Psychophysiology, 49*(12), 1571-1578.

Bayliss, A. P., Paul, M. A., Cannon, P. R., & Tipper, S. P. (2006). Gaze cuing and affective judgments of objects: I like what you look at. *Psychonomic Bulletin & Review*, *13*(6), 1061-1066.

Becchio, C., Bertone, C., & Castiello, U. (2008). How the gaze of others influences object processing. *Trends in cognitive sciences*, *12*(7), 254-258.

Beck, J., & Ambler, B. (1973). The effects of concentrated and distributed attention on peripheral acuity. *Perception & Psychophysics*, *14*(2), 225-230.

Bente, G., Rüggenberg, S., Krämer, N. C., & Eschenburg, F. (2008). Avatar-Mediated Networking: Increasing Social Presence and Interpersonal Trust in Net-Based Collaborations. *Human communication research*, *34*(2), 287-318.

Böckler, A., Hömke, P., & Sebanz, N. (2014). Invisible Man Exclusion From Shared Attention Affects Gaze Behavior and Self-Reports. *Social Psychological and Personality Science*, *5*(2), 140-148.

Böckler, A., Knoblich, G., & Sebanz, N. (2011). Observing shared attention modulates gaze following. *Cognition*, *120*(2), 292-298.

Böckler, A., van der Wel, R. P. R. D., & Welsh, T. N. (2014). Catching eyes: Effects of social and nonsocial cues on attention capture. *Psychological Science*, *25*, 720-727. doi: 10.1177/0956797613516147.

Broadbent, D (1958). *Perception and Communication*. London: Pergamon Press.

Brooks, R., & Meltzoff, A. N. (2005). The development of gaze following and its relation to language. *Developmental science*, *8*(6), 535-543.

Bruner, J. (1995). From joint attention to the meeting of minds: An introduction. In C. Moore & P. J. Dunham (Eds.), Joint attention: Its origins and role in development (pp. 1-14). Hillsdale, NJ: Erlbaum.

Butterworth, G. E. (1991). The ontogeny and phylogeny of joint visual attention. In A. Whiten (Ed.), Natural theories of mind (pp. 223-232). Oxford: Basil Blackwell.

Calder, A. J., Beaver, J. D., Winston, J. S., Dolan, R. J., Jenkins, R., Eger, E., & Henson, R. N. (2007). Separate coding of different gaze directions in the superior temporal sulcus and inferior parietal lobule. *Current Biology*, *17*(1), 20-25.

Cañadas, E., & Lupiáñez, J. (2012). Spatial interference between gaze direction and gaze location: A study on the eye contact effect. *The Quarterly Journal of Experimental Psychology*, *65*(8), 1586-1598.

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the society for research in child development*, i-174.

Caruana, N., Brock, J., & Woolgar, A. (2015). A frontotemporoparietal network common to initiating and responding to joint attention bids. *Neuroimage*, *108*, 34-46.

Catmur, C., & Heyes, C. (2013). Is It What You Do, or When You Do It? The Roles of Contingency and Similarity in Pro-Social Effects of Imitation. *Cognitive science*, *37*(8), 1541-1552.

Chance, M. R. (1967). Attention structure as the basis of primate rank orders. *Man*, 503-518.

Charman, T. (2003). Why is joint attention a pivotal skill in autism?. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1430), 315-324.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive development*, *15*(4), 481-498.

Chen, Z. (2012). Object-based attention: a tutorial review. *Attention, Perception, & Psychophysics*, *74*(5), 784-802.

Ciardo, F., Marino, B. F. M., Actis-Grosso, R., Rossetti, A., & Ricciardelli, P. (2014). Face age modulates gaze following in young adults. *Scientific Reports*, *4*, 4746.

Connor, K. M., Davidson, J. R., Churchill, L. E., Sherwood, A., Weisler, R. H., & FOA, E. (2000). Psychometric properties of the Social Phobia Inventory (SPIN) New self-rating scale. *The British Journal of Psychiatry*, *176*(4), 379-386.

Conty, L., Russo, M., Loehr, V., Hugueville, L., Barbu, S., Huguet, P., ... & George, N. (2010). The mere perception of eye contact increases arousal during a word-spelling task. *Social Neuroscience*, *5*(2), 171-186.

Conty, L., Tijus, C., Hugueville, L., Coelho, E., & George, N. (2006). Searching for asymmetries in the detection of gaze contact versus averted gaze under different head views: a behavioural study. *Spatial vision*, *19*(6), 529-545.

Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore and P.J Dunham (Eds). *Joint attention: Its origins and role in development* (131-158). New York: Psychology Press.

Dalmaso, M., Edwards, S. G. & Bayliss, A. P. (2016). Re-encountering individuals who previously engaged in joint gaze modulates subsequent gaze cueing. *Journal of Experimental Psychology: Learning, Memory & Cognition, 42(2), 271-284.*

Dalmaso, M., Galfano, G., Coricelli, C., & Castelli, L. (2014). Temporal dynamics underlying the modulation of social status on social attention. *PLoS ONE*, *9*, e93139.

Dalmaso, M., Galfano, G., Tarqui, L., Forti, B., & Castelli, L. (2013). Is social attention impaired in schizophrenia? Gaze but not pointing gestures is associated with spatial attention deficits. *Neuropsychology*, *27*, 608-613.

Dalmaso, M., Pavan, G., Castelli, L., & Galfano, G. (2012). Social status gates social attention in humans. *Biology Letters*, *8*, 450-452.

Deaner, R. O., Shepherd, S. V. & Platt, M. L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biology Letters*, *3*, 64-67.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual review of neuroscience*, *18*(1), 193-222.

Desrochers, S., Morissette, P., & Ricard, M. (1995). Two perspectives on pointing in infancy. *Joint attention: Its origins and role in development*, 85-101.

Doherty, M. J., McIntyre, A. H., & Langton, S. R. (2015). Developmentally distinct gaze processing systems: Luminance versus geometric cues. *Cognition*, *137*, 72-80.

Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology*, *92*,53-78.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509-540.

Edwards, S. G., Stephenson, L., Dalmaso, M., & Bayliss, A. P. (2015). Social orienting in gaze leading: A mechanism for shared attention. *Proceedings of the Royal Society: B*, *282*(1812). DOI: 10.1098/rspb.2015.1141

Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews*, *24*, 581-604.

Everling, S., & Fischer, B. (1998). The antisaccade: A review of basic research and clinical findings. *Neuropsychologia*, *36*, 885-899.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America*, *99*, 9602-9605.

Fischer, M. H., & Szymkowiak, A. (2004). Joint attention for pointing but not grasping postures. *Cortex*, *40*(1), 168-170.

Freeth, M., Foulsham, T., & Kingstone, A. (2013). What Affects Social Attention? Social Presence, Eye Contact and Autistic Traits. *PLoS ONE*, 8(1), e53286.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*, 490-495.

Friesen, C. K., & Kingstone, A. (2003). Abrupt onsets and gaze direction cues trigger independent reflexive attentional effects. *Cognition*, *87*(1), B1-B10.

Friesen, C. K., Ristic, J., & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception and Performance*, *30*, 319-329.

Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shifts evokes longer term inhibitory effects: Implications for social interactions, attention, and memory. *Journal of Experimental Psychology: General*, *133*, 516-533.

Frischen, A., & Tipper, S. P. (2006). Long-term gaze cueing effects: Evidence for retrieval of prior states of attention from memory. *Visual Cognition*, *14*, 351- 364.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin, 133,* 694-724. doi:10.1037/0033-2909.133.4.694.

Frischen, A., Smilek, D., Eastwood, J. D., & Tipper, S. P. (2007). Inhibition of return in response to gaze cues: The roles of time course and fixation cue. *Visual Cognition*, *15*(8), 881-895.

Frith, C. D. (2008). Social cognition. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *363*(1499), 2033-2039.

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *358*(1431), 459-473.

Galfano, G., Dalmaso, M., Marzoli, D., Pavan, G., Coricelli, C., & Castelli, L. (2012). Eye gaze cannot be ignored (but neither can arrows). *Quarterly Journal of Experimental Psychology*, *65*, 1895-1910.

Gallup, A. C., Chong, A., & Couzin, I. D. (2012). The directional flow of visual information transfer between pedestrians. *Biology letters*, rsbl20120160.

Gamer, M., & Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 705.

Gamer, M., Hecht, H., Seipp, N., & Hiller, W. (2011). Who is looking at me? The cone of gaze widens in social phobia. *Cognition and Emotion*, *25*(4), 756-764.

George, N., Driver, J., & Dolan, R. J. (2001). Seen gaze-direction modulates fusiform activity and its coupling with other brain areas during face processing. *Neuroimage*, *13*(6), 1102-1112.

Gibson, J. J. (2013). *The ecological approach to visual perception*. Psychology Press.

Gibson, J. J., & Pick, A. D. (1963). Perception of another person's looking behavior. *The American journal of psychology*, 73 (3), 386-394.

Gobbini, M. I., & Haxby, J. V. (2007). Neural systems for recognition of familiar faces. *Neuropsychologia*, *45*, 32-41.

Gordon, I., Eilbott, J. A., Feldman, R., Pelphrey, K. A., & Vander Wyk, B. C. (2013). Social, reward, and attention brain networks are involved when online bids for joint attention are met with congruent versus incongruent responses. *Social Neuroscience*, *8*(6), 544-554.

Gross, C. G., Rocha-Miranda, C. E., & Bender, D. B. (1972). Visual properties of neurons in inferotemporal cortex of the Macaque. *Journal of neurophysiology*, *35* (1), 96-111.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. *Science*, *198* (4319), 853-855.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. *Science*, *198*(4319), 853-855.

Hallet, P. E. (1978) Primary and secondary saccades to goals defined by instructions. *Vision Research*, *18*, 1279-1296.

Hare, B., & Tomasello, M. (1999). Domestic dogs (Canis familiaris) use human and conspecific social cues to locate hidden food. *Journal of Comparative Psychology*, *113*(2), 173.

Harmon-Jones, E., Gable, P. A., & Peterson, C. K. (2010). The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update. *Biological psychology*, *84*(3), 451-462.

Haun, D. B., & Call, J. (2008). Imitation recognition in great apes. *Current Biology*, *18*(7), R288-R290.

Hayes, A.E., Paul, M.A., Beuger, B. & Tipper S.P. (2007), Self Produced and Observed Actions Influence Emotion: The roles of action fluency and eye gaze, *Psychological research*, 72, 461–72.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior.*The American Journal of Psychology*, 57 (2), 243-259.

Hertel, P. T., & Mathews, A. (2011). Cognitive bias modification past perspectives, current findings, and future applications. *Perspectives on Psychological Science*, *6*(6), 521-536.

Hietanen, J. K., & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 1228-1243.

Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., & Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach–avoidance motivational brain systems. *Neuropsychologia*, *46*(9), 2423-2430.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature neuroscience*, *3*(1), 80-84.

Hoffman, E., McCabe, K., & Smith, V. L. (1996). Social distance and other-regarding behavior in dictator games. *The American Economic Review*, 653-660.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131-134.

Hudson, M., Nijboer, T. C. W., & Jellema, T. (2012). Implicit social learning in relation to autistic-like traits. *Journal of Autism and Developmental Disorders*, *42*, 2534-2545.

Itti, L., Koch, C., & Niebur, E. (1998). A model of saliency-based visual attention for rapid scene analysis. *IEEE Transactions on Pattern Analysis & Machine Intelligence*, 20 (11), 1254-1259.

Jenkins, R., Beaver, J. D., & Calder, A. J. (2006). I thought you were looking at me: Direction-specific aftereffects in gaze perception. *Psychological Science*, *17*(6), 506-513.

Jones, B. C., DeBruine, L. M., Main, J. C., Little, A. C., Welling, L. L., Feinberg, D. R., & Tiddeman, B. P. (2010). Facial cues of dominance modulate the short- term gaze-cuing effect in human observers. *Proceeding of the Royal Society B: Biological Sciences, 277*, 617-624.

Jones, S. (2015). The Mediating Effects of Facial Expression on Spatial Interference Between Gaze Direction and Gaze Location. *The Journal of general psychology*, *142*(2), 106-117.

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. *Nature, 504*, 427-431. doi:10.1038/nature12715.

Jonides, J (1981). Voluntary vs. automatic control over the mind's eye's movement. In J. B. Long & A. D. Baddeley (Eds.), Attentton and PerJbrmance IX (pp. 187-203). Hillsdale, NJ: Erlbaum

Kano, F., & Call, J. (2014). Cross-species variation in gaze following and conspecific preference among great apes, human infants and adults. *Animal Cognition, 91*, 136-150.

Kim, K., & Mundy, P. (2012). Joint attention, social-cognition, and recognition memory in adults. *Frontiers in Human Neuroscience*, *6*: 172. doi:10.3389/fnhum.2012.00172.

Kingstone, A., Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive joint attention depends on lateralized cortical connections. *Psychological Science, 11*(2), 159-166.

Klein, R. (2009). On the control of attention. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale,63*(3), 240.

Kleinke, C. L. (1986). Gaze and eye contact: a research review. *Psychological bulletin*, *100*(1), 78-100.

Kobayashi, H., & Kohshima, S. (1997). Unique morphology of the human eye. *Nature*, *387*, 767-768.

Kobayashi, H., & Kohshima, S. (2001). Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye. *Journal of human evolution*, *40* (5), 419-435.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: cognitive basis for stimulus-response compatibility--a model and taxonomy. *Psychological review*, *97*(2), 253.

Koval, M. J., Thomas, B. S., & Everling, S. (2005). Task-dependent effects of social attention on saccadic reaction times. *Experimental Brain Research*, *167*(3), 475-480.

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, & Psychophysics*, *71*, 314-327.

Kuhn, G., & Tipples, J. (2011). Increased gaze following for fearful faces. It depends on what you're looking for! *Psychonomic Bulletin & Review*, *18*, 89-95.

Kylliäinen, A., & Hietanen, J. K. (2004). Attention orienting by another's gaze direction in children with autism. *Journal of Child Psychology and Psychiatry*,*45*(3), 435-444.

Langton, S. R. (2000). The mutual influence of gaze and head orientation in the analysis of social attention direction. *The Quarterly Journal of Experimental Psychology: Section A*, *53*(3), 825-845.

Langton, S. R., & Bruce, V. (2000). You must see the point: Automatic processing of cues to the direction of social attention. *Journal of Experimental Psychology: Human Perception and Performance*, *26*(2), 747.

Langton, S. R., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in cognitive sciences*, *4* (2), 50-59.

Lavie, N., & Driver, J. (1996). On the spatial extent of attention in object-based visual selection. *Perception & Psychophysics*, *58*(8), 1238-1251.

LeBel, E. P., Borsboom, D., Giner-Sorolla, R., Hasselman, F., Peters, K. R., Ratliff, K. A., & Smith, C. T. (2013). PsychDisclosure.org: Grassroots Support for Reforming Reporting Standards in Psychology. *Perspectives on Psychological Science*, *8*, 424-432.

Leekam, S. R., Hunnisett, E., & Moore, C. (1998). Targets and Cues: Gaze-following in Children with Autism. *Journal of Child Psychology and Psychiatry*, *39*(7), 951-962.

Leonard, J. A. (1953). Partial advance information in a choice reaction time task British. Journal of Psychology, 49(2), 89–96.

Liuzza, M. T., Cazzato, V., Vecchione, M., Crostella, F., Caprara, G. V., & Aglioti, S. M. (2011). Follow my eyes: The gaze of politicians reflexively captures the gaze of ingroup voters. *PLoS ONE*, *6*, e25117.

Lobmaier, J. S., Fischer, M. H., & Schwaninger, A. (2006). Objects capture perceived gaze direction. *Experimental Psychology, 53*(2), 117-122.

Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review, 1*, 476-490.

Macrae, C. N., Hood, B. M., Milne, A. B., Rowe, A. C., & Mason, M. F. (2002). Are you looking at me? Eye gaze and person perception. *Psychological Science, 13*(5), 460-464.

Makris, S., Hadar, A. A., & Yarrow, K. (2013). Are object affordances fully automatic? A case of covert attention. *Behavioral Neuroscience*, *127*(5), 797.

Mareschal, I., Calder, A. J., & Clifford, C. W. (2013). Humans have an expectation that gaze is directed toward them. *Current Biology*, *23*(8), 717-721.

Marotta, A., Lupiañez, J., & Casagrande, M. (2012). Investigating hemispheric lateralization of reflexive attention to gaze and arrow cues. *Brain and Cognition*, *80*, 361-366.

Mathews, A., Fox, E., Yiend, J., & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition*, *10*, 823-835.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society B: Biological Sciences, 358*(1431), 491-500.

Moll, H., & Tomasello, M. (2007). Cooperation and human cognition: The Vygotskian intelligence hypothesis. *Philosophical Transactions of the Royal Society B: Biological Sciences, 362*(1480), 639-648.

Moore, C. & Dunham P.J. (1995, Eds.), *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.

Moore, C., & Dunham, P. (Eds.). (1995). *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.

Morales, M., Mundy, P., Delgado, C. E., Yale, M., Neal, R., & Schwartz, H. K. (2000). Gaze following, temperament, and language development in 6-month-olds: A replication and extension. *Infant Behavior and Development*, *23*(2), 231-236.

Mundy, P. (1995). Joint attention, social-emotional approach in children with autism. *Development and Psychopathology*, *7,* 63-82.

Mundy, P. (2003). Annotation: The neural basis of social impairments in autism: the role of the dorsal medial-frontal cortex and anterior cingulate system. *Journal of Child Psychology and Psychiatry*, *44*(6), 793-809.

Mundy, P., & Burnette, C. (2005). Joint attention and neurodevelopmental models of autism. *Handbook of Autism and Pervasive Developmental Disorders, Volume 1, Third Edition*, 650-681.

Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development*, *21*(3), 469-482.

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. Current Directions in Psychological Science, 16, 269–274.

Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development*, *78*(3), 938-954.

Mundy, P., Card, J., & Fox, N. (2000). EEG correlates of the development of infant joint attention skills. *Developmental psychobiology*, *36*(4), 325.

