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Direct gaze captures visuospatial attention

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This study investigated whether the direct gaze of others influences attentional disengagement from faces in an experimental situation. Participants were required to fixate on a centrally presented face with varying gaze directions and to detect the appearance of a peripheral target as quickly as possible. Results revealed that target detection was delayed when the preceding face was directly gazing at the subject (direct gaze), as compared with an averted gaze (averted gaze) or with closed eyes (closed eyes). This effect disappeared when a temporal gap was inserted between the offset of the centrally presented face and the onset of a peripheral target, suggesting that attentional disengagement contributed to the delayed response in the direct gaze condition. The response delay to direct gaze was not found when the contrast polarity of eyes in the facial stimuli was reversed, reinforcing the importance of gaze perception in delayed disengagement from direct gaze.

Faces provide a considerable amount of social information in many species, including humans (Darwin, 1872/1998; Fox, 1970; Schmidt & Cohn, 2001). Among facial characteristics, the direction of eye gaze reveals another's current attention and provides critical information about intention. Morphologically, the white sclera and darker iris of the human eye are unique among primates, and are thought to make it easier to discern where the eyes are looking, thus facilitating social communication by signalling rather than concealing eye gaze direction (Kobayashi & Kohshima, 1997, 2001), which might have been shaped by natural selection in our evolutionary history.

It is reasonable to assume that humans evolved the tendency to attend to other people's eye region and gaze direction. In fact, humans preferentially scan and pursue others' eyes from very early infancy (Maurer & Salapatek, 1976; Morton

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& Johnson, 1991). Failure to develop typical mutual gaze behaviour is one of the earliest signals of severe social and communicative disorders, or of autism (American Psychiatric Association, 1994; Baranek, 1999; Baron-Cohen, 1995). As Gibson comments, human eyes are ‘‘being looked at’’ (Gibson & Pick, 1963, p. 386).

Social information conveyed by gaze direction has two major components (Perrett & Emery, 1994). An averted gaze informs of attention towards the direction of the gaze, and predicts potential rewards (e.g., food) or threats (e.g., a predator) in the environment. Perception of an averted eye gaze triggered reflexive orienting to the corresponding direction in human adults (Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999; Friesen & Kingstone, 1998, 2003a, 2003b; Hietanen, 1999; Mansfield, Farroni, & Johnson, 2003; Ogawa, 2002; Schuller & Rossion, 2001; Senju & Hasegawa, 2001) and in infants (Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998), which was thought to establish ‘‘joint attention’’ (Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Moore & Corkum, 1998).

Direct gaze, on the other hand, signals the intention of the gazer towards the perceiver. In many species, perception of a direct gaze elicits an aversive response (Andrew, 1965; Blest, 1957; Fox, 1970; Gallup, Cummings, & Nash, 1972; Hinde, 1954). Direct gaze may be perceived as a signal of potential risk (a predator) or as a threatening display (Coss, 1970). In humans, by contrast, eye contact plays a major role in communication (Kleinke, 1986) and in affective bonding (Kleinke, 1986; Robson, 1967; Robson, Pedersen, & Moss, 1969). Even neonates prefer faces with a direct eye gaze over faces with closed or averted eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002), suggesting an inborn preference for the direct gaze.

In adults, several studies have found that direct gaze affects perception, cognition and arousal. For example, von Grünau and Anston (1995) reported that schematic eyes directed toward an observer were more quickly detected than were eyes with an averted gaze, in a visual search paradigm. In addition, when the gaze direction of others is ambiguous and difficult to perceive, people are biased to judge them as ‘‘looking at me’’ (Martin & Jones, 1982; Martin & Rovira, 1981, 1982). Direct gaze also increases autonomic arousal in adults (Gale, Kingsley, Brookes, & Smith, 1978; Gale, Spratt, Chapman, & Smallbone, 1975; Nichols & Champne, 1971).

Due to advances in cognitive neuroscience, we now have evidence as to how gaze is processed in the human brain. Brain imaging studies have revealed that the perception of eye gaze activates the superior temporal sulcus (STS) (Hoffman & Haxby, 2000; Pelphrey, Singerman, Allison, & McCarthy, 2003; Puce, Allison, Bentin, Gore, & McCarthy, 1998).

Several studies have found that the perception of direct gaze affects facial processing. George, Driver, and Dolan (2001) reported that when participants discriminated among presented faces by gender, direct gaze facilitated the activation of the fusiform gyrus, believed to process invariant aspects of faces such as identity and gender (Hoffman & Haxby, 2000; Kanwisher, McDermott, & Chun, 1997). This concurs with research on the facilitative role for direct gaze in the speed of gender discrimination (Macrae, Hood, Milne, Rowe, & Mason, 2002). In addition, Kampe, Frith, Dolan, and Frith (2001) found increased activation of the limbic dopagenetic regions, which are strongly linked to reward prediction in response to the direct gaze of an attractive face, when participants were rating facial attractiveness. Moreover, during analysis of emotional facial expressions (Wicker, Perrett, Baron-Cohen, & Decety, 2003), direct eye gaze increased the activity of the superior temporal gyrus, which is near the STS and is thought to process variant aspects of faces, such as gaze direction or emotion (Hoffman & Haxby, 2000). In contrast, other studies failed to find selective neural activity in response to a direct gaze when only passive viewing was required of the participants (Puce, Smith, & Allison, 2000; Taylor, George, & Ducorps, 2001a; Taylor, Itier, Allison, & Edmonds, 2001b; Watanabe, Kakigi, & Puce, 2001; Watanabe, Miki, & Kakigi, 2002; Wicker, Michel, Henaff, & Decety, 1998). These findings seem to suggest that the direct gaze plays a modulatory role, enhancing various kinds of social information processing with respect to the face that is ‘‘looking at me’’. How such modulation occurs is not known.

