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Pupillometry reveals reduced unconscious emotional reactivity in autism

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ABSTRACT

Recent theoretical conceptualisations have suggested that emotion processing impairments in autism stem from disruption to the sub-cortical, rapid emotion-processing system. We argue that a clear way to ascertain whether this system is affected in autism is by measuring unconscious emotional reactivity. Using backwards masking, we presented fearful expressions non-consciously (subliminally) as well as consciously (supraliminally), and measured pupillary responses as an index of emotional reactivity in 19 children with autism and 19 typically developing children, aged 2–5 years. The pupillary responses of the children with autism revealed reduced unconscious emotional reactivity, with no group differences on consciously presented emotion. Together, these results indicate a hyporesponsiveness to non-consciously presented emotion suggesting a fundamental difference in emotion processing in autism, which requires consciousness and more time.

1. Introduction

One of the most powerful ways to establish genuine interpersonal connections is through emotional communication (Rawlins, 1992). It is through the transfer of emotions and emotional arousal between people that relationships are built (Malloch & Trevarthen, 2009; Nummenmaa et al., 2012; Stern, 2010; Tomasello, Carpenter, Call, Behne, & Moll, 2005). For example, sharing a laugh, smile or even a cry with someone can bring about a sense of social closeness. Although much of our social-emotional lives is conscious, feeling states can lie below the threshold for conscious awareness (Damasio, 1999), and unconscious emotion (both non-consciously *triggered* and non-consciously *experienced*) influences and shapes our everyday perceptions, behaviour, and social judgements (e.g., Berridge & Winkielman, 2003; Hall, West, & Szatmari, 2007; Murphy & Zajonc, 1993; Niedenthal, 1990).

Emotional communication is a significant area of difficulty for individuals with Autism Spectrum Disorder (ASD), neurodevelopmental disorders defined by social-communicative difficulties and behavioural rigidity (American Psychiatric Association [APA], 2013). Research on individuals with ASD has indicated impairments in emotional reciprocity (Hobson, 1989; Rogers & Pennington, 1991), which are likely to stem from difficulties recognising subtle and briefly presented emotional expressions, from atypical physiological responses to emotion, and from the ambiguous spontaneous expressions of own feeling states towards others (for review, see Nuske, Vivanti, & Dissanayake, 2013). Despite these deficits, individuals with ASD can recognise basic emotions from still images of prototypical facial expressions, and can imitate these when told to do so, at least in the laboratory setting (Nuske, Vivanti, & Dissanayake, 2013). Moreover, although individuals with ASD are often reported to have atypical neurophysiological and physiological responses during emotion processing tasks (e.g., reduced amygdala activation), evidence suggests they have fewer abnormalities in neural and autonomic responding during *explicit* emotion tasks (e.g., emotion labelling), compared to *implicit* emotion tasks (e.g., gender labelling of emotional facial expressions; Critchley et al., 2000; Hubl et al., 2003; Kuchinke, Schneider, Kotz, & Jacobs, 2011). Together, this

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pattern of results suggests more difficulty with implicit emotional appraisals than when attention is explicitly directed towards the emotional nature of the stimuli (Nuske, Vivanti, & Dissanayake, 2013). This interpretation is consistent with suggestions that the emotion processing deficit in ASD stems from a fundamental problem with rapid, automatic or sub-cortically mediated emotion processing (e.g., Adolphs, Sears, & Piven, 2001; Dawson, Webb, Carver, Panagiotides, & McPartland, 2004; Johnson, 2005; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Oberman, Winkielman, & Ramachandran, 2009).

Furthermore, a greater reliance on explicit processing of emotion in ASD is consistent with documented perceptual differences in this population, compared to the typical population. For example, studies using the face-inversion paradigm have found that whilst the emotion recognition performance of typically developing individuals is shown to be diminished by turning the face up-side-down, this is not the case for individuals with ASD (Gross, 2008; Hobson, Ouston, & Lee, 1988). Other studies have found that people with ASD rely on featural or fine-grained details to process emotion (vs. using configural information or the gestalt, respectively; Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, & Da Fonséca, 2008; Ozonoff, Pennington, & Rogers, 1991). The results from these studies suggest an atypical approach to the processing of emotion from faces in ASD. Moreover, findings of greater activity in visual processing areas in ASD during explicit emotion recognition (Daly et al., 2012; Hadjikhani et al., 2009; Hubl et al., 2003; Kleinhans et al., 2010; Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008; Silani et al., 2008), indicate that these individuals may rely on rule-based, 'disembodied' explicit emotion processing strategies, possibly of visuo-perceptual origin (for a comprehensive review on the topic, see Winkielman, McIntosh, & Oberman, 2009). Such strategies may include noticing the widened eyes in fearful expressions, leading to recognition of the emotion and consequently triggering an emotional reaction, rather than a direct and more immediate internal simulation of the emotion. This notion of a relatively greater difficulty with implicit processing of emotion and the use of explicit, disembodied strategies for emotion tasks, is consistent with evidence of a temporal delay in emotion processing in ASD, as these explicit strategies are likely to take longer than implicit ones (e.g., Akechi et al., 2009; Bal et al., 2010; Korpilahti et al., 2007; Nuske, Vivanti, & Dissanayake, 2013; Nuske, Vivanti, & Dissanayake, 2014; Oberman et al., 2009; Wong, Fung, Chua, & McAlonan, 2008). Furthermore, difficulty with implicit processing and reliance on explicit cues for social information processing in ASD has been recently proposed outside of the realm of emotion (for eye gaze, theory of mind and imitation) (Senju, 2012), which perhaps suggests that all social cognition deficits in this disorder lie on the implicit level.

