Embodiment in affective evaluations:

The case of the facial feedback effect

Jakob Kaiser

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School of Psychology

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I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature:………………………………………

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Contents

Preface

This thesis is written as a ‘paper-style’ thesis, with each empirical chapter functioning as an independent research report in the style commonly found in peer-reviewed scientific journals. Chapter I functions as an overall introduction for the topic of the thesis. Chapter VI represent a summary discussion of the findings reported. At the time of submission, an edited version of Chapter III has been accepted for publication in a peer-reviewed journal:

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Slightly edited versions of Chapter II and Chapter IV have been submitted for publication. Graham Davey and Ryan Scott contributed to study design and data analysis for Chapter II, III and IV, and provided comments on the text of these chapters. Sarah Garfinkel contributed to the study design and data analysis for Chapter IV, and provided comments on the text of this chapter. Jennifer Meeres and Thomas Parkhouse took part in the data collection for Chapter III. Thomas Parkhouse took part in the data collection for Chapter V. Jamie Ward provided comments on all chapters. Authorship for resulting publications has been determined by all researchers involved in each case individually.

Summary

Theories of embodiment propose that our bodily states can influence affective processing. This thesis investigated the possibility that facial feedback (i.e., afferent signals from facial muscles) can influence the interpretation of affective stimuli. One study tested the effect of overt smiling and frowning on the interpretation of short descriptions of everyday events. Smiling, as compared to frowning, led to more positive evaluations, but only for participants who were aware of the emotional relevance of their expressions. A second study tested whether subtle changes in facial activation (elicited by unconsciously presented happy/angry facial expressions) led to changes in evaluations of ambiguous target symbols. While angry prime faces, as compared to happy prime faces, induced more frowning (as measured via electromyography), this change in facial activation did not translate into a behavioural effect on subsequent evaluations. A third study investigated the relation between naturally occurring facial reactions and interpretations of both clearly valenced and ambiguous facial expressions. Results indicate that facial reactivity predicts participants' self-reports of their own emotional reactions towards others' expressions (Experiment 1). A relation between facial reactions and interpretations of the expression senders' emotional states was only found in cases in which participants with high sensitivity towards their own bodily states (as measured with a test of interoceptive accuracy) tried to interpret ambiguous expressions (Experiment 2). In a last experiment, prolonged presentation of emotional prime faces led to expression-congruent facial reactions, but resulted in expression-incongruent behavioural reactions in both classification speed and interpretative tendency of emotional target faces. Overall, this thesis suggests that facial feedback is not generally involved in the interpretation of affective stimuli, but that it might contribute to evaluative processes only under special circumstances.

Chapter I: General Overview

Introduction

What is the body's role in our emotions? We are used to experience body reactions during our own emotional episodes (e.g., tension in our muscles, changes in heart rate and respiration), and we commonly draw inferences about others' affective states by observing their body states (e.g., their facial expressions or postures). Intuitively, it would be reasonable to assume that such peripheral body phenomena are merely the end result or expression of central emotional processes taking place in the brain. Theories of embodiment suggest that the body has a more important role: They argue that peripheral feedback from our body can influence our affective processing to such a degree that our emotions are effectively grounded in bodily activity (Barrett & Lindquist, 2008; Damasio, 2000; Niedenthal, 2007; Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015). This thesis investigates one specific example for a possible causal role between a bodily process and one aspect of our emotional reactions: the assumption that the tension in our facial muscles might influence our evaluative processing of affective stimuli in the environment. Simply put, the overarching question is whether smiling or frowning can make it more or less likely that we interpret something as positive or negative. The influence of facial muscles on psychological processes is often called a facial feedback effect (e.g., McIntosh, 1996; Strack, Martin, & Stepper, 1988). This chapter introduces the concept of embodiment of emotional processing in general, and the possible role of facial feedback in evaluative processing in particular. The first subsection briefly introduces the multiple-component nature of emotional reactions (i.e., the idea that emotional reactions involve changes in several bodily and psychological subsystems). Next, the notion of embodiment is introduced as related to a particular claim concerning the relationship between bodily and psychological processes: the assumption that bodily aspects of emotional reactions can causally influence affect-related psychological processes. Some prominent examples of embodiment theories are introduced that suggest that facial feedback influences evaluative decisions of environmental stimuli in general, and the interpretation of others' facial expressions in particular. This theoretical introduction is followed with a review of empirical studies investigating the link between facial activation and affective evaluations, either by measuring the correlation between naturally occurring facial reactions and measures of evaluative tendencies, or by testing the effect of experimentally induced facial expressions on evaluations. Finally, this chapter introduces four studies that were conducted for this thesis in order to investigate the relationship between facial activation and affective evaluations.

Embodiment of emotions

Multiple aspects in emotional reactions

Emotions are usually considered to be multi-component phenomena, i.e. a prototypical emotional reaction consists of several types of reactions generated by different response systems (Hatfield, Bensman, Thornton, & Rapson, 2014; Scherer, 2005). Types of reactions that might be typically involved in an emotional episode include phenomenological states (i.e., the subjective feeling of an emotion), cognitive processes (e.g., attentional and interpretative biases in the processing of our environment), behavioural tendencies (e.g., the likelihood to approach or withdraw), and bodily activation.

Bodily phenomena that have been related to emotional reactions include, for example, changes in respiration, cardiovascular activity, or electrodermal activation

(Kreibig, 2010). One reaction commonly associated with emotions is changes in facial muscle tension, which is used to form facial expressions (Keltner, Ekman, Gonzaga, & Beer, 2003). To a certain extent, these muscles can be controlled voluntarily, but changes in facial muscle activation also occur involuntarily or automatically in reactions towards stimuli in our environment (Dimberg, Thunberg, & Grunedal, 2002; Rinn, 1984). It is an open debate as to how much the relationship between specific facial expressions and emotions depends on culture or innate tendencies. Some researchers have suggested that, at least in some cases (e.g., for so-called 'basic' emotions, such as happiness, anger, or fear), the relation between emotions and specific expressions is innate, and thus culture-independent (Ekman, 1999; Izard, 1994; Keltner & Ekman, 2000; Schmidt & Cohn, 2001). Other researchers have questioned this assumption and have emphasized the influence of culture and learning on emotional facial expressions (Jack, Garrod, Yu, Caldara, & Schyns, 2012; Russell, 1994).

Overall, there is no general agreement about which bodily, behavioural, and cognitive components should be considered necessary for someone's reaction to qualify as an emotion (Frijda, 2000). Nor is there general agreement about what phenomena can be considered a direct part of an emotional reaction, as compared to simply a subsequent effect elicited by an emotion (Prinz, 2004). For example, some might see a change in interpretative tendencies as one component of an emotional reaction, while others would rather say that such a cognitive change is not a part of the emotion, but is instead caused by it. This renders the usage of the term *emotion* sometimes ambiguous (Russell, 2003). Independently of these terminological issues, to comprehend the functioning of emotional reactions in our daily life, it is of great interest to understand in detail how behavioural, bodily, and cognitive changes that typically occur during an emotional reaction might influence each other (Hatfield et al., 2014).

It has been suggested that orchestrating or synchronizing activation over different response systems is one of the primary functions of emotions, as this might facilitate adaptive responses towards the affect-evoking situation (Cosmides & Tooby, 2000; Nesse & Ellsworth, 2009). For example, an episode of fear might involve both bodily changes, which would prepare for flight movements (e.g., changes in heart rate), and cognitive changes, such as an attentional bias for detecting potential threats. How are emotional changes in different response systems related to each other? Emotion research often seems to assume response synchronicity, which means that emotion-specific reactions in different response systems should normally occur in unison (cf. Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). While this might be true in very intense emotional reactions, the relationship between different aspects of emotional reactions appears to be much more complex and is not yet clearly understood (Hatfield et al., 2014; Russell, 2003). Embodiment theories propose that affect-related bodily activation can have a causal effect on other aspects of typical emotional reactions, such as phenomenological states, changes in information processing, and related behavioural responses. The general idea of this proposal is introduced in the next section.

Lastly, it should be noted that different approaches exist for classifying emotional reactions. Most relevant for the experiments in this thesis are valence-based differentiations that distinguish between positive and negative emotions (and usually also include other dimensions, such as arousal; cf. Cacioppo & Bernston, 1999; Posner, Russell, & Peterson, 2005; Russell, 2003). However, other emotion theories emphasize the potentially huge difference between emotions of the same valence (e.g., between the two negative emotions, anger and fear) and postulate the existence of usually so-called basic emotions with distinct characteristics (Ekman, 1999).

Embodiment of emotional reactions

Saying that a psychological process is embodied often suggests a significant involvement of some form of bodily activation in that psychological process (Gallese & Sinigaglia, 2011; Winkielman et al., 2015). Most researchers would probably agree that showing that a change in a bodily state can reliably influence the measure of a psychological process would indicate that this process is partly reliant on bodily activity and that it therefore could be considered to be embodied (Glenberg, 2009). It should be noted, however, that the exact meaning of the term *embodiment* can vary among researchers. This concept is often used in the psychological literature in a manner that leaves considerable room for different interpretations (Goldman & Vignemont, 2009; Goldman, 2012; Wilson, 2002). It is common to contrast embodied explanations of a psychological phenomenon with non-embodied/amodal explanations (Barsalou, 1999; Goldman & Sripada, 2005; Schubert & Semin, 2009; Zahavi, 2010). While a non-embodied theory assumes that psychological processes can be modelled with little or no reference to the body in which these processes take place, theories of embodiment suggest that bodily states shape the outcome of psychological processes to such an extent that they should be considered to be part of the psychological phenomenon under investigation. Theories that focus on the possible contribution of bodily feedback often allow for a role for both embodied and non-embodied processes.

Different investigations concerning such proposals might examine two different types of body-related activity: 1) cases that involve an input from the actual periphery of the body (i.e., body activation outside of the central nervous system) and 2) cases where a psychological process involves no actual feedback from the body but that do entail activity in brain areas considered central for perceiving body feedback or for performing body movements (sometimes called ‘as-if loops’; Damasio, 2000). The experiments discussed in this thesis focussed on the role of actual peripheral bodily activation. The last chapter again takes up the possible role of as-if loops in the processes investigated here.

The concept of embodiment has played a considerable role in theories related to the processing of affective stimuli. This is probably due to the fact that emotional reactions are often seen as a phenomenon with a strong bodily component (Barrett & Lindquist, 2008). There are a number of review articles that have come to the conclusion that bodily feedback could play an important role in the processing of affective stimuli (Barrett & Lindquist, 2008; Briñol & Petty, 2008; Meier, Schnall, Schwarz, & Bargh, 2012; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Price, Peterson, & Harmon-Jones, 2011; Winkielman et al., 2015). The goal of such review articles has usually been to argue for the principal possibility of embodied processing, while emphasizing the need for further research in order to develop more specific accounts of how and when such phenomena play a role in our psychological functioning. Accordingly, they have often discussed a whole host of psychological or behavioural processes related to emotions that might be embodied. These have included, for example, judgements of preferences or liking (e.g., Briñol & Petty, 2008; Meier et al., 2012; Niedenthal et al., 2005), the understanding of emotional language (Glenberg, Webster, Mouilso, Havas, & Lindeman, 2009), and the interpretation of social signals, such as facial expressions (Goldman & Sripada, 2005; Hatfield et al., 2014; Niedenthal, Mermillod, Maringer, & Hess, 2010). Thus, most reviews of embodied approaches in emotion research have suggested that bodily feedback has some involvement in processes related to how we interpret affective stimuli. Bodily processes that have been named as potentially relevant for embodied processing include many bodily reactions related to emotions, such as visceral reactions (e.g., Herbert & Pollatos, 2012) and posture or body movements associated with approach and avoidance (e.g., Briñol & Petty, 2008).

One bodily aspect that has been mentioned in almost all reviews of embodied emotion processing is the possible role of feedback from emotional facial muscles. This makes facial feedback a prominent example for embodiment theories of emotions. Overall, the claim that emotional processing is embodied could describe a wider range of relationships among different bodily and psychological processes. This thesis focussed on one specific bodily process, emotion-related facial muscle tension. It investigated the claim that feedback from these muscles might influence how we interpret affect-evoking stimuli. More specific theories and empirical evidence concerning this claim are discussed in the following sections.

The role of facial feedback on affective evaluations

While several overview articles have suggested that facial feedback could influence aspects of affective evaluations, there are not many explicit models that make specific predictions about such an effect. The following paragraphs introduce four prominent embodiment theories, which suggest a role of facial feedback in interpreting affective stimuli. These accounts differ in the amount of attention paid to the role of facial feedback, as compared to other bodily feedback, and in their specific focus on the psychological processes they investigate. Most directly concerned with the role of facial activation is the *facial feedback hypothesis* according to which "skeletal muscle feedback from facial expressions plays a causal role in regulating emotional experience and behavio[u]r" (Buck, 1980). The *somatic marker theory* suggests that affect-related bodily states (including, but not limited to facial feedback) could play an important role in decision-making under uncertainty (Damasio, 2000). The *primitive emotion* *contagion theory* proposes that specifically understanding of others' emotional states can be guided by bodily feedback (with facial feedback playing a prominent role in formulations of this theory; cf. Hatfield, Cacioppo, & Rapson, 1994). Lastly, the *simulation of smiles* model suggests that facial feedback plays a role in the interpretation of facial expressions (Niedenthal et al., 2010). As will be seen, these theories seem to be compatible in many respects, and the empirical studies that they cite as evidence for their models accordingly overlap to a large degree. Thus, the following paragraphs briefly summarize these theoretical accounts, while empirical findings, insofar as they are directly relevant to the focus of this thesis, are discussed in subsequent sections.

Facial feedback hypothesis

The facial feedback hypothesis is the assumption that afferent signals from our facial muscles can have an impact on emotional processes (Adelmann & Zajonc, 1989; McIntosh, 1996). Some formulations of this idea specifically focus on the role of facial feedback in influencing subjective feeling states of emotions (Duclos et al., 1989; Flack, Laird, & Cavallaro, 1999; Hennenlotter et al., 2009). For example, according to this hypothesis, someone engaging in a smile could be expected to experience a more positive mood. A distinction is sometimes made between a strong version of this hypothesis, claiming that changes in facial expressions can induce a new emotional state, and a weak version, assuming that expressions can only modulate an emotional state that is elicited by another source (e.g., a stimulus in our environment; Reisenzein & Studtmann, 2007; Rutledge & Hupka, 1985). In practice, studies investigating this phenomenon have sometimes measured the impact of facial activation on self-report of emotional states in isolation, but they have more frequently investigated feedback effects on participants' reactions towards emotional stimuli via ratings of linking, pleasantness, etc. (e.g., Larsen, Kasimatis, & Frey, 1992; Strack, Martin, & Stepper,1988). In this context, it is customary to interpret facial expressions' impact on stimulus ratings as evidence for a change in participants' emotional state. Thus, it is sometimes assumed that an expression would influence one's own emotional state, which would in turn lead to a bias in the evaluation of environmental stimuli (e.g., Sato, Fujimura, Kochiyama, & Suzuki, 2013). The necessity of changes in conscious subjective feeling states as a mediator between facial activation and stimulus evaluations has, however, not been established. Accordingly, it has been suggested that facial feedback can impact evaluations without necessarily leading to changes in subjective feeling states (Davey, Sired, Jones, Meeten, & Dash, 2012; Niedenthal et al., 2010). For example, it might be possible that such feedback influences different cognitive and phenomenological aspects of affective processes independently of each other.

Independent of the role of conscious feeling states, it is usually assumed that feedback effects do not rely on participants' conscious knowledge about which expression they are holding. For example, a smile would be expected to positively influence one's feelings and/or evaluative tendencies, even if the individual was unaware that he or she was currently smiling. If facial feedback effects only occurred when a person was conscious of his or her expression, this phenomenon would be less relevant for embodiment theories. There are several non-embodied explanations as to why, for example, a consciously smiling person might report increased positive affect. First, there is the possibility of demand effects (i.e., a participant reacting in a way that he or she assumes matches the experimenter's desired outcome; Nichols & Maner, 2008). Secondly, a conscious smile could effectively function like a conscious emotional prime (i.e., triggering emotion-congruent associations and concepts in participants). Such an effect would not imply a special role of bodily feedback for emotional processes, since in this case any experimental effects could be explained by participants' conceptual assumptions about the relation between emotions and expressions, suppositions that exist independently of participants' actual current bodily states (Zajonc, Murphy, & Inglehart, 1989).

There is no general agreement about the exact mechanisms through which facial muscles might influence affective processes. It might be that such effects occur as direct biological consequences of the connections between facial muscles and emotion-relevant brain areas (i.e., as an automatic integration of afferent signals from facial muscles in brain areas related to affective processing; Hennenlotter et al., 2009). On the other hand, (nonconscious) cognitive-inferential processes could also mediate feedback effects (Laird, 1974; McIntosh, 1996). For example, self-perception theory proposes that, just as we infer others' emotional states from their nonverbal behaviour, we might infer our own emotions and preferences from observations of our body (Bem, 1972; Laird, 1974; Schnall & Laird, 2003). While conscious attention towards one's nonverbal signals might be enhanced via conscious deliberation, self-perception theory assumes that it also occurs unconsciously and automatically. Overall, the facial feedback hypothesis is usually understood to predict an effect of facial muscle tension on affective experience and behaviour, even in the absence of conscious awareness about the emotional relevance of one's expression. Beyond this proposal, this hypothesis does not make specific predictions concerning the circumstances under which a feedback effect should or should not be expected. Other affective embodiment theories do not focus solely on the role of facial feedback, but make more specific suggestions concerning the types of affect-related evaluations and interpretations that bodily feedback might especially influence. Examples of such theories are introduced in the next section.

Somatic marker theory

The somatic marker theory is concerned with the role of bodily feedback in decision-making (Bechara & Damasio, 2005; Damasio, 2000). It distinguishes between different decision-making strategies: 1) rule-based, more analytical approaches (e.g., a cost-benefit analysis) and 2) intuitive judgements that mostly rely on 'gut feelings'. More specifically, in this theory, more intuitive decisions are based on affect-related bodily signals (Damasio, 1996). According to this theory, such bodily-grounded decision-making approaches are more likely when a situation does not allow for a detailed analysis (e.g. because a situation is too complex to allow for a systematic analysis, or because it involves too many unknown factors). Concerning interpretations of affective stimuli, this theory might suggest that bodily activation could help one to form a judgement, especially when there is a need to judge more ambiguous stimuli (cf. Aïte et al., 2013). For example, faced with the necessity of choosing between two different options, a person could select the one that elicits a more positive bodily response, without necessarily being able to articulate the reasoning behind his or her preference. Bodily feedback can influence such decisions unconsciously. This biasing of decisions happens via somatic markers (i.e., brain activity that represents relevant somatic changes, which is then integrated with higher-order reasoning; for a discussion of possible brain regions see, for example, Bechara & Damasio, 2005; Damasio, 1996). Such activity could arise due to actual bodily feedback, but might also be triggered in its absence (i.e., as an as-if loop). It is not entirely clear under which circumstances as-if loops might replace actual bodily feedback, with some suggesting that situations with higher uncertainty might be more likely to rely on active bodily sensations.

The somatic marker theory potentially includes all types of affective body activation (including facial feedback; cf. Arminjon et al., 2015; Dunn, Dalgleish, & Lawrence, 2006) in this process. In practice, experiments explicitly referring to this theory have mostly investigated the relationship between electrodermal activation (indicating emotional arousal) and participants' performance in gambling tasks (for a review of such findings, see Dunn et al., 2006). The relative importance of different bodily processes for 'gut feeling' decisions has not been specified. Overall, the somatic marker theory would suggest that bodily (including facial) feedback could be relevant for evaluative decisions, especially in uncertain, ambiguous, or very complex situations. In that sense, the theory seems to be compatible with the facial feedback hypothesis, but it makes more specific predictions about what type of evaluative decisions might be more likely to rely on such feedback.

