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Note

Skin conductance reveals the early development of the unconscious processing of emotions

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ABSTRACT

The ability to rapidly distinguish between positive and negative facial expressions of emotions is critical for adaptive social behaviour. Increasing evidence has shown that emotions can be processed even at an unconscious level in adults. Yet, very little is still known about the early ontogeny of the unconscious processing of emotional signals conveyed by faces. Here, we investigated the processing of subliminally presented face emotional stimuli in infants as young as 3–4 months of age and sought to clarify its neural underpinnings by exploring the role of the autonomic nervous system. Using a visual preference paradigm, Experiment 1 determined the visibility threshold for happy and angry faces and established that infants detected both happy and angry faces at 200- but not at 100 msec. By measuring skin conductance response (SCR), Experiment 2 showed that the autonomic nervous system of infants reacted to both subliminally (100 msec) and supraliminally (200 msec) presented face expressions of emotions, and that SCR were higher for angry than happy facial expressions. Results revealed that 3–4 month-old infants respond to positive and negative emotions even at an unconscious level, but also show that angry faces possess an intrinsic alerting characteristics, suggestive of an adaptive meaning of the physiological response. Findings are discussed in terms of subcortical learning of emotions, and the possibility that the amygdala may be involved in such process.

1. Introduction

Adult human studies have shown that emotional functioning may occur outside conscious awareness. This unconscious route helps responding efficiently and quickly to the crucial social signals available in the environment (e.g., Dimberg, Thunberg, & Elmehed, 2000; Tamietto & De Gelder, 2010). This is particularly evident for negative emotions. When presented with extremely brief (i.e., subliminal) fearful and

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happy facial expressions, followed by a long (i.e., supraliminal) neutral expression, individuals explicitly reported seeing the neutral expressions; however, the fMRI scans revealed that the amygdala responded even to the subliminal portion of the stimuli, demonstrating the processing of emotional stimuli outside conscious awareness (Whalen et al., 1998; for a critical discussion about the topic, see; Pessoa, 2005).

Recently, there has been growing interest – yet still very little evidence – in the early development of the unconscious processing of human faces in infants. Gelskov and Kouider (2010) investigated the duration needed (i.e., the threshold) by 5-, 10-, and 15-month-old infants to discriminate a face from a scrambled face by means of an infant-friendly version of the backward masking paradigm. The face and the scrambled face had durations ranging between 50 and 500 msec, were simultaneously presented on the sides of a screen, and were followed by identical scrambled face-masks. The authors found that 5- and 10-month-old infants did not show any side preference for durations shorter than 100 msec, which could thus be considered below infants' visibility thresholds. In contrast, both age groups looked longer at the target faces than the scrambled faces for durations longer than 150 msec, which were therefore considered above infants' visibility thresholds. This developmental pattern was further confirmed in a study by Kouider et al. (2013), which, based on the visibility thresholds established in a previous paper (Gelskov & Kouider, 2010), demonstrated that infants between 5 and 15 months of age already show a neurophysiological marker of conscious and unconscious processing that resembles those of adults, as observed by the presence of a late nonlinear cortical response measured with event-related potentials.

Recently, two studies investigated whether unconscious processing in infants also extends to facial expression of emotions. Jessen and Grossmann (2015) showed that the electroencephalographic response of 7-month-old infants to subliminally and supraliminally presented stimuli – happy and fearful facial expressions – differed at specific electrode sites. Central electrodes responded differently as a function of the emotion, but not as a function of stimulus duration. In contrast, occipital electrodes had different responses to the two emotions only when emotions were presented supraliminally. These findings suggest that distinct brain processes underlie conscious and unconscious emotion processing early in development.

The above studies had the merit to pave the way for the investigation of the development of unconscious processing of emotions in infants. However, several issues remain unexplored. First, although Gelskov and Kouider (2010) showed that the visibility threshold for faces is 150 msec for infants aged 5- and 10-months, no study yet has assessed whether this is true for emotionally valenced faces. Indeed, Jessen and Grossmann (2015) found different brain processes for stimuli presented at 50–100 msec (unconscious level of processing) and 500 msec (conscious level of processing), but because they did not conduct a behavioural study to estimate the visibility threshold of their stimuli, they could not assess whether ERP responses reflected activity to different suprathreshold stimuli.

Second, the processes underpinning the unconscious processing in infants remain largely unknown. Jessen and Grossmann (2015) found that the unconscious processing of emotions occurs at later latencies (at central electrode sites) compared to the processing of conscious information. Interestingly, the authors suggested that this result could be explained in terms of recruitment of subcortical structures involved in the processing of unconscious information, which cannot be directly observed with ERPs.

Here, we investigated the early development of the response to conscious and unconscious emotionally valenced stimuli by presenting happy and angry faces to 3–4 month-old infants using a behavioural (Experiment 1) and a physiological approach (Experiment 2). Experiment 1 addressed the issue of the early development of visibility thresholds for emotional faces by testing 3–4 month-olds on an adapted version of Gelskov and Kouider (2010) and Jessen and Grossmann (2015) masking paradigm. We hypothesised that infants would detect happy and angry faces at 200- but not at 100 msec. Furthermore, to tap into the early roots of conscious and unconscious processing of emotional information, Experiment 2 used a physiological index – the skin conductance response (SCR) – to measure the activation of the autonomic system to positive and negative emotional facial expressions. We hypothesised that if the autonomic system reacts to both subliminally and supraliminally presented emotional stimuli, we would observe SC activity for both target durations (200 and 100 msec). Furthermore, if negative faces have a privileged access because of their adaptive meaning, we would find higher SCR to angry than happy faces.

Skin conductance is a classical physiological technique to investigate the response of the autonomic system. It tracks the momentary changes in the electrical resistance of the skin and reflects the functioning of the sweat glands controlled by the sympathetic nervous system (Dawson, Schell, & Filion, 2000). It is also a very well suited method to investigate emotional reactions, and correlates with activation of subcortical structures, in particular the amygdala (although it does not directly assess its activity). Neurophysiological studies have shown that fearful and angry facial expressions activate the amygdala, which has connections to both sensory areas and autonomic reflex centres (Davis & Whalen, 2001; Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). The central nucleus of the amygdala (CeA) projects to areas involved in the activation of the sympathetic autonomic nervous system, which in turn is activated during observation of fearful and angry facial expressions (Davis & Whalen, 2001; LeDoux, Iwata, Cicchetti, & Reis, 1988). Furthermore, lesion studies have shown that the amygdala influences SCR generation and amplitude (Mangina & Beuzeron-Mangina, 1996), and functional imaging studies have shown a correlation between BOLD signal in the amygdala and SC response amplitude (Hariri et al., 2002; Hoffman, Gothard, Schmid, & Logothetis, 2007). Skin conductance represents a non-invasive, suitable and reliable method to be used with young infants (Baker, Shelton, Baibazarova, Hay, & van Goozen, 2013; Ham & Tronick, 2008). 3–4 month-olds are the youngest infants who can be tested using SCR, as the sympathetic system associated with arousal develops during the first ten weeks of