Mundy, P., Sullivan, L., & Mastergeorge, A. M. (2009). A parallel and distributed-processing model of joint attention, social cognition and autism. *Autism research*, *2*(1), 2-21.

Munoz, D. P., & Everling, S. (2004). Look away: the anti-saccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience*, *5*, 218-228.

Nadel, J. (2002). Imitation and imitation recognition: Functional use in preverbal infants and nonverbal children with autism. *The imitative mind: Development, evolution, and brain bases*, 42-62.

Nichols, K. A., & Champness, B. G. (1971). Eye gaze and the GSR. *Journal of Experimental Social Psychology*, *7*(6), 623-626.

Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. Trends in *Cognitive Science*, *13*, 135-143.

Ohlsen, G., van Zoest, W., & van Vugt, M. (2013). Gender and facial dominance in gaze cuing: Emotional context matters in the eyes that we follow. *PLoS ONE*, *8*, e59471.

Palanica, A., & Itier, R. J. (2015). Eye gaze and head orientation modulate the inhibition of return for faces. *Attention, Perception, & Psychophysics*, 1-12. DOI 10.3758/s13414-015-0961-y

Pashler, H. (Eds.) (1996). *Attention*. Erlbaum Taylor & Francis: Hove, UK.

Paukner, A., Anderson, J. R., Borelli, E., Visalberghi, E., & Ferrari, P. F. (2005). Macaques (Macaca nemestrina) recognize when they are being imitated. *Biology Letters*, *1*(2), 219-222.

Pavan, G., Dalmaso, M., Galfano, G., & Castelli, L. (2011). Racial group membership is associated to gaze-mediated orienting in Italy. *PLoS ONE*, *6*, e25608.

Pelphrey, K. A., Singerman, J. D., Allison, T., & McCarthy, G. (2003). Brain activation evoked by perception of gaze shifts: the influence of context. *Neuropsychologia*, 41 (2), 156-170.

Perrett, D. I., Hietanen, J. K., Oram, M. W., Benson, P. J., & Rolls, E. T. (1992). Organization and functions of cells responsive to faces in the temporal cortex [and discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *335* (1273), 23-30.

Perrett, D. I., Hietanen, J. K., Oram, M. W., Benson, P. J., & Rolls, E. T. (1992). Organization and functions of cells responsive to faces in the temporal cortex [and discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *335*(1273), 23-30.

Perrett, D. I., Rolls, E. T., & Caan, W. (1982). Visual neurones responsive to faces in the monkey temporal cortex. *Experimental brain research*, *47* (3), 329-342.

Perrett, D. I., Smith, P. A., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., & Jeeves, M. A. (1984). Neurones responsive to faces in the temporal cortex: studies of functional organization, sensitivity to identity and relation to perception. *Human Neurobiology*, *3*(4), 197-208.

Perrett, D., & Emery, N.J. (1994). Understanding the intentions of others from visual signals: Neuropsychological evidence. Cahiers de Psychologie Cognitive, 13, 683–694.

Petrican, R., English, T., Gross, J. J., Grady, C., Hai, T., & Moscovitch, M. (2013). Friend or foe? Age moderates time-course specific responsiveness to trustworthiness cues. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *68*(2), 215-223.

Pfeiffer, U. J., Schilbach, L., Jording, M., Timmermans, B., Bente, G., & Vogeley, K. (2012). Eyes on the mind: Investigating the influence of gaze dynamics on the perception of others in real-time social interaction. *Frontiers in Psychology, 3*: 537.

Pfeiffer, U. J., Schilbach, L., Timmermans, B., Kuzmanovic, B., Georgescu, A. L., Bente, G., & Vogeley, K. (2014). Why we interact: on the functional role of the striatum in the subjective experience of social interaction. *Neuroimage*, *101*, 124-137.

Pfeiffer, U. J., Timmermans, B., Bente, G., Vogeley, K., & Schilbach, L. (2011). A non-verbal Turing test: Differentiating mind from machine in gaze-based social interaction. *PLoS ONE, 6*, e27591.

Pfeiffer, U. J., Vogeley, K., & Schilbach, L. (2013). From gaze cueing to dual eye-tracking: Novel approaches to investigate the neural correlates of gaze in social interaction. *Neuroscience and Biobehavioral Reviews*, *37*, 2516-2528.

Pickard, K. E., & Ingersoll, B. R. (2015). Brief report: High and low level initiations of joint attention, and response to joint attention: Differential relationships with language and imitation. *Journal of autism and developmental disorders*, *45*(1), 262-268.

Pönkänen, L. M., Alhoniemi, A., Leppänen, J. M., & Hietanen, J. K. (2010). Does it make a difference if I have an eye contact with you or with your picture? An ERP study. *Social cognitive and affective neuroscience*, doi:10.1093/scan/nsq068.

Posner M. I. (1978). *Chronometric Explorations of Mind.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Posner M. I. (2014). Orienting of attention: then and now. *The Quarterly Journal of Experimental Psychology,* 67, 1–12. 10.1080/17470218.2014.937446

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*, 3-25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. *Attention and performance X: Control of language processes*, *32*, 531-556.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology*, *58*, 1-23.

Posner, M. I., Nissen, M. J., & Ogden, W. C. (1978). Attended and unattended processing modes: The role of set for spatial location. In Pick, H. L. & Saltzmai, N. J., (Eds), *Modes of Perceiving and Processing Information.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive neuropsychology*, *2*(3), 211-228.

Redcay, E., & Saxe, R. (2013). Do you see what I see? The neural bases of joint attention. In J.M Metcalfe & H.S. Terrace (Eds.) *Agency and Joint Attention*, (216-237). NewYork: Oxford University Press.

Redcay, E., Dodell-Feder, D., Pearrow, M. J., Mavros, P. L., Kleiner, M., Gabrieli, J. D., & Saxe, R. (2010). Live face-to-face interaction during fMRI: a new tool for social cognitive neuroscience. *Neuroimage*, *50*(4), 1639-1647.

Redcay, E., Kleiner, M., & Saxe, R. (2012). Look at this: The neural correlates of initiating and responding to bids for joint attention. *Frontiers in Human Neuroscience, 6*: 169.

Ricciardelli, P., & Driver, J. (2008). Effects of head orientation on gaze perception: how positive congruency effects can be reversed. *The Quarterly journal of experimental psychology*, *61*(3), 491-504.

Ricciardelli, P., Baylis, G., & Driver, J. (2000). The positive and negative of human expertise in gaze perception. *Cognition*, *77*(1), B1-B14.

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, *9*(3), 507-513.

Saxe, R. (2006). Uniquely human social cognition. *Current Opinion in Neurobiology*, *16*(2), 235-239.

Scaife, M., & Bruner, J. (1975). The capacity for joint visual attention in the infant. Nature, 253, 265-266.

Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlicht, T., & Vogeley, K. (2013). Towards a second-person neuroscience. *Behavioral and Brain Sciences, 36*, 393-462. doi:10.1017/S0140525X12000660.

Schilbach, L., Wilms, M., Eickhoff, S. B., Romanzetti, S., Tepest, R., Bente, G., Shah, N. J., Fink, G. R., & Vogeley, K. (2010). Minds made for sharing: initiating joint attention recruits reward-related neurocircuitry. *Journal of Cognitive Neuroscience*, *22*(12), 2702-2715.

Schulze, L., Lobmaier, J. S., Arnold, M., & Renneberg, B. (2013). All eyes on me?! Social anxiety and self-directed perception of eye gaze. *Cognition & emotion*, *27*(7), 1305-1313.

Senju, A., & Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Visual cognition*, *12*(1), 127-144.

Senju, A., & Johnson, M. H. (2009). The eye contact effect: mechanisms and development. *Trends in cognitive sciences*, *13*(3), 127-134.

Senju, A., Csibra, G., & Johnson, M. H. (2008). Understanding the referential nature of looking: Infants' preference for object-directed gaze. *Cognition*, *108*(2), 303-319.

Senju, A., Tojo, Y., Dairoku, H., & Hasegawa, T. (2004). Reflexive orienting in response to eye gaze and an arrow in children with and without autism. *Journal of Child Psychology and Psychiatry*, *45*(3), 445-458.

Shepherd, S. V. (2010). Following gaze: Gaze-following behavior as a window into social cognition. *Frontiers in Integrative Neuroscience, 4*, 1-13.

Shepherd, S. V., Deaner, R. O., & Platt, M. L. (2006). Social status gates social attention in monkeys. *Current Biology*, *16,* R119-R120.

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. Retrieved from http://ssrn.com/abstract=2160588

Slessor, G., Laird, G., Phillips, L. H., Bull, R., & Filippou, D. (2010). Age-related differences in gaze following: Does the age of the face matter? *Journal of Gerontology: Psychological Sciences*, *65,* 536-541.

Smet, A. F., & Byrne, R. W. (2014). African elephants (Loxodonta africana) recognize visual attention from face and body orientation. *Biology Letters*, *10*(7), 20140428.

Smith, D. T., & Schenk, T. (2012). The premotor theory of attention: time to move on?. *Neuropsychologia*, *50*(6), 1104-1114.

Süßenbach, F., & Schönbrodt, F. (2014). Not afraid to trust you: Trustworthiness moderates gaze cueing but not in highly anxious participants. *Journal of Cognitive Psychology*, *26*(6), 670-678.

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., ... & Wheelwright, S. (1998). The frequency and distribution of spontaneous attention shifts between social and nonsocial stimuli in autistic, typically developing, and nonautistic developmentally delayed infants. *Journal of Child Psychology and Psychiatry*, *39*(05), 747-753.

Taylor, T. L., & Klein, R. M. (1998). On the causes and effects of inhibition of return. *Psychonomic Bulletin & Review*, *5*(4), 625-643.

Téglás, E., Gergely, A., Kupán, K., Miklósi, Á., & Topál, J. (2012). Dogs' gaze following is tuned to human communicative signals. *Current Biology*, *22*(3), 209-212.

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & psychophysics*, *49*(1), 83-90.

Thelen, M. H., Frautschi, N. M., Roberts, M. C., Kirkland, K. D., & Dollinger, S. J. (1981). Being imitated, conformity, and social influence: An integrative review. *Journal of Research in Personality*, *15*(4), 403-426.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review*, *9*(2), 314-318.

Tipples, J. (2008). Orienting to counterpredictive gaze and arrow cues. *Perception & Psychophysics*, *70*, 77-87.

Tipples, J., Johnston, P., & Mayes, A. (2012). Electrophysiological responses to violations of expectation from eye gaze and arrow cues. *Social cognitive and affective neuroscience,* doi:10.1093/scan/nss024.

Todorov, A., Gobbini, M. I., Evans, K. K, & Haxby, J. V. (2007). Spontaneous retrieval of affective person knowledge in face perception. *Neuropsychologia*, 45, 163-173.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 103–130). Hillsdale, NJ: Erlbaum.

Tomasello, M., & Carpenter, M. (2005). The emergence of social cognition in three young chimpanzees. Monographs of the Society for Research in Child Development, 70 (1), vii–132.

Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental science*, *10*(1), 121-125.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*(05), 675-691.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., ... & Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry research*, *168*(3), 242-249.

VanVoorhis, C. R. W., & Morgan, B. L. (2007). Understanding power and rules of thumb for determining sample sizes. *Tutorials in Quantitative Methods for Psychology*, *3*(2), 43- 50.

Wannig, A., Stanisor, L., & Roelfsema, P. R. (2011). Automatic spread of attentional response modulation along Gestalt criteria in primary visual cortex. *Nature neuroscience*, *14* (10), 1243-1244.

Warburton, W. A., Williams, K. D., & Cairns, D. R. (2006). When ostracism leads to aggression: The moderating effects of control deprivation. *Journal of Experimental Social Psychology*, *42*(2), 213-220.

Wilkowski, B. M., Robinson, M. D., & Friesen, C. K. (2009). Gaze-triggered orienting as a tool of the belongingness self-regulation system. *Psychological Science*, *20*(4), 495-501.

Wilms, M., Schilbach, L., Pfeiffer, U., Bente, G., Fink, G. R., & Vogeley, K. (2010). It’s in your eyes – using gaze-contingent stimuli to create truly interactive paradigms for social cognitive and affective neuroscience. *Social Cognitive and Affective Neuroscience*, *5*, 98-107.

Wirth, J. H., Sacco, D. F., Hugenberg, K., & Williams, K. D. (2010). Eye gaze as relational evaluation: Averted eye gaze leads to feelings of ostracism and relational devaluation. *Personality and Social Psychology Bulletin*. doi:10.1177/0146167210370032

Wolf, R. C., Philippi, C. L., Motzkin, J. C., Baskaya, M. K., & Koenigs, M. (2014). Ventromedial prefrontal cortex mediates visual attention during facial emotion recognition. *Brain*, *137*(6), 1772-1780. doi: 10.1093/brain/awu063.

Wolohan, F. D. A., & Crawford, T. J. (2012). The anti-orienting phenomenon revisited: effects of gaze cues on antisaccade performance. *Experimental Brain Research*, *221*, 385-392.

Wykowska, A., Wiese, E., Prosser, A., & Müller, H. J. (2014). Beliefs about the minds of others influence how we process sensory information. *PloS one*, *9*(4), e94339.

Yantis, S. (1993). Stimulus-driven attentional capture. *Current Directions in Psychological Science*, 2 (5), 156-161.

# Appendix A

Social orienting in gaze leading: A mechanism for shared attention

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**Abstract**

Here we report a novel social orienting response that occurs after viewing averted gaze. We show, in three experiments, that when a person looks from one location to an object, attention then shifts towards the face of an individual who has subsequently followed the person's gaze to that same object. That is, contrary to 'gaze following', attention instead orients in the opposite direction to observed gaze and towards the gazing face. The magnitude of attentional orienting towards a face that 'follows' the participants gaze is also associated with self-reported autism-like traits. We propose that this gaze leading phenomenon implies the existence of a mechanism in the human social cognitive system for detecting when one's gaze has been followed, in order to establish 'shared attention' and maintain the ongoing interaction.

Keywords: joint attention, shared attention, gaze perception, social orienting, social cognition

**Social orienting in gaze leading: A mechanism for shared attention**

Humans, amongst other species, spontaneously follow the gaze direction of other individuals to orient their own attention towards a common object – establishing 'joint attention' [see 1]. The attentional underpinnings of joint attention can be studied with the gaze cueing paradigm, which has shown that orienting in the direction in which someone else is looking appears to occur in a rapid and robust manner [e.g. 2, 3; see 4, for review]. Following gaze to establish joint attention is beneficial to the 'follower' as they may learn about important stimuli, infer the mental state of others, and predict their future actions [e.g. 5].

Where there is a follower, there is also a 'leader', who has effected change on their social environment. A great deal of research has focussed on investigating how we code others' gaze direction [e.g. 6]. In dynamic interactions, however, it is also important to detect the effects that our own gaze behaviour has on others [7], and relatively less is known about how this is achieved. Therefore, to understand the mechanisms underpinning joint attention more completely, we need to consider the 'initiator', in addition to the 'responder' [8, 9]. Some intriguing findings regarding gaze leading have recently been uncovered using gaze-contingent paradigms so that face stimuli 'respond' to the participant's gaze behaviour, showing that 'being followed' has consequences for various components of joint attention [e.g. 10, 11]. For example, gaze leading positively influences affective processing [12-14] and recognition memory for gaze leaders [15]. It is likely that gaze coding mechanisms, spatial attention and social systems could be involved in detecting and maintaining iterative social orienting behaviours such as when one's eyes are followed by a conspecific [7, 16-18].

Here we focus on elucidating the putative attention mechanisms engaged when one detects that one's gaze has been followed. It is reasonable to hypothesise the existence of a mechanism that emerged to potentiate beneficial social interactions by driving the detection of such positive interactions. In a sense, when our eyes are followed, another individual has ‘imitated’ our attentional state. Imitation is crucial for the development of social cognition [19], and many primate species recognise being imitated [20, 21, see also 22]. It is possible that having your gaze followed could be similarly salient. Therefore, here we ask whether causing another individual to change their attentional state to one of joint attention has an effect on spatial attention in the initiator. We hypothesise that the gaze leader – once followed – will shift their attention towards the follower. Discovering such a response would imply a mechanism that drives humans to establish a state of ‘shared attention’ [23]. Shared attention is where one individual follows another, but additionally, both individuals are aware of their common attentional focus. Shared attention is therefore a more elaborate, reciprocal, joint attention episode that is thought to be expressed only in humans [24-26] and may play a particularly crucial role in language acquisition [27].

To determine whether an orienting mechanism facilitates shared attention, we conducted a series of computer-based laboratory experiments in which we assessed attention shifts towards peripherally-presented faces. In each experimental trial, the participant would look from a fixation point in the lower portion of a display to an image of a real-world object located centrally. Our design therefore incorporates two important aspects of joint attention. Firstly, one agent actively re-orients attention elsewhere to gain visual information, and secondly this eye movement foveates a meaningful object [28]. The latter object-based nature of joint attention is required by definition [23], and is critical in human social development [29]. Then, one face would look at the location to which the participant had looked and another face would look in the opposite direction. By comparing manual reaction times to discriminate targets appearing on these faces, we could assess whether a face that follows participant’s eyes captures attention.

**Experiment 1**

Participants responded to targets appearing in four possible locations; on two faces to the immediate left and right of the centrally-presented object, and two other faces presented more peripherally (aligned horizontally, see Figure 1). After the participants had moved their eyes from the lower fixation cross to the central object, the two innermost faces would simultaneously open their eyes and look in a common direction (left or right), meaning one face looks towards the central object while the other looks away. A target letter would appear on the bridge of the nose of one of the four faces. The two innermost faces are the critical target loci for evaluating our hypothesis, but performance at the peripheral loci could also be informative. Our hypothesis is that participants will orient towards a face that suddenly looks at the location to which they are currently looking, and respond to targets appearing there more quickly than at any other location.

[Figure 1 about here]

**Method**

In all experiments we have reported how we determined our sample size, all data exclusions (if any), all manipulations, and all measures we have collected [see 30].

