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Short Communication

Hyper-volume of eye-contact perception and social anxiety traits

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ABSTRACT

Eye-contact facilitates effective interpersonal exchange during social interactions, but can be a considerable source of anxiety for individuals with social phobia. However, the relationship between the fundamental spatial range of eye-contact perception and psychiatric traits is, to date, unknown. In this study, I analyzed the eye-contact spatial response bias and the associated pupil response, and how they relate to traits of social interaction disorders. In a face-to-face situation, 21 pairs of subjects were randomly assigned to be either viewers or perceivers. The viewer was instructed to gaze either at the perceiver's eyes, or at a predetermined point, and the perceiver was asked to indicate whether eye-contact had been established or not. I found that the perceptual volume is much larger than the actual volume of eye-contact, and that the subjective judgment of eye-contact elicited greater pupil dilation in the perceiver. Furthermore, the relationship between behavioral performance and social anxiety traits was identified. These findings provide new indications that internal traits related to lower social anxiety are potentially related to a restriction of spatial response bias for eye-contact.

1. Introduction

In humans, information obtained from the gaze direction of others helps to establish interpersonal relationships during effective social interactions (Senju & Johnson, 2009a). Indeed, an individual's attention shifts in accordance with other's eye movements, and the gaze is often directed at the subject of their current interest and intention (Castiello, 2003; Mason, Tatkow, & Macrae, 2005; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). When individuals establish eye-contact, it evokes greater levels of cortical activity associated with the intensity of attention, interest, and emotion, as evidenced by neuroimaging findings demonstrating increased activation of the ventral striatum (Kampe, Frith, Dolan, & Frith, 2001), amygdala (Spezio, Huang, Castelli, & Adolphs, 2007), and superior temporal sulcus (Nummenmaa & Calder, 2009).

The degree of pupil dilation evoked by direct eye-contact also robustly reflects autonomic activity (Porter, Hood, & Troscianko, 2006; Steinhauer, Siegle, Condray, & Pless, 2004); the human iris dilator muscles are innervated by adrenergic excitatory and cholinergic inhibitory nerves (Yoshitomi, Ito, & Inomata, 1985), and an emotionally intense event activates parasympathetic pathways, thereby increasing pupil diameter (Bitsios, Szabadi, & Bradshaw, 2004) as well as activity in the amygdala and anterior cingulate cortex (Critchley, Tang, Glaser, Butterworth, & Dolan, 2005; Pissiota et al., 2003). However, eye-contact perception is highly subjective and often inaccurate even in healthy humans. For example, accuracy is gradually reduced as the viewers gaze moves from the center towards the periphery of the perceiver's face (Gibson & Pick,

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1963). Furthermore, increased pupil dilation occurs not when physical eye-contact itself is established, but when the subjective judgment of eye-contact is activated (Honma, Tanaka, Osada, & Kuriyama, 2012). Therefore, although physiological responses do reflect arousal for eye-contact perception, this appears, at least partly, to be subjective and dependent upon the perceiver's conscious awareness of the other person's gaze direction. Evidence from previous studies (Gibson & Pick, 1963; Honma et al., 2012) suggests that, while individuals commonly have a high degree of confidence in their tendency to perceive eye-contact in everyday life, this perception is in fact ambiguous and self-related. However, the fundamental nature of such a spatial range of eye-contact perception remains unclear.

Interestingly, eye-contact perception has been linked to psychiatric disorders characterized by a deficit in social interaction, such as autism spectrum disorder (ASD) and social anxiety disorder (SAD). Although there are controversial findings that individuals with ASD do not look at other's eyes (Senju & Johnson, 2009b), several studies of visual scanning of faces have reported that individuals with ASD are characterized by a reluctance to establish eye-contact (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002). This behavior could reflect a diminished level of interest in others (Senju & Johnson, 2009a), as evidenced by lower levels of activity in social brain networks (the amygdala, superior temporal sulci, fusiform area, and prefrontal cortex) (Adolphs, 2009). Similarly, in SAD, the viewing of directed-gaze faces initiates fear responses and avoidance behaviors (Horley, Williams, Gonsalvez, & Gordon, 2004; Moukheiber et al., 2010) and elicits increased activity in the fear circuit network (the amygdala, anterior cingulate, and prefrontal cortex) (Schneier, Kent, Star, & Hirsch, 2009; Schneier, Pomplun, Sy, & Hirsch, 2011). These findings strongly suggest that response bias to eye-contact is somewhat dependent on neurological and/or psychological trait differences between individuals.