Primitive emotion contagion theory

Thus far, the theoretical proposals could potentially be applied to a wide range of stimulus types that might evoke affective reactions. Some embodiment theories focus on the role of bodily feedback for more specific families of environmental stimuli. Special attention has been paid to the potential role of embodiment in the interpretation of others' nonverbal expressions of emotions, particularly others' facial expressions (Goldman & Sripada, 2005). This is probably due to the phenomenon of nonverbal mimicry (i.e. the automatic tendency to imitate motor movements of others during social interactions; Chartrand & Bargh, 1999). It has been speculated that imitating someone's emotion-related nonverbal signals might help to understand the emotional state of this person (Gueguen, Jacob, & Martin, 2009). Thus, making judgements about someone's emotional state would be partially embodied, because it relies, to a certain extent, on feedback from bodily states.

One example for such a theory is the model of primitive emotional contagion (Hatfield et al., 1993, 1994, 2014). This theory suggests that understanding someone's emotional state can involve both cognitive/analytical strategies (e.g., situational inferences) and bodily feedback processes. In this theory, primitive emotional contagion is the partial transfer of an emotional state between individuals via feedback from spontaneous bodily mimicry. This process is considered to support understanding of our interaction partners' feelings (and thus support empathic reactions and social bonding). The theory suggests a three-step process for how an observer might interpret a sender's feeling state. First, the observer automatically imitates the sender's nonverbal behaviour. Then, the changes in the observer's bodily state create afferent signals (i.e., bodily feedback), which causally change the observer's current emotional state. Lastly, the observer can directly infer from his or her own emotional state what the sender is feeling. Hatfield et al. include all types of nonverbal behaviour in their model (e.g., posture, vocalizations), but they focus a large part of their discussion on facial expressions. Importantly, mimicry is not seen solely as a result but also as a partial cause of getting into the same feeling state as the emotion sender. Thus, concerning facial expressions, this model could be described as a special case of the general facial feedback hypothesis.

Simulation of smiles theory

An embodiment theory that specifically focuses on the interpretation of emotional facial expressions is the *simulation of smiles* model (SIMS; Maringer, Krumhuber, Fischer, & Niedenthal, 2011; Niedenthal, Mermillod, Maringer, & Hess, 2010). This theory concentrates on the interpretation of others' smiles, but the authors have noted that there is no a priori reason why the same mechanism should not be applicable to other emotional expressions. The embodiment-based mechanism for interpreting expressions is similar to the one proposed by Hatfield, et al. (1993; i.e., mimicry creates bodily feedback that the perceiver can use to simulate another person's affective state). One difference between SIMS and the model of primitive emotion contagion lies in the role of conscious feeling states. While the contagion model seems to put much emphasize on the change in the perceiver's emotional state evoked by mimicking an expression, according to SIMS mimicry can support the interpretation of expressions without necessarily requiring the perceiver to consciously feel the same emotion as the expression sender (Niedenthal et al., 2010, p. 423).

The SIMS model states that interpretations of facial expressions can be reached by both bodily inferences (especially facial feedback) and non-embodied perceptual or conceptual means (e.g., perceptual pattern matching, situational assumptions). In cases of embodied interpretations, the model allows for both the possibility of actual feedback from facial muscles and for the influence of as-if loops, (i.e., neural activation related to somatosensory feedback, not necessarily involving facial muscle changes). No specific predictions are made for the conditions under which the role of actual facial activation is fulfilled by as-if loops. For investigating the role of facial feedback in interpretations it would be especially important to determine under which conditions embodied or non-embodied processes are prevalent. Niedenthal et al. mention that reliance on facial feedback might be less likely in cases where spontaneous mimicry is not possible, e.g. because it is experimentally blocked (see below for a discussion of related findings), or where expression identification can be achieved more easily via non-embodied means

(Niedenthal et al., 2010, p. 424). For example, people might not need facial feedback when identifying strong, prototypical expressions (since this might be easier accomplished by e.g. a superficial visual pattern matching strategy; cf. Hess & Blairy, 2001). Rather, individuals might rely on facial feedback when trying to interpret the meaning of subtle expressions or when an expression might have several meanings within the context in which it appears (Maringer et al., 2011). In this respect, SIMS might share similarities with the somatic marker theory. Both theories seem to imply that bodily feedback might be more relevant in judgements about stimuli with greater uncertainty. Here, bodily feedback would effectively constitute one additional source of information that might be tapped into to form judgements when, for example, the stimulus and its context on their own do not contain sufficient information for an evaluative decision (cf. Meier et al., 2012).

To conclude, several embodiment theories suggest that facial feedback could influence affective evaluations. While these theories differ in scope and in focus concerning the bodily and psychological phenomena they are interested in, they seem compatible in many ways. They either explicitly state or are compatible with the notion that facial activation is only one possible bodily influence. Additionally, they allow for both non-embodied/cognitive and embodied strategies to form a judgement or an interpretation concerning stimuli in our environment. The facial feedback hypothesis does not explicitly limit the scope of the facial feedback effect, i.e. based on this general suggestion one could expect feedback effects on a wide range of evaluative judgments. Other theories (e.g., the somatic marker theory or SIMS) seem to suggest that embodied processing is more likely for judgements under increased uncertainty (e.g., when having to make more subtle distinctions or when stimuli are more ambiguous). Overall, authors of such proposals have often emphasized that more detailed research is necessary in order to specify the boundary conditions of expected embodiment effects. In order to understand the role of facial feedback in affective evaluations, it seems important to clarify whether facial feedback is a commonly employed source of influence on the processing of affective stimuli, or whether its relevance is restricted to special circumstances. The next section reviews empirical evidence for a relation between facial activation and affective evaluations.

Facial feedback: correlational and causal findings

Naturally occurring facial reactions towards non-facial affective stimuli

Stimuli in our environment can lead to changes in our facial muscle tension. Since facial muscles can react relatively quickly towards the presentation of new environmental cues (e.g., within the first 500 ms after stimulus presentation, Dimberg & Thunberg, 1998), it has been suggested to call these changes in activation rapid facial reactions (RFRs; Moody, McIntosh, Mann, & Weisser, 2007). Importantly, RFRs do not necessarily lead to visible facial expressions (Cacioppo, Petty, Losch, & Kim, 1986; Tassinary & Cacioppo, 1992). The employment of electromyography (EMG) allows for an objective measurement of facial muscle activation, independent of its visibility (Fridlund & Cacioppo, 1986; Hess, 2009; Tassinary, Cacioppo, & Vanman, 2000). If facial feedback was involved in affective evaluations, one would expect that facial reactions would depend on the emotional valence of the stimuli. Importantly, one could expect that facial reactions would be correlated with measures of affective evaluations, especially subjective ratings of affect-evoking stimuli.

Most experiments investigating RFRs during emotional reactions have focussed on the measurement of the *zygomaticus major* muscle (which is involved in smiling expressions) and the *corrugator supercillii* (which is involved in frowning). Since smiling and frowning are commonly associated with emotional reactions of opposite (positive/negative) valence, measuring these two muscles allows to investigate selective reactions towards positive or negative stimuli (cf. Cacioppo et al., 1986). This section summarizes findings related to facial reactions towards non-facial stimuli.

Several studies have used EMG measurements to assess facial activity during emotional reactions and have found emotion-congruent facial reactions (i.e., more zygomaticus/corrugator activation during positive/negative emotional states, such as when participants engaged in emotional imagery; Brown & Schwartz, 1980; Gehricke & Shapiro, 2001; Schwartz, Fair, Salt, Mandel, & Klerman, 1976). Some studies have found emotion-congruent differences for both facial muscles and for participants' subjective ratings of their preference for positive versus negative stimuli, such as pictures of emotional scenes (Cacioppo et al., 1986) or emotional sounds (Hietanen, Surakka, & Linnankoski, 1998; Witvliet & Vrana, 2007). While in these cases the correlations between ratings and facial activation were not reported, some experiments have found that stronger zygomaticus and weaker corrugator reactions predicted more positive ratings of emotional scenes (Lang, Greenwald, Bradley, & Hamm, 1993; Larsen, Norris, & Cacioppo, 2003). This seems to indicate that facial reactivity differentiates according to the valence (i.e., between positive and negative stimuli).

It has also been suggested that RFRs might differentiate between emotions of the same valence. For example, while both anger and disgust are usually considered to be negative emotions, only the prototypical display of disgust is believed to contain as one discernible feature an upward movement of the upper lip via the *levator labii* muscle (Rozin, Lowery, & Ebert, 1994). Some studies have found increased EMG activation for this muscle during disgust inductions (de Jong, Peters, & Vanderhallen, 2002; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009; Vrana, 1993), while others have not (Neumann, Schulz, Lozo, & Alpers, 2014; Wolf et al., 2005). Overall, most empirical findings are consistent with the suggestion that spontaneous facial reactions correlate with the affective value of non-facial environmental stimuli. Most of these experiments have concentrated on the differentiation of positive and negative valence, usually by measuring corrugator and zygomaticus reactions. The question as to whether RFRs also differentiate between different emotional stimuli of the same valence has mostly been investigated in research related to emotional facial mimicry (i.e., the question in how far we imitate others' emotional facial expressions). Interpreting or identifying someone's facial expression can be considered a special case of an affective evaluation of an environmental stimulus. The next section discusses studies that have measured spontaneously occurring RFRs towards others' facial expressions.

Facial reactions towards emotional facial expressions

Many studies investigating facial reactions towards emotional stimuli have taken particular interest in participants' RFRs towards other peoples' facial expressions. RFRs towards other types of affective stimuli could be seen as evaluative responses (i.e., part of the observer's emotional reaction). Reactions towards facial expressions could also be explained through another mechanism: They might constitute, at least in part, a form of automatic motor mimicry (i.e., spontaneous imitation that potentially occurs, irrespective of the expression's emotional value; cf. Moody & McIntosh, 2011).

In accordance with studies employing other types of affective stimuli, it has been found that pictures or videos of expressions of positive/negative emotions (in most cases represented by happy/angry faces) evoke increased zygomaticus/corrugator activation (Dimberg, Thunberg, & Elmehed, 2000; Dimberg & Thunberg, 1998; Sato, Fujimura, & Suzuki, 2008). Evidence for differentiation in spontaneous reactions towards expressions of the same valence is less frequent. After a review of relevant studies, Hess and Fischer (2013) came to the conclusion that spontaneous facial reactions do not routinely mirror others' displays. Importantly, the same expression can produce different RFR patterns, depending on contextual factors. For example, emotion-congruent RFRs towards faces seem to increase when the matching emotional state is induced in the participant before the expression is presented (Moody et al., 2007). Additionally, happy faces that are associated with a negative context can actually lead to expression-incongruent reactions (i.e., increased frowning/corrugator activation and decreased zygomaticus/smiling activation in the observer; Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008, 2011). These results seem to indicate that the emotional value signalled by the expression within the context in which it appears can at least override potential tendencies for automatic motor imitation. Studies that have compared facial reactions between the presentation of emotional faces and other nonverbal emotional signals, such as body postures, found no clear differences in participants' emotion-congruent reactions towards these different nonverbal channels (Magnee, Stekelenburg, Kemner, & de Gelder, 2007; Tamietto et al., 2009). This suggests that, in these cases, motor imitation of the observed expressions did not have a strong additive effect. Studies measuring both participants' facial reactions and their evaluative tendencies are especially relevant for a possible role of facial feedback in the interpretation of facial expressions. Results from these studies have been mixed: Sato, Fujimura, Kochiyama, and Suzuki (2013) found that higher zygomaticus/lower corrugator activation predicted more positive ratings of facial expressions with a relatively clear valence (e.g., clearly happy or angry faces). However, other studies found no clear relation between participants' facial reactions and subjective ratings for clearly valenced expressions

(Blairy, Herrera, & Hess, 1999, Experiment 1; Hess & Blairy, 2001). Some studies have found that participants who were more likely to frown during the presentation of strongly ambiguous faces also tended to interpret these faces as more negative (Neta, Norris, & Whalen, 2009; Tottenham, Phuong, Flannery, Gabard-Durnam, & Goff, 2013). Neta et al. (2009) pointed out that their results can be explained by individual differences in participants' negative processing biases (i.e., some participants generally show more negative facial reactions, as well as negative ratings), and do not prove a trial-by-trial relation between facial reactions and individual ratings.

Overall, empirical studies have suggested that facial reactions differentiate between different emotional expressions, at least concerning their general valence. The evidence that such spontaneous facial reactions correlate with participants' ratings of these faces is mixed.

Causal effects of facial manipulations on evaluations of emotional stimuli

To provide evidence that facial activation plays a causal role in affective evaluations, one would need to show that a manipulation of emotion-related facial muscle tension can affect measures of evaluative tendencies. This section summarises experimental interventions that focus on behavioural measures directly related to the evaluation of affective stimuli. Findings concerning facial feedback effects on other dependent measures (e.g., changes in brain activation or physiology; cf. Hennenlotter et al., 2009; Levenson, Ekman, & Friesen, 1990) are not reviewed.

Experimental interventions testing for a causal relationship between facial actions and evaluations have aimed to either increase tension in emotion-related muscles (which would be expected to lead to stronger affect-congruent reactions) or to create some kind of interference that would be expected to block natural movements of such muscles (expected to lead to weaker affect-congruent reactions). As noted, embodiment theories usually assume that facial feedback effects occur even without awareness of one’s current expression. To test this assumption, studies have often tried to induce facial changes in ways that distract from their emotional meaning. Some studies have induced facial expressions via direct verbal instructions. Importantly, these instructions have usually described facial movements in anatomical terms and have avoided the use of vocabulary commonly associated with emotions. For example, a frown might be elicited by asking participants to “pull your eyebrows down and together” (Levenson et al., 1990). Cover stories have usually been employed to justify such tasks, such as an ostensible interest in studying the interaction between motor tasks (i.e., the facial manipulation) and cognitive processes (e.g., the processing of target stimuli), without mentioning the experimenters’ interest in studying emotions. Other studies have tried to make participants’ awareness of the actual purpose even less likely by employing tasks that could lead to relevant facial movements, while using fewer verbal instructions. A popular example is the pen method, invented by Strack et al. (1988). Here, participants are asked to hold a pen (or similar object) in their mouths. The original study claimed that this task’s ostensible purpose was to simulate the tool usage of people with physical disabilities. The instructions for holding the pen can be manipulated to either block smile movements (e.g., by asking participants to hold the pen by pressing lips together) or to enhance smiles (e.g., by asking participants to hold the pen between their teeth without letting the lips touch each other). A comparable method has been introduced for frowns (Larsen et al., 1992). Such blocking or enhancing methods have been used to study the effect of facial activation on ratings for different types of stimuli.

Some studies found that enhancing a smile, as compared to blocking it, leads to higher funniness ratings of cartoons (Dzokoto et al., 2014; Strack et al., 1988). However, a registered replication report of the original study by Strack et al. (the results of which were made available only shortly before the final submission of this thesis) could not replicate an effect of smiling on cartoon ratings, despite the fact that approximately 1,700 participants were tested in 17 independent lab groups (Wagenmakers et al., in press). More smiling/less frowning has also been found to lead to more positive ratings of pictures of emotional scenes (Larsen et al., 1992; Rutledge & Hupka, 1985). Soussignan (2004) did find an enhancing effect on ratings of emotional video clips, but only when using a modified version of the pen method that produced especially intense smiles (so-called *Duchenne* smiles, which, in addition to the lip movement, also involve a raising of the cheeks; cf. Ekman, Davidson, & Friesen, 1990). However, the ‘classic’ version of the pen method that is more commonly used in the literature (and does not necessarily lead to cheek raising) did not lead to feedback effects in that study.

Some studies have investigated the effect of muscle manipulations on the interpretation of emotional language. Blocking frowns has been found to increase reading times for sentences with negative (but not positive) meanings (Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010). A selective increase in reading times during the blocking/enhancing of smiles was also found for positive/negatives sentences (Havas, Glenberg, & Rinck, 2007, Exp. 1). Moreover, one experiment found similar effects for emotional words (Niedenthal et al., 2009, Exp. 3), but another did not (Havas et al., 2007, Exp. 2). It has been argued that processing whole emotional sentences, as compared to single words, is more complex, and that it thus might be more likely to benefit from bodily feedback (cf. Havas et al., 2007). Blocking smiles during the reading of positive sentences has also been found to increase an electroencephalographic (EEG) measure of processing effort (Davis, Winkielman, & Coulson, 2015). One could interpret these findings as evidence that facial feedback facilitates the processing of verbal emotional meaning. Since these studies used reading speed as their primary dependent measure, it is not clear whether facial feedback should also be expected to change participants' understanding of emotional sentences (e.g., leading to a more positive interpretation during smiling).

Using an evaluative priming procedure, Foroni and Semin (2011) found evidence that facial feedback might have a role in affective evaluations. A presentation of a positive/negative prime led to more positive/negative ratings of cartoons, but only for participants who were free to mimic during the priming. Participants whose smile muscles were blocked did not show a priming effect, suggesting that facial feedback could have mediated the priming effect (for a similar finding with a reaction time-based measure, see Foroni & Semin, 2012).

As with experiments investigating naturally occurring facial reactions via EMG, most face manipulation studies have concentrated on manipulations of the zygomaticus and/or corrugator muscles, predicting congruent changes in emotional valence. Some reports have also found emotion-specific effects of facial expressions for emotions, such as disgust (related to raising the upper lip) or surprise (related to raising muscles on the forehead; cf. Laird, 1974; Levenson et al., 1990; Rutledge & Hupka, 1985, but see also Reisenzein & Studtmann, 2007). Overall, several studies have found that facial muscle manipulations can have an effect on measures directly related to affective evaluations for a variety of stimuli types. Facial manipulation studies investigating feedback effects on the interpretation of others' facial expressions are discussed next.

Causal effects of facial manipulations on evaluations of facial expressions

Several studies have investigated the question as to whether manipulations of facial actions can influence the interpretation of others' facial expressions. Dimberg and Söderkvist (2011) found that induced smiling/frowning led to more positive/negative ratings of pictures of both clearly valenced and ambiguous facial expressions. In another study, participants did not give a valence rating for others' expressions, but instead had to classify expressions according to the emotions they represented. It was found that a manipulation intended to block smiles selectively led to a worse recognition rate of happy faces (Oberman, Winkielman, & Ramachandran, 2007). This finding was replicated and extended for the blocking of natural frowning movements, which was found to decrease the recognition rate of angry faces (Ponari, Conson, D'Amico, Grossi, & Trojano, 2012). A third study, measuring both recognition accuracy and recognition speed, found that a blocking manipulation had no effect on accuracy. However, it observed that the manipulation slowed down expression identification, as compared to a control group without any kind of intervention (Lydon & Nixon, 2014). In another experiment, participants were required to clench their teeth together (to block mimicry), while simultaneously receiving explicit instructions to avoid any facial mimicry. These participants showed slower reaction times in an emotional expression recognition task, as compared to a control group, in which participants were asked to keep their shoulders from moving (Stel & Knippenberg, 2014). The authors argued that both conditions should produce a similar amount of effort (but did not provide a measure to that effect), and they hence claimed that the slower reaction times were specifically due to an impairment of emotional mimicry.

The inhibition of smiles has also been shown to impair the differentiation between real smiles (intended to show genuine positive affect) and 'faked' smiles (i.e., purely social smiles; Maringer et al., 2011). This effect of smile inhibition disappeared when participants were offered additional information about the context of the smile. This supports the view that facial feedback is more important in the absence of alternative (e.g., external) information that might help one to interpret expressions. Another approach in this line of research has been to present morph sequences between different types of expressions (e.g., a change from happy to angry) and to ask participants to indicate the point at which the emotion of the expression changes. An earlier detection of an expression switch might be interpreted as the ability to detect subtle expression changes. Using the pen method, it was found that blocking smile movements made participants slower at this task, as compared to a control group without any intervention (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001). Another study with a similar design did not replicate the finding that the blocking condition could influence participants' performance (Kosonogov, Titova, & Vorobyeva, 2015). An experiment that used the pen method to both block and enhance smiles found that these two conditions had a differential effect, with blocking/enhancing leading to faster identifications of angry/happy faces, but only in morph sequences from neutral to emotional expressions (as opposed to transitions between, for example, happy and angry expressions; Lobmaier & Fischer, 2015). Based on these results, the authors suggested that facial interference might not hinder expression identification per se, but that it rather influences the perception of emotional intensity.

