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The effect of mouth opening in emotional faces on subjective experience and the early posterior negativity amplitude

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ABSTRACT

Previous studies have examined the role of the eye region in emotional expressions, but the mouth region is understudied. The main goal of this study was to examine how mouth opening in emotional faces affects subjective experience and early automatic attentional capture, as measured by the early posterior negativity (EPN) amplitude. Participants in two studies viewed angry, happy, and neutral faces with mouths open and closed while their electroencephalogram was recorded. Afterwards, participants indicated how unpleasant-pleasant (i.e., valence) and calming-arousing (i.e., arousal) each face made them feel. Angry and happy faces (and neutral faces to a lesser extent) with an open vs. closed mouth made observers feel more extreme valence and arousal. In addition, there generally was an EPN for angry and happy faces (and neutral faces to a lesser extent) with open vs. closed mouths, which suggests that emotional expressions with an open mouth capture early automatic attention more than expressions with a closed mouth. Finally, the effects of mouth opening were somewhat modulated by face gender, but not by observer gender. The current findings contribute to our knowledge of facial expressions and social interaction, but also have relevance for the growing fields of social robotics and digital animation.

1. Introduction

The fast and accurate decoding of facial expressions is crucial for human social interactions as these expressions signal another person's emotions, which in turn can induce emotional responses in the observer (Wild, Erb, & Bartels, 2001). The ability to recognize positive and negative emotions in others has survival value, most obviously when potential threat is signaled. Faces with an emotional expression capture more automatic attention than faces with a neutral expression (Vuilleumier, 2002) and induce more amygdala activation (e.g., Breiter et al., 1996). Facial expressions involve various regions of the face, most notably the eye and the mouth regions. Wide-open eyes, for example, are a characteristic of fearful expressions (Kohler et al., 2004). Congruently, the amygdala is sensitive to the amount of eye white visible (Whalen et al., 2004). Research on the eye region (including the roles of eye whites, gaze direction, pupil dilation, eye blinks, and tears) in facial expressions is abundant (see e.g., Hess, 1975; N'Diaye, Sander, & Vuilleumier, 2009; Porter & Ten Brinke, 2008; Provine, Krosnowski, & Brocato, 2009; Whalen et al., 2004). Exposed teeth are a characteristic of angry expressions and a raised upper lip is a characteristic of happy expressions (Kohler et al., 2004). Correspondingly, it has been shown that the mouth region is more responsible than the eye region for the detection advantage of angry (Horstmann & Bauland, 2006) and happy faces (Calvo & Nummenmaa, 2008) in visual search tasks. Nevertheless, neuroscientific research on the explicit role of mouth opening in facial expressions is scarce.

As noted above, facial expressions, including the mouth region, provide information about what the person displaying the facial expression is feeling (i.e., emotion perception), but they can also elicit emotions in the observer (Wild et al., 2001). Most previous studies concerning the mouth region have focused on emotion perception. For example, a study with computer generated faces has shown that slight smiles were perceived as more effective, genuine, and pleasant when no teeth are visible, and that broad smiles were perceived as more effective, genuine, and pleasant when teeth are visible (Helwig, Sohre, Ruprecht, Guy, & Lyford-Pike, 2017). In addition, angry and happy facial expressions were rated as more intense with open than closed mouths (Horstmann, Lipp, & Becker, 2012). Correspondingly, an avatar displaying a grimace was rated as more negative with than without teeth exposed. Moreover, the avatar displaying a grimace, smile, and

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mouth open expression was rated as more arousing with than without teeth exposed (daSilva et al., 2016). So, observers perceive facial expressions as more intense when the mouth is open than closed. It remains unclear, however, how the mouth region affects the emotional response in the observer, even though that is relevant for social interaction as well. Therefore, the first research question of the current study is whether and how mouth opening affects the subjective experience in response to angry, happy, and neutral expressions. Subjective experience was measured in two studies using self-reports of valence and arousal, where valence is the pleasantness of an emotion and arousal is the intensity of an emotion (Russell, 2003). It was expected that participants would report to experience more extreme valence and arousal when viewing angry and happy faces with mouths open than closed (hypothesis 1).

The mouth region may also affect how much attention is paid to the face. In a previous study, participants were better at detecting the presence of an emotional face when angry and fearful faces showed teeth compared to no teeth (Sweeny, Suzuki, Grabowecky, & Paller, 2013). Likewise, it has been shown that teeth visibility greatly contributes to the detection advantage of angry and happy faces in a crowd of neutral faces (Horstmann et al., 2012). These studies imply that the mouth region conveys important information that automatically captures attention. Attentional capture by emotional stimuli has often been studied using event-related potentials (ERPs). The early posterior negativity (EPN) is a relative negativity over the occipital scalp that occurs between 150 and 300 ms after stimulus onset and reflects early automatic attentional capture (Hajcak, Weinberg, MacNamara, & Foti, 2011; Schupp, Flaisch, Stockburger, & Junghöfer, 2006a). It is important to note that the EPN emerges as the *difference* between electrophysiological responses to experimental and control stimuli (Hajcak et al., 2011; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Flaisch, et al., 2006a). Several studies have shown that there is an EPN for emotional (vs. neutral) faces (Calvo & Beltrán, 2013; Holmes, Nielsen, & Green, 2008; Langeslag & Van Strien, 2018; Rellecke, Sommer, & Schacht, 2012; Schupp, Öhman, Junghöfer, Weike, & Hamm, 2004; Smith, Weinberg, Moran, & Hajcak, 2013; Yoon, Shim, Kim, & Lee, 2016). To our knowledge, it has not yet been examined how the mouth region affects the EPN amplitude to emotional faces. Therefore, the second research question is whether and how mouth opening affects early automatic attentional capture, as measured by the EPN amplitude in two studies, to angry, happy, and neutral expressions. It was expected that the EPNs in response to angry and happy faces in particular would be enhanced when mouths are open compared to closed (hypothesis 2).