Recent psychological studies by E. Fox and colleagues (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002), have found that enhanced dwell time to emotional facial stimuli provides a clue about the processes involved. In those studies, participants (especially anxious participants) took longer to respond to targets that appeared in different locations around emotionally expressive facial stimuli. The delayed response was explained as *enhanced dwell time* or *delayed disengagement* (Fox et al., 2001, 2002); an emotional signal captures the observer's attention and increases attentional dwell time (or delays disengagement).[1]

Because direct gaze is also an important social signal, delayed disengagement may also occur in response to a direct gaze. Moreover, if a direct gaze holds attention, it seems possible that faces with direct gaze are more deeply processed by the perceiver (George et al., 2001; Kampe et al., 2001; Wicker et al., 2003). Although enhanced orienting toward a direct gaze was suggested previously (von Grünau & Anston, 1995), whether direct gaze affects attentional dwell time has not yet been investigated.

To explore this issue, the current study examined whether direct gaze affects disengagement from the gazing face by investigating visual processing outside

[1] This hypothesis is in accord with Posner's recent attentional model (Posner, 1980; Posner, & Petersen, 1990), which claimed that attention has at least three components: Attentional shifting, engagement, and disengagement.

the area of the directly gazing face. Participants were required to attend to, and fixate on, a centrally presented face with varying gaze directions, and to detect a peripheral target as quickly as possible. If direct gaze enhances a perceiver's attentional dwell time, it was predicted that target detection outside the facial area would be delayed because of the increased cost of the attentional disengagement.

In addition, we adopted the gap paradigm (Saslow, 1967) to investigate whether perceived direct gaze affects spatial disengagement or disengagement from the content of the object being attended to (i.e., a gazing face). In the gap paradigm, participants are first required to fixate to a central stimulus and then respond to peripheral targets. Findings are that reaction times to a peripheral target are faster when the stimulus at fixation is extinguished just before target onset (gap condition) than when it continues to be presented after target onset (overlap condition). Although such a facilitative effect (the gap effect) has been mainly reported on saccadic latency (Kingstone & Klein, 1993; Pratt, Bekkering, & Leung, 2000; Saslow, 1967), it has also been found to affect manual responses (Gómez et al., 2002; Mackeben & Nakayama, 1993; Pratt & Nghiem, 2000; Tanaka & Shimojo, 2001). If direct gaze affects disengagement from spatial location, direct gaze should affect the detection of peripheral targets, even when the central face disappears before the onset of the target. Conversely, if the presence of the content is required to affect attentional disengagement, the effect of perceived direct gaze should diminish in the gap condition.

Another aim of this study was to investigate the time course of the effect of perceived direct gaze. For example, reflexive orienting to the direction of averted gaze is reportedly short-lived. It has been reported that nonpredictive gaze direction affects reaction times in the short to middle range of cue-to-target stimulus onset asynchrony (SOA), i.e., at around 100–700 ms (Driver et al., 1999; Friesen & Kingstone, 1998, 2003a, 2003b; Hietanen, 1999; Langton & Bruce, 1999; Mansfield et al., 2003; Ogawa, 2002; Schuller & Rossion, 2001; Senju & Hasegawa, 2001), while no reflexive orienting has been found in longer SOA, i.e., around 1000 ms SOA (Friesen & Kingstone, 1998; Langton & Bruce, 1999). Therefore, it would be fruitful to explore whether perceived direct gaze affects the detection of peripheral targets in short and long SOA.

EXPERIMENT 1

The purpose of this experiment was to examine whether the direct gaze of a centrally presented face slowed down the detection of a peripheral target. In this experiment, following the appearance of a central fixation point, facial stimuli with varying gaze directions (either direct gaze, averted gaze, or eyes closed) appeared at the fixation point of the participants. A peripheral target was then presented either to the left or to the right of central fixation, and participants were required to press a key as soon as they detected it. The facial stimulus was either extinguished 250 ms before the appearance of the target (gap condition), or was presented concurrently with the target (overlap condition). If direct gaze increases attentional dwell time, faces with direct gaze should be associated with delayed target detection in the overlap condition because participants must actively disengage their attention from the centrally presented face before shifting to the peripheral target.[2] In the gap condition, by contrast, direct gaze is not predicted to affect detection latency because attention has already reflexively disengaged from the face at its disappearance. In addition, the SOA between facial stimuli and peripheral targets varied across the trials that explored the time course of the effect of perceived direct gaze. If the effect of direct gaze is short-lived, like reflexive orienting toward the direction of averted gaze, such an effect should be evident only at shorter SOA.

Methods

Participants. Seven paid volunteers (three females, four males), who were graduate and undergraduate students at the University of Tokyo, participated in this experiment. All were blind to the purposes of the experiment, and their visual acuity was either normal or corrected-to-normal.

Apparatus. The experiment was run using Cedrus SuperLab software on a Dell OptiPlex GX50 computer with a 17-inch CRT monitor (SONY Multiscan E230). Participants' heads were fixed with a chin rest to be at a distance of 57 cm from the monitor. Participants' reaction times (RT) and accuracy were obtained from their keyboard-pressing responses.

Stimuli. A central cross, subtended by 0.35°, was used as the fixation point. The target stimulus was an asterisk subtended by 0.7° and positioned 12.5° to the left or right of the fixation point. The same basic image was used to produce three types of facial stimuli in which the eye regions of other pictures (with direct, averted, or closed eyes) of the same person were superimposed (Figure 1a). The images of the faces were cut into ovals and presented in full colour, measuring 6.5° wide and 10° high (with the eye region subtending 1.5° wide and 0.7° high). Faces were laterally averted (see Figure 1a) to make earlier-stage perceptual characteristics such as eye symmetry unavailable in the perception of direct gaze. Only vertically averted gazes were used in this experiment because averted eye gazes have been reported to trigger reflexive orienting toward the corresponding direction of the gaze (e.g., Driver et al., 1999). Thus, laterally averted eye gaze possibly affects detection of laterally presented targets.