Note that several of the studies discussed asked participants to perform muscle movements that would interfere with smiles, and compared their performance (e.g., at identifying happy faces) with a control condition in which participants did not perform a motor task. A decreased ability to identify facial expressions, or a tendency to interpret stimuli as more negative, is consistent with an affect-specific influence of facial feedback. In studies without a motor task in the control group, increased motor effort and its side effects could explain these effects (cf. Kosonogov et al., 2015). For example, having to tense muscle groups for a longer period of time could be distracting, thus decreasing performance, or could induce negative affect due to increased physical strain. Such explanations would not imply that facial activation has a special role in interpreting expressions. Studies that found differential effects (e.g., by comparing blocking and enhancing conditions, or by including manipulations for both smiling and frowning) might be considered as more unambiguous evidence for embodied interpretations of facial expressions (e.g., Dimberg & Söderkvist, 2011; Lobmaier & Fischer, 2015; Oberman et al., 2007; Ponari et al., 2012).

Overall, several published studies seem to support the idea that facial feedback can play a causal role in the interpretation of emotion expressions. However, differences between the results of these experiments, as well as a lack of appropriate control conditions in some cases, suggest that it is not possible to draw definite conclusions concerning the exact role of one's facial activation in the evaluation of facial expressions. At the very least, it does not seem clear whether facial feedback should be expected to influence the outcome of the interpretative process in terms of: 1) identifying more broad categories (e.g., the difference between clearly happy and angry faces; Oberman et al., 2007), 2) creating a bias in more fine-grained decisions (e.g., the difference between slightly more or less happy expressions; e.g., Niedenthal et al., 2001), or 3) affecting interpretation speed (without necessarily affecting the interpretative tendency; cf. Lydon & Nixon, 2014).

Facial manipulations studies: methodological considerations

The previous two sections discussed a number of studies showing that facial muscle manipulations can have a causal effect on dependent measures related to emotional evaluations. To assess the generalizability of these experiments, some common methodological challenges in feedback studies are reviewed: the standard for assessing participants' expression awareness, and the intensity and duration of expression manipulation.

As discussed, facial feedback is usually assumed to be possible without participants' awareness of the emotional relevance of their expressions, since otherwise such effects could be explained by non-embodied mechanisms, such as situational demand effects or the conscious priming of conceptual knowledge about emotions (McIntosh, 1996; Strack et al., 1988). Therefore, the instructions of typical experiments in this field have not made the relationship between expression and emotion explicit in their instructions. Moreover, they have often utilized cover stories to make it less likely that participants will identify the actual study purpose. However, the success of these techniques in preventing awareness has not always been clear. Ideally, participants' awareness of the true purpose of their expressions should be measured. Some studies employing cover stories have not reported any awareness tests (Davis et al., 2015; Dzokoto et al., 2014; Helt & Fein, 2016; Lewis, 2012). Many studies have reported facial feedback effects for participants whom the experimenters classified as unaware of the emotional relevance of their expressions (e.g., Davey, Sired, Jones, Meeten, & Dash, 2012; Davis et al., 2009; Ito, Chiao, Devine, Lorig, & Cacioppo, 2006; Rutledge & Hupka, 1985; Strack et al., 1988). There are no generally accepted standards for what constitutes a sufficient test of awareness in facial feedback studies. The most commonly used approach in the area of facial feedback studies seems to be a verbal post-experiment interview by the experimenter, who then decides, based on the participant's answers, whether the cover story was successful. Verbal debriefing interviews can produce demand characteristics for both participants and experimenters (Orne, 1962). For example, the experimenter usually has a strong desire for his or her cover story to be successful and thus might show an implicit bias for classifying participants' answers as not showing awareness. Some studies have addressed this issue by explicitly specifying in advance their questions and their criteria for classifying answers (and have still found facial feedback effects; e.g., Davey et al., 2012; Laird, 1974; Soussignan, 2002). However, many publications in this area have not reported the usage of a standardized, pre-defined set of questions for such interviews, nor have they explicitly stated their criteria for classifying answers as showing awareness.

Considering that the presence or absence of awareness could lead to very different interpretations of facial feedback findings, critics of facial feedback studies might argue that the amount of evidence for facial feedback effects is less conclusive than the considerable number of published findings would suggest. Depending on how much a researcher is willing to rely on the experimenters' (apparently often ad hoc) decisions about the awareness of their participants, this methodological question might either seem to be a minor issue or rather a noteworthy limitation of the current literature. Overall, research in this area would probably profit from more explicit reporting of the procedures employed for assessing awareness, as well as from finding ways to avoid demand effects both for participants and experimenters (e.g., by using written rather than verbal debriefing questionnaires, with pre-defined assessment criteria; cf. Soussignan, 2004).

A second potential issue with facial manipulation studies concerns their practical relevance. In these studies, facial inductions have usually led to relatively intense changes in expressions. Additionally, participants have usually been asked to keep their facial muscles in such a state for a relatively long time, often several seconds (e.g., during the perception and evaluation of an emotional stimulus). Thus, facial feedback studies have shown that very strong and prolonged expressions might be able to influence affective processes. This seems to be a reasonable approach for providing evidence for the principal possibility of facial feedback effects. However, intense facial expressions are arguably less common in our daily life than are more subtle displays of emotions, and when they occur, they are not likely to remain at maximum intensity for longer durations. It is noteworthy that spontaneous facial reactions towards emotional stimuli often do not lead to any visible facial movements (cf. Cacioppo et al., 1986; Tassinary & Cacioppo, 1992). Theoretically, such RFRs could potentially deliver facial feedback in our daily lives. But, can we consider the effects of voluntary, strong facial activation in causal studies as a valid representation of more common, spontaneous, and subtle reactions?

In order to investigate the role of facial feedback, it is important to look at both experiments that artificially manipulate expressions, and studies that measure correlations between naturally occurring facial reactions and measures of evaluative tendencies. Experimental manipulations can provide actual causal evidence for embodiment theories (if possible alternative explanations, such as awareness effects, are adequately addressed), but they often create more extreme, and arguably artificial, expressions. Correlational studies cannot prove a causal role of facial activation, but allow researchers to test predictions under more realistic conditions by using passive EMG measurements of naturally occurring facial muscle tension. Importantly, findings that naturally occurring facial reactions do not correlate with evaluative outcomes would not support the idea that facial feedback influences affective evaluations. Thus, correlational studies can help to investigate the boundary conditions of facial feedback phenomena, by identifying evaluative tasks where facial activation cannot account for participants' decisions.

Overview of chapters

The following chapters extend previous research by testing for a relationship between facial activation and affective evaluations under different conditions. More specifically, all of these chapters investigated variants of the following hypothesis: Increased smiling/frowning should lead to changes in behavioural measures that indicate a tendency to interpret environmental stimuli as more positive/negative. Note that this operationalization is based on a basic valence-based distinction (i.e., the difference between positive and negative emotional reactions). Focussing on a valence-based differentiation has the advantage of maximising the possibility of establishing a differential effect of facial activity, while at the same time such a finding would still be consistent with potential differences between emotion-related reactions of the same valence.

Experiments reported in the following text employed ambiguous stimuli, as well as stimuli with a clear positive or negative valence. Some theories of affective embodiment (e.g., somatic marker theory and SIMS; cf. Damasio, 2000; Niedenthal et al., 2010) suggest that bodily feedback might be more relevant for judgements under uncertainty. If that was the case, one might expect that the relation between facial activation and interpretative tendencies would be stronger for evaluations of ambiguous stimuli.

Chapter II investigated the relationship between strong (experimentally induced) facial activation and the evaluation of verbal statements that described either clearly valenced (positive/negative) or ambiguous daily life situations. If facial feedback was an important factor for our evaluative tendencies, one might expect that induced smiling, as compared to frowning, would lead to more positive interpretations of such statements. Based on the assumption that facial feedback might be more relevant for the interpretation of uncertain situations, one might expect that such an effect would be more pronounced for ambiguous statements. Additionally, the role of awareness of one's facial expression was addressed in this experiment. While many previous facial manipulation studies used verbal debriefing interviews, often without explicit criteria for evaluating participants' awareness, the experiment reported here employed a written debriefing questionnaire for classifying participants' level of awareness. This allowed for a comparison of feedback effects between aware und unaware participants.

Chapter III investigated the relationship between subtle, nonconsciously evoked facial activation and the evaluation of ambiguous stimuli. Previous research has found that nonconsciously presented emotional facial expressions can evoke emotion-congruent RFRs (Dimberg et al., 2000), and that they also have emotion-congruent priming effects on the evaluation of ambiguous stimuli (Kouider, Berthet, & Faivre, 2011; Murphy & Zajonc, 1993; Winkielman, Berridge, & Wilbarger, 2005). Theories of embodiment could suggest a relationship between these bodily and behavioural priming effects (Foroni & Semin, 2011). We employed gaze-contingent crowding (Faivre, Berthet, & Kouider, 2012; Kouider et al., 2011) to present videos of happy and angry expressions outside of awareness. Participants' zygomaticus and corrugator reactions were recorded via EMG. Directly after each video, participants had to evaluate the subjective pleasantness of symbols that were ambiguous to them (Chinese characters for non-Mandarin speakers). If this procedure led to affective priming, one would predict that priming with happy faces, as compared to with angry faces, would lead to more zygomaticus/less corrugator activation, as well as to more positive ratings of the stimuli. If facial feedback was relevant for affective evaluations, the inducement of more smiling and less frowning could be expected to correlate with more positive evaluations. Chapter IV investigated the relation between naturally occurring facial activation and interpretations of emotional facial expressions. Theories concerning bodily influence on affective evaluations often name the interpretation of facial expressions as a psychological process in which facial feedback might be particularly relevant (Goldman & Sripada, 2005; Hatfield et al., 2014; Niedenthal et al., 2010). These theories propose that feedback can influence our interpretations of others' emotional states. In two experiments, participants were presented with clearly valenced (positive/negative) and ambiguous facial expressions. Their zygomaticus and corrugator reactions towards the expressions were measured via EMG. They either had to rate their own emotional reaction towards the faces (Experiment 1) or the feeling state of the person presented to them (Experiment 2). If facial feedback supported the interpretation of facial expressions, one could expect that participants' facial reactions would predict their ratings. Additionally, this experiment investigated the role of individual differences for the importance of facial feedback. More specifically, it has been suggested that bodily feedback should be more relevant for people who are generally more sensitive towards their own bodily signals (Herbert & Pollatos, 2012). It was tested whether better performance on a heartbeat perception test (assumed to test sensitivity towards affect-related bodily signals; cf. Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015; Pollatos, Gramann, & Schandry, 2007) predicted a stronger relation between facial activation and ratings.

Using a reaction time-based measure, Chapter V investigated the possible role of facial feedback in the affective priming of expression interpretation tendencies. More specifically, we presented happy/angry prime expressions in order to induce facial activation (more smiling/frowning, as measured with EMG) in the participants. Directly after each prime, participants were presented with either a clearly valenced or an ambiguous target face, which they then had to classify as positive or negative. If facial feedback facilitated the interpretation of facial expressions, one would expect that target faces congruent with participants' primed facial activation (as compared to incongruent ones) would lead to a faster classification speed. If facial feedback influenced interpretative tendencies for facial expressions, one would expect that especially ambiguous target faces would be more likely to be classified with the valence congruent with participants' induced facial activation.

Overall, the following chapters investigate specific examples for a possible involvement of facial activation (particularly smiling and frowning) in affective evaluations of clearly valenced and ambiguous stimuli. These chapters function as self-contained reports that have been or are planned to be submitted to peer-reviewed scientific journals. The last chapter contains an overview discussion that draws conclusions concerning the merits of theories that suggest that affective evaluations rely on facial feedback.

Chapter II: The effect of facial feedback on the evaluation of statements describing everyday situations and the role of awareness

Abstract

According to the facial feedback hypothesis, enacting emotional facial expressions can influence affective processes, such as our evaluations of environmental stimuli. Previous studies found that increasing the tension in one's smiling or frowning muscles can positively or negatively influence ratings for stimuli, such as cartoons, video clips, or facial expressions. Importantly, this effect has been present even for participants unaware of their current facial expressions. In order to test the extent of this phenomenon, the current study tested the effect of smiling and frowning on the evaluation of sentences describing everyday situations that were either clearly positive/negative or ambiguous in their valence. While most previous studies based their assessment of awareness on verbal debriefing interviews without explicitly defined criteria, we employed a written debriefing questionnaire in order to avoid any potential bias when identifying participants' awareness. Our results indicated that smiling/frowning increased/decreased the ratings for emotional sentences, with ambiguous sentences being influenced most strongly, but only for participants classified as aware. This emphasizes the importance of more rigorous awareness tests in facial feedback studies, and it demonstrates the feasibility of an easy-to-implement questionnaire for this purpose. The findings suggest that while facial activation might automatically bias evaluations of relatively simple stimuli, its influence depends on participants' conscious knowledge of their expressions in more complex decision-making situations.

Introduction

Human beings constantly evaluate their surroundings to identify both beneficial opportunities and situations that might pose potential threats. Theories of embodiment suggest that our evaluations are partly shaped by the states of our bodies (Barrett & Lindquist, 2008; Laird & Lacasse, 2013; Niedenthal, 2007). For example, it has been suggested that afferent feedback from the tension in our emotion-relevant facial muscles can influence our processing of affective stimuli (McIntosh, 1996; Adelmann & Zajonc, 1989). Simply put, we might perceive our surroundings as more positive when smiling and as more negative when frowning. Previous studies investigated this idea by asking people to make evaluations while enacting facial expressions. It was found that people who are enacting smiles (as opposed to either frowning or being prevented from smiling) rate cartoons as funnier (Laird, 1974; Strack et al., 1988; Dzokoto, Wallace, Peters, & Bentsi-Enchill, 2014; but see Wagenmakers et al., in press) and give higher pleasantness ratings to pictures of facial expressions (Dimberg & Söderkvist, 2011) or short video clips (Davis et al., 2009; Soussignan, 2002). These results demonstrate the possibility that facial muscle action influences evaluative outcomes, but the nature and extent of this influence remains uncertain. Are our decisions throughout the day amenable to the state of our facial muscles, or might their influence be limited to the less consequential evaluations of comparatively simple stimuli, such as those often employed in experimental contexts? The current experiment tested the effect of facial muscle activation (smiling and frowning) on the evaluation of sentences describing everyday situations. These situations were chosen to be either clearly positive/negative or ambiguous in their affective value, to establish whether facial influence is stronger in cases where the valence value of a situation is less determined.

Previous studies employed the evaluation of short statements describing common life events as an approximation of everyday decision-making, especially with respect to trait-related interpretation biases. It was found that people with high levels of trait anxiety (Hirsch & Mathews, 1997; Voncken, Bögels, & De Vries, 2003; Wenzel & Lystad, 2005) or diagnosed anxiety disorders (Eysenck, Mogg, May, Richards, & Mathews, 1991; Stopa & Clark, 2000) tend to interpret especially ambiguous statements as more negative. Some findings have even suggested that such interpretation biases might help to maintain emotional disorders (Hayes, Hirsch, Krebs, & Mathews, 2010; Murphy, Hirsch, Mathews, Smith, & Clark, 2007; Salemink, van den Hout, & Kindt, 2010; Stopa & Clark, 2000). While such maladaptive interpretative tendencies have often been explained with respect to cognitive mechanisms (e.g., Behar, DiMarco, Hekler, Mohlman, & Staples, 2009; Clark, 2001; Mathews & MacLeod, 2005), embodiment theories propose that body activity is important for affective processing (Barrett & Lindquist, 2008; Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015). The current study tested the possibility that manipulating participants' facial muscle activation might influence the rating of verbal descriptions of events similar to those employed in experiments measuring pathologically relevant interpretation biases. Since some theories of embodiment propose that bodily feedback might be especially relevant when making decisions under uncertainty (Bechara & Damasio, 2005), we tested the effect of facial feedback on both clearly valenced and ambiguous descriptions. As the latter are less determined in their emotional value, one could suspect that any influence due to changes in facial expressions would be stronger in such cases.

Investigating the role of facial feedback for the processing of affective sentences is also relevant for theories of languages processing. Embodiment accounts suggest that understanding a sentence might partially rely on bodily feedback related to its meaning (Barsalou, 1999; Buccino et al., 2005; Zwaan, 2004). In line with this view, it has been found that selective suppression of facial feedback during the reading of emotional sentences (e.g., blocking of smiles for positive statements) can lead to an increase in comprehension time (Havas et al., 2010, 2007), as well as electroencephalographic responses (EEG) indicating increased processing effort (Davis et al., 2015). While these studies mainly measured the effect of facial activity on the time and effort needed to comprehend emotional sentences, it is less clear whether muscle tension also affects the actual interpretative outcome. For example, Davis et al. (2015) found no effect of facial feedback on subsequent ratings of target sentences. Since their procedure was optimized for EEG measurements during reading, the ratings were performed only after a delay of several seconds, when emotion-relevant facial activation was no longer enacted, which might have diminished the effect on the ratings. Thus, the current study more directly tested the role of facial feedback on evaluative outcomes by ensuring that facial activation was present during both the reading and the rating of emotional sentences.

A further goal of the current study was to investigate the role of task-awareness for the facial feedback effect on evaluations. Knowingly enacting emotional expressions might activate emotion-congruent associations and/or experimental expectancy effects, leading to biased evaluations of stimuli in the environment (Laird, 1974; Zajonc et al., 1989). Previous studies using non-emotional cover stories, in order to avoid participants becoming aware of the emotional relevance of their expressions, found feedback effects, even after the exclusion of task-aware participants (e.g. Dimberg & Söderkvist, 2011; Ito, Chiao, Devine, Lorig, & Cacioppo, 2006; Strack et al., 1988). This suggests that facial feedback has a direct influence on affective processes, even when one is not consciously aware of one’s facial expression. Since the presence or absence of awareness is crucial for the theoretical interpretation of feedback effects, it is important to consider how task awareness should be assessed. Almost all facial feedback studies have reported the use of a verbal debriefing interview to measure participants' task awareness. However, research on experiment compliance suggests that participants are less likely to admit experiment-relevant knowledge in verbal debriefings, as compared to questionnaire-based debriefings (Newberry, 1973). Most publications concerning facial feedback have not reported a standardized, pre-defined set of debriefing questions or stated explicit criteria for classifying answers as showing task awareness. This makes it hard for other researchers to critically evaluate the experimenters' claims concerning the awareness of their participants. Importantly, debriefings interviews are themselves susceptible to demand effects (Orne, 1962), both on the side of the experimenter (who might be implicitly biased in wanting the cover story to succeed) and on the side of the participant (who might be reluctant to contradict the 'authoritative' cover story in a direct conversation; Blackhart, Brown, Clark, Pierce, & Shell, 2012). As a possible improvement in this respect, Davis et al. (2009) and Soussignan (2004) used a written debriefing questionnaire and explicit criteria for identifying task-aware participants. While these studies excluded task-aware participants from their analyses, the current study employed this approach for a direct comparison of aware and unaware participants. This can help to clarify the extent to which any effect of facial feedback on verbal statements might depend on participants' conscious knowledge about their facial expressions.