**Participants.** Thirty-two adults (age; *M*=19.2 years, *SD*=1.6 years; eight males) took part in return for course credit or payment (as in this experiment and in all others). Due to calibration and tracking difficulties three participants completed only three of four blocks. Participants in all experiments reported normal or corrected-to-normal vision. We aimed to collect data from approximately 30 participants and stopped at *n*=32, for convenience, at the end of a block of booked testing sessions.

**Apparatus and Stimuli.** Face stimuli consisted of greyscale photographs taken from an existing stimulus set [31]. Eight identities with a calm facial expression were used (four female). For each face identity, three images were used such that each identity could be displayed with closed-eyes, leftward gaze, or rightward gaze. Each face image measured 50mm × 64mm. Two faces appeared on each side of the central cross; the centre-point of the inner-most faces was 33mm away from the centre, the centre-point of the outer-most faces was 84mm away from the centre. Participants began each trial fixating a second cross 65mm directly below the central cross. Face identities were randomly assigned to each position on each trial, with the constraint that a given identity could only appear in one location per trial. The referent object of the joint attention episode was one of sixteen not-to-scale images of objects commonly found in the kitchen, randomly selected on each trial [32]. Target letters (N or H; 18pt purple bold Arial, 4mm × 4mm), were presented on a white background (6mm × 6mm). Stimulus presentation was controlled by a standard desktop computer with a 46cm screen (1024 × 768px), and manual responses were made on a standard keyboard. Participants were positioned comfortably in a chin-rest. Right eye position was recorded (Eyelink 1000, SR Research, Ontario, Canada; spatial resolution 0.1°, 500 Hz). In this and subsequent experiments, the Autism Spectrum Quotient (AQ) questionnaire was used to measure autism-like traits of participants [33], which has previously been shown to share a relationship with social orienting of attention [34-36].

**Design.** A 4 (Target Location; ‘Face with eyes closed and looked away from’, ‘Joint Attention Face’, ‘Non-Joint Attention Face’, ‘Face with eyes closed and being looked at’) × 2 (cue-target stimulus onset asynchrony – ‘SOA’; 100ms, 400ms) within-subjects design was used. Although we used four target locations, the two critical target locations are the innermost ones (‘Joint Attention Face’ and ‘Non-joint Attention Face’). We used the additional target locations to assess how attention was distributed beyond these two locations. Reaction times (RTs) and accuracy rates were measured.

**Procedure.** Participants sat approximately 70cm away from the display. Each trial started with the two fixation crosses (central, and 65mm below) along with the four faces aligned on the horizontal midline, two either side of the central cross (see Figure 1A), on a black background. On each trial, the participant first had to fixate the lower cross for 500ms, which would trigger the replacement of the central cross with an image of an object, which was their cue to saccade to and fixate the object. After fixating the object for 300ms, the innermost faces were then both displayed with averted gaze in a common direction (left or right) for either a 100ms or 400ms SOA prior to target appearance (see Figure 1C). Thus, for example, the face to the left of fixation would 'look' rightwards towards the central object, while the face to the right of fixation, also looking rightwards, looked away from the object. Next, a target letter was presented on the bridge of the nose of one of the four faces until a response was made, or until timeout (5000 ms), whichever came first. Note that although participants were asked to fixate the central object in order to progress through each trial, they were given no specific instructions regarding maintaining fixation following cue or target appearance. Participants responded to targets with their preferred index finger on the H key for 'H' targets and with the thumb of the same hand on the spacebar for 'N' targets. Speed and accuracy of manual response was emphasised. Finally, a feedback screen was displayed for 1500ms – this was a black screen after a correct response, but showed a red central cross after an incorrect or non-response. The experimenter was present for the duration of the session. Female experimenter LJS tested eighteen participants, male experimenter SGE tested fifteen participants. The experiment comprised 256 trials and the session took approximately 60 minutes.

**Results and Discussion**

Mean and standard deviations for accuracy and reaction times for each condition (and all Experiments) are found in Table 1. Trials with correct reaction times 3*SD*s above or below the participant's mean were removed before the calculation of means for each condition. The same criteria were used in each of the three experiments.

[Table 1 about here]

**Accuracy.** A 4 (Target location; Joint Attention, Non-Joint Attention, Looked at, Not looked at) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA was carried out on mean accuracy (96.0% of trials, *SD* = 3.51%). There was no significant main effect of Target Location, $F(3,93)<1$, SOA, $F(1,31)=3.62$, $p=.066$, $\eta^2_p=.105$, and no significant interaction $F(3,93)=1.03$, $p=.38$, $\eta^2_p = .03$.

**Reaction times.** 1.7% of trials were discarded as outliers. A 4 (Target location; Joint Attention, Non-Joint Attention, Looked at, Not looked at) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA showed that the main effect of Target Location was significant, $F(3,93)=49.6$, $p<.001$, $\eta^2_p=.62$. There was a significant main effect of SOA, $F(1,31)=52.0$, $p<.001$, $\eta^2_p=.63$. The interaction was not significant, $F(3,93)=1.86$, $p=.14$, $\eta^2_p=.06$. To determine the source of the Target Location main effect, a 2 (Target location; Joint Attention, Non-Joint Attention) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA of the inner locations showed that – as predicted - RTs at the Joint Attention face target location (597ms) were faster than at the Non-joint attention face (616ms), $F(1,31)=19.0$, $p<.001$, $\eta^2_p=.38$ (see Figure 2). This effect was reliable at the 100ms SOA, $t(31)=-3.45$, $p=.002$, $dz=.61$, and the 400ms SOA, $t(31)=-2.60$, $p=.014$, $dz=.46$. Additionally, the main effect of SOA was significant, $F(1,31)=17.37$, $p<.001$, $\eta^2_p=.36$, and the interaction was non-significant, $F(1,31)<1$. The same 2 × 2 ANOVA for peripheral locations revealed faster RTs at the 'Not looked at' face, than at the 'Looked at' face, $F(1,31)=9.02$, $p=.005$, $\eta^2_p=.23$. The SOA main effect was significant, $F(1,31)=72.76$, $p<.001$, $\eta^2_p=.70$, and the interaction was not, $F(1,31)=3.60$, $p=.067$, $\eta^2_p=.10$.

[Figure 2 about here]

In summary, responses were faster to targets appearing on the face that had looked at the object to which the participant had looked. This is in line with our prediction and is the first evidence that faces that follow our gaze to an object capture attention. Indeed, in this experiment, attention shifted in the opposite direction to that which would be predicted by 'gaze cueing', which is somewhat surprising given how powerful gaze following can be. Could our data in fact reflect gaze cueing after the engagement of inhibitory mechanisms of attention (i.e. inhibition of return, IOR [38])? This is unlikely as IOR is extremely difficult to observe in gaze cueing paradigms, emerging only at very long SOAs exceeding 2000ms [39, 40]. Our effects emerge at 100ms and 400ms SOAs – time intervals at which it is not straightforward to elicit IOR even with sudden onset cues [39-41]. Facilitation of attention towards the location of a person who has followed one's gaze is the parsimonious explanation for our observation. This therefore shows for the first time that attention orients towards a face that has looked at the same object to which an initiator of joint attention has looked: the gaze leading effect.

## Experiment 2

It is necessary to replicate this novel finding and to validate our paradigm. In Experiment 2 we simplified the display by removing the peripheral faces, providing only two target locations (the innermost locations). The outermost target locations have been informative in Experiment 1, being consistent with - but not critical to the evaluation of - our hypothesis.

### Method

Thirty-two adults (five men; mean age = 19.6 years, *SD*=1.5 years) took part. Due to technical difficulties three participants completed only three of the four blocks. The stimulus display was similar to Experiment 1, except that only two faces were displayed (in the innermost positions). There were now only two possible target locations, and thus half as many trials (4 blocks of 32 trials) in a 2 (Target Locations) × 2 (SOA) repeated measures design. Experimenter SGE tested all participants.

### Results and Discussion

**Accuracy.** A 2 (Target location; Joint Attention, Non-Joint Attention) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA was carried out on the accuracy rates of participants (97.2% of trials, *SD*=2.69%). The effect of Target Location was non-significant, $F(1,31)=3.81$, $p=.060$, $\eta^2_p=.110$; the trend is in the same direction as the RT effect (described below). The main effect of SOA was significant, $F(1,31)=12.0$, $p=.002$, $\eta^2_p=.28$. The interaction was not significant $F(1,31)<1$.

**Reaction times.** 1.5% of trials were discarded as outliers. A 2 (Target location; Joint Attention, Non-Joint Attention) × 2 (SOA; 100ms, 400ms) repeated measures ANOVA revealed a significant main effect of Target Location, $F(1,31)=8.03$, $p=.008$, $\eta^2_p=.21$, due to faster responses at the Joint Attention (616ms), versus Non-Joint Attention (630ms) location. There was a significant main effect of SOA, $F(1,31)=59.0$, $p<.001$, $\eta^2_p=.66$. The interaction was not significant, $F(1,31)<1$. The effect of Target Location was not significant at the 100ms SOA, $t(31)=-1.66$, $p=.11$, $dz=.29$, and was significant at the 400ms SOA, $t(31)=-2.10$, $p=.044$, $dz=.37$. Therefore, we replicated the gaze leading effect, again showing that attention shifts preferentially towards the face of an individual that has followed the participant's gaze.

## Experiment 3

In Experiments 1 and 2, only the Joint Attention face looks towards an object. Thus, it may be plausible that instead of this phenomenon being a 'gaze leading effect', related to shared attention, it could be that observing a face look at an object more strongly captures attention than a face that looks away from an object. Therefore in Experiment 3 we replicated Experiment 2, adding copies of the centrally-presented object to the far left and right of the faces (see Figure 2). This meant that both faces would always look a common direction and at an identical meaningful object. However, only one of the looked-at objects would be a joint attention referent. We predicted that the gaze leading effect will again emerge under these conditions.

### Method

Thirty-two adults took part (age; *M*=19.8 years, *SD*=1.5 years, 11 males). Due to technical difficulties two participants completed only three of the four blocks. The stimulus display was identical to that of Experiment 2 except that the same object image that appeared at the central location simultaneously appeared to the left and right of the faces, positioned so that each face was equidistant from the central and a peripheral object (see Figure 2). Experimenter SGE tested all participants.

### Results and Discussion

**Accuracy.** Participants responded correctly on 96.17% of trials (*SD* = 3.58%). There was no main effect of Target Location or SOA, *F*s(1,31)<1, but there was a significant interaction, *F*(1,31)=6.48, *p*=.016, $\eta^2_p$=.173, due to slightly lower accuracy for the shorter SOA at the Joint Attention location than at the Non-Joint Attention location, whereas the reverse was the case at the longer SOA (see Table 1).

**Reaction times.** 1.4% of trials were discarded as outliers. The main effect of Target Location was significant, *F*(1,31)=4.45, *p*=.043, $\eta^2_p$=.13, due to significantly faster responses at the Joint Attention (589ms), versus Non-Joint Attention face (599ms) location. There was a significant main effect of SOA, *F*(1,31)=114, *p*<.001, $\eta^2_p$=.79. The interaction was not significant, *F*(1,31)<1. Like Experiment 2, the effect was not reliable at the 100ms SOA, *t*(31)=-1.40, *p*=.17, *dz*=.25, but was at 400ms SOA, *t*(31)=-2.06, *p*=.048, *dz*=.36. The gaze leading effect of faster RTs towards targets appearing on the Joint attention face was again replicated. Therefore, this phenomenon is unlikely to be due solely to viewing a face look towards an object per se, but instead a result of engaging specifically in an interaction in which one's gaze is followed to a common object.

**Relationship between gaze leading effect and autism traits**

Participants in each experiment completed the autism spectrum quotient, which is designed to assess sub-clinical autism traits [33]. Gaze leading effect magnitude were calculated for each participant (mean RT to targets appearing on 'Non-Joint Attention' faces minus RT to targets on 'Joint Attention' faces). None of the individual experiments revealed a significant relationship with AQ score: Experiment 1, *r*(32)=-.21, *p*=.25, Experiment 2, *r*(32)=-.28, *p*=.12, Experiment 3, *r*(32)=-.21, *p*=.26. Nevertheless, individual differences measures are less reliable with the sample sizes that we used here - principally to detect a behavioural effect at the group level [e.g. 42]. So we note, with caution, that combining the samples from Experiments 1-3 revealed a significant negative relationship, *r*(96)=-.22, *p*=.03. This indicates that participants with more self-reported autism-like traits show weaker attentional orienting towards faces that had followed their gaze, compared with individuals with lower AQ scores. Such a relationship has been noted before between gaze *cueing* and the AQ [34]. This finding could prove particularly insightful regarding gaze leading, as it has been noted that social attention deficits in autism spectrum disorders may be more pronounced in *initiating* joint attention than gaze following [43].

## General Discussion

We have demonstrated, for the first time, that people rapidly orient their attention towards an individual who has followed their gaze and established joint attention. When participants move their eyes to a newly-appeared object, they then shift their attention preferentially to a face that subsequently looks at that same object. This effect implies the existence of an attentional mechanism that prioritizes conspecifics whose overt attention we have influenced – thereby establishing a state of shared attention where both parties are aware of their common overt attention towards a referent object. This mechanism may serve a critical function in supporting social interaction and cooperation [25].

We contend that the object-based nature of joint attention is critical to the sophisticated mechanisms underpinning social orienting. That two parties are attending the same object rather than merely orienting in the same direction distinguishes the definition of joint attention from mere gaze following [23]. We have empirical evidence for this notion that we briefly note here. Prior to the three-experiment series reported above, we conducted two preliminary experiments, similar to Experiment 1. In one of these experiments ($n$=32), we only displayed a fixation cross in the centre of the screen – no image of a real-world object was presented. Here, the gaze leading effect was not reliable (5ms, $p$=.44). We propose that this is because a fixation cross does not constitute an ecologically-valid ‘object’ with which one can engage in joint attention. The kitchen object stimuli used in Experiments 1-3 are everyday items with an intrinsic expectation of interaction. When someone follows our gaze to an item which affords interaction we can expect that the joint attention responder will interact with that object [44, 45] or make an inference about our state of mind about it [46].

It is notable that although this orienting behaviour is consistent with evolutionary [23] and developmental theories of social cognition [23, 29, respectively], this effect necessarily implies that to achieve a state of shared attention, one must counter-intuitively orient in the *opposite direction to observed gaze*. Our data therefore are in direct opposition to dozens of reports on gaze cueing [see 4, for review], including some papers that presented faces outside the fovea [3, 47]. So it is very surprising that our stimulus array did not produce gaze cueing. However, in another preliminary experiment ($n$=18) we did demonstrate gaze cueing could emerge with our stimuli. Here, we used no referent object image but moreover we did not ask participants to make an 'initiation' eye movement. Here, participants oriented in the direction of observed gaze (11ms gaze cueing effect, $p$=.016). Hence, when there is no active initiation of joint attention, the exact same stimulus layout can elicit a different social orienting response. This demonstrates that these effects are highly context-dependant in a manner that is directly predicted from theories of social attention that emphasise the importance of the actively establishing joint attention with objects [24, 48, 49].

When the 'gaze cueing' effect was first examined in the laboratory [2, 50, 51], one question that was immediately posed was whether gaze cueing reflected the operation of specialised social mechanisms. The finding that arrow cues cause an almost identical cueing effect implies that a domain general attention mechanism could underpin both effects [28]. Does the same apply to the gaze leading effect? In a follow-up experiment identical to Experiment 1 but with arrows in oval placeholders instead of faces, we found no effect of cue direction ($n$=32; $p$=.80). So this suggests that, unlike gaze cueing, the gaze leading effect is an orienting response that only faces can elicit, and therefore could be a special form of social orienting. However, we make this claim with caution because the explanatory power of direct comparisons between peripherally-presented gaze and arrow cues is not completely clear [but see 52, 53].

If an individual does not efficiently detect the effects they have had on their social partners, they may be less likely to continue successfully with on-going reciprocal interactions. So it is interesting to note that, across Experiments 1-3, the overall strength of the gaze leading phenomenon correlated negatively with participants' self-reported autism-like traits. Therefore, a particularly important avenue for future work is to investigate whether this orienting response is present in clinical groups with impaired spontaneous social orienting [e.g. autism spectrum conditions, 54, and neuropsychological patients, 17, 55]. If this social orienting response is particularly impaired in autism, then this could go some way to accounting for deficits in initiating joint attention behaviours found in these individuals [56].

Initiating joint attention has also been specifically related to brain regions associated with representing the self [see 56], and reward [14]. The gaze leading effect is consistent with the existence of neural substrates dedicated to gaze processing, and that it dissociates from gaze cueing supports the notion that distinct cognitive and neural mechanisms are engaged in either initiating, or responding to, joint attention [9, 10, 14, 57]. We suggest that the cognitive mechanism relies on the peripheral detection of gaze, likely supported by neural structures such as the amygdala [17]. The detected gaze direction is encoded in anterior superior temporal sulcus (aSTS), and reorienting of attention driven by inferior parietal lobule [16, 18, 58]. From other studies that implicate the ventral striatum as being involved when initiating joint attention, we suggest that this phenomenon may be driven by social motivation and reward [14, 10], and expect future research will benefit from exploring how attention and reward systems interact in typical and atypical social attention.

A further avenue of interest might be to explore this effect as one of social influence. Detecting that you have caused an individual to re-orient their attention to align their attention with yours may be a socially rewarding experience [7, 14], akin to a social approach [59], or detecting that one has been imitated [22]. We already know that macaque [60, 61] and human [62, 63] social attention is influence by affiliation, perceived dominance or status of the other individual; one could speculatively the converse - that being followed could empower the 'leader'. Further, the neural correlates of joint attention initiation have also been suggested to be involved with self-monitoring [57] and as noted above, actively initiating joint attention is critical. Therefore, an interesting future line of enquiry to further explore the cognitive mechanisms of initiating joint attention will be to establish whether a feeling of agency in the gaze leader is important in these episodes, for which the temporal course of these interactions will be critical [48].

Many other species, particularly primates, display highly sophisticated use of the social attention cues of conspecifics and other animals [see 61, 64-67]. Although many species follow gaze, skills in initiating joint attention are better developed in humans [e.g. 68, 9; see also 56]. Since we know that shared attention is important in human language acquisition [27], it is possible that the phenomenon we report reflects an attentional mechanisms that co-evolved with language. It of course remains to be tested, but it is possible that the mechanism that facilitates the detection that one's eyes have been followed is unique to humans.