[2] This overlap condition is similar to the experimental design used in Fox et al. (2001, Exp. 5), which presented words with varying emotional valence at fixation and recorded the speed of recognizing peripherally presented words. This seemed to suit the current purpose of directly investigating attentional dwell time at centrally presented stimuli.

Figure 1. Facial stimuli presented in Experiment 1 (a) and Experiment 2 (b). (a): Left: Direct gaze. Centre: Averted gaze. Right: Closed eyes. (b): Left: Direct gaze. Right: averted gaze. Facial stimulus with closed eyes was the same as in Experiment 1. Facial stimuli were presented in full colour, and appeared a little below the fixation point, so that the eye region would appear centrally.

Design. There were four within-participant factors: Gaze direction (direct gaze, averted gaze, or closed eyes), trial type (gap condition or overlap condition), stimulus onset asynchrony (SOA) between facial stimuli and target (500 or 1200 ms), and target position (left or right), which were crossed to yield 24 experimental conditions.

Procedure. The typical stimulus sequence is presented in Figure 2. At the beginning of each trial, a fixation cross appeared in the centre of the screen. Participants were asked to fixate on this cross and to maintain fixation at the centre of the screen throughout the experiment. After a delay of 500 ms, the fixation cross was replaced by a facial stimulus, positioned slightly below the centre of the screen so that its eye region would appear to be in the centre. Following the SOA (500 or 1200 ms), a target asterisk appeared, with equal

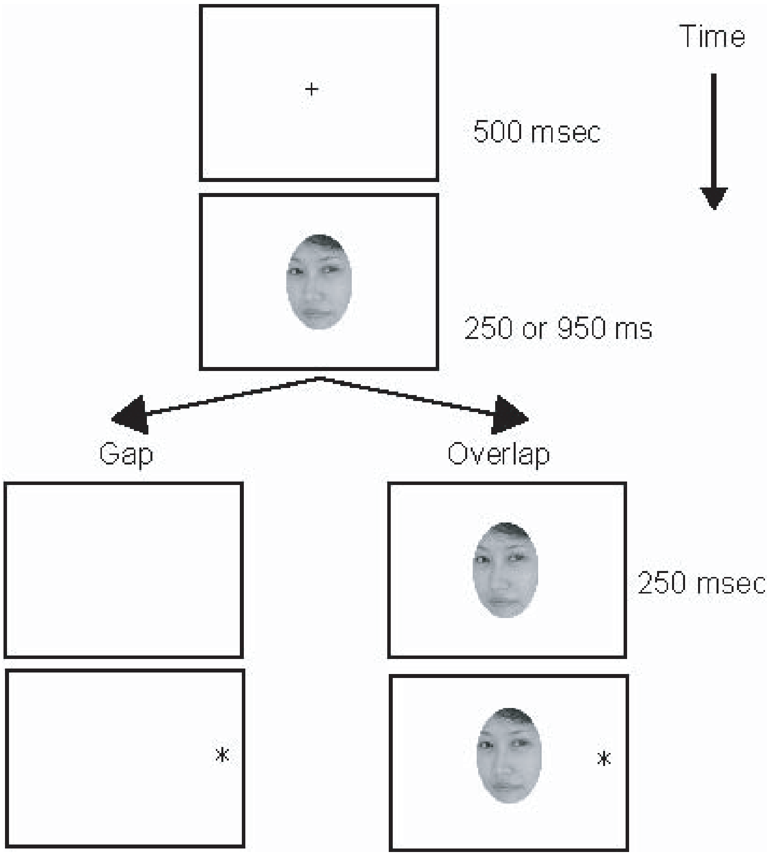

Figure 2. Trial sequences for gap and overlap conditions. The target randomly appeared equally to either the left or right of fixation, and speeded key press responses, without eye movement, to the target were required of the participants.

probability, either to the left or to the right of central fixation. Participants were required to press the space bar on the keyboard with their preferred hand as quickly as possible when they detected the target. In the gap condition, the centrally presented face disappeared 250 ms prior to the appearance of the target. In the overlap condition, by contrast, facial stimuli were presented on the screen until a participant responded. Participants completed five blocks of 120 trials. Each block consisted of four repetitions of each of 24 experimental conditions and a set of 24 ''catch'' trials in which no target was presented. In catch trials, inserted in order to discourage anticipatory responses, participants were required to refrain from key presses. Feedback was presented on the screen following each participant response.

The first block was regarded as a practice block and was not included in the analyses. Trials were randomized within all blocks. The experiment lasted around 45 min and participants were allowed to take a short break between blocks if desired.