Overall, the current study assessed the effect of smiling, frowning, or (as a control) no specific facial movement on affective evaluations of a range of statements involving everyday situations that were positive, negative, or ambiguous in their emotional valence. The main dependent variable of interest was participants' ratings of these situations while performing the intended facial expressions. In order to ensure that the emotional muscles were selectively activated during the ratings, we also measured facial muscle activation of the corrugator supercilii ('frowning') and the zygomaticus major ('smiling') muscles via electromyography (EMG; Tassinary, Cacioppo, & Vanman, 2000). We motivated the facial movements with a non-emotional cover story, but we employed a structured debriefing questionnaire that allowed comparison of effects in aware and unaware participants. The facial feedback hypothesis predicts that smiling/frowning leads to a more positive/negative evaluation of situations, irrespective of whether participants are aware of that feedback. As the meaning of ambiguous situations should be more amenable to contextual influences, the effect could be expected to be more pronounced for such scenarios. The comparison of task-aware and task-unaware participants allowed us to determine whether any effect of facial feedback on sentence evaluations was dependent on a conscious mediation, such as expectancy effects or the activation of emotion-congruent associations.

Method

Participants

Participants were 121 undergraduate students (93 female) from Sussex University, taking part for course credit or financial reimbursement of £5. The mean age was 19.97 years (SD = 2.88).

Materials

An initial set of 50 sentences describing positive, negative, or ambiguous situations was created. In a pilot study, 32 participants rated the valence of each sentence on a 9-point-scale ranging from -4 (*negative*) to +4 (*positive*). Based on these ratings, we chose 9 clearly positive situations (each with a mean rating greater than 2, overall M = 3.66, SD = 0.13; e.g., “I’ve had a really productive day and am looking forward to a relaxing evening.”), 9 clearly negative sentences (each with a mean rating less than -2, M = -3.69, SD = 0.44; e.g., “I have so much work already, and now I hear we have another test next week.”), and 9 ambiguous sentences (each having a mean rating between -1 and +1, M = 0.20, SD = 0.44; e.g., “The person from the other table looked over to me again and again”). The three types of sentences did not differ in their mean length, $F(2, 24) < 1$.

Procedure

Participants were informed that the purpose of the study was to investigate how the activation of different muscle groups around the eyes might influence reading speed (cf. Topolinski & Strack, 2009, Experiment 4). For this reason, participants would be expected to perform reading tasks while contracting muscle groups either directly above or under the eye. Initially, they were instructed to lower their eyebrows whenever the message *above eye* was shown on the screen, and to raise their cheeks upwards and outwards as much as possible following the message *below eye*. These instructions had been identified in pilot trials as leading to typical frowning and smiling movements, respectively. Our instructions for smiling did not include any direct mention of the lips, as referring to a body part directly under the eyes was more consistent with our cover story. Additionally, smiles that incorporate cheek movements are believed to be more strongly related to positive emotions than are smiles without cheek involvement (Ekman et al., 1990). In a short training phase, participants practiced the movements while fixating on a cross in the middle of the screen (presented to them as a baseline measurement). The experimenter corrected participants’ movements when necessary, until participants produced the desired expressions. Participants were told to hold their muscle movements until they received new instructions on the screen, and not to make any of the two movements when the message *neither* was shown.

The main phase of the experiment consisted of three blocks. In each block, all of the 27 situations were presented once, with an equal number of each type assigned to one of the three movement instructions. The initial assignment of movements to situations was randomized and counterbalanced between the blocks (i.e., each sentence was rated once under each of the three facial movement conditions). Each trial started with the display of a movement instruction (*above eye*, *below eye*, or *neither*) for one second, followed by the presentation of one of the situations. After three seconds, a straight line with the two anchors, *negative* and *positive*, appeared below the sentences, functioning as a continuous rating scale from -420 to +420. The range of the scale was based on its length on the screen. We chose to maximize the length/range of the rating scale (taking into account space for the anchors left and right from the scale), since it was assumed that a larger range would maximize the chances of identifying subtle differences in ratings. Participants used the mouse to select a position on this scale reflecting their evaluation of the situation described, but they did not receive any numerical feedback about their ratings. They were told that these ratings were necessary to ensure that they truly processed the meaning of each sentence. After each trial the instruction *neither* appeared, and a three-second pause followed to allow the facial muscles to relax. Thus, participants performed the facial movements during both the reading and the rating of each situation. Additionally, the experiment contained 15 distractor trials per block. During these trials, a random letter combination and a moving dot (ostensibly representing a typical reading pattern) were displayed instead of a sentence. Participants were instructed to follow this dot with their eyes. While they were told that this was meant to identify effects of muscle activation during non-semantic processing, these trials only functioned to reinforce the cover story and had no relevance for the main task.

In order to evaluate participants' awareness that their facial muscle activation was related to emotional expressions, two approaches were tested: an open-response task, in which participants had to formulate the study purpose in their own words, and a prompted awareness task, which asked participants to select applicable study purposes from a list of possibilities. More specifically, a two-page debriefing questionnaire was administered after the main task. On the first page, participants were instructed to write down what they believed had been the purpose of the experiment. No further instructions were given, and no upper or lower limit for the length of the answer was indicated. The second page of the questionnaire included a prompted awareness task, which included descriptions of 13 items that might or might not have been relevant to the experiment. Some of these items related to the cover story (e.g., "the pattern of your eye movements"), some described aspects relevant to neither the cover story nor the actual study purpose (e.g., "your gender"), and, importantly, two target items were directly relevant to the true goal ("the emotions related to your facial expressions" and "your mood"). Participants were asked to mark all the items on the list that they believed to be relevant to the experiment. An indication of awareness during an open response might be seen as a stricter criterion of awareness, since here the participant had to formulate the study purpose on his or her own. Choosing the actual purpose from a given list can be seen as a more liberal criterion (since reading the actual purpose after the experiment might actually trigger awareness), but could potentially have the benefit of identifying aware participants that were unwilling or unable to formulate the study purpose on their own.

EMG Measurements

Two pairs of 4 mm Ag-AgCl electrodes were used for recording EMG activity from the corrugator and zygomaticus muscles. Electrode placement followed the recommendations of Fridlund and Cacioppo (1986). The signal was recorded by a Biopac Mp36 measurement unit at a sample rate of 2000 Hz. After filtering the signal in order to attenuate noise artefacts (high pass: 10 Hz, low pass: 500 Hz), the signal was further treated with a moving average integrator with a window size of 100 samples.

For each trial, the mean EMG activation of the three-second display of the sentence was calculated, and the mean value of one second directly before trial onset (i.e., before the movement instruction appeared) was subtracted from this value. The resulting values of all trials were transformed to z-scores for each participant individually.

Results

Assessment of task awareness

First, the free response section of the debriefing questionnaire was evaluated. Participants were classified as task-aware if any mention was made of 1) facial movements in the task being related to emotional expressions, 2) the expressions being intended to or actually influencing affective states, or 3) the expressions being intended to or actually influencing the sentence ratings. Following these criteria, 54 participants were considered to be task-aware. Secondly, participants' responses to the list of possible study purposes were assessed. Here, they were classified as showing 'prompted awareness' if they indicated that either of the true purposes of the study given on the list were relevant. Twenty-six participants showed only prompted awareness (i.e., they did not indicate any signs of awareness in their text, but when subsequently presented with a list of possible study purposes, they checked at least one of the relevant target items). Forty-one participants did not indicate task awareness in either their written statements or on the subsequent checkbox list and were hence considered clearly task-unaware.

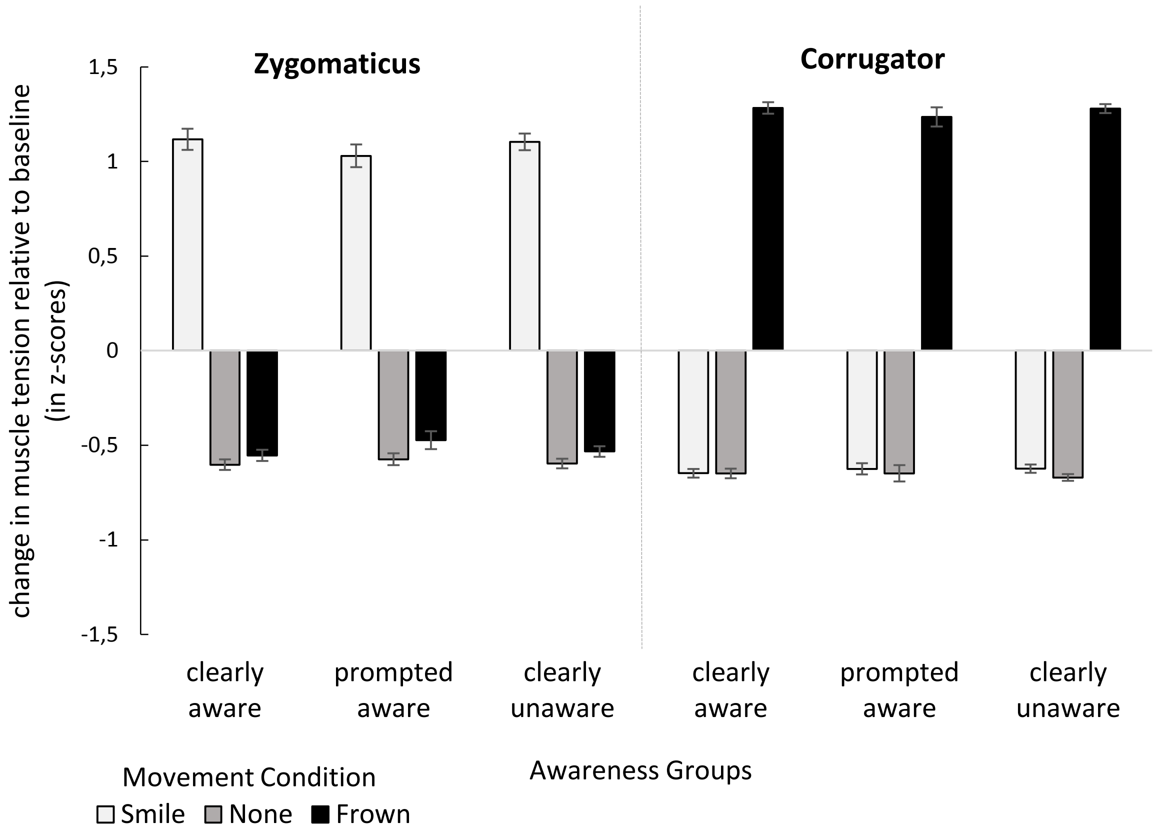

*Figure 2.1.*Changes in facial muscle tension (in z-scores) evoked by the movement instruction for zygomaticus (left) and corrugator (right). Error bars represent standard errors.

Manipulation check

We employed EMG data to test the success of the movement instructions in generating the appropriate facial muscle activation (see Figure 2.1). We also evaluated the possibility that a difference in task awareness might have led to different degrees of muscle movements. For both the corrugator and the zygomaticus, we conducted separate 2-way mixed ANOVAs with the within factor instruction (above eye/below eye/neither) and the between factor awareness level (no awareness/prompted awareness/full awareness). For both muscles, we observed a main effect of instruction, zygomaticus: $F(2, 236) = 1107.43$, $p < .001$, $\eta_p^2 = .90$; corrugator: $F(2, 236) = 2969.50$, $p < .001$, $\eta_p^2 = .96$. In both cases, there was no main effect of awareness level, zygomaticus: $F(1, 118) = 0.16$, $p = .85$, $\eta_p^2 < .01$; corrugator: $F(1, 118) = 1.84$, $p = .16$, $\eta_p^2 = .03$, nor an instruction*awareness interaction, zygomaticus: $F(4, 236) = 0.71$, $p = .59$, $\eta_p^2 = .01$; corrugator: $F(2, 236) = 0.37$, $p = .82$, $\eta_p^2 = .01$. This indicates that the instructions led to different degrees of smiling and frowning, with no difference in their effect between unaware and aware participants. The *below eye* instruction led to significantly more zygomaticus activity than the *neither* instruction, $t(120) = 38.00$, $p < .001$, $d = 3.45$, and the *above eye* instruction, $t(120) = 33.91$, $p < .001$, $d = 3.08$. There was also less zygomaticus activity for the *neither* instruction than for the *above eye* condition, $t(120) = -5.13$, $p < .001$, $d = 0.47$. For the corrugator, the *above eye* instruction led to significantly more activity than did the *neither* instruction, $t(120) = 66.10$, $p < .001$, $d = 6.01$, and the *below eye* instruction, $t(120) = 68.98$, $p < .001$, $d = 6.27$, which did not significantly differ from each other, $t(120) = -1.06$, $p > .99$, $d = -0.10$. Thus, the movement instructions selectively increased smiling in the *below eye* condition, and frowning in the *above eye* condition.

Table 2.1

Mean (and standard deviations) of the ratings for different sentence types, expressed as z-scores.

	Clearly unaware (n = 41)			Prompted awareness (n = 26)			Clearly aware (n = 54)		
	Smile	None	Frown	Smile	None	Frown	Smile	None	Frown
Pos.	1.119	1.141	1.125	1.143	1.152	1.154	1.163	1.101	1.085
	(0.23)	(0.21)	(0.23)	(0.14)	(0.13)	(0.12)	(0.13)	(0.14)	(0.17)
Amb.	-0.019	-0.037	-0.052	-0.108	-0.056	-0.077	0.093	-0.011	-0.139
	(0.21)	(0.19)	(0.20)	(0.22)	(0.22)	(0.21)	(0.23)	(0.17)	(0.25)
Neg.	-1.091	-1.090	-1.087	-1.068	-1.069	-1.070	-1.049	-1.087	-1.156
	(0.18)	(0.28)	(0.23)	(0.11)	(0.14)	(0.14)	(0.17)	(0.14)	(0.12)

Effects of facial expressions on sentence ratings

Sentence ratings were z-transformed separately for each participant (see Table 2.1). Average ratings were higher for positive sentences (M = 1.126, SD = 0.16) than for ambiguous sentences (M = -0.038, SD = 0.17) or negative ones (M = -1.089, SD = 0.16). Additionally, overall sentence ratings were higher during smiling (M = 0.029, SD = 0.03) than during frowning (M = -0.032, SD = 0.09) or when no particular expression was produced (M = 0.004, SD = 0.04). In order to test in how far differences in ratings depended on the awareness of the participants, a 3-way mixed ANOVA was conducted on the ratings with the factors expression (smiling/frowning/neither), situation type (negative/positive/ambiguous), and awareness level (unaware/prompted awareness/clearly aware). This revealed a main effect of situation, $F(2, 236) = 3474.87$, $p < .001$, $\eta_p^2 = .97$, and of expression, $F(2, 236) = 6.75$, $p = .01$, $\eta_p^2 = .05$, but no main effect of awareness, $F(2, 118) < .001$, $p > .90$, $\eta_p^2 < .001$. There was a situation*expression interaction, $F(4, 472) = 3.20$, $p = .01$, $\eta_p^2 = .03$, and an awareness*expression interaction, $F(4, 118) = 9.42$, $p < .001$, $\eta_p^2 = .14$, but no situation*awareness interaction, $F(4, 118) = 0.64$, $p = .63$, $\eta_p^2 = .01$. All of these effects were qualified by a situation*expression*awareness interaction, $F(8, 472) = 3.15$, $p = .002$, $\eta_p^2 = .05$. These results indicate a difference in the effects between participants of different awareness levels. Thus, for each awareness level, a 2-way expression (smiling/frowning/neither) x situation type (negative/positive/ambiguous) within ANOVA was conducted. There was a main effect of emotion for all groups, unaware: $F(2, 80) = 786.16$, $p < .001$, $\eta_p^2 = .95$; prompted awareness: $F(2, 50) = 952.18$, $p < .001$, $\eta_p^2 = .97$; clearly aware: $F(2, 106) = 2893.67$, $p < .001$, $\eta_p^2 = .98$. For both the clearly unaware and prompted awareness group, there was neither a main effect of muscle, clearly unaware: $F(2, 80) = 0.37$, $p = .69$, $\eta_p^2 = .01$; prompted: $F(2, 50) = 1.22$, $p = .31$, $\eta_p^2 = .05$, nor a muscle*situation interaction, clearly unaware: $F(4, 160) = 1.23$, $p = .30$, $\eta_p^2 = .03$; prompted: $F(2, 100) = 0.72$, $p = .58$, $\eta_p^2 = .03$. For clearly aware participants, there was a main effect of muscle, $F(2, 106) = 17.30$, $p < .001$, $\eta_p^2 = .25$, as well as a muscle*situation interaction, $F(4, 212) = 8.89$, $p < .001$, $\eta_p^2 = .14$. Thus, in all awareness classes, the ratings depended on the type of situation, but only for clearly aware participants did the rating depend on the expression performed during the evaluation. In all classes, ratings were significantly higher for positive situations than for ambiguous and negative ones, and they were lower for negative situations than for ambiguous situations (all p-values $< .01$, see Table 2.1 for means and standard deviations).

For the clearly aware group only, smiling led to higher ratings than did no expression, $t(53) = 3.73$, $p < .001$, $d = 0.51$ and frowning, $t(53) = 4.36$, $p < .001$, $d = 0.59$. Frowning led to lower ratings than no expression, $t(53) = -3.93$, $p < .001$, $d = 0.53$. The muscle*situation interaction suggested that for some situation types, the effect of the expression might have been stronger. To be able to compare the degree of influence on ratings produced by different expressions in the aware participants, we calculated a change score by subtracting the ratings during frowning from the ones during smiling. The higher this score, the more amenable to facial feedback a sentence type could be considered to be. Difference scores for ambiguous situations ($M = 0.23$, $SD = .38$) were significantly higher than for positive situations ($M = 0.08$, $SD = .22$), $t(53) = 3.95$, $p < .001$, $d = 0.54$, or for negative ones ($M = 0.11$, $SD = .19$), $t(53) = 3.41$, $p = .004$, $d = 0.46$), with no difference between the latter two, $t(53) = -1.40$, $p = .17$, $d = -0.19$. Thus, while all sentences were influenced by the facial expressions, this effect seemed to have been most pronounced for descriptions of ambiguous situations. Overall, while in all groups ratings depended on the situation’s valence, facial feedback only had an influence for clearly aware participants. The influence here was strongest for ambiguous situations.

Given that unaware participants did not show a facial feedback effect, it was relevant to know whether this result might have been due to a lack of statistical power (i.e., the number of unaware participants being insufficient) or if it could be seen as positive evidence for the absence of an expression effect. We explored this question with a Bayes factor analysis (Dienes, 2014; Jarosz & Wiley, 2014; Wagenmakers, 2007). A Bayes factor (BF) is a numerical value that can differentiate between strong evidence for a hypothesis (usually BF > 3; for recommended interpretation thresholds see Jarosz & Wiley, 2014), strong evidence against it (BF < 1/3), and inconclusive data (due to a lack of statistical power, 1/3 < BF < 3). Since the prompted awareness group showed the same pattern of results as did the clearly unaware group, suggesting that participants the prompted awareness group were actually unaware during the experiment, both groups were considered to be unaware, and were hence included in this analysis. Using JASP (JASP Team, 2016), Bayes factors were calculated for the conclusiveness of the null hypothesis (i.e., no effect) in the unaware participants for the non-significant expression main effect and for the non-significant expression*situation interaction (see above). For both expression, BF = 46.70, and expression*situation, BF = 5942.16, the resulting BF suggested that our data provides strong evidence for the null hypothesis. Thus, the absence of an expression influence in unaware participants cannot be explained by, for example, a lack of statistical sensitivity. Rather, it provides positive evidence that muscle activation failed to influence the ratings.