In the present study, I measured the spatial response bias of eye-contact in participants, in a face-to-face situation, on the basis of behavioral and physiological responses. I also investigated the relationship between behavioral performance and traits associated with psychiatric disorders related to deficits in social interaction. Specifically, I measured eye-contact perception in nonclinical subjects within a three-dimensional perceptual range, and compared this measurement with the actual range. I also recorded the pupil diameter of the perceiver and compared pupil dilation during the judgment of eye-contact with that during the judgment of no eye-contact. Furthermore, I examined traits related to psychiatric disorders, such as ASD and SAD, by using screening tests. I hypothesized that the spatial response bias for eye-contact perception is attributable to traits of psychiatric disorders related to social interaction deficits, even in healthy humans. My predictions were as follows: perceptual volume is larger than actual volume; pupil diameter increases during the subjective judgment of eye-contact; and behavioral performance is correlated with the severe traits of psychiatric disorders such as ASD and SAD.

2. Materials and methods

2.1. Participants

A total of 42 university students, aged between 20 and 23 years (20 males and 22 females, mean age = 21.2 years, S.D. = 0.23) participated in the study. None of the participants had any history of drug or alcohol abuse, nor of neurological or psychiatric disorders. All had normal vision (uncorrected visual acuity $\geqslant 0.7$ on the Landolt ring chart), and all were right-eye dominant. Written informed consent was obtained from all participants prior to the study. The Research Ethics Committee reviewed and approved all experimental procedures, which complied with the Declaration of Helsinki.

2.2. Procedures

Participants of the same gender were randomly paired, and each was assigned the role of either viewer or perceiver (female pairs: 11; male pairs: 10). Each member of a pair was unfamiliar with the other. The participants were paired with a stranger of the same gender in order to avoid any potential inter-gender and familiarity interactions within the roles of viewer and perceiver. Each pair was seated facing each other, with a distance of 114 cm between their foreheads. Eye height was standardized using chin and forehead rests. An index-pole tip for the viewer's gaze was randomly placed between them. The control point (coordinate axes $x, y, z = 0, 0, 0$) was set 7 cm away from the midpoint between the perceiver's eyes. The index-pole tip contained 605 points: 11 (x-axis) by 11 (y-axis) by 5 (z-axis), with reference to the control point. The measurement range was 40,000 cm^3 (x-axis: 20 cm; y-axis: 20 cm; z-axis: 100 cm). Before each trial, the viewer was asked to gaze at the chin rest of the perceiver, and the perceiver was asked to close her/his eyes. A visual instruction was given to each viewer, requiring them to gaze at a predetermined point located either midway between the perceiver's eyes (viewing eyes condition), or at the tip of the pole (viewing pole condition). The perceiver was then asked to open her/his eyes and to press one of two buttons in order to indicate whether she/he judged that eye-contact was established. Task trials per pair were 1210, and trials were conducted without repetition, in a random order. The inter-trial interval was 15 s. The experiment was organized to allow participants to take a break every 121 trials. Pupil diameter in the perceivers and gaze point in the viewers were recorded at 60 Hz by using two eye-tracking devices with a resolution of 0.02 mm (EMR-8; Nac Image Technology, Inc., Tokyo).

2.3. Data analysis

Viewer's gaze fixations directed towards the pole tip were confirmed by the eye-tracking device, and the error distances for all points were within 0.5 degrees of the target (mean = 0.22; S.E.M. = 0.09). Perceiver's pupil diameter while his/her eyes