Results

As target position did not affect the results, this factor was pooled in subsequent analyses. The median reaction times (RTs) of the errorless trials are shown in Figure 3. The interparticipant averages of the median RTs were subjected to a three-factor analysis of variance (ANOVA) with gaze direction (direct gaze, averted gaze, or closed eyes), trial type (gap condition or overlap condition), and SOA between facial stimuli and target (500 or 1200 ms) as factors. Since the pilot analysis found no effect of target position (left or right), this factor was collapsed in the analysis. Multiple comparisons were examined as necessary using Tukey HSD tests. There was a main effect of trial type, $F(1, 6) = 56.75$, $p < .001$. Temporal gap accelerated response latency (gap effect). Neither gaze direction nor SOA were significant, all Fs $<$ 2.3, $p > .1$. There was a significant interaction between gaze direction and trial type, $F(2, 12) = 10.00$, $p < .01$. A simple effects test revealed that gaze direction was significant only in the overlap condition, $F(2, 12) = 8.19$, $p <$ .01, and not in the gap condition, $F(2, 12) = 0.08$, $p > 0.1$. Moreover, in the

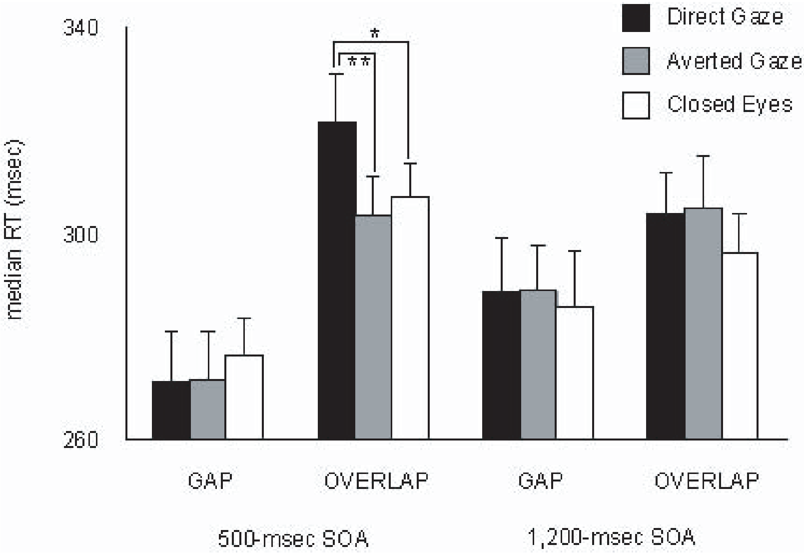

Figure 3. Reaction times in Experiment 1 for each gaze condition, trial type, and stimulus onset asynchrony (SOA). Error bar: *SE*. $^{**}p < .01$, $^{*}p < .05$.

overlap condition, response times to targets were longer in response to direct gaze than to averted gaze ($p < .05$) or to closed eyes ($p < .01$), which did not differ significantly from each other.

In addition, there was a significant interaction between trial type and SOA, $F(1, 6) = 44.00$, $p < .001$, as the gap effect was larger at the 500 than at the 1200 ms SOA. Simple tests revealed that RTs were faster at the 500 than at the 1200 ms SOA in the gap condition, $F(1, 6) = 6.11$, $p < .05$, but SOA had no effect in the overlap condition. There was another significant interaction between gaze direction and SOA, $F(2, 12) = 6.39$, $p < .05$, which appeared due to the differential effect of SOA for each gaze condition. The rate of catch trial errors was less than 2% and was unaffected by any experimental factor.

Although the three-way interaction between gaze direction, trial type, and SOA was not significant, $F(2, 12) = 1.93$, $p = .19$, it was worth analysing the effect of perceived direct gaze according to each SOA, in order to explore whether the delayed response to direct gaze was short-lived, like the reflexive orienting that was triggered by an averted gaze (Friesen & Kingstone, 1998; Langton & Bruce, 1999). Thus, gaze direction in the overlap condition was further analysed at each SOA. At the 500 ms SOA, direct gaze slowed down target detection more than the averted gaze ($p < .01$) and closed eye conditions ($p < .05$), which did not differ from each other. In contrast, gaze direction had no effect on reaction times at the 1200 ms SOA.

Discussion

The most important finding was that in the 500 ms SOA overlap trials, participants were slower to respond to the target that followed the facial stimulus with a direct gaze. Such an effect of direct gaze was only found in the overlap condition, which required active disengagement from the centrally presented face, as compared to the gap condition where offset reflexively disengaged participant attention from the central face. The slower responses to peripheral targets following direct gaze seems best explained by increased attentional dwell time from facial stimuli that convey biologically important signals (Fox et al., 2001, 2002). This gaze direction effect was short-lived, disappearing 1200 ms after the onset of the gazing face, and suggests the involvement of transient attention. Similarly, a reflexive attentional shift, triggered by an averted gaze, was also short-lived (Friesen & Kingstone, 1998: Langton & Bruce, 1999). In addition, and consistent with previous studies, the temporal gap between central fixation offset and the onset of the peripheral target accelerated target detection latency and replicated the gap effect with a key-press response (Mackeben & Nakayama, 1993; Tanaka & Shimojo, 2001). The gap effect was more pronounced at shorter SOAs between presentation of the central face and peripheral target, due to the faster response at shorter SOA in the gap condition; this result may also have occurred because transient attention to the central fixation, triggered by the abrupt onset of facial stimuli, facilitated attentional disengagement and the operation of a spatial-orienting mechanism (Tanaka & Shimojo, 2001).

Although the results of this study demonstrated an effect of direct gaze, there is another possible interpretation. Only a vertically averted gaze was used as a control stimulus in the current study, in order to avoid reflexive orienting toward targets elicited by a laterally averted gaze. As a result, the eye region consists a bigger area of black and white contrast in direct gaze stimulus than in the other two kinds of stimuli. Thus, it is possible that earlier-stage perceptual features of direct gaze, such as higher saliency of exposed sclera and iris, could account for the increased attentional dwell time. To further examine this possibility, another experiment was conducted.

EXPERIMENT 2

The purpose of Experiment 2 was to examine whether earlier-stage perceptual features of the eye region, especially higher saliency, could account for the delayed response times to the peripheral targets in response to a direct gaze discovered in Experiment 1. Stimuli in Experiment 2 were the same as in Experiment 1, except that the contrast polarity of sclera and iris was reversed (i.e., white iris surrounded by black sclera) in Experiment 2. Because eye negation effectively disrupts gaze perception (Ricciardelli, Baylis, & Driver, 2000), this stimulus modification was predicted to have a detrimental effect on gaze perception while preserving high contrast between sclera and iris. If gaze perception is critical to increased attentional dwell time, target detection should not be affected by gaze direction from contrast-reversed eyes. But if earlier-stage perceptual features, such as higher saliency of widely exposed eye regions, are sufficient to increase attentional dwell time, the direct gaze with reversed eyes would delay responses to the peripheral stimuli.