Discussion

The current study tested the effect of emotional facial muscle activation (smiling and frowning) on the evaluation of sentences describing clearly positive/negative or ambiguous situations. We employed a written debriefing questionnaire with explicit criteria for probing the extent to which any affect might depend on participants' awareness of the emotional relevance of their facial movements. It was found that only for participants with awareness facial activation influenced the evaluation of the described situations, with ambiguous situations being influenced significantly stronger by the movement instructions. As there was no difference in muscle activation between unaware and aware participants, these results cannot be explained by a difference in task compliance between the groups. Additionally, Bayesian analysis of the data indicates that the number of unaware participants was large enough to interpret the results as positive evidence for a null effect (i.e., a higher number of unaware participants could not have been expected to produce a different finding).

Methodologically, these results demonstrate the importance of finding a reliable way to identify task awareness in research concerning facial feedback. Only participants classified as aware based on their free-text answers showed an effect of facial actions on ratings. Participants who only indicated awareness when directly presented with the true study purpose (i.e., prompted awareness) did not differ in their effect from clearly unaware participants, suggesting that this approach for identifying awareness can lead to an overestimation of aware participants, because the answers here might represent participants' post-experimental beliefs elicited by the mentioning of the actual purpose in the questionnaire. Future studies could try to distinguish between different possible cognitive mechanisms that might mediate the relationship between task awareness and the behavioural outcome. While participants might react to perceived experimental demand, especially in the case of facial feedback, it is conceivable that they could also behave according to their own conceptual knowledge about the relation between certain expressions and emotions (Barrett, 2006; Bem, 1972; Schnall & Laird, 2003). Overall, many studies exist that have reported facial feedback effects in participants identified as unaware, using a wide range of different experimental designs and outcome measures (e.g., Andréasson & Dimberg, 2008; Dimberg & Söderkvist, 2011; Ito et al., 2006; Lewis, 2012; but see Reisenzein & Studtmann, 2007; Wagenmakers et al., in press).

This makes a positive case for the theory that facial muscle tension can causally influence our affective processing, at least in some aspects, even in the absence of awareness. However, as most feedback studies have used verbal debriefing interviews with no explicit criteria for their classification (or sometimes have reported no awareness test for their cover stories at all), there might be a risk of a bias for classifying aware participants as unaware in some studies. Our results suggest that such a bias, combined with the currently widely discussed tendency not to publish null results (Ferguson & Heene, 2012a; Kühberger, Fritz, & Scherndl, 2014) might lead to an overestimation of the extent and intensity of facial feedback effects.

While previous studies found an effect of facial activation without awareness on evaluations of mainly pictorial stimuli, such as cartoons or short video clips (e.g., Davis et al., 2009; Soussignan, 2004; Strack et al., 1988), we found no effect on ratings of sentences describing relatively common life events, corroborating a similar finding by Davis et al. (2015). Other studies investigating facial effects on emotional sentences did not measure evaluative outcomes, but found that selectively blocking smiling/frowning increased reading times of emotion-congruent sentences (Havas et al., 2010, 2007). These divergent results suggest that theories concerning facial feedback need to identify in more specific terms what kinds of evaluative processes can be influenced by facial activation. For example, dual-process models of decision-making often distinguish between intuitive (potentially relatively quick) and analytical (usually more elaborated) decisions (Chen & Chaiken, 1999; Evans & Stanovich, 2013). Some theories of embodiment suggest that bodily feedback might function as an additional heuristic for decisions when external information is not readily available, effectively allowing for intuitive ‘gut feeling’ decisions (Damasio, 1996; Sütterlin, Schulz, Stumpf, Pauli, & Vögele, 2013). Language processing has sometimes been linked to more analytical processing (cf. Evans, 2008; Sadler-Smith, 2011). It might be possible that the task of evaluating sentences in the current study led to a more elaborated or analytical decision-making approach in the participants than the evaluation of, for example, cartoons, and thus made it more likely for participants to base their ratings on cognitive strategies rather than on facial feedback. The effect on reading times in earlier studies might suggest a trade-off between processing effort and amenability to facial feedback (e.g., maybe participants invest processing resources into tuning out potentially misleading bodily feedback in these cases). Such an interpretation can only be tentative, as there is currently a lack of studies directly comparing facial feedback effects for different types of evaluations. Future studies could address this distinction by contrasting the effect of facial muscle activation under conditions that encourage more or less elaborated decision-making (e.g., by manipulating the time available for forming a judgment).

Overall, the current study is in line with a limited view of facial feedback effects, suggesting that facial feedback is a determinant of evaluative outcomes only under specific circumstances (Davis et al., 2015; Maringer et al., 2011). Experimentally distinguishing between affect-related processes that are or are not dependent on the state of our facial muscles will be necessary to further our understanding of the role of bodily feedback in our everyday lives.

Chapter III: Effects of unconsciously perceived dynamic facial expressions on facial activation and affective evaluations

Abstract

Can facial expressions of emotions influence us even when we do not perceive them consciously? Methods to investigate this question have usually relied on the presentation of static faces images for periods of just a few milliseconds to prevent stimulus awareness. In contrast, real facial expressions are dynamic and can unfold over several seconds. Recent studies have shown that the gaze-contingent crowding paradigm (GCC) can block awareness of dynamic expressions, while still inducing behavioural priming effects (more positive ratings of Chinese characters after happy expressions than after angry expressions). The current experiment tested for the first time if this method can change participants' facial activity. Videos of happy or angry expressions were presented outside of participants' central viewing field, surrounded by unrelated flankers to block conscious access. Electromyographic measurements (EMG) confirmed that participants showed significantly more frowning during angry videos than during happy videos. However, an effect on ratings of subsequently presented characters was not found. Additionally, changes in facial activation did not predict participants' ratings. Potential reasons for the divergence between bodily and behavioural priming are discussed. Overall, the current experiment demonstrated for the first time that the unconscious presentation of dynamic facial expressions achieved using GCC could influence emotion-related muscular activity. The failure to find an analogue behavioural effect suggests that facial and behavioural priming effects are not necessarily related.

Introduction

Facial expressions of emotion are an important part of human social interaction – so important that human beings have evolved the ability to process such expressions both extremely quickly and automatically. It is now generally accepted that an emotional face can affect an observer even when he or she is not aware of its presence (Morris, Öhman, & Dolan, 1998; Tamietto & de Gelder, 2010). For example, previous studies found that even in the absence of conscious recognition, emotional expressions influenced participants' evaluative decisions (Almeida, Pajtas, Mahon, Nakayama, & Caramazza, 2013; Kouider et al., 2011; Murphy & Zajonc, 1993), activated affect-related brain regions, such as the amygdala (Whalen et al., 1998; Williams, Morris, McGlone, Abbott, & Mattingley, 2004), and led to emotion-congruent reactions in participants' own facial muscles (Dimberg et al., 2000). Overall, measuring the impact that unconsciously perceived facial expressions have on an observer can help to elucidate the automatic aspects of face processing and to disentangle such effects from more conscious, strategic reactions towards others' expressions (Eastwood & Smilek, 2005). While several approaches for blocking visual awareness exist, virtually all of them impose certain limitations on the types of stimuli that can be employed (for a review of several techniques, see Kim & Blake, 2005). To date, the most commonly employed method for blocking awareness of facial stimuli has been visual backward masking. Here, the presentation of an emotional face is immediately followed by a non-emotional picture (e.g., a photo of a neutral expression), which helps to block the awareness of the main stimulus of interest (see Kouider & Dehaene, 2007 for a review of theoretical explanations for this phenomenon). Crucially, preventing awareness in this way is only possible if the emotional face is presented for a very short time, usually

10 to 30 milliseconds (Aguado, Serrano-Pedraza, & García-Gutiérrez, 2014; Esteves & Öhman, 1993). This constraint on the duration of exposure has usually limited experimental studies of nonconscious face processing to the use of static facial images.

In contrast to the static images used in backward masking studies, the facial expressions we experience in real life are dynamic (i.e., we usually encounter facial muscle movements that can unfold and change over several seconds). Importantly, a growing body of evidence suggests that the movement and timing of an expression might play a role in how we process it in both quantitative and qualitative terms. Quantitatively, previous studies found that consciously viewing dynamic facial expressions, as compared to their static counterparts, leads to more intense ratings (Biele & Grabowska, 2006), creates stronger activation in brain regions associated with the processing of socially relevant stimuli (Arsalidou, Morris, & Taylor, 2011; LaBar & Crupain, 2003), and leads to stronger facial reactions in the observer (Sato, Fujimura, & Suzuki, 2008). Qualitatively, some experimental evidence suggests that people rely on an expression's timing to interpret its meaning (Ambadar, Schooler, & Cohn, 2005), for example, when distinguishing between authentic and posed displays of emotions (Sato & Yoshikawa, 2004; Krumhuber & Kappas, 2005). Is the influence of such dynamic aspects of expressions dependent on their conscious appreciation, or can it derive from automatic processing? To shed light on such questions, it would be desirable to have the possibility of presenting truly dynamic facial stimuli without awareness. The ability to employ dynamic face stimuli in research concerning nonconscious processing could also help to increase the ecological validity of future experimental findings (Krumhuber, Kappas, & Manstead, 2013).

Sato, Kubota, and Toichi (2014) suggested an approach to address this limitation within the backward masking paradigm by showing three photos in quick succession (presenting an expression at its onset, its midlevel, and its peak), which were then masked by a neutral stimulus. This effectively resulted in a short backward masked stop-motion animation. While this presents an improvement in terms of being able to employ dynamic face stimuli in unconscious presentations, the reliance on backward masking still limits the possible face animation duration (~30 ms in Sato et al., 2014) in a substantial way. Importantly, the resulting need to rely on a stop-motion animation of only three pictures produces stimuli that are arguably different in richness than a natural, dynamic display of emotions.

A recent alternative approach has been presented by Kouider, Berthet, and Faivre (2011), who used the so-called gaze contingent crowding paradigm (GCC) to prevent awareness of videos of facial expressions. In their study, dynamic happy and angry faces were shown parafoveally (i.e., in the periphery of people's viewing fields), in such a way that participants were not able to directly focus on the videos. These expressions were closely surrounded by unrelated objects ('flankers') giving rise to the so-called crowding effect – the phenomenon that objects close to each other in one's peripheral vision are perceived as blurring together, making the identification of the crucial face stimuli substantially harder (Levi, 2008). The advantage of preventing awareness using this method is that it is not directly dependent on the duration of the target stimulus; it thus permits the presentation of naturally unfolding dynamic expressions over several seconds. The findings of Kouider et al. (2011) indicated that while participants could no longer consciously identify videos of happy and angry expressions, they tended to rate Chinese characters presented immediately after happy faces as more positive than after angry ones (see also Faivre, Berthet, & Kouider, 2012; Faivre, Charron, Roux, Lehéricy, & Kouider, 2012).

While these previous studies found evidence that crowded nonconscious presentation can elicit behavioural priming, the current experiment tested for the first time whether this technique can be used to induce facial reactions in the observer. When seeing others' expressions, people have a tendency to form facial expressions themselves (Hess & Fischer, 2014). While such reactions are often too subtle to be directly visible, they can be detected and quantified via electromyographic measurements (EMG; Tassinary, Cacioppo, & Vanman, 2000). Most studies employing EMG have found that these responses are emotion-congruent. More specifically, people usually reacted towards consciously presented positive face stimuli (as compared to negative ones) with increased activation of the zygomaticus major (the muscle responsible for smiling movements) and decreased activation of the corrugator supercilii (responsible for frowning; e.g., Dimberg & Thunberg, 1998; for a recent review, see Hess & Fischer, 2013). It is still a matter of debate in how far such reactions represent a case of motor mimicry (i.e., an automatic, not necessarily affect-related tendency to imitate others' motor movements), or whether they are part of the observer's emotional response towards the affective expressions (Hess & Fischer, 2014; Moody & McIntosh, 2011). Dimberg et al. (2000) found evidence that emotion-congruent facial reactions also occur when awareness of the faces was blocked via backward masking. Investigating whether the GCC paradigm can elicit such responses in the absence of expression awareness is important for several reasons. First, different techniques for the prevention of awareness most likely rely on different perceptual and neural mechanisms (cf. Faivre, Berthet, & Kouider, 2014). Therefore, it is of theoretical interest to establish if an unconscious effect (here: changes in facial muscle activation) can only be evoked with one specific technique, such as backward masking, or if it is independent of the choice of awareness prevention method. Establishing that GCC can induce unconscious facial reactivity would support the assumption that this phenomenon does not rely on peculiarities of the backward masking paradigm, but that it might instead be a general feature of unconscious visual processing. Second, it could be seen as a demonstration of the suitability of the GCC paradigm for experiments concerned with mimicry or emotional reactivity. Given the advantage of GCC in terms of its possibility to present more natural dynamic stimuli, this would open up new possibilities for researchers wishing to study the influence of dynamic aspects of facial expressions in the absence of awareness.

Additionally, including a measure of facial reactions might also help to shed light on a possible interplay between bodily and behavioural effects, such as the influence of nonconscious expressions on pleasantness ratings of Chinese characters found in earlier studies (Kouider et al., 2011). Affective stimuli, such as emotional expressions, are known to influence both evaluative tendencies (e.g., ratings of subsequently presented stimuli) as well as bodily reactions (such as facial activity or physiological reactions; cf. Kreibig, 2010). Many theories of emotions assume that these different aspects of emotional reactivity are closely interrelated and should occur in synchronization (e.g., Frijda, 2000; Scherer, 2005), a concept sometimes called *emotion response coherence* (Mauss et al., 2005). Some theories of embodiment even go so far as to propose that a bodily reaction towards a stimulus, such as a change in facial expression, can causally influence evaluative decisions (Barrett & Lindquist, 2008; McIntosh, 1996). A prominent example of such a theory is the facial feedback hypothesis, which states that facial activation can influence affective processes (Buck, 1980; Lewis, 2012). If such accounts were true, one would expect to find a relationship between a participant’s facial reaction and rating tendency, so that a higher degree of smiling/frowning would predict a more positive/negative rating. For conscious presentations of facial expressions, some previous studies have found results in line with these assumptions (Korb, With, Niedenthal, Kaiser, & Grandjean, 2014; Sato et al., 2013), while others have found no evidence for a link between participants' facial and evaluative reactions (Hess & Blairy, 2001). Concerning the effect of nonconscious presentations of emotional faces, the existing evidence is relatively sparse. While several studies have presented evidence either for its ability to influence bodily responses (Bailey & Henry, 2009; Dimberg et al., 2000) or evaluative decision-making (Murphy & Zajonc, 1993), there is to date little data on the possible relation between these two aspects. One study (using backward masking) found evidence for a dissociation between facial and behavioural effects (i.e., facial reactions towards nonconscious emotional faces but no influence on subsequent ratings of ambiguous stimuli; Rotteveel, de Groot, Geutskens, & Phaf, 2001; Exp. 2). However, Foroni and Semin (2011) found that nonconscious presentations of emotional expressions did not lead to a behavioural priming effect for participants when they were asked to press their lips together, resulting in continuous muscular interference. Understanding if and when different aspects of emotional reactivity are related to each other, even when emotional priming occurs in the absence of awareness, might help both to elucidate the nature of nonconscious emotion processing and to clarify the function of different emotional response systems in general. Thus, a further aim of this study was to investigate whether any changes in facial muscle activation resulting from the nonconscious presentation of emotional faces predicted the rating tendency of ambiguous stimuli presented immediately following each emotional prime.

To summarize, the current study utilized the GCC paradigm by Kouider et al. (2011) that allows for the presentation of dynamic happy and angry facial expressions towards participants, while blocking their awareness of the type of expression shown to them. As an important extension to previous work, we measured test participants' reactivity of the corrugator (frowning) muscle and zygomaticus (smiling) muscle towards those facial stimuli via EMG. If the GCC technique was capable of influencing participants' facial muscles, one would expect differential reactions towards the face videos, with less frowning and more smiling activity during the presentation of happy videos as compared to during the presentation of angry expression videos. Furthermore, as in previous studies, we measured the behavioural effect of these nonconscious emotional faces by letting participants evaluate a potentially ambiguous stimulus (Chinese characters for non-Chinese speaking participants) presented directly after the affective prime face. This allowed us to test whether the degree of any effects of the nonconscious emotional faces on participants' facial muscles could predict their behavioural rating tendency, as hypothesized by models that assume coherence (cf. Mauss et al., 2005) or even casual connections (Barrett & Lindquist, 2008; Landau, Meier, & Keefer, 2010) between bodily (here: facial muscle activity) and behavioural reactions towards emotional stimuli.

Method

Participants

Participants were 111 students (70 female) from the University of Sussex. All participants reported corrected-to-normal vision and had no prior knowledge of the Chinese characters used for test stimuli. Since preliminary analysis of the EMG data revealed that 3 participants showed average activation more than 2.5 standard deviations above the sample mean, these were treated as outliers and excluded from the final analysis, resulting in a sample of 108 students, with a mean age of 27.77 years (SD = 10.18 years).

Materials

Face stimuli comprised of 16 video clips, previously employed by Kouider, Berthet, and Faivre (2011), each showing the face of one of eight actors performing either a happy or angry expression. Each clip lasted for 2.5 s, whereby in the first second, each actor showed a neutral expression, followed by the enactment of the happy or angry expression during the next 0.5 s, which was then maintained at peak intensity for the last second. To facilitate the crowding effect, 45 non-informative, quasi-random patterns were employed as flankers around the face stimuli. These flankers had a similar size and oval shape as the faces in the videos and were again the same as those employed by Kouider et al. (2011). For testing the effect of the face presentations on subsequent evaluations, 80 Chinese characters were taken from an internet database (http://en.glyphwiki.org/), each of which consisted of the same number of brush strokes. All stimuli were presented in greyscale against a black background on a 20” Dell Trinitron P1130 monitor with a refresh rate of 85 Hz and a screen resolution of 1280 X 1024 pixels.

Procedure

Participants were seated in a chair with their heads leaning on a chin rest at a distance of 54 cm from the display screen. Since it has been suggested that performing a motor action might increase sensitivity to observations of similar actions (Schütz-Bosbach & Prinz, 2007), the experiment started with a conscious observation and imitation task of the facial expression stimuli. More specifically, all videos were presented in the centre of the screen, with each appearing twice in randomized order, and participants were asked to imitate the expressions they saw. It was hypothesized that such a conscious imitation might help to facilitate priming effects during the ensuing unconscious presentation of the videos.

The main part of the experiment consisted of parafoveal, crowded displays of the expression videos. Each trial started with a white fixation cross (approx. size: 1˚ width × 1˚ height) appearing towards the top of the screen. Participants were instructed to focus on this cross at all times. After one second, while the fixation cross remained present, one of the videos (3.2° x 3.8°) appeared towards the bottom of the screen, surrounded by six randomly chosen flankers (3° x 3°; 3.2°centre-to-centre eccentricity between face and flankers). The video presentation lasted for 2.5 seconds. During the trials, participants' gaze position was measured via an eye tracker. Whenever their point of fixation deviated from the fixation cross by more than 5°, the video was replaced by an upward arrow. This approach ensured that test subjects could not identify the videos by directly focusing on them. Participants were told that if they saw the arrow, they should treat it as a reminder to remain focused on the fixation cross. The GCC procedure consisted of three separate phases: awareness threshold detection, the priming phase, and a post-experiment awareness test.

The awareness threshold detection determined the distance between the fixation cross and the face videos for each participant individually. While a larger distance should make it harder to consciously identify the stimuli, there is some evidence that smaller distances might lead to stronger priming effects (Marzouki & Grainger, 2008). Thus, the goal was to determine a fixation-video distance that was as close as possible to a participant's central viewing field, but far enough away to block conscious expression identification.

As has been pointed out before (Cheesman & Merikle, 1986; Murphy & Zajonc, 1993; Öhman, 1999), it is perfectly possible in priming procedures to maintain the discrimination ability of prime type above chance level, even in the absence of subjective awareness (i.e., participants might still be able to distinguish prime stimuli, although they have the subjective impression of not being able to do so). Thus, our procedure aimed for subjective unconsciousness (i.e., the goal was to reach a fixation-prime distance at which participants repeatedly reported having to guess what kind of video was shown to them, irrespective of their objective discrimination rate; see Dienes, 2004).