In conclusion, we suggest that the 'gaze leading' orienting response underpins the establishment of shared attention and promotes the continuation of a reciprocal social interaction. The finding may provide insights into conditions associated with deficits in social cognition, human development, and comparative psychology. These data show that social orienting responses are critical not only for processing first-order social behaviour but also for interpreting the iterative effects that our own social signals have on the behaviour of others.

## Ethics statement

Ethical approval was granted by the University of East Anglia, School of Psychology's Ethics panel. Written consent was obtained from each participant prior to participation.

## Data accessibility statement

The data will be available on the Dryad Data Deposition.

## Competing interest statement

We have no competing interests.

## Author contributions

S. G. Edwards and A. P. Bayliss conceived the idea and experimental design. S. G. Edwards and M. Dalmaso developed and programmed the experiments. S. G. Edwards and L. J. Stephenson collected the data. S. G. Edwards analysed the data. S. G. Edwards, L. J. Stephenson and A. P. Bayliss interpreted the results. S. G. Edwards and A. P. Bayliss wrote the paper. All authors made critical revisions to drafts and approved the final version for submission.

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**References**

1. Moore, C., & Dunham, P. (Eds.). (1995). *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.
2. Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509-540.
3. Friesen, C. K., & Kingstone, A. (2003). Abrupt onsets and gaze direction cues trigger independent reflexive attentional effects. *Cognition*, *87*(1), B1-B10.
4. Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin, 133,* 694-724. doi:10.1037/0033-2909.133.4.694.
5. Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. *Trends in Cognitive Sciences*, *13*(3), 135-143.
6. Jenkins, R., Beaver, J. D., & Calder, A. J. (2006). I thought you were looking at me: Direction-specific aftereffects in gaze perception. *Psychological Science, 17*(6), 506-513.
7. Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlicht, T., & Vogeley, K. (2013). Towards a second-person neuroscience. *Behavioral and Brain Sciences, 36*, 393-462. doi:10.1017/S0140525X12000660.
8. Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development*, *21*(3), 469-482.
9. Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current Directions in Psychological Science*, *16*(5), 269-274.
10. Redcay, E., Kleiner, M., & Saxe, R. (2012). Look at this: The neural correlates of initiating and responding to bids for joint attention. *Frontiers in Human Neuroscience*, *6*: 169.
11. Wilms, M., Schilbach, L., Pfeiffer, U., Bente, G., Fink, G. R., & Vogeley, K. (2010). It's in your eyes – using gaze-contingent stimuli to create truly interactive paradigms for social cognitive and affective neuroscience. *Social Cognitive and Affective Neuroscience, 5*, 98-107.

12. Bayliss, A. P., Murphy, E., Naughtin, C. K., Kritikos, A., Schilbach, L., & Becker, S. I. (2013). 'Gaze leading': Initiating simulated joint attention influences eye movements and choice behavior. *Journal of Experimental Psychology: General*, *142*(1), 76-92. doi: 76.10.1037/a0029286.
13. Gordon, I., Eilbott, J. A., Feldman, R., Pelphrey, K. A., & Vander Wyk, B. C. (2013). Social, reward, and attention brain networks are involved when online bids for joint attention are met with congruent versus incongruent responses. *Social Neuroscience*, *8*(6), 544-554.
14. Schilbach, L., Wilms, M., Eickhoff, S. B., Romanzetti, S., Tepest, R., Bente, G., Shah, N. J., Fink, G. R., & Vogeley, K. (2010). Minds made for sharing: initiating joint attention recruits reward-related neurocircuitry. *Journal of Cognitive Neuroscience*, *22*(12), 2702-2715.
15. Kim, K., & Mundy, P. (2012). Joint attention, social-cognition, and recognition memory in adults. *Frontiers in Human Neuroscience*, *6*: 172. doi:10.3389/fnhum.2012.00172.
16. Perrett, D. I., Hietanen, J. K., Oram, M. W., Benson, P. J., & Rolls, E. T. (1992). Organization and functions of cells responsive to faces in the temporal cortex [and discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *335*(1273), 23-30.
17. Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature*, *433*, 68-72. doi:10.1038/nature03086.
18. Calder, A. J., Beaver, J. D., Winston, J. S., Dolan, R. J., Jenkins, R., Eger, E., & Henson, R. N. (2007). Separate coding of different gaze directions in the superior temporal sulcus and inferior parietal lobule. *Current Biology*, *17*(1), 20-25.
19. Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1431), 491-500.

20. Haun, D. B., & Call, J. (2008). Imitation recognition in great apes. *Current Biology*, *18*(7), R288-R290.

21. Paukner, A., Anderson, J. R., Borelli, E., Visalberghi, E., & Ferrari, P. F. (2005). Macaques (Macaca nemestrina) recognize when they are being imitated. *Biology Letters*, *1*(2), 219-222.

22. Nadel, J. (2002). Imitation and imitation recognition: Functional use in preverbal infants and nonverbal children with autism. *The imitative mind: Development, evolution, and brain bases*, 42-62.

23. Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews, 24,* 581-604. doi:10.1016/S0149-7634(00)00025-7.

24. Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental science*, *10*(1), 121-125.

25. Moll, H., & Tomasello, M. (2007). Cooperation and human cognition: The Vygotskian intelligence hypothesis. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *362*(1480), 639-648.

26. Saxe, R. (2006). Uniquely human social cognition. *Current Opinion in Neurobiology*, *16*(2), 235-239.

27. Baldwin, D.A. (1995). Understanding the link between joint attention and language. In C. Moore and P.J Dunham (Eds). *Joint attention: Its origins and role in development* (131-158). New York: Psychology Press.

28. Böckler, A., van der Wel, R. P. R. D., & Welsh, T. N. (2014). Catching eyes: Effects of social and nonsocial cues on attention capture. *Psychological Science, 25*, 720-727. doi: 10.1177/0956797613516147.

29. Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development*, *78*(3), 938-954.

30. Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. Retrieved from http://ssrn.com/abstract=2160588.

31. Bayliss, A. P., Bartlett, J., Naughtin, C. K., & Kritikos, A. (2011). A direct link between gaze perception and social attention. *Journal of Experimental Psychology: Human Perception and Performance, 37*(4), 634-644.

32. Bayliss, A. P., Paul, M. A., Cannon, P. R., & Tipper, S. P. (2006). Gaze cuing and affective judgments of objects: I like what you look at. *Psychonomic Bulletin & Review*, *13*(6), 1061-1066.

33. Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5-17.

34. Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism-spectrum as a function of target context. *British Journal of Psychology, 96*(1), 95-114.

35. Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention*. Quarterly Journal of Experimental Psychology, 58A*(4), 631-650.

36. Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgments: Should eye trust you? *Psychological Science*, *17*(6), 514-520.

37. Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review, 1*, 476-490.

38. Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. *Attention and performance X: Control of language processes*, *32*, 531-556.

39. Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shift evokes longer term inhibitory effects: Implications for social interactions, attention, and memory. *Journal of Experimental Psychology: General*, *133*(4), 516-533.
40. Frischen, A., Smilek, D., Eastwood, J. D., & Tipper, S. P. (2007). Inhibition of return in response to gaze cues: The roles of time course and fixation cue. *Visual Cognition*, *15*(8), 881-895.
41. Taylor, T. L., & Klein, R. M. (1998). On the causes and effects of inhibition of return. *Psychonomic Bulletin & Review*, *5*(4), 625-643.
42. VanVoorhis, C. R. W., & Morgan, B. L. (2007). Understanding power and rules of thumb for determining sample sizes. *Tutorials in Quantitative Methods for Psychology*, *3*(2), 43- 50.
43. Mundy, P. (2003). Annotation: The neural basis of social impairments in autism: the role of the dorsal medial ‐ frontal cortex and anterior cingulate system. *Journal of Child Psychology and Psychiatry*, *44*(6), 793-809.
44. Gibson, J. J. (2013). *The ecological approach to visual perception*. Psychology Press.
45. Makris, S., Hadar, A. A., & Yarrow, K. (2013). Are object affordances fully automatic? A case of covert attention. *Behavioral Neuroscience*, *127*(5), 797.
46. Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology*, *13*(4), 379-398.
47. Kingstone, A., Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive joint attention depends on lateralized cortical connections. *Psychological Science*, *11*(2), 159-166.
48. Pfeiffer, U. J., Schilbach, L., Jording, M., Timmermans, B., Bente, G., & Vogeley, K. (2012). Eyes on the mind: Investigating the influence of gaze dynamics on the perception of others in real-time social interaction. *Frontiers in Psychology*, *3*: 537.
49. Lobmaier, J. S., Fischer, M. H., & Schwaninger, A. (2006). Objects capture perceived gaze direction. *Experimental Psychology*, *53*(2), 117-122.

50. Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*(3), 490-495.

51. Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131-134.

52. Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, *9*(3), 507-513.

53. Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review*, *9*(2), 314-318.

54. Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. *Nature*, *504*, 427-431. doi:10.1038/nature12715.

55. Wolf, R. C., Philippi, C. L., Motzkin, J. C., Baskaya, M. K., & Koenigs, M. (2014). Ventromedial prefrontal cortex mediates visual attention during facial emotion recognition. *Brain*, *137*(6), 1772-1780. doi: 10.1093/brain/awu063.

56. Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*(05), 675-691.

57. Redcay, E., & Saxe, R. (2013). Do you see what I see? The neural bases of joint attention. In J.M Metcalfe & H.S. Terrace (Eds.) *Agency and Joint Attention*, (216-237). NewYork: Oxford University Press.

58. Perrett, D. I., Smith, P. A., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., & Jeeves, M. A. (1984). Neurones responsive to faces in the temporal cortex: studies of functional organization, sensitivity to identity and relation to perception. *Human Neurobiology*, *3*(4), 197-208.

59. Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., & Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach–avoidance motivational brain systems. *Neuropsychologia*, *46*(9), 2423-2430.

60. Shepherd, S. V., Deaner, R. O., & Platt, M. L. (2006). Social status gates social attention in monkeys. *Current Biology*, *18*(4), R119-R120. doi: 10.1016/j.cub.2006.02.013.

61. Micheletta, J., & Waller, B. M. (2012). Friendship affects gaze following in a tolerant species of macaque, Macaca nigra. *Animal Behaviour*, *83*(2), 459-467.

62. Jones, B. C., DeBruine, L. M., Main, J. C., Little, A. C., Welling, L. L. M., Feinberg, D. R., & Tiddeman, B. P. (2010). Facial cues of dominance modulate the short-term gaze-cueing effect in human observers. *Proceedings of the Royal Society B: Biological Sciences*, *277*, 617-624.

63. Dalmaso, M., Pavan, G., Castelli, L., & Galfano, G. (2012). Social status gates social attention in humans. *Biology Letters*, *8*, 450-452.

64. Tomasello, M., & Call, J. (1997). *Primate Cognition*. Oxford University Press.

65. Kano, F., & Call, J. (2014). Cross-species variation in gaze following and conspecific preference among great apes, human infants and adults. *Animal Behaviour*, *91*, 137-150.

66. Smet, A. F., & Byrne, R. W. (2014). African elephants (Loxodonta africana) recognize visual attention from face and body orientation. *Biology Letters*, *10*(7), 20140428.

67. Téglás, E., Gergely, A., Kupán, K., Miklósi, Á., & Topál, J. (2012). Dogs' gaze following is tuned to human communicative signals. *Current Biology*, *22*(3), 209-212.

68. Tomasello, M., & Carpenter, M. (2005). The emergence of social cognition in three young chimpanzees. Monographs of the Society for Research in Child Development, 70 (1), vii–132.

**Table 1.**

Mean and Standard Deviations (in parentheses) for reaction times (ms) and accuracy (%) in all conditions, and the gaze leading effect magnitude (ms; RT at Non-Joint Attention face minus RT at Joint Attention face. Note: positive numbers indicate a bias towards the Joint Attention face) in Experiments 1-3. Face types are referred to as: N = Not looked at, JA = Joint Attention, nJA = Non-Joint Attention, L = Looked at by both faces.

| | | SOA 100 ms | | | | SOA 400 ms | | | | Gaze leading effect (nJA-JA) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | JA | nJA | L | N | JA | nJA | L | 100 ms SOA | 400 ms SOA | Overall |
| E1 | RT | 666 (121) | 612 (110) | 631 (123) | 676 (119) | 616 (177) | 582 (118) | 601 (125) | 643 (125) | 19.0 (31.1) | 18.9 (41.2) | 18.8 (24.5) |
| | Accuracy | 95.4 (5.0) | 95.2 (4.6) | 96.2 (3.9) | 96.1 (3.5) | 96.7 (3.5) | 96.5 (4.6) | 95.6 (4.2) | 96.7 (4.2) | | | |
| E2 | RT | | 642 (146) | 653 (146) | | | 589 (133) | 605 (126) | | 11.3 (38.3) | 16.4 (44.1) | 13.7 (27.4) |
| | Accuracy | | 97.1 (2.5) | 96.2 (4.2) | | | 98.2 (2.9) | 97.3 (2.7) | | | | |
| E3 | RT | | 613 (126) | 623 (129) | | | 566 (124) | 576 (131) | | 9.6 (39.0) | 10.3 (28.4) | 10.0 (26.7) |
| | Accuracy | | 95.1 (4.3) | 97.0 (4.3) | | | 96.6 (4.2) | 96.0 (4.1) | | | | |

**Figure captions**

**Figure 1.** Example trial from Experiment 1, where the target (here letter H) has appeared on the Joint Attention face. Participants were firstly asked to look at the lower cross for 500 ms (Panel A). After that, the upper cross was replaced with an object and participants were asked to look at the object for 300 ms (Panel B). Then, the two innermost faces were shown with averted gaze in a common direction for either 100 or 400 ms, depending on SOA (Panel C). Finally, a target letter (N or H) would appear on one of the faces until identification (or until timeout - 5000 ms; Panel D). A centrally presented red cross would follow response on incorrect trials. Targets could appear on the bridge of the nose of any one of the faces.

**Figure 2.** Upper panel: Graphs show RTs for critical target locations in Experiments 1-3. Error bars are within-subjects standard error of the mean [see 37] from the main effect term in the 2 × 2 ANOVA performed on performance at these locations. Asterisks denote statistically significant effects, ***p* <.01, **p* <.05 (see also Table 1). Lower panel: Examples of stimuli displays immediately prior to target presentation in Experiments 1-3.

# Appendix B

Re-encountering individuals who previously engaged

in joint gaze modulates subsequent gaze cueing

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Running head: Previous interactions alter gaze cueing

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## Abstract

We assessed the extent to which previous experience of joint gaze with people (i.e., looking towards the same object) modulates later gaze cueing of attention elicited by those individuals. Participants in Experiments 1 and 2a/b first completed a saccade/antisaccade task while a to-be-ignored face either looked at, or away from, the participants' eye movement target. Two faces always engaged in joint gaze with the participant, whereas two other faces never engaged in joint gaze. Then, we assessed standard gaze cueing in response to these faces to ascertain the effect of these prior interactions on subsequent social attention episodes. In Experiment 1, the face's eyes moved before the participant's target appeared, meaning that the participant always gaze-followed two faces and never gaze-followed two other faces. We found that this prior experience modulated the timecourse of subsequent gaze cueing. In Experiments 2a/b, the participant looked at the target first, then was either followed (i.e., the participant initiated joint gaze), or was not followed. These participants then showed an overall decrement of gaze cueing with individuals who had previously followed participants' eyes (Experiment 2a), an effect that was associated with autism spectrum quotient scores and modulated perceived trustworthiness of the faces (Experiment 2b). Experiment 3 demonstrated that these modulations are unlikely to be due to the association of different levels of task difficulty with particular faces. These findings suggest that establishing joint gaze with others influences subsequent social attention processes that are generally thought to be relatively insensitive to learning from prior episodes.

Keywords: gaze behaviour, social learning, social attention, social cognition, eye tracking.

## Re-encountering individuals who previously engaged in joint gaze modulates subsequent gaze cueing

As humans, we are social beings and spend a considerable amount of time interacting with each other. During such social interactions, we seem to be especially sensitive to the eye region (e.g., Emery, 2000; Kano & Call, 2014; Shepherd, 2010). This propensity to focus on eyes represents an essential ability because, from other people's eye gaze, we are able to detect their focus of attention, and orient our own attention towards the same object: 'Joint attention' (see Emery, 2000). Joint attention helps us to infer goals and predict future actions of the individuals we are interacting with and it is important for social development (e.g., Baron-Cohen, 1995; Charman, 2003; Mundy, 1995; Nummenmaa & Calder, 2009; Tomasello, 1995). Our first experiences of joint attention are likely to be as the *responder*, following the gaze of another towards a source of interest. Indeed, the mechanisms required to respond to joint attention develop early (e.g., Farroni, Csibra, Simion, & Johnson, 2000), and crucially they do so earlier than those required to experience joint attention from the initiator's perspective (Mundy & Newell, 2007). Thus, the experiences related to each side of a joint attention episode, whether initiating or responding, can be seen as distinct but highly related components of social orienting (Bayliss et al., 2013; Caruana, Brock, & Woolgar, 2015; Mundy & Newell, 2007; Pickard & Ingersoll, 2015; Schilbach et al., 2010).

Engaging with others in joint attention is thus a highly natural, reflexive and usually advantageous behaviour to engage in. Indeed, we may hold an expectation that our gaze will be followed (Pfeiffer, Timmermans, Bente, Vogeley, & Schilbach, 2011), and that following others' gaze will lead us to find interesting objects (Bayliss & Tipper, 2006). In this study, we were interested in examining the extent to which social orienting in response to others' looking behaviour is affected by the quality of previous social orienting interactions one has had with particular individuals. Specifically, we asked whether the strength of responding to joint attention, assessed in a gaze cueing paradigm, is modulated by whether the participant had successfully engaged in joint attention with the cueing faces in previous encounters, or had failed to, either by previously following their gaze (Experiment 1) or by leading their gaze (Experiments 2a/b). In other words, is the social attention system sensitive to knowledge about which people are reliable joint attention partners?