Methods

Experimental design, procedure, apparatus and stimuli were exactly the same as those used in Experiment 1, except for the aforementioned contrast negation of the eye region of the stimuli. As shown in Figure 1(b), facial stimuli with direct gaze and averted gaze were now in two-toned colour with negative contrast in the eye region (i.e., black sclera and white iris). Adobe Photoshop software was used to create the stimuli, following Ricciardelli et al. (2000). The facial stimulus with closed eyes was the same as in Experiment 1.

Eight graduate and undergraduates of the University of Tokyo (three females, five males) participated in this experiment. All were blind to the experimental hypothesis, had normal or corrected-to-normal visual acuity, and were paid for their participation.

Results

The interparticipant averages of the median RTs of the errorless trials appear in Table 1, and were subjected to a three-factor ANOVA with gaze direction (direct gaze, averted gaze, or closed eyes), trial type (gap or overlap), and SOA between facial stimuli and target (500 or 1200 ms) as factors. As in Experiment 1, the pilot analysis found no effect of target position (left or right) and this factor was collapsed in the analysis. Multiple comparisons were examined as necessary using Tukey HSD tests. As in Experiment 1, the factor of target position was pooled. There was a main effect of trial type, $F(1, 7) = 52.07$, $p < .001$, replicating the gap effect found in Experiment 1. The only significant interaction was between trial type and SOA, $F(1, 7) = 31.71$, $p < .001$. The gap effect was larger at shorter SOAs between facial stimuli and target, as in Experiment 1. A simple test revealed that RTs were faster at the 500 than at the 1200 ms SOA in the gap condition, $F(1, 7) = 6.92$, $p < .05$, but SOA had no effect in the overlap condition. No other main effects or interactions approached significance,all Fs < 1.5, $p > .1$. The rate of catch trial errors was less than 2% and was unaffected by any experimental factor.

Discussion

In this experiment, most significantly, there were no main effects or interactions of gaze direction, which clearly contrasts with the results of Experiment 1. As the only difference between Experiment 1 and Experiment 2 was that of the colour of the eyes of the facial stimuli, it may be that contrast negation of the eyes eliminated delayed target detection in response to a direct gaze. Current results seem to support the importance of gaze perception in enhanced attentional dwell time, since negating contrast polarity effectively disrupts gaze perception without reducing the higher contrast between sclera and iris (Ricciardelli et al., 2000). However, one caveat must be noted. As Figure 1(b) shows, the eye region of the current stimuli was shown in ''two-tone colour'', rather

TABLE 1
Mean reaction times with standard errors (mean±SE) for Experiment 2

Gaze condition	*Direct*	*Averted*	*Closed*
500 ms SOA			
Gap	280.3±11.7	273.2±10.0	272.1±10.2
Overlap	313.2±9.8	310.3±10.8	311.2±10.3
1200 ms SOA			
Gap	283.2±12.9	285.7±10.8	289.4±11.9
Overlap	303.7±9.6	300.9±9.2	304.8±9.9

than in the ''full colour'' of the stimuli used in Experiment 1. Although we believe that it is quite unlikely, we cannot completely rule out the possibility that it was conversion of the coloured eye to monochrome, not the reversal of its contrast polarity, that eliminated the delayed response to the direct gaze found in Experiment 2. Further studies with stricter controls are required to investigate this possibility. Our results did at least eliminate the possibility that the results of Experiment 1 can be attributed to the larger black and white area in the direct gaze stimulus.

Except for the effect of gaze direction, current results replicated those of Experiment 1 in both the facilitative effect of a gap (gap effect) and the larger gap effect at shorter fixation-to-target SOAs. This is due to faster responses at shorter SOAs in the gap condition, and may reflect the facilitative effect of attentional orienting induced by the abrupt onset of a centrally presented face (Tanaka & Shimojo, 2001).

GENERAL DISCUSSION

The current study investigated whether perception of another's direct gaze increases attentional dwell time to the gazing face and delays responses to the area outside of the facial region. Since direct gaze signals intention towards the perceiver, and thus provides critical social and communicative information, it was predicted that direct gaze would capture the perceiver's attention and make it difficult to disengage. As predicted, Experiment 1 revealed that peripherally presented targets were slower to be detected when the centrally presented face was in a direct gaze condition than when its eye gaze was averted or when its eyes were closed. The authors believe that this is the first report of an inhibitory effect of direct gaze on visual processing outside the facial area.

The effect of direct gaze on increased attentional dwell time disappeared when a temporal gap was inserted between the offset of the centrally presented face and the onset of a peripheral target. It suggests that attentional disengagement from a face gazing toward the perceiver, rather than disengagement from the spatial location of the facial stimuli, contributes to delayed target detection in response to a direct gaze. Gaze direction did not affect target detection at longer SOAs between facial stimuli and target, which implies that enhanced attentional dwell time to direct gaze is transient like the reflexive orienting toward the direction of averted gaze (Friesen & Kingstone, 1998; Langton & Bruce, 1999). In sum, the results of this study suggest that the perception of a direct gaze increases attentional dwell time to the gazer's face and delays disengagement from it. But with a small sample size and a non-significant three-way interaction including SOA, we need to be careful about concluding that the results suggest a transient effect and further study will be required.