More specifically, after each video presentation, participants had to indicate 1) whether the face presented was smiling or frowning (as a measure of their objective discrimination ability), and 2) whether they were “at least a bit confident” in their answer or were “just guessing” about the expression (as a measure of their subjective awareness). If a participant reported at least some confidence in his or her ability to see an expression, and if he or she identified it correctly, the distance between prime and the fixation cross was increased for all subsequent trials. When a participant reported just guessing the answer (i.e., having no subjective awareness) or did not correctly identify the face, the next trial used the same fixation-prime distance. This procedure continued until a participant reported no subjective awareness on eight consecutive trials. The so-determined fixation-video distance was employed in the remainder of the experiment, with a post-experiment awareness test (see below) used to confirm its effectiveness after the experimental trials.

The priming phase was used to measure the behavioural and bodily priming effect of the crowded videos. Facial EMG measurements during the video presentations were used to assess the influence of the video type on muscle activity. To measure behavioural effects, a Chinese character (2.8˚ × 3.5˚) appeared in the position of the fixation cross for 150 ms directly after the end of each video presentation. On a subsequent screen, participants were asked to rate the pleasantness of this character on a 4-point scale (1 = *rather unpleasant*; 4 = *very pleasant*). Overall, there were 80 prime trials with each character presented once, and each prime video presented five times. The order of the characters and prime videos, as well as the assignment of videos to the Chinese symbols, was randomized for each participant.

The post-experiment awareness test assessed participants' subjective awareness at the fixation-video distance determined at the start of the study. This test was administered after the main priming phase to confirm that the threshold distance required for unconscious exposure had not altered during testing. The task was identical to the one in the threshold identification phase (i.e., participants were asked to identify faces and had to indicate if their answers were based on at least some confidence or were guesses), with the only difference being that the fixation-video distance was kept constantly at the level used during the main priming phase. This test lasted for 32 trials, with each of the prime faces presented twice in randomized order.

Measurement setup

Participants' eye gaze was measured via a head-mounted SR Research Eyelink II eye tracker with a sampling rate of 250 Hz and a spatial resolution of 0.01˚. Facial EMG during the video presentations was measured with pairs of 4 mm AG/AG-Cl touch-proof electrodes filled with conductive paste (Biopac GEL 100). Prior to electrode attachment, participants' skin was cleaned with Nuprep skin preparation gel to reduce resistance. Electrodes were then placed on the regions of interest, according to the recommendations of Fridlund and Cacioppo (1986). The signal was recorded via a Biopac MP36 measurement device with a sampling rate of 2000 Hz.

Results

Data preprocessing

In order to obtain an objective measure of task adherence, the percentage of time that a participant kept his or her gaze on the fixation cross was evaluated for each trial. Since the prime videos were removed from the screen whenever participants did not look at the cross (and hence no priming was possible a priori), we excluded all trials from the data analysis where participants' gaze deviated from the intended point of fixation for more than half of the trial length (3.72% of all trials).

Concerning the EMG signal, filtering (high pass: 10 Hz, low pass: 500 Hz) was employed to attenuate noise artefacts. Offline, a moving-average integrator with a window size of 100 samples was used. For each trial in the priming phase, average activity of each muscle site in the last 1000 ms was calculated, as only in this time period the expressions in the videos were shown fully developed at peak level. These values were then baseline-corrected by subtracting the mean activation one second prior to stimulus onset. The resulting change scores were transformed to z-scores for each participant. Hence, the final values expressed the degree of change in muscle activation during each trial, relative to the average change in activity in all of a participant's trials. To account for strong anomalies due to, for example, movement artefacts, trials with z-scores higher than 2.5 were excluded from the final analysis (2.43% of all trials).

Effectiveness of awareness prevention

To test for the presence of subjective awareness of the parafoveal expressions, we employed the zero-correlation criterion of unconscious knowledge (Dienes, 2007). This criterion evaluates the relationship between confidence and accuracy and asserts that where accuracy is no greater in the presence of confidence versus in the absence of confidence, any knowledge employed to make the judgement was unconscious. This criterion was clearly fulfilled in our data; the percentage of correct responses for judgments made with confidence (*M* = 50.10, *SD* = 0.40) was both non-significantly different from chance performance (50%), *t*(107) = 0.03, *p* = .98, *d* < .01,and non-significantly different from the percentage correct when reporting guessing (*M* = 54.65, *SD* = 0.13), *t*(107) = -1.25, *p* = .21, *d* = .13.Accuracy when reporting confidence was, in fact, slightly *lower* than when reporting guessing. Thus, our participants demonstrated no conscious awareness of the nature of the different expressions.

Effects of videos on character ratings

The effect of the prime videos on the ratings of the Chinese symbols was tested by comparing participants' average ratings for characters shown after happy videos (*M* = 2.63, *SD* = 0.39) with their average ratings after angry videos (*M* = 2.62, *SD* = 0.37). No significant difference was found, *t*(107) = 0.39, *p* = .70, *d* = .04. Given that: 1) nonconscious prime effects can be relatively small, and 2) previous studies employing the same paradigm and prime stimuli found a behavioural effect (e.g., Kouider et al. 2011), we decided to test whether the present null finding could be explained with statistical insensitivity. A Bayes factor was calculated following the procedure described in Dienes (2011). More specifically, we modelled the Bayes factor on the size of the priming effect found by Kouider et al. (7% higher proportion of pleasant ratings versus unpleasant ratings after happy versus angry primes), using a half-normal distribution with a standard deviation equivalent to this previous result (for a detailed description of this approach, see Dienes, 2011). This analysis resulted in a Bayes factor of 0.5. A Bayes factor of less than one-third is a commonly recommended threshold for interpreting nonsignificant results as strong evidence for the null hypothesis (Jarosz &

Wiley, 2014). Therefore, it would still be possible to argue that with a larger participant sample, we might have observed a behavioural effect.

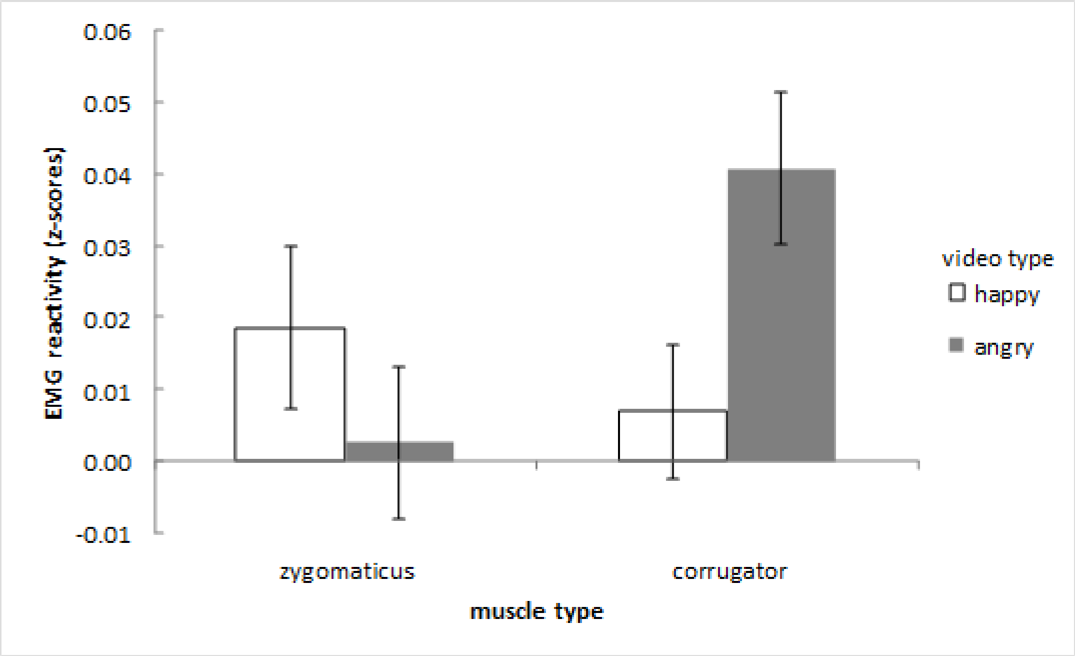

*Figure 3.1.*Mean muscle reactivity by video prime (+/- 1 S.E.M). Values represent standardized changes in EMG signals from the pre-video baseline.

Effects of videos on facial activity

The mean and standard error of participants' facial reactions towards the videos are shown in Figure 3.1. To test the effects of the expression primes on participants' facial activity a 2 (muscle: zygomaticus/corrugator) by 2 (prime type: happy/angry) repeated measures ANOVA was conducted. Results revealed no significant main effect of muscle group, $F(1, 107) = 1.59$, $p = .21$, $\eta_p^2 = .02$, or prime type, $F(1, 107) = 0.78$, $p = .38$, $\eta_p^2 = .01$. Importantly, there was a significant muscle x prime interaction, $F(1, 107) = 7.20$, $p = .008$, $\eta_p^2 = .06$, indicating that the smiling and frowning muscles were affected differently by the two video types. To explore this interaction, the effects of prime type were calculated individually for each muscle. For the corrugator muscle, angry video primes produced significantly more activation than did happy videos, $t(107) = 2.15$, $p = .03$, $d = .21$. For the zygomaticus muscle, a difference in the opposite direction (i.e., more smiling in response to happy videos than to angry videos) was observed but failed to reach significance, $t(107) = -1.40$, $p = .17$, $d = .13$.

Relationship between facial activity and evaluative tendencies

While there was no general behavioural priming effect as such, the possibility still remained that participants' evaluative decisions were related to their smiling or frowning activity. If that was the case, participants should have given higher ratings in trials where they showed stronger zygomaticus and/or lower corrugator reactions. Using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015), we tested whether zygomaticus or corrugator activation on individual trials predicted participants' ratings. We included participant as a cluster variable to account for the hierarchical structure of our data (i.e., several trials nested within each participant). Neither zygomaticus, b = 0.006, SE = 0.018, $t(7773) = 0.35$, p = .72, nor corrugator activation, b = 0.006, SE = 0.018, $t(7773) = 0.35$, p = .72, significantly predicted ratings. Thus, ratings were not significantly influenced by changes in either smiling or frowning.

Discussion

This study employed the GCC paradigm to present dynamic happy and angry facial expressions to participants without awareness. For the first time, we investigated whether this technique is capable of inducing emotion-congruent facial reactions in the zygomaticus ('smiling') and corrugator ('frowning') muscles. Results indicated that participants' muscles showed a differential response towards the videos, in line with the assumption that nonconsciously presented primes can evoke facial muscle responses. This effect was most pronounced for the corrugator muscle, which showed significantly more EMG activation for angry prime faces than for happy prime faces. Descriptively, the zygomaticus showed the opposite pattern of activation, however, the difference for this muscle group was not significant. The nonsignificant effect for the zygomaticus is consistent with studies that found less pronounced differentiations between positive and negative affect for the zygomaticus muscle than for the corrugator muscle (Larsen et al., 2003), while other publications have reported stronger effects for the zygomaticus (Moody & McIntosh, 2011). Since the upper and lower face muscles are partly innervated by different brain regions (Adolphs, 2002), it would be worth investigating whether these results indicate that the reactivity of these muscles are mediated by different processes.

Evidence for nonconscious facial activity was previously limited to the backward masking paradigm (Dimberg et al., 2000). Finding similar results with the alternative GCC technique supports the notion of unconscious facial reactivity as a general feature of our visual processing. More research will be needed to explore the precise mechanisms behind this phenomenon. More specifically, future studies could investigate in how far facial reactions during nonconscious presentations are due to automatic non-emotional motor mimicry, or are part of an affective response (cf. Tamietto & de Gelder, 2010), e.g. by measuring the effect of both emotional and non-emotional facial expressions (for a similar approach during conscious viewing, see Moody & McIntosh, 2011).

While our results show an influence of the nonconscious face primes on participants' facial muscle activation, there was no evidence for a behavioural influence (i.e., no significant effect on the subsequent ratings of Chinese character) or for a relationship between facial and behavioural responding (i.e., participants' smiling/frowning tendencies on individual trials did not predict more positive/negative evaluations on the same trial). Since embodiment theories of emotion propose that evaluative decisions can be influenced by the state of one's facial muscles via proprioceptive feedback (e.g., Davis, Senghas, & Ochsner, 2009; Larsen et al., 1992), it would be of great interest to better understand the relation between these factors in nonconscious priming. Foroni and Semin (2011) found that nonconscious emotional faces ceased to influence subsequent behavioural evaluations when participants' spontaneously occurring facial reactions were suppressed via a muscle interference task. In line with the current results, Rotteveel et al. (2001) found facial reactions towards nonconscious emotional faces (using backward masking) but no influence on subsequent ratings of ambiguous stimuli. Note that both Rotteveel et al. (2001) as well as the current study relied on EMG measurements of naturally occurring facial activation (which tends to be very subtle, see Tassinary & Cacioppo, 1992), while Foroni and Semin (2011) employed artificially induced, comparatively strong muscle tension. Thus, it might be possible that muscle activation needs to reach a certain level of intensity before it can influence the behavioural consequences of a nonconscious priming procedure. The current data should not be interpreted as a clear rejection of facial feedback theories, as the Bayes Factor analysis indicates that (despite our substantial sample size, N = 108) the behavioural results, although non-significant, do not present strong evidence for the null hypothesis (but might, for example, be due to statistical insensitivity, see Dienes, 2014).

It is possible that both the absence of a behavioural effect and the failure to observe a significant relationship between facial reactions and behaviour reflect a relatively weak influence by the nonconscious primes. More specifically, it has been suggested that different aspects of emotions, such as bodily and behavioural reactions, are more likely to show synchronous response patterns with each other in more intense emotional episodes (cf. Mauss et al., 2005). For example, Rosenberg and Ekman, (1994) found that participants' facial reactions showed more pronounced relations with their affective ratings when they were in stronger emotional states. In contrast, nonconscious priming typically results in relatively subtle effects (cf. Sato et al., 2008). In the present study, the differential response of participants' facial muscles reached an effect size of η_p^2 = .06, or a small to medium effect, according to Cohen (1992; see also Richardson, 2011). Thus, looking into approaches to increase the impact of parafoveal primes might lead to both a higher chance of the priming translating into a measurable behavioural effect and to the possibility of observing a relationship between facial reactions and ratings. In this respect, it might be informative to compare the methodological details of the current experiment with previous GCC experiments that did find an effect of emotional primes on subsequent character ratings (but did not measure participants' facial reactions; Faivre, Berthet, et al., 2012; Kouider et al., 2011).

One potentially relevant difference between the current and previous GCC studies concerns the placement and possible side-effects of the prime awareness trials (i.e., trials testing for prime awareness by asking people to try to classify the parafoveal expressions). Where previous studies (Faivre, Berthet, et al., 2012; Kouider et al., 2011) presented these prime identification trials randomly interspersed with the main character rating trials, in the current experiment, the awareness test was conducted in one block at the end of the procedure. Since it has been shown that increased mental and/or physical effort can induce tension in the facial muscles (de Morree & Marcora, 2012; Topolinski & Strack, 2015), we wanted to avoid the possibility that participants' on-going efforts to identify the prime faces during the priming procedure could create additional muscle tension. We therefore chose to assess awareness in a separate block after the main priming trials. However, the inclusion of awareness test trials in the main test phase of earlier studies could have arguably increased participants' attention towards the faces and/or the relevance of their emotional content for the rating task. Such an assumption would be in line with earlier investigations of nonconscious priming that found that focussing participants' attention towards primes increases their effect on subsequent behavioural measures (Naccache, Blandin, & Dehaene, 2002; Schubert, Palazova, & Hutt, 2013; see also Kiefer, Adams, & Zovko, 2012), as well as with studies that only found emotion-related effects when the task context emphasized the affective relevance of the primes (Eckstein & Perrig, 2007; Spruyt, de Houwer, Everaert, & Hermans, 2012). Note that in all of these studies increased effects were observed, despite participants remaining unaware of the primes. Future experiments could more directly probe the relevance of prime identification trials in nonconscious priming paradigms by varying their occurrence (intermixed with the character-rating trials versus after them) as a between-subject factor. In general, investigations into factors that might increase the effects of parafoveal priming would be beneficial from a methodological point of view, by increasing statistical power, and would also help to address the important theoretical question as to which factors moderate our reactivity to non-conscious facial and emotional primes.

To conclude, our results demonstrate that GCC can be employed to induce affect-related facial reactions via nonconscious emotional expressions. Moreover, these facial reactions can occur in the absence of significant behavioural effects on pleasantness ratings or a relationship between these two measures.

Chapter IV: Embodiment and emotional faces - When do our facial reactions predict how we evaluate others' expressions?

Abstract

Theories of embodiment suggest that we rely on feedback from our own facial muscles to interpret others' facial expressions. The current study investigated under which circumstances observers' facial muscle tension is related to affective decisions about emotional expressions. Participants viewed faces that were either clear (happy/angry) or ambiguous in their valence (neutral/surprised), while their spontaneous facial reactions in the zygomaticus ('smiling') and corrugator ('frowning') muscles were measured via electromyography (EMG). Participants rated either their own emotional reactions towards the faces (self-rating, Experiment 1) or the emotional state of the expression sender (other-rating, Experiment 2). Additionally, sensitivity towards participants' own body signals was assessed via a heartbeat tracking task. More smiling and less frowning predicted higher ratings of participants' own emotional reactions for both happy and angry faces, but not for ambiguous faces. For clearly valenced faces, there was no consistent evidence for a relation between facial activity and evaluations of the sender's affective state. For participants with higher body sensitivity (i.e., greater interoceptive accuracy), more frowning predicted more negative interpretations of ambiguous expressions, an effect that was not present in individuals with low interoceptive accuracy. These results suggest that spontaneous facial reactions reflect our own affective reactions, but that they are not generally involved in our interpretations of others' facial expressions. People more sensitive to their own bodily activity might, however, rely on feedback from their facial muscles when having to interpret ambiguous social stimuli.

Introduction

Successfully interacting with other human beings often demands making estimates about their current feelings. Others' facial expressions are an important source of information concerning their emotions. How do we make inferences about how someone feels from looking at his or her face? Simulationist or embodiment theories assume that we partly rely on the activity of our own facial muscle to interpret facial expressions (Goldman & Sripada, 2005; Hatfield et al., 1994; Niedenthal et al., 2010). To evaluate the merit of such theories, it is important to investigate under which circumstances the state of our facial muscles (e.g., the tension in our smiling or frowning muscles) can predict our evaluative decisions related to the expression we observe. The current study investigated the relation between observers' spontaneous facial reactions towards emotional expressions and their affective judgments, and the extent to which it depends on the focus of the judgment (rating of one's own emotional reaction versus rating of the emotional state of the expression sender), the ambiguity of the expression (clearly valenced expressions versus ambiguous expressions), and the observer's ability to perceive his or her own body signals (as measured using the heartbeat tracking task to determine individual differences in interoceptive accuracy; Schandry, 1981).

According to theories of embodiment, our own bodily activation facilitates the processing of emotionally relevant information and influences its interpretation (Niedenthal, 2007). In the case of the interpretation of facial expressions, it has been argued that we rely at least partly on *facial feedback* (McIntosh, 1996; Strack et al., 1988). That is, the afferent feedback from our own facial muscle tension might influence our judgments about others' faces (Goldman & Sripada, 2005; Hatfield et al., 1993; Maringer et al., 2011). Since in this case we would rely on our facial muscles to interpret someone else's expression, this proposed process is sometimes called an embodied simulation (Niedenthal et al., 2010, 2009). To test for a causal influence from facial activation on affective interpretations, some previous studies actively manipulated participants' facial muscle tension. It was found that when participants were performing overt smiles or frowns, they tended to judge the emotional impact of affective stimuli as more positive or negative (Davis et al., 2009; Larsen et al., 1992; Strack et al., 1988). Importantly, such an influence on emotional evaluations has also been shown for both ambiguous and nonambiguous facial expressions (Dimberg & Söderkvist, 2011). When participants' spontaneous facial movements were blocked (e.g., by asking them to press their lips together to prevent smiles), it was found that recognition of matching facial expressions was impaired (Lobmaier & Fischer, 2015; Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Stel & Knippenberg, 2014, but see Kosonogov, Titova, & Vorobyeva, 2015). These results would support the view that that facial muscle activation can influence the interpretation of facial expressions. As such experiments have relied on artificially induced strong muscle movements, the question remains as to whether their results imply that naturally occurring, often more subtle facial activation plays a relevant factor in the interpretations of facial expressions that we perform in daily life.