The aforementioned 'gaze cueing paradigm' is one way to assess gaze following (responding to joint attention) and uses a modified version of the Posner cueing paradigm (Posner, 1980; see Driver et al., 1999, Friesen & Kingstone, 1998; and for a review see Frischen, Bayliss, & Tipper, 2007). In such experiments, a central face is presented with direct gaze, which then moves its eyes towards a specific spatial location. After a certain time period ('stimulus onset asynchrony', SOA), a target requiring some kind of response appears at a peripheral location that can be congruent or incongruent to gaze direction. Generally, this task triggers rapid (e.g., Friesen & Kingstone, 1998) and reflexive (e.g., Driver et al., 1999; Galfano et al., 2012) shifts of attention towards the spatial location indicated by gaze – 'gaze cueing'. The rapid nature of gaze cueing has been shown through experiments demonstrating that gaze cueing can emerge at cue-target stimulus onset asynchronies (SOAs) of just 14 ms (Hietanen & Leppänen, 2003), though SOAs of 100-300 ms are frequently used to demonstrate strong cueing effects (e.g., Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Marotta, Lupiañez, & Casagrande, 2012; Tipples, 2008). Typically, cueing effects are absent by around one second following cue onset (e.g., 1200 ms, Frischen & Tipper, 2004; 1005 ms, Friesen & Kingstone, 1998).

One question about the gaze cueing effect concerns the extent to which person information is coded. We know that gaze cueing is strong when using stimuli that are impoverished representations of people (e.g., schematic faces) that do not necessarily possess the usual characteristics of social agents (e.g., Dalmaso, Galfano, Tarqui, Forti, & Castelli, 2013; Kuhn & Kingstone, 2009; Marotta et al., 2012; Ristic, Friesen, & Kingstone, 2002). Nevertheless, when gaze cueing studies do manipulate the social information about the faces they use in the studies, some subtle and intriguing modulations of this apparently robust and automatic social attention mechanism can be uncovered. One way in which social information might influence social orienting has been addressed by examining the influence of invariant visual features of the face (e.g., masculinity/dominance, Jones et al., 2010; Ohlsen, van Zoest, & van Vugt, 2013, ethnicity, Pavan, Dalmaso, Galfano, & Castelli, 2012, or age, Ciardo, Marino, Actis-Grosso, Rossetti, & Ricciardelli, 2014; Slessor, Laird, Phillips, Bull, & Filippou, 2010). Changeable aspects of face information, for example facial expression, have also been examined (e.g., Kuhn & Tipples, 2011; Mathews, Fox, Yiend, & Calder, 2003).

Another way to investigate the influence of face properties on social attention is to instead manipulate social knowledge about the individual stimuli, rather than by manipulating physical characteristics. Indeed, in everyday life we tend to re-encounter people we have previously interacted with or whom we could know aspects relating to their identity. 'Person knowledge' about individuals would incorporate representations of their personal traits and biographical information, but would also involve knowledge of previous behavioural interactions that could be used to guide future interactions with these people (see Gobbini & Haxby, 2007; see also Bayliss, Naughtin, Kritikos, Lipp, & Dux, 2012; Todorov, Gobbini, Evans, & Haxby, 2007). Only a few studies have assessed the role of this non-visual information associated with faces in modulating social orienting. For example, faces of known individuals (Deaner, Shepherd, & Platt, 2007; see also Frischen & Tipper, 2006), or those belonging to one's own political group (Liuzza et al., 2011), have been shown to produce a greater gaze cueing effect. Moreover, in other studies the social knowledge relating to faces was acquired by having participants read short biographies about the faces with which they were going to encounter in a gaze cueing task, with a greater gaze cueing effect being observed for high, compared with low, social status faces (Dalmaso, Pavan, Castelli, & Galfano, 2012; Dalmaso, Galfano, Coricelli, & Castelli, 2014, see also Hudson, Nijboer, & Jellema, 2012).

Interestingly, processing others' gaze direction not only elicits shifts of attention in an observer but it is also a relevant facial cue that leads to profound influences on basic aspects of interpersonal perception. There seems to be a benefit for interpersonal evaluation for those who engage in joint attention with us – we tend to evaluate as more trustworthy faces that consistently look towards an object to which we must orient, than faces that consistently look towards the opposite direction (e.g., Bayliss, Griffiths, & Tipper, 2009; Bayliss & Tipper, 2006). This latter result fits with the notion that a key role of joint attention is to share information, to use others' gaze as a reliable indicator of interesting objects, for example food or predators. Accordingly, we would tend to assign more positive traits to an individual that provides reliable and valid information about the location of interesting objects.

In the aforementioned studies by Bayliss and colleagues showing that we trust faces that provide valid information about the location of objects, there was only evidence that the socio-evaluative system learns about the individuals from their pattern of interaction and no evidence that the social attention system itself treats faces with different behavioural histories differently. Indeed, previous exposure to gaze stimuli is linked to later gaze cueing within the gaze processing system (see Bayliss, Bartlett, Naughtin, & Kritikos, 2011). However, whether specific gaze based interactions can modulate the way social attention mechanisms respond to specific identities is a relatively unexplored question – to our knowledge Frischen and Tipper (2006) is the only contribution to this issue, finding that single exposures to a gaze cue by a given (famous) identity modulates how attention orients when re-encountering that individual a second time, based on memory encoding of individual episodes. Here, we were more interested in the influence of exposure to consistent patterns of gaze behaviour on subsequent gaze-based interactions.

**The Present Study**

In the present study we conducted three experiments (Experiments 1 and 2a/b) to directly assess the impact of the gaze behaviour of a set of to-be-ignored faces – who could act cooperatively with participants looking, or not, towards the same object (i.e., *joint/disjoint gaze*) –

on the subsequent gaze cueing effect. Furthermore, in order to confirm that our results reflected a genuine social process, we conducted a control experiment (Experiment 3) to investigate the influence of associating a non-social factor with faces on subsequent gaze cueing. In more detail, in Experiments 1 and 2a/b, we were interested in examining to what extent engaging in joint gaze episodes (as opposed to not engaging in joint gaze episodes), influences subsequent gaze cueing with individual faces. In other words, does the quality of previous social attention experiences with an individual modulate how social attention operates when that same individual is encountered later?

On this basis, we employed a novel paradigm composed of two tasks. Firstly, participants were asked to take part in a social learning phase. This consisted of a gaze-contingent eye-tracking experiment using a saccade/antisaccade task to expose participants to different faces that would consistently either engage in joint gaze, or consistently look at a different location to the participant’s eye movement target. A saccade/antisaccade task requires participants to respond to the onset of a stimulus by either a) looking directly at it (saccade), or on other trials b) looking at the contralateral location on the display (antisaccade; e.g., Everling & Fischer, 1998; Munoz & Everling, 2004). In Experiment 1, this saccade/antisaccade task was set up such that centrally placed faces would show averted gaze prior to the onset of the peripheral stimulus that acted as an instruction cue for the participant (see Figure 1, Panels A and B). Therefore, after the participant performed the required eye movement (i.e., a saccade or an antisaccade), according to the colour of the peripheral stimulus, they would find themselves either in a condition in which they were fixating towards the same position as the face’s eyes (i.e., joint gaze) or towards the opposite position (i.e., disjoint gaze). In this experiment, the face always looked at the stimulus, but two faces would look at the stimulus that instructed the participants to execute a saccade and two faces would look at the stimulus that indicated that an antisaccade should be performed. This meant that participant responses were subsequent to the face’s behaviour, and therefore would engage in overt gaze following with the faces that were associated with 'saccade' trials, but should never overtly follow the eyes of faces that were associated with 'antisaccade' trials.

In Experiments 2a/b, the participant was the gaze *leader*, moving their eyes first (see Bayliss et al., 2013), and the faces associated with 'saccade' trials would always follow the participant's eyes, while faces appearing on 'antisaccade' trials would never follow the participant's eyes. That is, the temporal relationship was reversed, with the instruction cue (i.e., the onset of the peripheral stimulus) being presented before the central face moved its eyes. Hence, in both experiments, two faces always led to a state of joint gaze with the participant whereas two others never led to a state of joint gaze with the participant.

Next, the same faces were employed in a standard gaze cueing task, identical in Experiments 1, 2a/b, in which a peripheral to-be-discriminated target could be congruent or incongruent to the gaze direction of the central face. Importantly, in the gaze cueing task, gaze direction was equally non-predictive of target location for all faces. This second task allowed us to examine the influence of prior joint gaze episodes (successful or unsuccessful gaze following in Experiment 1 and successful or unsuccessful gaze leading in Experiments 2a/b) on subsequent social orienting with the same individual faces.

In these experiments, we expected to observe a greater gaze cueing effect for faces who had engaged in joint gaze with participants, because of the positive traits they should convey to an observer (see Bayliss & Tipper, 2006). Furthermore, this question was tested using two different SOAs (i.e., 200 ms and 1200 ms), in order to explore the time course of attention shifting elicited by the two groups of faces, if any. At the first SOA, we anticipate strong gaze cueing that could be modulated by prior experience. At the longer SOA, it is typical to find a null effect of gaze cues on attention. However, our manipulation may lead to sustained orienting of attention under some conditions hence we included the condition in all Experiments. Finally, as our manipulation during the saccade/antisaccade task also – by definition – involves comparing an easier task (saccade) with a more difficult task (antisaccade), in Experiment 3, we investigated the influence of prior association with faces as a function of non-socially related task difficulty, in which we predicted a null effect.

## Experiment 1: Gaze following

Participa

nts in Experiment 1 were exposed to four faces, two of whom they would always follow (saccade toward the direction in which the face was looking) and two whom they would never follow (look at the opposite location). They then completed the gaze cueing task. In this and all four experiments, we have reported how we determined our sample size, all data exclusions (if any), all manipulations, and all measures we have collected (see Simmons, Nelson, & Simonsohn, 2012; see also LeBel et al., 2013).

### Method

**Participants.** Nineteen students at the University of East Anglia (*Mean age* = 21 years, *SD* = 4.1 years; 8 men) participated in return for payment (£7) or course credits. All had normal or corrected-to-normal vision, were naïve to the purpose of the experiment and gave written consent. The ethics committee for psychological research at the University of East Anglia approved the study. We had decided a priori to test around 20 participants, which is standard for gaze cueing tasks; we stopped at $n$ = 19 for convenience (end of a block of testing sessions). Data from two participants was not recorded for one of the experimental tasks, therefore $n$ = 17 for the saccade/antisaccade task only, and $n$ = 19 for the gaze cueing task, which is of primary interest.

**Apparatus and stimuli.** A PC running E-Prime 2.0 (Psychology Software Tools, Pittsburgh, USA) handled stimulus presentation. A video-based (infrared) eye tracker (Eyelink 1000, SR Research, Ontario, Canada) recorded right eye position (spatial resolution of 0.1°, 500 Hz).

Participants placed their head on a chinrest in front of a 19-inch monitor (1024 × 768 px, 75 Hz). Viewing distance was 65 cm. A standard keyboard collected manual response.

Four smiling faces of white adults (2 males) were taken from the NimStim face set (Tottenham et al., 2009). Smiling faces were chosen because of the positive context they create appears to encourage social learning processes (e.g., Bayliss et al., 2009). Faces of the same gender were matched for age and attractiveness (see Bayliss et al., 2009; Bayliss et al., 2012). Then, one male face and one female face were randomly allocated to Face Group A, and the others to Face Group B and used in the experimental blocks. An additional smiling face of a white adult male was used in the practice block only.

**Design and Procedure.**

***Task 1: Saccade/antisaccade task.*** Each trial began with a central black fixation cross (0.8° height × 0.8° width) on a dark grey background flanked by two white square placeholders (1° height × 1° width ) with black contours (0.2° width) placed 9.8° rightwards and leftwards from the cross. Participants were asked to fixate on the cross and press the space bar once they had achieved fixation. This procedure ensured that participants fixated the centre of the screen and allowed us to perform a drift checking. Six hundred milliseconds after the key press, the fixation cross was replaced by a central face with direct gaze (11° height × 8° width) for 1500 ms, followed by the same face with averted gaze rightwards or leftwards. After a 200 ms or 1200 ms SOA, the white area of the gazed-at placeholder turned green or red (instruction cue). Participants were instructed to move their eyes towards the placeholder if it turned green (i.e., a saccade), or to move their eyes towards the opposite placeholder if it turned red (i.e., an antisaccade). A trial ended after participants had maintained their eyes on the correct placeholder for 500 ms, assessed by a gaze-contingent trigger (see Figure 1, Panel A).

-- FIGURE 1 ABOUT HERE --

The instruction cue always appeared at the location to which the face looked – in other words it was spatially congruent to the gaze direction of the central face. For half of the participants, faces belonging to Face Group A always appeared on 'saccade' trials. So, they always looked towards the same placeholder (green) that the participant was required to look at, whereas faces belonging to Face Group B always appeared on 'antisaccade' trials. So, they always looked towards the opposite placeholder (red) to which the participant was asked to look. In this way, one set of faces always led to a state of joint gaze with the participants, while the other faces never engaged in joint gaze with the participant. For the other half of the participants, the type of trial associated with each face was reversed.

Participants were instructed to move their eyes as quickly and as accurately as possible and to ignore the faces and gaze direction. There were 16 practice trials followed by 240 experimental trials divided into three blocks of 80 trials each. Each block was composed of an equal number of trials presented in a random order and each experimental condition was presented equally. A 5-point calibration was conducted at the beginning of each block. At the end of the task a brief break was granted.

***Task 2: Gaze cueing task.*** Each trial began with a central black fixation cross (0.8° height × 0.8° width) on a dark grey background flanked by two white square placeholders (1° square) with black contours (0.2° width) placed 9.8° rightwards and leftwards from the cross. After 600 ms, the fixation cross was replaced by a central face with direct gaze for 1500 ms, followed by the same face with averted gaze rightwards or leftwards. The faces were the same as those in Task 1. After 200 ms or 1200 ms, depending on SOA, a black target line (1° height × 0.2° width) appeared centrally placed inside one of the placeholders (see Figure 1, Panel C). The inclination of the target line could be vertical or horizontal. Half of the participants were instructed to press the 'H' key with the middle finger of their dominant hand if the line was vertical, and the space bar with the index finger of their dominant hand if the line was horizontal. The other half of the participants responded using the opposite mapping between key and target letter. Both face and target line remained visible until the participant responded or 3000 ms elapsed, whichever came first. The centrally placed red words ‘ERROR’ or ‘NO RESPONSE’ replaced the central face for 500 ms in the case of a wrong or a missing response, respectively.

Contrary to Task 1, now the participants were instructed to maintain their eyes at the centre of the screen. Moreover, although in Task 1 there was a clear mapping between face identity and trial type, there was no such mapping here. In fact, all faces could produce valid or invalid gaze cues equally often with respect to target position – in other words the target line, independently by its inclination, was spatially congruent or incongruent to gaze direction of the central face with the same probability.

Participants were asked to respond as quickly and as accurately as possible and to ignore the faces and their gaze direction. There were 10 practice trials followed by 256 experimental trials in which all the experimental conditions, each of them consisting of an equal number of trials, were chosen randomly. A 5-point calibration was conducted at the beginning of the practice block. The whole Experiment (Task 1 and Task 2) lasted about one hour.

**Results**

***Task 1: Saccade/antisaccade task.*** The behaviour of participants in the gaze cueing task (Task 2) was of primary interest, however it was important to ensure that we could replicate the standard decrement of performance on antisaccade trials in our paradigm before investigating subsequent effects on later gaze cueing (e.g., Hallet, 1978; Wolohan & Crawford, 2012). Eye tracking data from the first two participants were not recorded due to technical problems, leaving a sample of 17 participants for this analysis (*Mean age* = 21 years, *SD* = 4.3 years; 7 men). Eye movement onset latency was defined as the time that elapsed from the instruction cue (colour change of the placeholder) to the initiation of the first saccade/antisaccade. The first saccade/antisaccade was defined as the first eye movement with a velocity exceeding 35°/sec and an acceleration exceeding 9500°/sec$^2$. Only saccades/antisaccades with a minimum amplitude of 1° were analysed (for a similar procedure, see Kuhn & Tipples, 2011).

Trials containing blinks (0.7 % of trials) were removed. Errors, namely trials in which the first saccade/antisaccade was in the opposite direction according to the instruction cue (8.56 % of trials), were excluded from calculation of saccadic Reaction Times (sRT) and analysed separately. Outliers, defined as trials in which sRT exceeded 3 *SD* above or below participant's mean (1.14 % of trials) were also discarded.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 200 ms vs. 1200 ms) as within-subjects factors. The main effect of Task was significant, $F(1,16) = 11.060$, $p = .004$, $\eta^2_p = .409$, owing to less errors for the saccade movements ($M = 5.4$ %, $SD = 4.1$ %) than for the antisaccade movements ($M = 11.6$ %, $SD = 9.5$ %), whereas the main effect of SOA approached statistical significance, $F(1,16) = 4.130$, $p = .059$, $\eta^2_p = .205$, reflecting fewer errors at the longer SOA ($M = 7.5$ %, $SD = 6.5$ %) than at the shorter SOA ($M = 9.5$ %, $SD = 6.4$ %). The Task × SOA interaction was significant, $F(1,16) = 10.333$, $p = .005$, $\eta^2_p = .329$. Paired comparison between antisaccade and saccade movements for each SOA revealed that the percentage of errors was smaller for the saccade than for the antisaccade movements at the shorter SOA, $t(16) = 3.846$, $p = .001$, $d_z = .92$, but not at the longer SOA, $t(16) = .070$, $p = .945$, $d_z = .02$.

A second ANOVA was conducted on mean sRT with the same factors considered for the analysis of the errors. The main effect of Task was significant, $F(1,16) = 4.941$, $p = .041$, $\eta^2_p = .236$, owing to smaller sRT for the saccade movements ($M = 267$ ms, $SD = 36.2$ ms) than for the antisaccade movements ($M = 282$ ms, $SD = 45.8$ ms), whereas the main effect of SOA did not reach statistical significance, $F(1,16) = 2.475$, $p = .135$, $\eta^2_p = .134$. The Task × SOA interaction was significant, $F(1,16) = 6.484$, $p = .022$, $\eta^2_p = .288$. Paired comparisons between antisaccade and saccade movements for each SOA revealed that sRT were smaller for the saccade than for the antisaccade movements at the shorter SOA, $t(16) = 3.142$, $p = .006$, $d_z = .76$ (25 ms), but not at the longer SOA, $t(16) = .660$, $p = .519$, $d_z = 0.16$ (5 ms).