In Experiment 2 the contrast polarity of eyes in the facial stimuli, while preserving high contrast between iris and sclera, was reversed in order to disrupt gaze perception, (Ricciardelli et al., 2000). This stimulus modification eliminated the effect of direct gaze, supporting the explanation that perception of direct gaze is necessary to hold attention onto the gazing face. It is, therefore, inappropriate to attribute the gaze direction effect in Experiment 1 to the earlier-stage perceptual features of facial stimuli, such as higher saliency of a widely exposed eye region. In addition, the results of Experiment 2 again demonstrate the importance of contrast polarity in gaze perception (Ricciardelli et al., 2000).

Our data thus support previous findings that attention can be fixed on biologically important stimuli such as emotional facial expressions (Fox et al., 2001, 2002) or pictures of threatening environments (Yiend & Mathews, 2001). Although discussion here has been mainly confined to the attentional dwell time to potentially threatening stimuli,[3] current results seem to suggest that such increased attentional dwell time can be elicited by biologically important stimuli in general, since a direct gaze is not necessarily threatening to human perceivers (Kleinke, 1986; Robson, 1967; Robson et al., 1969). It is adaptively important to attend to the face of the other who is ''looking at me'', since that face signals an intention (communicative, affective, friendly, hostile, or sexual) towards oneself. In addition, the gazer's face is usually rich in additional information such as expression, gender, age, and identity.

People exhibit other tendencies relative to another's direct gaze: A direct gaze is more rapidly detected (von Grünau & Anston, 1995); an ambiguous gaze is likely to be considered a direct gaze (Martin & Jones, 1982; Martin & Rovira, 1981, 1982); and a direct gaze elaborates arousal level (Gale et al., 1975, 1978; Nichols & Champne, 1971). There is also evidence that a direct gaze facilitates facial processing of the gazer. Macrae et al. (2002) reported that a direct gaze speeds up gender discrimination and enhances semantic memorization of the gazing face. Current results, as well, reveal that a direct gaze modulates facial perception and cognition. Although rather tentative, it seems reasonable to assume that such increased attentional dwell time might account for the enhancement of various kinds of neural processing for faces in direct gaze (George et al., 2001; Kampe et al., 2001; Wicker et al., 2003). Future neuroimaging research will be necessary to investigate these issues.

Increased attentional dwell time in response to direct gaze was transient in the current study. This is consistent with previous studies of reflexive orienting toward the direction of the averted gaze, which may trigger automatic attention (Driver et al., 1999; Friesen & Kingstone, 1998; Ogawa, 2002; Senju & Hasegawa, 2001). Although the 500 ms SOA used in the current experiments is longer than those previously reported to elicit automatic orienting (e.g., Posner,

[3] Fox et al. (2002, Exp. 1), however, have reported that not only an angry face (threatening signal) but also a happy face (nonthreatening, but an important social signal) holds perceivers' attention.

1980), the absence of an effect of direct gaze at longer SOAs suggests that increased attentional dwell time to a direct gaze, as well as orienting towards the direction of an averted gaze, works in a reflexive, automatic manner rather than by influencing controlled or endogenous attentional components. Further studies with varying SOAs will be required to investigate this issue in detail. However, due to the lack of the significant three-way interaction including SOA, we need to be cautious about the time course of the effect of perceived direct gaze in current results and further study will be required.

Recently, Friesen and Kingstone (2003b) reported an independent study that examined the effect of gaze direction and the offset of central facial stimuli on the saccadic and manual response times for peripheral targets. They presented a schematic face with either direct, leftwards, or rightwards eye gaze, which preceded peripheral targets that appeared either left or right of the central face. The participants were required to respond with either a manual key press while maintaining central fixation or with a saccade to the target as soon as possible. Their findings for the manual response condition were that (1) RT in direct gaze trials was not delayed relative to RT with averted gaze, and (2) there was no gap effect, both of which contradict our findings.

For the effect of direct gaze, the discrepancy between our study and that of Friesen and Kingstone (2003b) could be due to a number of factors, such as the properties of the facial stimuli (schematic vs. photographic), facial orientation (front view vs. lateral view), or the direction of ''averted gaze'' (lateral vs. downwards). Further research is required to examine which factors are responsible for the differences between our results and those of Friesen and Kingstone (2003b).

With regard to the presence/absence of a gap effect, the lack of eye movement recording makes it quite difficult to compare our results with those of Friesen and Kingstone (2003b) directly. Although we strongly instructed the participants to fixate their eyes throughout the experiments, we cannot eliminate the possibility that the participants might have elicited small saccades in the direction of the target in some trials, bringing the target nearer the fovea and making it easier to detect. Another possibility is that the gap effect that we found resulted from a warning effect (Kingstone & Klein, 1993; Pratt et al., 2000), because the target always appeared 250 ms after the offset of the central face, and this could have acted as a warning signal. Since Friesen and Kingstone (2003b) found no gap effect for manual responses while monitoring eye movement and making the timing of target onset unpredictable, a better controlled study is required to determine the nature of the ''gap effect'' found in our study. This limitation, however, does not diminish our main finding that direct gaze affects behavioural response latency to the periphery, while making it difficult to address the visual mechanism underlying the effect. Because participants tried hard to fixate throughout the experiments, the most probable components responsible for the increased response times to direct gaze are increased attentional dwell time, which could be somewhat independent from the oculomotor system. We cannot, however, totally eliminate the possibility that overt attention, such as an inhibitory control of saccadic eye movement, might account for delayed orienting to the peripheral target following perception of the directly gazing face. The underlying visual mechanism in delayed disengagement from direct gaze is also of interest, and future studies utilizing eye-tracking devices will be required to further investigate the relative involvement of attentional and oculomotor mechanisms.