Given that explicit attention and conscious awareness are "intimately bound together" (Crick & Koch, 1990, p. 269), if atypical emotional reactivity in ASD is due to the greater recruitment of disembodied, explicit strategies and a lesser reliance on embodied, implicit processes, one would expect a greater difficulty with unconscious, compared to conscious emotion processing in ASD, as the latter allows for explicit attention.

1.1. Unconscious emotion processing

Some of the most convincing empirical work on unconscious emotion processing has been conducted with individuals who are cortically blind. Here, when emotionally inducing stimuli are presented to the individuals' blind visual field, despite the absence of conscious registration of the stimuli, robust emotional reactions (facial, pupillary and neural) are triggered in these individuals (Morris, DeGelder, Weiskrantz, & Dolan, 2001; Pegna, Khateb, Lazeyras, & Seghier, 2005; Tamietto et al., 2009). Likewise, studies on individuals with right-parietal lobe damage, who show *spatial extinction* (a pathological form of inattentional blindness for contralesionally presented stimuli presented simultaneously with stimuli to the ipsilesional visual field; Mack & Rock, 1998), have shown amygdala activation to non-consciously presented fearful faces (Vuilleumier et al., 2002; Williams & Mattingley, 2004).

In typical development, unconscious emotion has been mainly studied through experimental manipulations that suppress conscious awareness of the emotional stimuli through backward masking (Esteves & Öhman, 1993; Raab, 1961). Emotional faces are presented briefly (≈30 ms), and immediately followed by a 'mask' which is usually either a scrambled image of a face or an emotionally neutral face. Many studies have confirmed that emotional faces presented in such a way cannot be consciously recalled (e.g., Dannlowski et al., 2007; Dimberg, Thunberg, & Elmehed, 2000; Morris, Öhman, & Dolan, 1998; Murphy & Zajonc, 1993; Whalen et al., 1998; Winkielman, Zajonc, & Schwarz, 1997). Nevertheless, brief emotion exposure with such backward masking has been found to trigger neural (Morris et al., 1998; Morris, Öhman, & Dolan, 1999; Pegna, Landis, & Khateb, 2008; Smith, 2012; Whalen et al., 1998), facial reactivity (Bornemann, Winkielman, & van der Meer, 2012; Dimberg et al., 2000; Rotteveel, de Groot, Geutskens, & Phaf, 2001; Tamietto et al., 2009) and skin conductance responses (Esteves, Dimberg, & Öhman, 1994; Öhman & Soares, 1994). According to Le Doux (1996), these low-level emotional reactions can be triggered without consciousness due to the phylogenetically early design of the brain, which allows for the processing of emotional stimuli to bypass the primary visual cortex, through the rapid, subcortical, colliculo-thalamo-amygdala neural pathway, rather than being processed via the newer (and slower) cortical route (i.e., thalamus-sensory cortex-amygdala).

1.1.1. Unconscious emotion processing in autism

Few studies have measured unconscious emotion processing in individuals with ASD, despite this arguably being one of the clearest ways to ascertain whether basic, low-level, sub-cortical emotional processes are deficient in this group. To examine how unconscious emotion affects later judgements of individuals with ASD, Kamio, Wolf and Fein (2006) used a modified version of the subliminal priming task by Murphy and Zajonc (1993). They found that the liking ratings of participants with ASD about (previously unseen) Japanese ideographs were unaffected by preceding, subliminally-presented emotional faces, but that they were in typically developing participants. Likewise, Hall et al. (2007) found that the face friendliness ratings of children with ASD were less likely be influenced by subliminally presented emotional information, compared to those of matched controls.

Only two studies have measured neurophysiological responses during the viewing of backwardly masked emotions in individuals with ASD. In measuring brain activation to fearful faces presented with backward masking, Kleinhans et al. (2011) found reduced activation in the superior colliculi, pulvinar (an area of the thalamus), and amygdala (as well as in the fusiform gyrus) in individuals with ASD, relative to controls. On the basis of the numerous reports, mentioned above, there may be less sub-cortical engagement in ASD during emotion processing, especially in the absence of explicit attention to, or conscious awareness of the emotion (e.g., Critchley et al., 2000). However, also using a backward masking task, Hall, Doyle, Goldberg, West, & Szatmari (2010) found that adults with ASD had a similar magnitude of amygdala response (although reduced fusiform response), compared to matched controls. Given the limited research to date on response to unconscious emotions in ASD, and the contradictory current findings, more research is needed to establish whether there are indeed abnormalities in automatic and implicit, unconscious emotional reactivity in individuals with ASD.