Overall, these results showed that the oculomotor task required of participants varied in the degree of difficulty. In particular, performing a saccade movement was easier than performing an antisaccade movement, consistent with previous studies (e.g., Wolohan & Crawford, 2012). This was expected, given that a saccade is an eye movement towards the same location occupied by a target, whereas an antisaccade movement requires more cognitive effort in order to localize the position of the target and to program the consequent eye movement towards the opposite spatial location. More interestingly, each of the saccade and antisaccade tasks were always associated with a specific and distinct set of faces. So, participants may have learned this association, which could be reflected in the subsequent gaze cueing task, in which the same faces were used.

***Task 2: Gaze cueing task.*** Errors (5.24 % of trials) and outliers, defined as trials in which Reaction Times (RT) were 3 *SD* above or below participant's mean (1.79 % of trials), were discarded from manual RT analysis. The mean error percentages for each participant in each condition were submitted to a 2 × 2 × 2 repeated-measures ANOVA with Cue-target spatial congruency (2: congruent vs. incongruent), SOA (2: 200 ms vs. 1200 ms) and Type of face (2: disjoint gaze face vs. joint gaze face) as within-subjects factors. No main effects or interactions emerged ($F$s < 1.9, $p$s > .185).

A second ANOVA was conducted on mean RT with the same factors considered for the analysis of the errors. The main effect of Cue-target spatial congruency was significant, $F(1,18) = 18.498$, $p < .001$, $\eta^2_p = .507$, owing to smaller RT on congruent trials ($M$ = 651 ms, $SD$ = 101.7 ms) than on incongruent trials ($M$ = 670 ms, $SD$ = 109 ms), as well as the main effect of SOA, $F(1,18) = 5.884$, $p = .026$, $\eta^2_p = .246$, owing to smaller RT at the longer SOA ($M$ = 651 ms, $SD$ = 103.6 ms) than at the shorter SOA ($M$ = 670 ms, $SD$ = 109 ms). Neither the main effect of Type of face nor any two-way interactions were significant ($F$s < 1, $p$s > .355). Critically, the Cue-target congruency × SOA × Type of face three-way interaction was significant, $F(1,18) = 9.112$, $p = .007$, $\eta^2_p = .336$. Paired comparison between congruent and incongruent trials for each Type of face and SOA revealed that participants shifted their attention in response to disjoint gaze faces at the longer SOA, $t(18) = 4.031$, $p < .001$, $d_z = .92$, but not at the shorter SOA, $t(18) = .351$, $p = .73$ $d_z = .08$. On trials in which they viewed a face that had – in Task 1 – engaged them in joint gaze, the reverse pattern emerged. These faces produced reliable gaze cueing at the shorter SOA, $t(18) = 3.657$, $p = .002$, $d_z = .84$, but not at the longer SOA, $t(18) = .669$, $p = .512$, $d_z = .14$ (see Figure 2).

-- FIGURE 2 ABOUT HERE --

**Discussion**

In this experiment, we found that the timecourse of gaze cueing was markedly influenced by the type of previous interaction the participant had earlier experienced with the face producing the gaze cue. Faces that had earlier looked at the participant’s eye movement target, later elicited a standard gaze cueing effect that was strong at an early stage of visuospatial orienting, but was absent at the later SOA. This is what has been shown in numerous gaze cueing studies that did not manipulate the faces in any way (e.g., Driver et al. 1999; Friesen et al., 1998). A completely different pattern of data emerged from the faces that had always looked away from the participant’s eye movement target (i.e., they looked at the imperative stimulus, but away from the location to which the participant had to look in the antisaccade task). Now, the gaze of these faces did not elicit the usual early gaze cueing effect, but strikingly – and contrary to any other report of gaze cueing – produced a strong gaze cueing effect only at a late SOA (i.e., 1200 ms). Hence, the two face types diverged in the timecourse of attention orienting that their gaze evoked; faces with whom participants had previously engaged in joint gaze by following their eyes produced a standard gaze following response, while a delayed attentional orienting response was elicited by the averted gaze of faces that had previously always looked away from the participants saccade goal.

## Experiment 2a: Gaze leading

In order to further explore the influence of prior joint gaze experiences on subsequent gaze cueing, in Experiment 2a, we altered the first task (i.e., saccade/antisaccade task) while keeping the second task (i.e., gaze cueing task) identical to Experiment 1. In this Experiment, the faces in the saccade/antisaccade task looked towards or away from the participant's eye movement target *after* the participant had executed their eye movement and fixated the correct placeholder. This had the effect of having two faces consistently *following the participant* to engage in joint gaze, while two other faces would always look at the opposite location. In other words, now the participant would experience joint gaze by *leading*, rather than *following*, the face's eyes. We were interested in determining how these previous interactions would influence subsequent gaze cueing.

### Method

**Participants.** Twenty-three students at the University of East Anglia (*Mean age* = 24 years, *SD* = 4.3 years; 3 men) participated in return for payment (£7) or credit course. All had correct or corrected-to-normal vision, were naïve to the purpose of the experiment and gave written consent approved by the local ethics committee. We decided to target a sample size of around 20 and stopped at 23 for convenience at the end of a run of booked experimental sessions.

**Apparatus and Stimuli.** Apparatus and stimuli were the same as in Experiment 1.

**Design and Procedure.**

***Task 1: Saccade/antisaccade task.*** The procedure was the same as Experiment 1 (Task 1) with the following exceptions: after the fixation cross, a central face with direct gaze appeared for

1700 ms or 2700 ms, depending on SOA. These two SOAs were chosen in order to present faces for a temporal duration comparable to that in Experiment 1. After that, the instruction cue appeared and participants were asked to move their eyes towards the correct placeholder (i.e., on saccade trials, towards the placeholder that turned green and, on antisaccade trials, towards the opposite placeholder with respect to the one that turned red). After 300 ms of fixating the placeholder the eyes of the central face moved to either look at, or away from the placeholder at which the participant was looking.

Like in Experiment 1, the gaze direction of the central face was always spatially congruent to the instruction cue position. For half of the participants, faces belonging to Face Group A always looked towards the same placeholder (green) that a participant was looking at (joint gaze faces), whereas faces belonging to Face Group B always looked towards the opposite placeholder (red) that a participant was looking at (disjoint gaze faces). For the other half of the participants, this association was reversed. After 500 ms, with the participant still looking at the placeholder and the face's eyes still averted, the trial ended (see Figure 1, panel B).

***Task 2: Gaze cueing task.*** The procedure was the same as that in Task 2 of Experiment 1 (see Figure 1, Panel C). The whole Experiment (Task 1 and Task 2) lasted about 1 hour.

**Results**

***Task 1: Saccade/antisaccade task.*** Saccades/antisaccades were extracted using the same procedure as that in Experiment 1 (Task 1). Trials containing blinks (3.1 % of trials) were removed. Errors, namely trials in which the first saccade/antisaccade was in the opposite direction according to the instruction cue (4.5 % of trials), were excluded from RT analysis and analysed separately. Outliers, defined as trials in which sRT were 3 standard deviations above or below participant's mean (1.09 % of trials), were discarded from analysis.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 1700 ms vs. 2700 ms) as within-subjects factors. The main effect of task was significant, $F(1,22) = 5.910$, $p = .024$, $\eta^2_p = .212$, owing to less errors for the saccade movements ($M$ = 2.7 %, $SD$ = 3.4 %) than for the antisaccade movements ($M$ = 5.8 %, $SD$ = 6.8 %). Neither the main effect of SOA nor the Task × SOA interaction approached statistical significance ($F$s < 1, $p$s > .399).

A second ANOVA was conducted on mean sRT with the same factors considered for the analysis of the errors. The main effect of Task was significant, $F(1,22) = 11.197$, $p = .003$, $\eta^2_p$ = .337, owing to smaller sRT for the saccade movements ($M$ = 330 ms, $SD$ = 59.7 ms) than for the antisaccade movements ($M$ = 354 ms, $SD$ = 65.6 ms), as well as the main effect of SOA, $F(1,22)$ = 31.578, $p < .001$, $\eta^2_p = .589$, owing to smaller sRT at the longer SOA ($M$ = 327 ms, $SD$ = 63.1 ms) than at the shorter SOA ($M$ = 356 ms, $SD$ = 59.7 ms). The Task × SOA interaction was not significant ($F < 1$).

Taken together, these results confirmed that saccades were easier to perform than antisaccades, in line with Experiment 1.

***Task 2: Gaze cueing task.*** Errors (3.45 % of trials) and outliers, defined as trials in which RT were 3 $SD$ above or below participant's mean (1.9 % of trials), were discarded from RT analysis. The percentages of errors for each participant in each condition were submitted to a 2 × 2 × 2 repeated-measures ANOVA with Cue-target spatial congruency (2: congruent vs. incongruent), SOA (2: 200 ms vs. 1200 ms) and Type of face (2: disjoint gaze face vs. joint gaze face) as within-subjects factors. The main effect of Cue-target spatial congruency approached statistical significance, $F(1,22) = 3.048$, $p = .095$, $\eta^2_p = .122$, reflecting more errors on incongruent trials ($M$ = 3.8 %, $SD$ = 3.3 %) than on congruent trials ($M$ = 3.1 %, $SD$ = 2.7 %). The Cue-target spatial congruency × SOA interaction was significant, $F(1,22) = 9.469$, $p = .006$, $\eta^2_p = .301$. Paired comparisons between congruent and incongruent trials for each SOA showed that at the shorter SOA participants committed more errors on incongruent than on congruent trials, $t(22) = 3.087$, $p$

= .005, $d_z$ = .66, whereas no differences emerged at the longer SOA, $t(22) = .755$, $p = .458$, $d_z$ = .15. No other main effects or interactions approached significance (*F*s < 1, *p*s > .45).

A second ANOVA was conducted on mean RT with the same factors considered for the analysis of the errors. The main effect of Cue-target spatial congruency was significant, $F(1,22)$ = 22.758, $p < .001$, $\eta^2_p = .508$, owing to smaller RT on congruent trials (*M* = 687 ms, *SD* = 126 ms) than on incongruent trials (*M* = 708 ms, *SD* = 128 ms), as well as the main effect of SOA, $F(1,22)$ = 5.298, $p = .031$, $\eta^2_p = .194$, owing to smaller RT at the longer SOA (*M* = 689 ms, *SD* = 132.9 ms) than at the shorter SOA (*M* = 706 ms, *SD* = 122.6 ms). The SOA × Type of face interaction was significant, $F(1,22) = 7.075$, $p = .014$, $\eta^2_p = .243$ (see Figure 2). Also the Cue-target spatial congruency × Type of face interaction was significant, $F(1,22) = 4.972$, $p = .036$, $\eta^2_p = .184$. Further analysis was performed on the latter interaction; paired comparisons between congruent and incongruent trials for each type of face revealed that participants oriented their attention in response both to disjoint gaze faces, $t(22) = 4.409$, $p < .001$, $d_z$ = .91, and to joint gaze faces, $t(22)$ = 2.182, $p = .04$, $d_z$ = .46. However, the magnitude of the gaze cueing was larger in the former case (31 ms vs. 12 ms). The Cue-target spatial congruency × SOA × Type of face three-way interaction was not significant ($F < 1$). Nevertheless, for completeness paired comparison between congruent and incongruent trials divided by Type of face and SOA revealed that participants shifted their attention in response to disjoint gaze faces at both SOAs (*p*s < .01) but not in response to joint gaze faces at either SOAs (*p*s > .135).

**Discussion**

This experiment showed that faces with whom participants had previously led to a common gaze target were later less effective as gaze cues than faces who never followed the participants' gaze. This is counter to our initial hypothesis, where the idea was that people with whom we have shared a joint gaze experience in the past would be stronger social attention partners in other contexts. This can be interpreted as a further evidence that initiating – in addition to responding to – a state of joint gaze can lead to the emergence of intriguing and unexpected social behaviours over subsequent interactions with individuals (see Bayliss et al., 2013).

**Experiment 2b: Gaze leading - replication and extension**

In order to further examine the underlying mechanisms that lead to the intriguing results of Experiment 2a, we performed a direct replication, with a larger sample and some additional post-task measures. Specifically, participants were asked to rate the faces they had encountered for perceived dominance and trustworthiness. It is possible that leading some faces to follow our participants gaze resulted in our participants feeling dominant over these individuals, which would result in reduced perceived dominance ratings of those faces. This notion does have empirical support – we know that lower-dominant individuals tend to strongly follow the gaze direction of superiors, a robust result reported both in humans (e.g., Dalmaso et al., 2012; Jones et al., 2010) and in non-human primates (e.g., Shepherd, Deaner, & Platt, 2006).

Trustworthiness was chosen because many studies reported a link between this variable and gaze behaviour. In particular, faces who engage in joint gaze with us are generally evaluated as more trustworthy than faces that consistently look elsewhere (e.g., Bayliss et al., 2009; Bayliss & Tipper, 2006), so it is possible that a similar effect could emerge here.

Finally, participants were asked to complete the Autism-Spectrum Quotient questionnaire (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), because it is well known that autistic-like traits that vary within the non-clinical population can heavily shape social attention in a straightforward (Bayliss, di Pellegrino, & Tipper, 2005) or highly context-sensitive manner (Bayliss & Tipper, 2005).

Here we were also interested in investigating a crucial question concerning the longevity of Task 1’s influence on the subsequent Task 2, which could reasonably decay over time.

## Method

**Participants.** Thirty-eight students at the University of East Anglia (*Mean age* = 19 years, *SD* = 1.1 years; 4 men) were recruited in return for payment (£8.5) or course credit. All had correct or corrected-to-normal vision, were naïve to the purpose of the experiment and gave written consent. We decided to target a sample size of around 40 and stopped at 38 for convenience at the end of a run of booked experimental sessions. Two participants did not complete Task 1; one due to technical failure and another did not follow instructions. Additionally, data from one participant was not recorded for Task 1 due to technical failure. Therefore $n$ = 35 for the saccade/antisaccade task, and $n$ = 36 for the gaze cueing task.

**Materials, Design and Procedure.** The procedure was identical to Experiment 2a, except that there were additional measures taken after Task 2. Participants first rated how dominant, and then how trustworthy, they thought each face was (7-point Likert-type scale, from 1 = "low" to 7 = "high"). Participants then completed the AQ questionnaire. The whole Experiment (Task 1, Task 2 and questionnaires) lasted about 75 minutes.

## Results

***Task 1: Saccade/antisaccade task.*** Saccades/antisaccades were extracted using the same procedure as in previous experiments (Task 1). Trials containing blinks (3.64 % of trials) were removed. Errors, namely trials in which the first saccade/antisaccade was in the opposite direction according to the instruction cue (12.16 % of trials), were excluded from RT analysis and analysed separately. Outliers, defined as trials in which sRT were 3 standard deviations above or below participant's mean (1.38 % of trials), were discarded from analysis.

The percentages of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Task (2: antisaccade vs. saccade) and SOA (2: 1700 ms vs. 2700 ms) as within-subjects factors. The main effect of task was significant, $F(1,34) = 44.786$, $p < .001$ , $\eta^2_p = .568$, owing to less errors for the saccade movements ($M$ = 4.57 %, $SD$ = 3.68 %) than for the antisaccade movements ($M$ = 19.79 %, $SD$ = 12.9 %), as well as the main effect of SOA, $F(1,34)$ = 4.866, $p$ = .034 , $\eta^2_p$ = .125, owing to less errors at the longer SOA ($M$ = 11.22 %, $SD$ = 6.82 %) than at the shorter SOA ($M$ = 13.14 %, $SD$ = 7.49 %). The Task × SOA interaction was not significant ($F$ = 2.710, $p$ = .109).

A second ANOVA was conducted on mean sRT with the same factors considered for the analysis of the errors. The main effect of Task was significant, $F(1,34)$ = 41.569, $p$ < .001, $\eta^2_p$ = .550, owing to smaller sRT for the saccade movements ($M$ = 306 ms, $SD$ = 49.9 ms) than for the antisaccade movements ($M$ = 348 ms, $SD$ = 58.5 ms), as well as the main effect of SOA, $F(1,34)$ = 89.556, $p$ < .001, $\eta^2_p$ = .725, owing to smaller sRT at the longer SOA ($M$ = 315 ms, $SD$ = 52.8 ms) than at the shorter SOA ($M$ = 340 ms, $SD$ = 49.9 ms). The Task × SOA interaction was also significant, $F(1,16)$ = 9.422, $p$ = .004, $\eta^2_p$ = .217. Paired comparison between antisaccade and saccade movements for each SOA revealed that sRT were smaller for the saccade than for the antisaccade movements both at the shorter SOA, $t(34)$= 6.592, $p$ < .001, $d_z$ = .91, and at the longer SOA, $t(34)$= 5.333, $p$ < .001, $d_z$ = 0.59, but this difference was bigger in the former case (50 ms vs. 34 ms)

Taken together, these results confirmed that saccades were easier to perform than antisaccades, in line with previous experiments.

***Task 2: Gaze cueing task.*** Errors (4.68 % of trials) and outliers, defined as trials in which RT were 3 *SD* above or below participant's mean (2.05 % of trials), were discarded from RT analysis. The percentages of errors for each participant in each condition were submitted to a 2 × 2 × 2 repeated-measures ANOVA with Cue-target spatial congruency (2: congruent vs. incongruent), SOA (2: 200 ms vs. 1200 ms) and Type of face (2: disjoint gaze face vs. joint gaze face) as within-subjects factors. There were no significant interactions or main effects ($F$s < 2.52, $p$s > .121).