Individual differences in sensitivity to direct gaze are interesting and should be investigated. In previous research into attentional disengagement from threatening facial (Fox et al., 2001, 2002) or pictorial (Yiend & Mathews, 2001) stimuli, differing effects of the degree of state and trait anxiety on attention were reported. Although the small sample sizes and the absence of state and trait measurements in the current experiments did not permit analysis of the effects of individual differences, it is possible that traits, especially those correlating to social behaviour, might differentially affect attentional dwell time in response to direct gaze.

It is also important to investigate populations who suffer from developmental disorders or brain damage that affect social behaviour. Our recent work with high-functioning children with autism, who were within typical ranges of intellectual functioning but who had severe social difficulties, determined that direct gaze did not facilitate orienting in children with autism, in contrast to more typically developed children (Senju, Yaguchi, Tojo, & Hasegawa, 2003). It is quite possible that individuals with autism also fail to demonstrate increased attentional dwell time in response to direct gaze. Moreover, difficulties in discriminating direct/averted gazes have been reported not only in individuals with autism (Howard et al., 2000) but also in other psychiatric or brain-damaged populations, such as individuals with Turner syndrome (Elgar, Campbell, & Skuse, 2002) and patients with amygdala lesions (Broks et al., 1998; Young, Aggleton, Hellawell, Johnson, Broks, & Hanley, 1995). Investigating direct gaze processing, including attentional dwell time, in these populations will contribute to our understanding of the neural and developmental nature of visual social cognition and, hopefully, lead to an effective intervention.

REFERENCES

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Andrew, R. J. (1965). The origins of facial expressions. *Scientific American*, *213*, 88–94.

Baranek, G. T. (1999). Autism during infancy: A retrospective video analysis of sensory-motor and social behaviors at 9–12 months of age. *Journal of Autism and Developmental Disorders*, *29*, 213–224.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. *Infant Behavior and Development*, *23*, 223–229.

Blest, A. D. (1957). The function of eyespot patterns in the Lepidoptera. *Behaviour*, *11*, 209.

Broks, P., Andrew, W., Young, A. W., Maratos, E. J., Coffey, P. J., Calder, A. J., Isaac, C. L., Mayes, A. R., Hodges, J. R., Montaldi, D., Cezayirli, E., Roberts, N., & Hadley, D. (1998). Face processing impairments after encephalitis: Amygdala damage and recognition of fear. *Neuropsychologia*, *36*, 59–70.

Butterworth, G., & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual-attention in infancy. *British Journal of Developmental Psychology*, *9*, 55–72.

Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P. Durham (Eds.), *Joint attention: Its origins and role in development* (pp. 61–83). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Coss, R. G. (1970). Perceptual aspects of eye-spot patterns and their relevance to gaze behaviour. In S. J. Hutt & C. Hutt (Eds.), *Behaviour studies in psychiatry* (pp. 121–147). Oxford, UK: Pergamon Press.

Darwin, C. (1998). *The expressions of the emotions in man and animals* (3rd ed.). London: Fontana Press. (Original work published 1872)

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.

Elgar, K., Campbell, R., & Skuse, D. (2002). Are you looking at me? Accuracy in processing line-of-sight in Turner syndrome. *Proceedings of the Royal Society of London, Series B: Biological Sciences*, *269*, 2415–2422.

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

Farroni, T., Johnson, M. H., Brockbank, M., & Simion, F. (2000). Infants' use of gaze direction to cue attention: The importance of perceived motion. *Visual Cognition*, *7*, 705–718.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, *130*, 681–700.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, *16*, 355–379.

Fox, M. W. (1970). A comparative study of the development of facial expressions in canids; wolf, coyotes and foxes. *Behaviour*, *36*, 49–73.

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

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

Friesen, C. K., & Kingstone, A. (2003b). Covert and overt orienting to gaze direction cues and the effects of fixation offset. *Neuroreport*, *14*, 489–493.

Gale, A., Kingsley, E., Brookes, S., & Smith, D. (1978). Cortical arousal and social intimacy in human female under different conditions of eye contact. *Behavioural Processes*, *3*, 271–275.

Gale, A., Spratt, G., Chapman, A. J., & Smallbone, A. (1975). EEG correlates of eye contact and interpersonal distance. *Biological Psychology*, *3*, 237–245.

Gallup, G. G., Cummings, W. H., & Nash, R. F. (1972). The experimenter as an independent variable in studies of animal hypnosis in chickens. *Animal Behavior*, *20*, 166–169.

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*, 1102–1112.

Gibson, J. J., & Pick, A. D. (1963). Perception of another person's looking behavior. *American Journal of Psychology*, *76*, 386–394.

Gómez, M., Delinte, A., Vaquero, E., Atienza, M., Cantero, L., Vazquez, M., Crommelinck, M., & Roucoux, A. (2002). Sensory and motor attentional modulation during the manual gap effect in humans: A high-density ERP study. *Experimental Brain Research*, *142*, 385–394.

Hietanen, J. K. (1999). Does your gaze direction and head orientation shift my visual attention? *Neuroreport*, *10*, 3443–3447.

Hinde, R. A. (1954). Factors governing the changes in strength of a partially inborn response, as shown by the mobbing behaviour of the chaffinch (*Fringilla coelebs*): I. The nature of the response and an examination of its course. *Proceedings of the Royal Society of London, Series B: Biological Sciences*, *142*, 306–331.

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*, 80–84.

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

Howard, M. A., Cowell, P. E., Boucher, J., Broks, P., Mayes, A., Farrant, A., & Roberts, N. (2000). Convergent neuroanatomical and behavioural evidence of an amygdala hypothesis of autism. *Neuroreport*, *11*, 2931–2935.

Kampe, K. K. W., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Reward value of attractiveness and gaze. *Nature*, *413*, 589.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, *17*, 4302–4311.