Several studies have found that that seeing others' facial expressions can trigger spontaneous changes in our facial muscle tension, with most studies finding that expressions with a clear valence elicit a congruent reaction (e.g., Dimberg & Thunberg, 1998; Sato, Fujimura, & Suzuki, 2008; for a review and discussion of the influence of the social context, see Hess & Fischer, 2013). More specifically, happy face stimuli, as compared to angry face stimuli, tend to elicit more activation in the zygomaticus major (the muscle mainly responsible for smiling) and less activity in the corrugator supercilii (mainly responsible for frowning). Such *rapid facial reactions* (RFRs; Moody, McIntosh, Mann, & Weisser, 2007) seem to occur automatically (Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002) and are initiated relatively quickly (e.g., within the first second after the presentation onset of facial displays, see Dimberg & Thunberg, 1998). Importantly, in contrast to the strong, overtly visible movements in facial feedback studies, most spontaneously occurring RFRs evoked by viewing others' facial expressions are comparatively weak and do not lead to visible movements (Cacioppo et al., 1986; Tassinary & Cacioppo, 1992). Thus, it might be possible that only relatively strong, but not the arguably more common, subtle RFRs, are capable of influencing interpretative tendencies.

The relation between naturally occurring facial reactions and our evaluations of emotional expressions can be investigated by recording spontaneous RFRs towards emotional expressions via electromyographic measurements (EMG; Hess, 2009; Tassinary, Cacioppo, & Vanman, 2000) and testing if these predict participants' expression evaluations. While this approach does not allow us to draw definite conclusions concerning the causal influence of face activation on affective evaluations, it does test predictions of embodied simulation accounts under more ecologically valid conditions. Results of studies investigating the role of naturally occurring RFRs have been equivocal, with some experiments finding a relationship between facial activation and face interpretations (Sato et al., 2013; Tottenham et al., 2013), while others did not find evidence for such a link (Blairy, Herrera, & Hess, 1999, Exp.1; Hess & Blairy, 2001). While previous studies differed widely in the specifics of their evaluative tasks, as well as the types of expressions that had to be evaluated, they have usually taken a participant-wise approach to analysis. That is, after measuring RFRs and scores on a rating task on a number of trials with different facial expression stimuli, they investigated whether participants' average muscle reactions predicted their average tendency to interpret expressions in a certain way. For example, they examined whether a person who tends to frown more on average is more likely to interpret faces as negative. Such a finding would be consistent with simulationist theories of face interpretations. The participant-wise approach does not, however, guarantee that facial activity predicts ratings of individual expressions. For example, it might be that participants who tend to frown more might also be more likely to give more negative ratings, but that increased frowning and negative interpretations do not occur for the same expressions (i.e., on the same trial). It would be necessary to establish a trial-wise relation between facial activation and interpretations in order to support the assumption that we rely on facial activation in our evaluations of facial expressions. Thus, while previous studies mostly investigated participant-wise averaged relationships between facial activation and evaluative tendencies for facial expressions, we tested for a trial-wise relation (i.e., if changes in facial activation evoked by an individual facial expression stimulus predicted its evaluation).

While previous findings have suggested the possibility that facial activation can influence our interpretation of facial expressions, it has been pointed out that the extent and boundary conditions need to be explored more closely (cf. Maringer et al., 2011; Niedenthal et al., 2010). Should embodiment theories assume that facial feedback is a central and general mechanism, or is it rather a special case for how we interpret facial expressions? We investigated the relationship between spontaneously occurring facial reactivity and judgements of the observer's own emotional reactions (Experiment 1), or his or her interpretation of the sender's expressed emotional state (Experiment 2), for both clearly valenced and ambiguous expressions. By employing a heartbeat tracking task, we also tested whether the relation between muscle reactions and affective interpretations might be moderated by individual differences in sensitivity towards bodily feedback.

Social stimuli, like facial expressions, involve two affective processes: the emotional state presented by the sender, and the emotional reaction that his or her expression elicits in the observer. The observer’s affective state and his or her judgements about the sender’s state are often likely to be related, either because of mood contagion from sender to observer (Hatfield et al., 1993) or because of the observer’s emotional bias in interpreting the sender’s expression (Bouhuys et al., 1995; cf. Blanchette & Richards, 2010; Forgas, 1995; for experimental dissociations between sender's and observer's affective state, see Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008; Weyers, Mühlberger, Kund, Hess, & Pauli, 2009). Crucial for embodiment theories, however, is whether facial reactivity is related to an observer’s own emotional state, his or her interpretation of the sender’s feelings, or both. Accordingly, we conducted two experiments: In a first study, we investigated the relation between facial reactions and self-report about one’s own emotional reactions towards facial expression stimuli (self-judgement, Experiment 1). In the second study, we tested for a relation between muscle activation and ratings of the emotional state of the expression sender (other-judgment, Experiment 2).

The relevance of facial feedback might be different when interpreting ambiguous social signals, as compared to relatively clear social signals. Earlier theories (Hatfield et al., 1993) suggested that facial feedback can support the interpretation of clearly valenced expressions (e.g., a clearly angry face), since in this case, matching RFRs in the observer (e.g., reacting with a frown to an angry face) would be potentially informative concerning the sender’s mood state (but note that in social situations the degree of ambiguity does not only depend on the expression as such, but also on the context in which it occurs; Maringer et al., 2011; Wieser & Brosch, 2012). For the interpretation of more ambiguous social signals, additional information is usually taken into account (Kim et al., 2004; Neta, Davis, & Whalen, 2012; Richards et al., 2002). Theories of embodiment suggest that our current bodily states can function as a contextual variable that influences our judgments in situations of uncertainty (Briñol & Petty, 2008; Damasio, 1996; Sütterlin, Schulz, Stumpf, Pauli, & Vögele, 2013). Thus, facial feedback might be relevant for the interpretation of ambiguous stimuli. In line with this view, some previous studies have found that participants who, on average, elicited stronger corrugator activation were also more likely to interpret ambiguous faces as negative (Neta et al., 2009; Tottenham et al., 2013). The current study investigated the relationship between RFRs and evaluative judgements for both clearly valenced (happy/angry) expressions and expressions that were ambiguous in valence (neutral faces and expressions of surprise, which can be elicited by both positive and negative events; see Kim, Somerville, Johnstone, Alexander, & Whalen, 2003; Topolinski & Strack, 2015).

The relation between facial activation and evaluative decisions might also depend on a person's ability to perceive his or her own bodily feedback. One approach for assessing such individual differences is the heartbeat tracking task (Schandry, 1981). This test evaluates participants' so-called interoceptive sensitivity by measuring their ability to correctly perceive their own heartbeats without manually measuring their pulse. Thus, in this context, sensitivity refers to participants' objective performance in a perception task ('interoceptive accuracy'), and not to their subjective impressions of how prevalent body sensations feel to them ('interoceptive sensibility'; see Garfinkel et al., 2016). Previous studies found that performance on this test predicted the sensitivity to other bodily phenomena (Herbert, Blechert, Hautzinger, Matthias, & Herbert, 2013;

Tsakiris, Tajadura-Jiménez, & Costantini, 2011), especially when they were related to emotional processes (Barrett, Quigley, Bliss-Moreau, & Aronson, 2004; Herbert, Herbert, & Pollatos, 2011; Pollatos, Kirsch, & Schandry, 2005). Concerning facial expressions, Terasawa, Moriguchi, Tochizawa, and Umeda (2014) found that people with higher scores on the heartbeat task were better at identifying subtle emotional expressions. Thus, the current study employed heartbeat perception as an approximation of body sensitivity, to test whether performance on this test might moderate the relation between bodily (here: facial muscle) reactions and evaluative decisions about facial expressions.

Overall, the current study tested the prediction of the embodied simulation account that RFRs elicited by facial expressions should be related to the emotional evaluations of those faces. For that purpose, participants were presented with pictures of expressions, and their ratings of affective value, as well as their corrugator (frowning) and zygomaticus (smiling) muscle responses, were recorded. If participants based their decisions on facial feedback, higher zygomaticus/corrugator activation should predict more positive/negative ratings. While previous studies mostly investigated this question with respect to differences between participants (e.g., if participants that, on average, smile more often are more likely to make positive evaluations; see Blairy et al., 1999; Hess & Blairy, 2001; Neta, Norris, & Whalen, 2009; Sato et al., 2013), the current experiments tested for trial-wise relations (i.e., if facial reactions towards an individual expression could predict ratings for that specific face). We investigated the presence of such a relation for both the evaluations of one's own emotional reaction (Experiment 1) and the emotional state of the person presented (Experiment 2). Finding a relationship between muscle activity and self-judgment would be consistent with the idea that RFRs might reflect, or even casually influence, the observer's emotional state. If RFRs could influence the interpretation of the sender's expression, one would expect a muscle-rating relationship for other-judgments.

In both experiments, we included expressions that were either clear in their valences (happy/ angry) or strongly ambiguous (neutral/surprised). It might be possible that we rely on facial activation to evaluate both clearly valenced expressions (where a facial reaction congruent with the expression could facilitate its interpretation) and ambiguous expressions (where our facial activity could function as a contextual factor influencing our judgment). Additionally, we included a heartbeat tracking test as a measure of body sensitivity. If one's muscle activation was capable of influencing evaluative judgements, one could expect that the relation between RFRs and evaluations would be stronger for people who more accurately perceived signals from their bodies.

Experiment 1

Method

Participants

Participants were 98 students from the University of Sussex, taking part for course credit or a financial reimbursement of £ 6. One participant had to be excluded due to an equipment failure, resulting in a sample of 97 students (71 female), with a mean age of 20.77 years (SD = 5.02).

Materials

Face pictures were taken from the Karolinska Directed Emotional Faces Database (Lundqvist, Flykt, & Öhman, 1998) and consisted of photos of 30 actors, each with two clearly valenced (happy/angry) expressions and two potentially ambiguous expressions ('neutral', i.e., no facial muscle movement/surprised), resulting in 120 stimuli in total. Stimuli were presented on a 22’ 120 Hz LCD Monitor (SAMSUNG 2233RZ).

Procedure

Participants were seated in front of the monitor with a viewing distance of approximately 60 cm. The experiment started with the administration of a heartbeat tracking task modelled after the procedure used by Garfinkel, Seth, Barrett, Suzuki, and Critchley (2015). The task consisted of six trials of varying lengths (25, 30, 35 40, 45, and 50 seconds) in randomized order. For each trial, participants were asked to count their own heartbeat, without manually checking their pulse. The beginning and end of the counting period were indicated by the presentation of the words START and STOP in the middle of the screen. After the STOP signal, participants had to type in the number of heartbeats they had detected via keyboard. They did not receive any feedback about the accuracy of their estimates.

The main phase of the experiment consisted of viewing and rating each face picture in randomized order. Each trial began with the presentation of a fixation cross in the middle of the screen for one second, followed by one of the pictures at the same position for two seconds. After this interval, a mouse cursor and a quasi-continuous scale with the anchors *very negative* and *very positive* appeared directly below the picture. Participants were instructed to select a position on the scale via mouse click that represented “how viewing this person makes you feel right now”. Depending on the position they chose, a rating between -250 (*very negative*) and +250 (*very positive*) was recorded. Participants did not receive any numerical feedback about their ratings. After each rating, there was a pause of two seconds before the next trial started.

Measurement setup

In order to count participants' number of heartbeats during the heartbeat tracking task, pulse was measured via a photoplethysmogram transducer (Biopac SS4LA) attached to the left index finger. Facial EMG was measured with 4 mm AG/AG-Cl touch-proof electrodes (Biopac EL254S) filled with conductive gel (Biopac GEL 100). In order to reduce resistance, participants' skin was first cleaned with Nuprep skin preparation gel. Electrodes were then placed on the regions of interest for the measurement of corrugator and zygomaticus activity, following the guidelines by Fridlund and Cacioppo (1986). A Biopac MP36 measurement system with a sample rate of 2000 Hz was used to record both the pulse and the EMG signal.

Results

Data preprocessing

The recorded pulse data was used to count the number of heartbeats during the heartbeat tracking task. For each of the six trials, participants' interoceptive accuracy was calculated by comparing their heartbeat estimates with the actual number of heartbeats. More specifically, the following formula was used (following Garfinkel et al., 2015) to generate a sensitivity score (with higher scores meaning more accurate estimates) for each trial: $1 - (|nbeats_{actual} - nbeats_{estimate}|)/((nbeats_{actual} + nbeats_{estimate})/2)$. Scores from all six trials were averaged, resulting in an overall measure of a participant's ability to perceive his or her own heartbeat, which for the purpose of this study was operationalized as an estimate of body sensitivity.

Facial EMG data was filtered (high pass: 10 Hz, low pass: 500 Hz) to attenuate noise artefacts, then processed with a moving-average integrator with a window size of 100 samples. For each muscle site separately, activation during each trial's two-second viewing period was averaged and then baseline-corrected by subtracting the mean activation one second directly before trial onset. Z-scores of the resulting values were calculated, so that each final value represented the magnitude of change in EMG activity during a trial, relative to the average change during all of a participant's trials. To account for outliers due to movement artifacts, trials deviating more than 2.5 standard deviations from the mean were excluded (2.53% of all trials).

Table 4.1

Mean (and standard deviations) of facial reactions towards and ratings of the facial stimuli, expressed as z-scores.

	Experiment 1 (Self-Rating)			Experiment 2 (Other-Rating)		
	Corrugator	Zygo-maticus	Rating	Corrugator	Zygo-maticus	Rating
Happy	-0.032 (0.17)	0.088 (0.12)	1.031 (0.30)	-0.087 (0.19)	0.105 (0.14)	1.270 (0.12)
Angry	0.038 (0.15)	0.053 (0.10)	-0.793 (0.31)	0.075 (0.15)	0.038 (0.11)	-1.041 (0.23)
Neu-tral	0.133 (0.17)	0.044 (0.15)	-0.282 (0.26)	0.087 (0.13)	0.037 (0.12)	-0.243 (0.21)
Sur-prised	0.039 (0.16)	0.059 (0.12)	0.044 (0.23)	0.088 (0.14)	0.042 (0.12)	0.015 (0.20)

Ratings of face pictures

Table 4.1 contains the means and standard deviations of participants' ratings of their emotional reactions towards the face stimuli, expressed as z-scores. A one-way ANOVA, with expression type (happy/angry/neutral/surprised) as the within-subject factor, revealed a main effect of the expressions on the ratings, $F(3, 288) = 553.71$, $p < .01$, $\eta_p^2 = .85$. Clearly valenced happy pictures led to significantly more positive ratings than did angry, $t(96) = 31.69$, $p < .01$, d = 3.22, neutral, $t(96) = 31.69$, $p < .01$, d = 3.22, and surprised ones, $t(96) = 23.34$, $p < .01$, d = 2.37. Angry pictures led to significantly less positive ratings than both neutral, $t(96) = -10.75$, $p < .01$, d = -1.09, and surprised pictures, $t(96) = -20.66$, $p < .01$, d = -2.10. Among the ambiguous expressions, neutral ones were associated with significantly lower ratings than were surprised ones, $t(96) = -7.25$, $p < .01$, d = - 0.74.

Facial activity during picture viewing

Means and standard deviations of the facial reactions evoked by the different picture types are shown in Table 4.1. Concerning the zygomaticus ('smiling') muscle, a one-way ANOVA with expression type as the within factor indicated a main effect of expression on the induced change in muscle activity, $F(3, 288) = 3.10$, $p = .03$, $\eta_p^2 = .03$. Happy faces induced marginally significantly more zygomaticus activation than did angry faces, $t(96) = 2.44$, $p = .09$, d = 0.25, and significantly more activation than did neutral expressions, $t(96) = 3.04$, $p = .02$, d = 0.31, with no significant difference between happy and surprised ones, $t(96) = 2.17$, $p = .18$, d = 0.22. There was no difference in zygomaticus activity between angry, surprised, and neutral pictures (all p-values > .4). For the corrugator ('frowning') muscle, we found an analogous main effect on expression type on its activation, $F(3, 288) = 14.57$, $p < .01$, $\eta_p^2 = .13$. Happy faces induced marginally significantly less corrugator activity than did angry expressions, $t(96) = -2.67$, p = .053, d = -0.27, significantly less than did neutral, $t(96) = -6.63$, p < .01, d = -0.67, or surprised expressions, $t(96) = -2.85$, p = .03, d = -0.29. There was a significant difference in corrugator activation between angry and neutral pictures, $t(96) = -3.64$, p = .03, d = -0.37, as well as between neutral and surprised pictures, $t(96) = 3.73$, p = .02, d = 0.38, but none between angry and surprised expressions, $t(96) = -0.04$, p > .90, d = 0.01.

Relationship between facial activity and ratings

To test for a trial-wise relation between facial activation and ratings, we employed a multi-level regression, which allowed for the inclusion of all individual trials in the model, while treating different participants as a cluster variable (i.e., controlling for the fact that participants might have different patterns of RFRs and ratings; see Hayes, 2006; Richter, 2006). Predictors in our model were corrugator and zygomaticus activation of each trial, with the corresponding rating as the outcome. In order to investigate a possible difference between clearly valenced and ambiguous expressions, we tested for a moderation of the muscle-rating relationship by ambiguity by including ambiguity as a dummy-coded variable (with 0 = clear valence, 1 = ambiguous) and its interaction term with corrugator and zygomaticus in the model in a separate step (cf. Aguinis, Gottfredson, & Culpepper, 2013; Richter, 2006). This analysis revealed that overall higher zygomaticus reactions, b = 0.102, SE = 0.019, $t(11040) = 5.25$, p < .001, and lower corrugator reactions, b = -0.083, SE = 0.011, *t*(11040) = -7.28, $p < .001$, predicted significantly more positive ratings. This relation was qualified by both a significant zygomaticus*ambiguity interaction, b = -0.102, SE = 0.038, *t*(11040) = -3.12, $p < .001$, and by a corrugator*ambiguity interaction, b = 0.063, SE = 0.023, *t*(11040) = 2.77, p = .001, suggesting that the muscle-rating relationship was stronger for clearly valenced pictures. Coefficients of the regression models for the individual expression types are shown in Table 4.2. Within the clearly valenced pictures, both happy and angry expressions showed significant regression weights for both muscles. Within the ambiguous pictures, there was marginal evidence (p = .057) for a negative relation between corrugator activation and ratings for the surprised pictures, but not for the zygomaticus, or for any of the muscles for the neutral stimuli. Thus, for clearly valenced pictures, muscle activation could predict within-expression differences in ratings (i.e., differences in ratings of pictures of the same valence), whereas for ambiguous expressions, there was almost no evidence for a muscle-rating relationship.

Table 4.2

Coefficients (and standard errors) for the regression of ratings on corrugator and zygomaticus activation for individual picture types.