A second ANOVA was conducted on mean RT with the same factors considered for the analysis of the errors. The main effect of Congruency was significant, $F(1,35) = 13.890$, $p = .001$, $\eta^2_p = .284$, owing to faster RT on congruent trials ($M$ = 673 ms, $SD$ = 100 ms) than on incongruent trials ($M$ = 687 ms, $SD$ = 103 ms), as well as the main effect of SOA, $F(1,35) = 6.956$, $p = .012$, $\eta^2_p = .166$, owing to faster RT at the longer SOA ($M$ = 671 ms, $SD$ = 104.3 ms) than at the shorter SOA ($M$ = 690 ms, $SD$ = 99.2 ms). There was also a significant effect of Type of face, $F(1, 35) = 4.936$, $p = .033$, $\eta^2_p = .124$, showing that RT were faster with disjoint gaze faces ($M$ = 677 ms, $SD$ = 99.4 ms) than joint gaze faces ($M$ = 684 ms, $SD$ = 104 ms). No interactions reached significance ($F$s < 1). Nevertheless, although – in stark contrast to Experiment 2a – the Cue-target spatial congruency × Type of face interaction did not approach statistical significance in this experiment, $F(1,35) < 1$, we performed the planned comparisons as in Experiment 2a. These revealed the same pattern of data as in Experiment 2a. Indeed, participants showed reliable cueing of attention only in response to disjoint gaze faces, both at the shorter SOA, $t(35) = 2.33$, $p = .026$, $d_z = .39$ (16 ms), and at the longer SOA, $t(35) = 2.46$, $p = .020$, $d_z = .40$ (15 ms). On the contrary, no gaze cueing emerged in response to joint gaze faces, both at the shorter SOA, $t(35)= 1.61$, $p = .116$, $d_z = .27$ (14 ms), and at the longer SOA, $t(35)= 1.58$, $p = .123$, $d_z = .26$ (12 ms). Clearly, given the null two-way interaction, these contrasts can only be interpreted in a limited fashion, but it is notable that these cues – produced by faces that had previously engaged in joint gaze – did not elicit reliable cueing effects at in a sample of $n = 36$, when the basic gaze cueing effect can routinely be detected in very small samples indeed (e.g., $n = 8$, Driver et al., 1999).

**Face ratings.** Mean ratings of the faces on *dominance* and *trustworthiness* can been seen in Table 1. There was no difference in ratings of dominance between the two face types, $t(35) = -.699$, $p =.489$, $d_z = .12$. However, faces that had, in Task 1, always followed the gaze of the participant were rated as more trustworthy than those faces that repeatedly looked elsewhere, $t(35) = 2.203$, $p =.034$, $d_z = .37$.

-- TABLE 1 ABOUT HERE --

**Autism Spectrum Quotient.** In order to explore the possible underlying mechanisms of the observed differences in cueing power of joint gaze and disjoint gaze faces, AQ score was correlated against the cueing effect magnitude (i.e., RT on incongruent trials – RT on congruent trials) of each type of face. AQ did not correlate with the cueing effect elicited by disjoint gaze faces, $r(34) = -.028$, $p = .87$, two-tailed. However, there was a significant positive correlation between AQ and the cueing effect elicited by joint gaze faces, $r(34) = .37$, $p = .03$, two-tailed, indicating that participants with more self-reported autistic-like traits were cued by the joint gaze faces more than those with lower AQ scores (see Figure 3).

--- FIGURE 3 ABOUT HERE ---

**Longevity of impact of gaze leading on subsequent gaze cueing.** An interesting question concerns the longevity of gaze leading task's influence (Task 1) on subsequent gaze cueing of attention (Task 2). In order to investigate this aspect with appropriate statistical power, we combined samples from Experiments 2a/b ($n = 59$). Here we expected that the modulation of the type of face might have been stronger at the beginning of the gaze cueing task, and then progressively dissipated. The analysis supported this notion. In the first half of trials, the critical Cue-target spatial congruency × Type of face interaction was significant, $F(1,58) = 4.139$, $p = .046$, $\eta^2_p = .067$, due to 20 ms cueing from disjoint gaze faces and only 12 ms cueing from joint gaze faces. In the second half, the Cue-target spatial congruency × Type of face interaction was not significant, $F(1, 58) < 1$, which suggests that that the face's behaviour in Task 1 was no longer influencing gaze cueing by the second half of Task 2.

**Discussion**

Overall this replication and extension is in line with the pattern of the results observed in Experiment 2a.

Indeed, at both SOAs participants showed a reliable gaze cueing effect only in response to faces who had not previously followed their gaze. However, this effect was not as stable at the group-level as in Experiment 2a since the critical interaction did not approach significance. Nevertheless, we uncovered further interesting features about the influence of prior gaze interactions on subsequent gaze cueing. As faces that followed participants' gaze were rated as more trustworthy than those that did not, it would appear that the two face types have been evaluated differentially in a socially relevant way. Most intriguingly, participants with higher AQ scores were still cued by faces that had previously followed them, which suggests a specific difference in how having our eye-gaze followed is interpreted. In effect, those with high AQ scores were less contextually-sensitive to the behavioural history of the different face types (see also Bayliss & Tipper, 2005). Participants with low AQ scores modulated their interactions with faces they had previously encountered in a similar way to that which was fully statistically reliable in Experiment 2a.

In sum, it is notable that in both Experiments 2a/b, the standard gaze cueing effect was not reliable over four comparisons (at each SOA in each experiment) for faces that had previously engaged in joint gaze episodes with the participants. On the other hand, gaze cueing was reliable for faces that had never engaged in joint gaze with the participants. The critical interaction supporting this effect was only significant in Experiment 2a and when considering only the first half of trials in a combined Experiment 2a/b analysis. However, where the effect appears unreliable – in Experiment 2b – individual differences are shown to contribute to the effect, with people with higher AQ scores being relatively uninfluenced by the context in which the faces were previously encountered.

Thus, repeatedly engaging in joint gaze, or not (Task 1), appears to impact future gaze interactions (Task 2), but this effect appears to decline rapidly. It is notable that as Task 2 is a non-predictive gaze-cueing procedure, all face identities are equally non-predictive. Therefore, a possible explanation for this effect dissipating through the time course of Task 2 could be that participants are correcting their learning – now the gaze behaviour of the two face types is identical, and thus over time they are less distinguishable.

**Experiment 3: Control for difficulty**

In Experiments 1 and 2a/b we manipulated whether the faces to which the participants were exposed engaged in joint gaze with the participants or not. However, this was confounded with whether the participants were performing an easier task (i.e., saccade/joint gaze) or a more difficult task (i.e., antisaccade/disjoint gaze). In this experiment, instead of associating faces with a social contingency, we associated different faces with an easier or a more difficult perceptual task. We predicted that the later-performed gaze cueing task would not be influenced by the task-related difficulty faces had been associated with.

**Method**

**Participants.** Nineteen students at the University of East Anglia (*Mean age* = 23 years, *SD* = 4 years; 4 men) participated in return for payment (£7) or course credits. All had correct or corrected-to-normal vision, were naïve to the purpose of the experiment and gave a written consent approved by the local ethics committee. We were aiming for a sample size of around 20 and stopped at 19 for convenience at the end of a block of booked testing sessions.

**Apparatus and stimuli.** Apparatus and stimuli were the same as in Experiment 1.

**Design and Procedure.**

***Task 1: Difficulty manipulation task.*** The procedure was the same as that in Experiment 1 (Task 1) with the following exceptions: participants were instructed to maintain their eyes always at the centre of the screen, placeholders were absent and after the averted gaze face onset, a black target line (1.3° height × 0.4° width) appeared 9.8° rightwards or leftwards from fixation.

The target line could be vertically inclined of ±5° or ±45°. Participants were instructed to press the 'Z' key with their left index finger if the line was inclined leftwards (i.e., −5° or −45°), and the 'M' key with their right index finger if the line was inclined rightwards (i.e., +5° or +45°). In this manner, a different degree of difficulty was associated to the task required of participants.

The target line was always congruent to gaze direction of the central face. For half of the participants, faces belonging to Face Group A always looked towards a target line inclined ±5°, so they were associated with a more difficult response, whereas faces belonging to Face Group B looked always towards a target line inclined ±45°, so they were associated with an easier response. For the other half of the participants, this association was inverted.

***Task 2: Gaze cueing task.*** The procedure was the same as that in Experiment 1 (Task 2). The whole Experiment (Task 1 and Task 2) lasted about 1 hour.

**Results and Discussion**

***Task 1: Difficulty manipulation task.*** Errors (3.66 % of trials) and outliers, defined as trials in which RT were 3 *SD* above or below participant's mean (1.4 % of trials), were discarded from RT analysis.

The percentage of errors for each participant in each condition were submitted to a 2 × 2 repeated-measures ANOVA with Target inclination (2: ±5° vs. ±45°) and SOA (2: 200 ms vs. 1200 ms) as within-subjects factors. Only the main effect of the inclination of the target was significant, $F(1,18) = 5.052$, $p = .037$, $\eta^2_p = .219$, owing to fewer errors in response to targets inclined ±45° ($M$ = 2.8 %, $SD$ = 6.16 %) than ±5° ($M$ = 4.5 %, $SD$ = 5.26 %). Neither the main effect of SOA nor the Target inclination × SOA interaction approached statistical significance ($F$s < 1, $p$s > .517).

A second ANOVA was conducted on mean RT with the same factors considered for the analysis of the errors. The main effect of Target inclination was significant, $F(1,18) = 128.482$, $p < .001$, $\eta^2_p = .877$, owing to smaller RT in response to targets inclined ±45° ($M$ = 541 ms, $SD$ = 100.5

ms) than ±5° ($M$ = 625 ms, $SD$ = 120.7 ms) whereas the main effect of SOA did not reach statistical significance, $F(1,18) < 1$, $p = .726$. The Target inclination × SOA interaction was significant, $F(1,18) = 7.011$, $p = .016$, $\eta^2_p = .28$. Paired comparison between targets inclined ±5° and ±45° divided by SOA revealed that RT were smaller in response to the ±45° target inclination both at the shorter, $t(18) = 8.340$, $p <.001$ $d_z = 1.92$, and at the longer, $t(18) = 10.873$, $p < .001$, $d_z = 2.52$, SOA, but the difference between target inclination was greater in the former case (100 ms vs. 68 ms).

Taken together, these results confirmed that a different degree of difficulty was associated with the task required of participants. In particular, identifying the direction of a target line was easier when it was inclined ±45° rather than ±5°, reflecting the performance associated with saccade and antisaccade movements emerged in the oculomotor task of Experiments 1 and 2a/b.

***Task 2: Gaze cueing task.*** Errors (4.15 % of trials) and outliers, defined as trials in which RT were 3 $SD$ above or below participant's mean (2.08 % of trials), were discarded from analysis. The percentages of errors for each participant in each condition were submitted to a 2 × 2 × 2 repeated-measures ANOVA with Cue-target spatial congruency (2: congruent vs. incongruent), SOA (2: 200 ms vs. 1200 ms) and Difficulty associated to face identity (2: easy vs. difficult) as within-subjects factors. No main effects or interactions emerged ($p$s > .12).

A second ANOVA was conducted on mean RT with the same factors considered for the analysis of the errors. The main effect of Cue-target spatial congruency was significant, $F(1,18) = 8.340$, $p = .01$, $\eta^2_p = .317$, owing to smaller RT on congruent ($M$ = 656 ms, $SD$ = 87.37 ms) than on incongruent ($M$ = 671 ms, $SD$ = 95.66 ms) trials. No other main effects or interactions approached statistical significance, confirming the presence of a comparable gaze cueing effect across conditions ($F$s < 1, $p$s > .37; see Table 2). As previous association with an easier or a more difficult perceptual tasks did not modulate the degree to which a given face could elicit gaze cueing, these results suggest that differences in task difficulty are unlikely to explain the pattern of the results observed in the subsequent gaze cueing task in Experiments 1 and 2a/b.

-- TABLE 2 ABOUT HERE --

**General discussion**

Here we conducted Experiments 1 and 2a/b to assess how the gaze behaviour of a set of faces impacted their subsequent power to elicit gaze cueing in observers. We were interested in uncovering whether previous encounters with people in which joint gaze was established – or not – can subsequently modulate gaze cueing of attention with those individuals. In Experiment 1, participants were asked to move their eyes towards one of two possible spatial positions *after* the eye movement of the central face (i.e., gaze following condition). In Experiments 2a/b this sequence was reversed, namely participants moved their eyes *first* and then the central face moved its eyes (i.e., gaze leading condition). In all these experiments, we expected to observe a greater gaze cueing effect in response to faces that elicited a joint gaze state rather than a disjoint gaze state.

Results from Experiment 1 somewhat supported our hypothesis. Faces that had earlier looked at the participant's eye movement target (i.e., leading to joint gaze) later elicited a strong gaze cueing effect at the shorter SOA, but no effect at the longer SOA, a result in line with several previous studies in which face identities were not manipulated (e.g., Frischen & Tipper, 2004; Friesen & Kingstone, 1998). On the contrary, faces that had always looked away from the participant's eye movement target (i.e., leading to disjoint gaze) did not produce the usual gaze cueing effect at the shorter SOA, as expected. Curiously, however, a reliable gaze cueing effect did emerge at the longer SOA. This latter result is somewhat surprising as it is unusual to observe gaze cueing at SOAs longer than 1000 ms.

Thus, the timecourse of attentional orienting in response to these disjoint gaze faces appears to be delayed, probably reflecting a delay in the processing of gaze cues from these faces.

This delay could be due to Task 1's request to suppress the natural tendency to generate a saccade, in favour of an antisaccade. Therefore, in Task 2 this learned unnatural oculomotor behaviour may have delayed the emergence of the gaze cueing effect, necessitating the activation of more volitional attentional components. Similarly, because disjoint gaze faces had potentially enhanced the participant's ability to process the instruction cue (see Koval, Thomas, & Everling, 2005), the delay in processing of these faces could relate to the dichotomy of helping participants to process the cue while also avoiding engaging in joint gaze with them. However, a higher level explanation may also suggest that this delay in attentional orienting could be due to continuing social evaluation of these faces who are, in effect, deceptive. Indeed, it is known that deceptive faces capture attention in an observer (see Vanneste, Verplaetse, Van Hiel, & Braeckman, 2007). In all these scenarios, our data suggest that non-cooperative individuals impact social attention peculiarly.

With regards to Experiments 2a/b, a reliable gaze cueing effect emerged in response to faces that had led to a state of disjoint gaze with participants but not in response to faces that had led to a state of joint gaze. Strikingly, the same pattern of results emerged at both SOAs, suggesting that whether someone has reliably followed our eye-gaze, or not, leads to somewhat robust changes in how our social attention system will interact with him/her later.

As relatively less research has assessed the role of the initiator in a joint gaze scenario, the results of Experiments 2a/b are particularly interesting. It is possible that in Task 1 the gaze direction of the disjoint gaze faces may have been evaluated as particularly informative, probably in terms of "correcting" an unnatural eye movement (i.e., orienting attention away from a stimulus), whereas the gaze direction of the joint gaze faces was completely redundant. Therefore, participants may have learned these differences in the faces' gaze behaviour, subsequently impacting gaze cueing.

Considering previous literature, there are also a number of social factors that could have contributed to this pattern of results, and Experiment 2b was conducted in order to empirically assess some of these factors. Firstly, we reasoned that a reliable gaze cueing effect emerged only in response to disjoint gaze faces because these were perceived by participants as more dominant individuals. Indeed, it is known that dominant individuals tend to ignore the gaze direction of subordinates (Dalmaso et al., 2012; Jones et al., 2010; Shepherd et al., 2006). Conversely, joint gaze faces might be perceived as subordinates, as the participant has affected change of their eye-gaze. However, both disjoint and joint gaze faces were rated equally for dominance, therefore excluding the potential role of this variable in shaping gaze behaviour, at least within the present paradigm. Although no explicit rating differentiation was shown for dominance, in Experiment 2b we did find that participants rated joint gaze faces as more trustworthy. This fits well with the literature, where it has been shown that we tend to evaluate as more trustworthy faces who engage in joint gaze bids with us, rather than faces that consistently look elsewhere (e.g., Bayliss et al., 2009; Bayliss & Tipper, 2006). Interestingly, to the best of our knowledge, so far only one study has observed a modulation of trustworthiness on gaze cueing in young adults, reporting greater gaze cueing in response to trustworthy faces (Süßenbach & Schönbrodt, 2014; see also Petrican et al., 2013, for a similar results in older adults). However, it is important to note that Süßenbach and Schönbrodt (2014) manipulated trustworthiness explicitly before the gaze cueing task, while in our study differences in trustworthiness emerged as a direct consequence of the gaze behaviour requested of participants in the saccade/antisaccade task, which suggests we respond differently to first hand experiences compared with second hand information.

Individual differences can also be highly informative with regards to social orienting processes. For example, autistic-like traits in the normal population are linked to social attention (e.g., Bayliss, di Pellegrino, & Tipper, 2005; Bayliss & Tipper, 2005). Thus, in Experiment 2b, participants completed the AQ questionnaire (Baron-Cohen et al., 2001). Interestingly, the magnitude of the gaze cueing effect elicited by joint gaze faces positively correlated with AQ scores, meaning that the higher the number of autistic-like traits a participant had, the greater the magnitude of orienting in response to joint gaze faces was, with no such correlation emerging with disjoint gaze faces. In other words, individuals with high AQ scores were not sensitive to the social context in which joint gaze faces were previously presented, which in turn has lead to different social orientating behaviours later. At first glance, the finding that cueing effects were larger in high AQ participants *in any condition* may be surprising, given a negative correlation is typically found (Bayliss et al., 2005). However, Bayliss & Tipper (2005) noted that although cueing effects may generally be modulated by AQ overall, it is the context in which the cues are presented that may drive AQ effects.

The present evidence, and the explanations that they afford, are of course not exhaustive and future work is necessary to test other potential hypotheses. For example, it may be that the stronger cueing by disjoint gaze faces is actually an attempt to reconnect with an individual who has previously ostracised the participant by not engaging with him/her. Ostracism can profoundly impact on gaze behaviour (e.g., Böckler, Hömke, & Sebanz, 2013; Wilkowski, Robinson, & Friesen, 2009) and people who are ostracised tend to (re)establish contact with individuals who are the source of such exclusion (e.g., Wirth, Sacco, Hugenberg, & Williams, 2010), thus the enhanced gaze-cueing provided by these faces may relate to the participant’s need to (re)establish control of the social situation (e.g., Warburton, Williams, & Cairns, 2006) or, more generally, satisfy the need to "close the loop" (see Frith, 2007).