Kingstone, A., & Klein, R. M. (1993). Visual offsets facilitate saccadic latency: Does predisengagement of visuospatial attention mediate this gap effect? *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 1251–1265.

Kleinke, C. (1986). Gaze and eye-contact: A research review. *Psychological Bulletin*, *100*, 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*, 419–435.

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, *6*, 541–567.

Mackeben, M., & Nakayama, K. (1993). Express attention shift. *Vision Research*, *33*, 85–90.

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*, 460–464.

Mansfield, E., Farroni, T., & Johnson, M.H. (2003). Does gaze perception facilitate overt orienting? *Visual Cognition*, *10*, 7–14.

Martin, W. W., & Jones, R. F. (1982). The accuracy of eye-gaze judgment: A signal-detection approach. *British Journal of Social Psychology*, *21*, 293–299.

Martin, W. W., & Rovira, M. L. (1981). An experimental-analysis of discriminability and bias in eye-gaze judgment. *Journal of Nonverbal Behavior*, *5*, 155–163.

Martin, W. W., & Rovira, M. L. (1982). Response biases in eye-gaze perception. *Journal of Psychology*, *110*, 203–209.

Maurer, D., & Salapatek, P. (1976). Developmental-changes in scanning of faces by young infants. *Child Development*, *47*, 523–527.

Moore, C., & Corkum, V. (1998). Infant gaze following based on eye direction. *British Journal of Developmental Psychology*, *16*, 495–503.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: A two-process theory of infant face recognition. *Psychological Review*, *98*, 164–181.

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

Ogawa, T. (2002). Tasya no shisenn houkou ni yoru tyuui shift no tokusei ni tsuite [Nature of the visual orienting triggered by gaze perception]. *Kisoshinrigaku Kenkyu*, *21*, 31–35.

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*, 156–170.

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

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32A*, 3–25.
Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25–42.
Pratt, J., Bekkering, H., & Leung, M. (2000). Estimating the components of the gap effect. *Experimental Brain Research*, *130*, 258–263.
Pratt, J., & Nghiem, T. (2000). The role of the gap effect in the orienting of attention: Evidence for express attentional shifts. *Visual Cognition*, *7*, 629–644.
Puce, A., Allison, T., Bentin, S., Gore, J. C., & McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *Journal of Neuroscience*, *18*, 2188–2199.
Puce, A., Smith, A., & Allison, T. (2000). ERPs evoked by viewing facial movements. *Cognitive Neuropsychology*, *17*, 221–239.
Ricciardelli, P., Baylis, G., & Driver, J. (2000). The positive and negative of human expertise in gaze perception. *Cognition*, *77*, B1–B14.
Robson, K. S. (1967). The role of eye-to-eye contact in maternal–infant attachment. *Journal of Child Psychology and Psychiatry*, *8*, 13–25.
Robson, K. S., Pedersen, F. A., & Moss, H. A. (1969). Developmental observations of dyadic gazing in relation to the fear of strangers and social approach behavior. *Child Development*, *40*, 619–627.
Saslow, M. G. (1967). Effects of components of displacement-step stimuli upon latency for saccadic eye movement. *Journal of the Optical Society of America*, *57*, 1024–1029.
Schmidt, K. L., & Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression research. *Yearbook of Physical Anthropology*, *443*, 4–21.
Schuller, A., & Rossion, B. (2001). Spatial attention triggered by eye gaze increases and speeds up early visual activity. *Neuroreport*, *12*, 2381–2386.
Senju, A., & Hasegawa, T. (2001). Shisen ha tyuui ni tsuite nani wo kataruka—Shisen ni yoru judouteki na teii hannnou [What the gaze tells us about attention? Reflexive orienting by gaze perception]. *Kisoshinrigaku Kenkyu*, *20*, 33–34.
Senju, A., Yaguchi, K., Tojo, Y., & Hasegawa, T. (2003). Eye contact does not facilitate detection in children with autism. *Cognition*, *89*, B43–B51.
Tanaka, Y., & Shimojo, S. (2001). Temporal and spatial characteristics of attention to facilitate manual and eye-movement responses. *Perception*, *30*, 283–302.
Taylor, M. J., George, N., & Ducorps, A. (2001a). Magnetoencephalographic evidence of early processing of direction of gaze in humans. *Neuroscience Letters*, *316*, 73–177.
Taylor, M. J., Itier, R. J., Allison, T., & Edmonds, G. E. (2001b). Direction of gaze effects on early face processing: Eyes-only versus full faces. *Cognitive Brain Research*, *10*, 333-340.
von Grünau, M., & Anston, C. (1995). The detection of gaze direction: A stare-in-the-crowd effect. *Perception*, *24*, 1297–1313.
Watanabe, S., Kakigi, R., & Puce, A. (2001). Occipitotemporal activity elicited by viewing eye movements: A magnetoencephalographic study. *NeuroImage*, *13*, 351–363.
Watanabe, S., Miki, K., & Kakigi, R. (2002). Gaze direction affects face perception in humans. *Neuroscience Letters*, 325, 163–166.
Wicker, B., Michel, F., Henaff, M. A., & Decety, J. (1998). Brain regions involved in the perception of gaze: A PET study. *NeuroImage*, *8*, 221–227.
Wicker, B., Perrett, D. I., Baron-Cohen, S., & Decety, J. (2003). Being the target of another's emotion: A PET study. *Neuropsychologia*, *41*, 139–146.
Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *Quarterly Journal of Experimental Psychology*, *54A*, 665–681.
Young, A. W., Aggleton, J. P., Hellawell, D. J., Johnson, M. H., Broks, P., & Hanley, J. R. (1995). Face processing impairments after amygdalotomy. *Brain*, *118*, 15–24.