There are gender differences in emotional processing. In the case of facial expressions, both the gender of the face and the gender of the observer may play a role. For example, a literature review revealed that women express emotions more and recognize emotions better, but that men are more responsive to threatening cues such as angry faces (Kret & De Gelder, 2012). In a study by Proverbio (2017), women demonstrated a stronger self-perceived responsivity to human face stimuli as they rated faces as more positive and more arousing than men. In addition, a borderline significant interaction of the viewer's gender and the face gender was observed for these ratings. Women tended to rate male faces as more pleasant and arousing than female faces, whereas men showed the opposite pattern (Proverbio, 2017). To our knowledge, no studies have tested gender differences in the role of the mouth region in eliciting emotional responses in the observer. Therefore, the third research question was whether the effects of mouth opening in angry, happy, and neutral faces on subjective experience and the EPN amplitude vary with the gender of the face and the gender of the observer in Study 2. Because of the explorative nature of this research question, we had no specific hypotheses regarding interactions between the gender of the face, the gender of the observer, and mouth opening.

Answering the three research questions will contribute to our fundamental knowledge of facial expressions and social interaction. It will also have applied relevance for social robotics, and for animating digital characters in movies, video games, and virtual reality, for example.

2. Study 1

2.1. Methods

2.1.1. Participants

Twenty-one students (mean age = 25.4 yrs, range = 22–38 yrs, 5 men, 16 women) of the Erasmus University Rotterdam in The Netherlands participated as part of a course requirement. This sample size was based on the previous study regarding the effects of the visibility of teeth that had a final sample of 20 participants (daSilva et al., 2016). The current study was approved by the institutional review board of the Erasmus University Rotterdam and participants provided written informed consent according to the Declaration of Helsinki at the start of the testing session.

2.1.2. Stimuli

The stimuli were 60 face pictures from the NimStim Set of Facial Expressions (Tottenham et al., 2009). The pictures were of 10 Caucasian individuals (5 women, 5 men), each with angry, happy, and neutral facial expressions, and each expression with mouth open and closed, see Fig. 1 for example stimuli. All stimuli were 506 × 650 pixels and were shown on a medium gray background at a distance of 120 cm on a 20 in. PC monitor, with a resolution of 1280 × 1024 pixels.

2.1.3. Procedure

While their electroencephalogram (EEG) was recorded, participants viewed the stimuli in a rapid serial visual presentation (RSVP) task, which is a prototypical task to elicit the EPN (Junghöfer, Bradley, Elbert, & Lang, 2001; Schupp, Flaisch, et al., 2006a; Schupp, Stockburger, et al., 2006b; Van Strien, Christiaans, Franken, & Huijding, 2016; Van Strien, Eijlers, Franken, & Huijding, 2014; Van Strien, Franken, & Huijding, 2009; Van Strien, Franken, & Huijding, 2014). In this RSVP task, participants passively viewed the pictures and did not make any overt responses. The presentation rate was three pictures per second, with no blank between pictures. Each picture was presented 30 times, resulting in a total of 300 trials per condition (i.e., angry open, angry closed, happy open, happy closed, neutral open, neutral closed). In total, 1800 trials were presented in subsequent cycles of 60 unique pictures, without rest between cycles. Picture order was random within each cycle of 60 unique pictures. The random stimulus order resulted in pictures of each condition being preceded by pictures of all of the conditions equally often, which leads to any carry-over effects from preceding stimuli being the same between conditions.

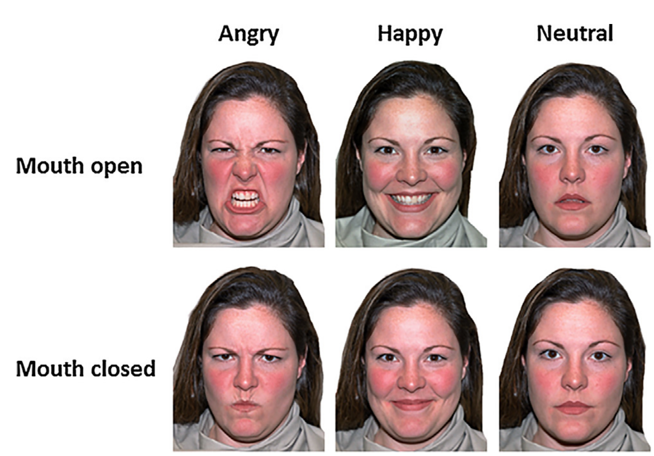

Fig. 1. Example stimuli.