Finally, there are also a number of methodological considerations that may have contributed to the present findings. For instance, on antisaccade trials (Task 1), while the face stimulus looked towards the instruction cue, the participant did not, but still had to attend covertly to this cue in order to make the antisaccade away from it. Conversely, on saccade trials, both the face stimulus and participant looked towards the same target. Thus, every single trial in Task 1 had an initial component of joint attention and therefore saccade and antisaccade trials differed mainly in terms of the overt component of orienting. Furthermore, in Experiments 2a/b (i.e., gaze leading condition) the learning process of face identities was impoverished: as participants moved their eyes first, they could only see the gaze direction of the facial stimuli through their peripheral vision. In turn, this might have influenced the modulation of the subsequent gaze cueing effect, at least to some extent. Future studies are necessary to further address this unexplored research question.

To recap, the present series of experiments show, for the first time, that the social attention system is sensitive to gaze-based person information. Specifically, Experiments 1 and 2a/b show that the quality of previous interactions with an individual impacts that individual's ability to later influence our attention. So, when we re-encounter someone with whom we have previously interacted, our knowledge of this person (particularly regarding our previous interaction with them) is recalled, and thus influences how we then interact with them. Therefore, we have further evidence suggesting a direct link between gaze perception and subsequent attentional processes (see Bayliss et al., 2011), but we can now also conclude that the social orienting system is sensitive to information from previous gaze based interactions when re-encountering individual people.

In conclusion, the present results are interesting for a number of reasons. Firstly, they present further evidence of the importance of others' gaze behaviour in modulating our own behaviour, suggesting that the system underlying interpersonal perception plays a key role in shaping social attention mechanisms. In particular, we reported that even social learning of information related with gaze behaviour (i.e., joint gaze) can subsequently impact both gaze-mediated orienting of attention with the same people and person perception. Secondly, they confirm the importance of distinguishing between *initiating* joint gaze and *responding* to joint gaze; both initiating and responding lead to modulations in future gaze behaviour, but they did so in different manners. Finally, this work also highlights the potential benefits of employing social stimuli in interactive gaze-contingent eye-tracking tasks in order to create innovative paradigms (see also Pfeiffer, Vogeley, & Schilbach, 2013). A large scale implementation of such paradigms may provide researchers the opportunity to enlarge and expand the investigation of social attention. For these reasons we feel that, due to relative novelty of these interactive paradigms, many different avenues of research are available that will expand our knowledge concerning mechanisms that underlie social cognition with particular emphasis to attentional processes.

**References**


Baron-Cohen, S. (1995). The eye direction detector (EDD) and the shared attention mechanism (SAM): Two cases for evolutionary psychology. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 41–59). Hillsdale, NJ: Erlbaum.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*, 5-17.

Bayliss, A. P., Bartlett, J., Naughtin, C. K., & Kritikos, A. (2011). A direct link between gaze perception and social attention. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(3), 634-644.

Bayliss, A. P., di Pellegrino G., & Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology*, *58*, 631-650.

Bayliss, A. P., Griffiths, D., & Tipper, S. P. (2009). Predictive gaze cues affect face evaluations: The effect of facial emotion. *European Journal of Cognitive Psychology*, *21*, 1072-1084.

Bayliss, A. P. Murphy, E., Naughtin, C. K., Kritikos, A., Schilbach, L., & Becker, S. I. (2013).'Gaze leading': Initiating simulated joint attention influences eye movements and choice behaviour. *Journal of Experimental Psychology: General*, *142*, 76-92.

Bayliss, A. P., Naughtin, C. K., Kritikos, A., Lipp, O. V., & Dux, P. E. (2012). Make a lasting impression: The neural consequences of re-encountering people who emote inappropriately. *Psychophysiology, 49*, 1571-1578.

Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism-spectrum as a function of target context. *British Journal of Psychology, 96,* 95–114.

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgements: Should eye trust you? *Psychological Science*, *17*, 514-520.

Böckler, A., Hömke, P., & Sebanz, N. (2103). Invisible man: Exclusion from shared attention affects gaze behavior and self-reports. *Social Psychological and Personality Science*, *5*, 140-148.

Caruana, N., Brock, J., & Woolgar, A. (2015). A frontotemporoparietal network common to initiating and responding to joint attention bids. *NeuroImage*, *108*, 34-46.

Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*, 315-324.

Ciardo, F., Marino, B. F. M., Actis-Grosso, R., Rossetti, A., & Ricciardelli, P. (2014). Face age modulates gaze following in young adults. *Scientific Reports*, *4*, 4746.

Dalmaso, M., Galfano, G., Coricelli, C., & Castelli, L. (2014). Temporal dynamics underlying the modulation of social status on social attention. *PLoS ONE*, *9*, e93139.

Dalmaso, M., Galfano, G., Tarqui, L., Forti, B., & Castelli, L. (2013). Is social attention impaired in schizophrenia? Gaze but not pointing gestures is associated with spatial attention deficits. *Neuropsychology*, *27*, 608-613.

Dalmaso, M., Pavan, G., Castelli, L., & Galfano, G. (2012). Social status gates social attention in humans. *Biology Letters*, *8*, 450-452.

Deaner, R. O., Shepherd, S. V. & Platt, M. L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biology Letters*, *3*, 64-67.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*, 509-540.

Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews*, *24*, 581-604.

Everling, S., & Fischer, B. (1998). The antisaccade: A review of basic research and clinical findings. *Neuropsychologia*, *36*, 885-899.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America*, *99*, 9602-9605.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*, 490-495.

Friesen, C. K., Ristic, J., & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception and Performance*, *30*, 319-329.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*, 694-724.

Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shifts evokes longer term inhibitory effects: Implications for social interactions, attention, and memory. *Journal of Experimental Psychology: General*, *133*, 516-533.

Frischen, A., & Tipper, S. P. (2006). Long-term gaze cueing effects: Evidence for retrieval of prior states of attention from memory. *Visual Cognition*, *14*, 351- 364.

Frith, C. D. (2007). *Making up the mind: How the brain creates our mental world*. Oxford, UK: Blackwell.

Galfano, G., Dalmaso, M., Marzoli, D., Pavan, G., Coricelli, C., & Castelli, L. (2012). Eye gaze cannot be ignored (but neither can arrows). *Quarterly Journal of Experimental Psychology*, *65*, 1895-1910.

Gobbini, M. I., & Haxby, J. V. (2007). Neural systems for recognition of familiar faces. *Neuropsychologia*, *45*, 32-41.

Hallet, P. E. (1978) Primary and secondary saccades to goals defined by instructions. *Vision Research*, *18*, 1279-1296.

Hietanen, J. K., & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 1228-1243.

Hudson, M., Nijboer, T. C. W., & Jellema, T. (2012). Implicit social learning in relation to autistic-like traits. *Journal of Autism and Developmental Disorders*, *42*, 2534-2545.

Jones, B. C., DeBruine, L. M., Main, J. C., Little, A. C., Welling, L. L., Feinberg, D. R., & Tiddeman, B. P. (2010). Facial cues of dominance modulate the short- term gaze-cuing effect in human observers. *Proceeding of the Royal Society B: Biological Sciences*, *277*, 617-624.

Kano, F., & Call, J. (2014). Cross-species variation in gaze following and conspecific preference among great apes, human infants and adults. *Animal Cognition*, *91*, 136-150.

Koval, M. J., Thomas, B. S., & Everling, S. (2005). Task-dependant effects of social attention on saccadic reaction times. *Experimental Brian Research*, *167*, 475-480.

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, & Psychophysics*, *71*, 314-327.

Kuhn, G., & Tipples, J. (2011). Increased gaze following for fearful faces. It depends on what you're looking for! *Psychonomic Bulletin & Review*, *18*, 89-95.

LeBel, E. P., Borsboom, D., Giner-Sorolla, R., Hasselman, F., Peters, K. R., Ratliff, K. A., & Smith, C. T. (2013). PsychDisclosure.org: Grassroots Support for Reforming Reporting Standards in Psychology. *Perspectives on Psychological Science, 8*, 424-432.

Liuzza, M. T., Cazzato, V., Vecchione, M., Crostella, F., Caprara, G. V., & Aglioti, S. M. (2011). Follow my eyes: The gaze of politicians reflexively captures the gaze of ingroup voters. *PLoS ONE*, *6*, e25117.

Marotta, A., Lupiañez, J., & Casagrande, M. (2012). Investigating hemispheric lateralization of reflexive attention to gaze and arrow cues. *Brain and Cognition*, *80*, 361-366.

Mathews, A., Fox, E., Yiend, J., & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition*, *10*, 823-835.

Mundy, P. (1995). Joint attention, social-emotional approach in children with autism. *Development and Psychopathology*, *7*, 63-82.

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. Current Directions in Psychological Science, 16, 269–274.

Munoz, D. P., & Everling, S. (2004). Look away: the anti-saccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience*, *5*, 218-228.

Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. Trends in *Cognitive Science*, *13*, 135-143.

Ohlsen, G., van Zoest, W., & van Vugt, M. (2013). Gender and facial dominance in gaze cuing: Emotional context matters in the eyes that we follow. *PLoS ONE*, *8*, e59471.

Pavan, G., Dalmaso, M., Galfano, G., & Castelli, L. (2011). Racial group membership is associated to gaze-mediated orienting in Italy. *PLoS ONE*, *6*, e25608.

Petrican, R., English, T., Gross, J. J., Grady, C., Hai, T., & Moscovitch, M. (2013). Friend or foe? Age moderates time-course specific responsiveness to trustworthiness cues. *The Journal of Gerontology: Series B: Psychological Sciences and Social Sciences*, *68B*, 215-223.

Pfeiffer, U. J., Timmermans, B., Bente, G., Vogeley, K., & Schilbach, L. (2011). A non-verbal Turing test: Differentiating mind from machine in gaze-based social interaction. *PLoS ONE*, *6*, e27591.

Pfeiffer, U. J., Vogeley, K., & Schilbach, L. (2013). From gaze cueing to dual eye- tracking: Novel approaches to investigate the neural correlates of gaze in social interaction. *Neuroscience and Biobehavioral Reviews*, *37*, 2516-2528.

Pickard, K. E., & Ingersoll, B. R. (2015). High and low level initiations of joint attention, and response to joint attention: Differential relationships. *Journal of Autism and Developmental Disorders*, *45*, 262-268.

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*, 3-25.

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, 9, 507-513.

Schilbach, L., Wilms, M., Eickhoff, S. B., Romanzetti, S., Tepest, R., Bente, G., et al. (2010). Minds made for sharing: Initiating joint attention recruits reward-related neurocircuitry. *Journal of Cognitive Neuroscience*, *22*, 2702-2715.

Shepherd, S. V. (2010). Following gaze: Gaze-following behavior as a window into social cognition. *Frontiers in Integrative Neuroscience*, *4*, 1-13.

Shepherd, S. V., Deaner, R. O., & Platt, M. L. (2006). Social status gates social attention in monkeys. *Current Biology*, *16*, R119-R120.

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. Retrieved from http://ssrn.com/abstract=2160588

Slessor, G., Laird, G., Phillips, L. H., Bull, R., & Filippou, D. (2010). Age-related differences in gaze following: Does the age of the face matter? *Journal of Gerontology: Psychological Sciences*, *65*, 536-541.

Süßenbach, F., & Schönbrodt, F. (2014). Not afraid to trust you: Trustworthiness moderates gaze cueing but not in highly anxious participants. *Journal of Cognitive Psychology*, *26*, 670-678.

Tipples, J. (2008). Orienting to counterpredictive gaze and arrow cues. *Perception & Psychophysics*, *70*, 77-87.

Todorov, A., Gobbini, M. I., Evans, K. K, & Haxby, J. V. (2007). Spontaneous retrieval of affective person knowledge in face perception. *Neuropsychologia*, 45, 163-173.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 103–130). Hillsdale, NJ: Erlbaum.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*, 242-249.

Vanneste, S., Verplaetse, J., Van Hiel, A., & Braeckman, J. (2007). Attention bias toward noncooperative people: A dot probe classification study in cheating detection. *Evolution and Human Behavior*, *28*, 272-276.

Warburton, W. A., Williams, K. D., & Cairns, D. R. (2006). When ostracism leads to aggression: The moderating effects of control deprivation. *Journal of Experimental Social Psychology*, *42*, 213-220.

Wilkowski, B. M., Robinson, M. D., & Friesen, C. K. (2009). Gaze-triggered orienting as a tool of the belongingness self-regulation system. *Psychological Science*, *20*, 495-501.

Wirth, J. H., Sacco, D. F., Hugenberg, K., & Williams, K. D. (2010). Eye gaze as relational evaluation: Averted eye gaze leads to feelings of ostracism and relational devaluation. *Personality and Social Psychology Bulletin*, 36, 869-882.

Wolohan, F. D. A., & Crawford, T. J. (2012). The anti-orienting phenomenon revisited: effects of gaze cues on antisaccade performance. *Experimental Brain Research*, *221*, 385-392.

**Figure Captions**

*Figure 1.* Panel A: Stimuli, trial sequence and timing of the saccade/antisaccade task (Task 1) used in Experiment 1. An example of joint gaze is depicted, in which a participant is asked to make a saccade (green instruction cue), and the central face looks towards the same placeholder. Panel B: Stimuli, trial sequence and timing of the saccade/antisaccade task (Task 1) used in Experiments 2a/b. An example of disjoint gaze is depicted, in which a participant is asked to make an antisaccade (red instruction cue), and the central face looks towards the opposite placeholder. Panel C: Stimuli, trial sequence and timing of the gaze cueing task (Task 2) common to all the experiments. An example of an incongruent trial is depicted, in which a vertical target line appears in the opposite placeholder with respect to the placeholder gazed at by the central face. Schematic eyes below each picture frame represent the correct eye movement requested of participants during the saccade/antisaccade task (Panel A and B) whereas in the gaze cueing task participants were asked to maintain their eyes at the centre of the screen (Panel C). Stimuli are not drawn to scale.

*Figure 2.* Mean RT for the gaze cueing task (Task 2) divided by type of face and SOA in Experiments 1 and 2a/b. Error bars represent standard error of the mean. Double asterisk denote $p < .01$. NS = non-significant.

*Figure 3.* Correlations between AQ scores and the gaze cueing-effect (i.e., RT on incongruent trials – RT on congruent trials) for disjoint gaze faces (left panel) and joint gaze faces (right panel).

# Appendix C

## AQ Questionnaire

### Autism Spectrum Quotient Questionnaire (AQ)

Participants are asked to answer each question by selecting one of the following statements;

Definitely agree, slightly agree, slightly disagree or definitely disagree.

Questions:

1. I prefer to do things with others rather than on my own.
2. I prefer to do things the same way over and over again.
3. If I try to imagine something, I find it very easy to create a picture in my mind.
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.
5. I often notice small sounds when others do not.
6. I usually notice car number plates or similar strings of information.
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.
8. When I'm reading a story, I can easily imagine what the characters might look like.
9. I am fascinated by dates.
10. In a social group, I can easily keep track of several different people's conversations.
11. I find social situations easy.
12. I tend to notice details that others do not.
13. I would rather go to a library than a party.
14. I find making up stories easy.
15. I find myself drawn more strongly to people than to things.
16. I tend to have very strong interests which I get upset about if I can't pursue.
17. I enjoy social chit-chat.
18. When I talk, it isn't always easy for others to get a word in edgeways.
19. I am fascinated by numbers.
20. When I'm reading a story, I find it difficult to work out the characters' intentions.
21. I don't particularly enjoy reading fiction.
22. I find it hard to make new friends.
23. I notice patterns in things all the time.
24. I would rather go to the theatre than a museum.
25. It does not upset me if my daily routine is disturbed.
26. I frequently find that I don't know how to keep a conversation going.
27. I find it easy to "read between the lines" when someone is talking to me.
28. I usually concentrate more on the whole picture, rather than the small details.
29. I am not very good at remembering phone numbers.
30. I don't usually notice small changes in a situation, or a person's appearance.

31. I know how to tell if someone listening to me is getting bored.
32. I find it easy to do more than one thing at once.
33. When I talk on the phone, I'm not sure when it's my turn to speak.
34. I enjoy doing things spontaneously.
35. I am often the last to understand the point of a joke.
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, I can switch back to what I was doing very quickly.
38. I am good at social chit-chat.
39. People often tell me that I keep going on and on about the same thing.
40. When I was young, I used to enjoy playing games involving pretending with other children.
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).
42. I find it difficult to imagine what it would be like to be someone else.
43. I like to plan any activities I participate in carefully.
44. I enjoy social occasions.
45. I find it difficult to work out people's intentions.
46. New situations make me anxious.
47. I enjoy meeting new people.
48. I am a good diplomat.
49. I am not very good at remembering people's date of birth.
50. I find it very easy to play games with children that involve pretending.

## Appendix D

**SPIN Questionnaire**

| **0** | **1** | | **2** | **3** | **4** |
|---|---|---|---|---|---|

| **Not at all** | **A little bit** | **Somewhat** | **Very much** | **Extremely** |
|---|---|---|---|---|

1. I fear people in authority.

   0 1 2 3 4

2. I am bothered by blushing.

   0 1 2 3 4

3. I fear parties and social events.

   0 1 2 3 4

4. I avoid talking to strangers.

   0 1 2 3 4

5. I fear criticism.

   0 1 2 3 4

6. I avoid embarrassment.

   0 1 2 3 4

7. I am distressed by sweating.

   0 1 2 3 4

8 I avoid parties.

   0 1 2 3 4

9 I avoid being the center of attention.

0 1 2 3 4

10. I fear talking to strangers.

0 1 2 3 4

11. I avoid speeches.

0 1 2 3 4

12. I avoid criticism.

0 1 2 3 4

13. I am distressed by palpitations.

0 1 2 3 4

14. I fear others watching me.

0 1 2 3 4

15 I fear embarrassment.

0 1 2 3 4

16 I avoid talking to authority figures.

0 1 2 3 4

17. I am distressed by trembling of shaking.

0 1 2 3 4