	Experiment 1 (Self-Rating)			Experiment 2 (Other-Rating)		
	Intercept	Zygomaticus	Corrugator	Intercept	Zygomaticus	Corrugator
Happy	1.025*** (0.03)	0.085*** (0.03)	-0.053** (0.02)	1.260*** (0.01)	0.036* (0.02)	-0.014 (0.01)
Angry	-0.799*** (0.03)	0.058* (0.03)	-0.053** (0.02)	-1.045*** (0.02)	0.020 (0.01)	0.008 (0.01)
Neu-tral	-0.281*** (0.03)	-0.018 (0.03)	-0.013 (0.02)	-0.241*** (0.02)	0.021 (0.02)	-0.015 (0.01)
Sur-prised	0.042 (0.03)	0.039 (0.03)	-0.031 (0.02)	0.012 (0.02)	0.057* (0.02)	- 0.028 (0.02)

* p< .05, ** p < .01, *** p < .001

Influence of body sensitivity on muscle-rating relationship

The average score on the heartbeat tracking task was M = 0.51, SD = 0.27. In order to investigate whether the relation between facial activity and ratings depended on participants' body sensitivity, we tested whether their sensitivity scores moderated the relationship between muscles and the pictures by including body sensitivity, and its interaction with the corrugator and zygomaticus muscles, as predictors in the model. We also investigated a possible difference in the moderating effect of body sensitivity between clearly valenced and ambiguous expressions, by testing for a three-way interaction between muscle activation, body sensitivity, and ambiguity in a separate step. There was neither a significant zygomaticus*sensitivity interaction, b = 0.004, SE = 0.070, $t(11040) = -0.64$, p = .52, nor a significant corrugator*sensitivity interaction, b = -0.068, SE = 0.043 $t(11040) = -1.57$, p = .12. In both cases, the corresponding muscle*sensitivity*ambiguity interaction term was not significant either (all p-values > .2). Thus, body sensitivity did not moderate the relation between facial activation and ratings for either clearly valenced or ambiguous expressions.

Discussion

We found consistent evidence for a relationship between facial activation and participants' ratings of their own emotional reactions towards clearly valenced facial expressions. Importantly, corrugator and zygomaticus activation could predict differences in ratings between expressions of the same type (e.g., between a slightly more or less happy-looking person).

Among the ambiguous faces, neutral faces lead, on average, to more negative reactions than surprised ones, corroborating a similar finding by Tottenham et al. (2013, see also Tottenham et al., 2009). This might reflect the possibility that blank, expressionless faces are less common and could be perceived as less engaging in social interactions (c.f. Leekam, Solomon, & Teoh, 2010). Importantly, both neutral and surprised faces were, on average, rated as less positive than were happy faces, but as more positive than were angry ones, confirming the assumption that their valence is less clear. As found previously (Topolinski & Strack, 2015; Vrana & Gross, 2004), RFRs towards ambiguous expressions and negative expressions were similar. Task demand has been linked to negative affect in general (Winkielman, Schwarz, Fazendeiro, & Reber, 2002), and to less smiling and more frowning in particular (Galak & Nelson, 2011; Topolinski & Strack, 2009; Winkielman & Cacioppo, 2001). Thus, RFRs towards ambiguous expressions could partly reflect the increased difficulty of interpreting such facial displays. Importantly, no evidence for a relation between participants' RFRs and their self-reported emotional reactions was found. One reason might be that in this case, making emotional judgements could be expected to be more challenging, and thus, facial reactions due to increased task demand are more likely to be a confounding factor. It has also been suggested that the likelihood of a coherence between subjective feelings and bodily aspects of emotional reactions (such as the RFRs measured here) increases in more intense emotional episodes (Rosenberg & Ekman, 1994; cf. Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Participants' subjective ratings towards ambiguous faces were significantly less positive than their ratings towards happy faces, and significantly less negative than their ratings towards angry ones. Thus, the changes in emotional states evoked by stimuli without a clear valence might have been too feeble to be generally reflected in facial muscle activity.

For both ambiguous and clearly valenced expressions, the relation between facial reactions and subjective ratings was not moderated by participants' heartbeat tracking score, suggesting no special influence of individual differences in body sensitivity here. Overall, the results are consistent with the view that facial reactions reflect, or even causally influence, our own emotional reactions towards clearly valenced facial expressions. For simulationist accounts concerning the affective interpretation of others' faces, it would be crucial to specify under which conditions a relation can be found between facial activation and judgements of the affective state. This question was considered in a second experiment that also employed a face-rating task, but that asked participants to evaluate the expression sender's current emotional state.

Experiment 2

Method

Participants

Participants were 96 students from the University of Sussex, taking part for course credit or a financial reimbursement of £ 6. Only students who had not taken part in Experiment 1 were eligible for the study. Data of one participant was not analysed, as after the experiment, the person expressed that he or she had not understood the task instructions, due to a lack of proficiency in English. Furthermore, four participants had to be excluded due to equipment failures, resulting in a sample of 91 students (65 female) with a mean age of 21.43 years (SD = 4.03 years).

Materials and procedure

Materials and procedure were identical to Experiment 1, except for the instructions for the rating task. While in Experiment 1 participants had to rate "how viewing this person makes you feel right now", they were now asked to indicate "how this person is feeling right now".

Results

Data preprocessing

See Experiment 1.

Ratings of face pictures

Ratings followed a similar pattern as in Experiment 1 (see Table 4.1). A one-way ANOVA with expression type (happy/angry/neutral/surprised) as the within-subject factor again showed a significant main effect on the ratings, $F(3,270) = 1676.16$, $p < .01$, $\eta_p^2 = .95$. Clearly valenced happy pictures were rated as significantly more positive than were clearly angry ones, $t(90) = 82.60$, $p < .01$, $d = 8.66$. Ratings for both types of ambiguous pictures were significantly less positive than ratings for happy pictures, neutral: $t(90) = 59.07$, $p < .01$, $d = 6.19$, surprised: $t(90) = 42.60$, $p < .01$, $d = 4.47$, and significantly more positive than ratings for angry ones, neutral: $t(90) = 18.83$, $p < .01$, $d = 1.97$, surprised: $t(90) = 28.97$, $p < .01$, $d = 3.04$. As in Experiment 1, neutral expressions were rated as less positive than were surprised ones, $t(90) = -7.62$, $p < .01$, $d = -0.80$.

Facial reactivity during picture viewing

Mean facial reactions are shown in Table 4.1. For the zygomaticus, a one-way ANOVA with expression type as within factor indicated a significant main effect of expression on muscle activation, $F(3, 270) = 8.74$, $p < .01$, $\eta_p^2 = .09$. Happy faces led to significantly more zygomaticus activity than did angry faces, $t(90) = 3.81$, $p < .01$, $d = 0.40$, neutral faces, $t(90) = 3.88$, $p < .01$, $d = 0.41$, and surprised faces, $t(90) = 3.56$, $p < .01$, $d = 0.37$, with no difference in zygomaticus activity between the last three (all p-values $> .4$). There was also a significant main effect of expression type on corrugator activation, $F(3, 270) = 23.91$, $p < .01$, $\eta_p^2 = .21$. For happy faces it was significantly lower than for angry faces, $t(90) = -5.41$, $p < .01$, $d = -0.57$, neutral faces, $t(90) = -6.55$, $p < .01$, $d = -0.69$, and surprised faces, $t(90) = -7.00$, $p < .01$, $d = -0.73$. There was no significant difference in corrugator activation between angry and neutral or surprised pictures (all p-values $> .5$)

Relationship between facial activity and ratings

A regression with corrugator and zygomaticus activation as predictors, and the ratings as outcome, revealed that overall, more zygomaticus activity, b = 0.119, SE = 0.018, $t(10370) = 6.74$, $p < .001$, and less corrugator activity, b = -0.103, SE = 0.012, $t(10370) = -8.56$, $p < .001$, predicted higher ratings. A significant zygomaticus*ambiguity interaction, b = -0.140, SE = 0.035, $t(10370) = -4.00$, $p < .001$, as well as a significant corrugator*ambiguity interaction term, b = 0.144, SE = 0.024, $t(10370) = 6.04$, $p < .001$, indicated that the relation between EMG activity and expression evaluations was stronger for clearly valenced pictures than for ambiguous ones. Summary statistics for the regression models for the individual expression types are shown in Table 4.2. As in Experiment 1, among the ambiguous faces, there was almost no relation between muscle activation and ratings for neutral pictures. For surprised pictures only, the zygomaticus showed a significant positive relation towards the ratings. Concerning the clearly valenced faces, only one significant positive relation between zygomaticus and higher ratings for happy faces emerged. This suggests that the overall significant muscle-rating relationship (i.e., when all expressions are included in the model) reflects broad categorical differences between happy faces (that are associated with high ratings/zygomaticus activation and low corrugator activation) and angry faces (that are associated with low ratings/zygomaticus activation and high corrugator activation). Muscle activation was mostly unable to account for more subtle within-expression differences in ratings.

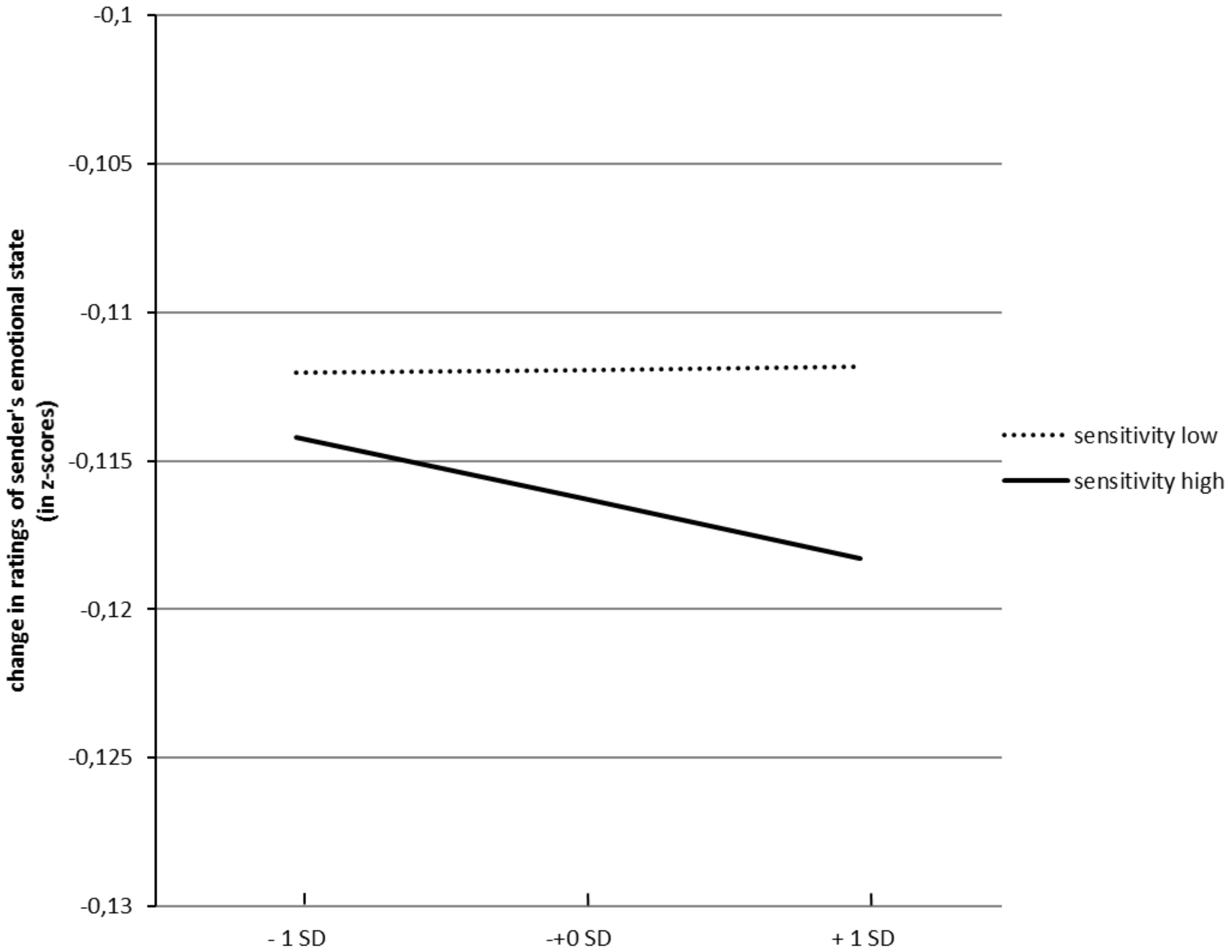

*Figure 4.1.*Mediation of the effect between corrugator activity and face ratings via body sensitivity, represented by regression lines showing the predicted relation between corrugator activity and ratings of ambiguous face stimuli, for higher (n = 43) and lower (n = 48) trait levels of body sensitivity. No mediation effect was found for zygomaticus activity.

Influence of body sensitivity on muscle-rating relationship

We again tested if interoceptive scores (M = 0.49, SD = 0.32) moderated the relationship between the muscles and the pictures, by including this variable and its interaction with corrugator and zygomaticus as predictors in the model. As in

Experiment 1, we tested for a possible difference in the moderating effect of body sensitivity between clearly valenced and ambiguous expressions, by including ambiguity as a dummy-coded predictor and the corresponding interaction terms in a separate step. Overall, there was neither a significant zygomaticus*body sensitivity interaction, b = -0.059, SE = 0.053, *t*(10370) = -1.11, p = .27, nor a corrugator*body sensitivity interaction, b = -0.020, SE = 0.037, *t*(10370) = -0.54, p = .59. The zygomaticus*body sensitivity*ambiguity interaction term was not significant, b = 0.091, SE = 0.011, *t*(10370) = 0.87, p = .38. These results indicate that for both clearly valenced and ambiguous expressions, body sensitivity did not moderate the zygomaticus-rating relationship.

There was a significant corrugator*body sensitivity*ambiguity interaction, b = -0.110, SE = 0.074, *t*(10370) = -2.39, p = .02. This suggests a difference in the moderating effect of body sensitivity between clearly valenced and ambiguous expressions. For clearly valenced pictures, a nonsignificant corrugator*body interaction indicated no influence of body sensitivity on the muscle-rating relationship, b = 0.06, *t*(5178) = 0.88, p = .38. For ambiguous expressions, a significant corrugator*body sensitivity interaction was found, b = -0.105, SE = 0.03, *t*(5137) = -3.23, p = .001. This suggests that as body sensitivity increases, more corrugator activation becomes a better predictor of less positive ratings. To clarify this effect, we separately plotted the relation between corrugator activation and ratings for participants in our sample with higher-than-average body sensitivity, n = 43, b = -0.039, SE = 0.016, *t*(2429) = -2.47, p = .014, and participants with lower-than-average sensitivity, n = 48, b = 0.002, SE = 0.013, *t*(2712) = 0.13, p = .90, see Figure 4.1.

Overall, these results suggest that only for participants with higher body sensitivity scores more frowning activation was a stronger predictor of less positive ratings for ambiguous, but not for clearly valenced stimuli. For both clearly valenced (happy/angry) and ambiguous (neutral/surprised) expressions, there was no difference between the two types of expressions belonging to each category concerning the moderating effect of body sensitivity (all p-values > 2).

Discussion

Experiment 2 tested in how far an observer's facial activation might predict judgements of the expression sender's affective state. While there was a relation between zygomaticus/corrugator activation and more positive/negative ratings when all expression types were included in the analysis, evidence for a relation between muscle activity and within-expression differences was only present in the case of zygomaticus activity predicting more positive evaluations of happy faces, but not for any other muscle or expression type. Thus, overall there was no consistent evidence for a general relation between facial activation and within-expression differentiations concerning evaluations of the sender's affective state. These findings suggest that RFRs are not central or always necessary for expression interpretations. More specifically, based on the current data, it would not be reasonable to assume that we generally rely on our muscles to distinguish between different degrees of the same expression type.

It would still be possible to propose that facial feedback might help us with making basic distinctions between, for example, happy and angry faces. Such a view would only allow only for a very limited role of embodied simulations in the interpretation of facial expressions. Arguably, most people encounter intense prototypical displays of emotions less often in their everyday interactions than more subtly changing expressions, (also depending on culture-specific display rules; see Matsumoto, 1990). As has been argued before (Hess & Blairy, 2001), broad categorical differentiations could probably be achieved more easily by visual pattern matching strategies relying on the clear configurational differences between, for example, prototypical happy and angry expressions (cf. Adolphs, 2002). These reasons seem to favour a more parsimonious interpretation of the current findings, specifically that RFRs were not generally involved in our participants' interpretations of the expression sender's feelings.

Additionally, there was no general relation between facial activation and the interpretation of ambiguous expressions. However, we found evidence for a moderating effect of trait body sensitivity on corrugator activation and the ratings for ambiguous faces. More specifically, higher body sensitivity predicted a higher muscle-rating relationship in this case. This would be compatible with the view that more sensitive people are more likely to rely on their facial activation when trying to interpret ambiguous expressions. Why would body sensitivity only be relevant for the evaluation of ambiguous social signals? While clearly valenced faces often contain sufficient information to determine their valence, resolving ambiguity usually depends on the integration of additional information or heuristics (Aïte et al., 2013; Neta et al., 2012; Russell & Fehr, 1987). Theories of embodiment have proposed that our own bodily states can constitute a contextual factor that we might employ when making decisions under uncertainty (Bechara, Damasio, Damasio, & Anderson, 1994; Briñol & Petty, 2008). One could assume that people who are generally more sensitive to their bodies would be more likely to rely on bodily feedback (here: facial muscle activation) for such decisions, while less sensitive people might instead employ alternative heuristics (e.g., a cognitive interpretation bias; see Eysenck, Mogg, May, Richards, & Mathews, 1991; Mathews & MacLeod, 2005). Following this view, body sensitivity would be less relevant for the interpretation of clearly valenced expressions, as these are less dependent on the integration of additional sources of information. It might be worthwhile to relate these findings to a previous study, which found that the interpretation of the same expression in a socially ambiguous context (as opposed to a nonambiguous situation) might be more likely to rely on facial feedback (Maringer et al., 2011). Integrating these findings would suggest that the potential influence of facial feedback might depend on the overall ambiguity that is created by the interaction of the information value of the expression and the context of its occurrence. Thus, overall we found no consistent evidence for a general incorporation of facial feedback in the interpretation of an expression sender’s feelings, but an indication that facial activation might play a role for more body-sensitive people in their interpretations of ambiguous social signals.

Comparison of Experiment 1 and Experiment 2

With respect to clearly valenced faces, it is noteworthy that Experiment 1 (self-rating) found consistent evidence for a muscle-rating relationship within each expression type, while the same was not true for Experiment 2 (other-rating). While the two experiments were conducted separately and not planned as a between-subject design, we decided to explore whether a difference between the two studies could be substantiated statistically. More specifically, for both happy and angry expressions, we repeated the regression analysis with ratings as the outcome and zygomaticus and corrugator activation as predictors, but we included the zygomaticus*experiment interaction and the corrugator*experiment interaction (0 = self-rating, 1 = other-rating). In both cases, this revealed a significant corrugator*experiment interaction, (happy: b = 0.040, SE = 0.020, $t(5274) = 1.98$, $p = .048$; angry: b = 0.061, SE = 0.032, $t(5209) = 3.01$, $p < .01$), but no significant zygomaticus*experiment interaction, (happy: b = -

0.048, SE = 0.032, *t*(5286) = -1.49, p = .14; angry: b = -0.037, SE = 0.032, *t*(5222) = -1.16, p = .25). For ambiguous faces, no significant differences in muscle-rating relationship between the experiments could be found (all p-values > .2). Thus, we found evidence that the corrugator was a significantly more negative predictor of ratings within the clearly valenced facial categories during self-ratings.

General discussion

The present experiments investigated factors that might determine a relationship between one's own facial muscles and judgements related to other's facial expressions, by asking people to evaluate emotional expression pictures while their corrugator ('frowning') and zygomaticus ('smiling') activation was measured. While earlier studies focussed on participant-wise averaged relations between facial activation and evaluations (e.g., Hess & Blairy, 2001; Sato et al., 2013), we investigated whether facial reactions for individual expressions could predict their evaluations. We tested for a muscle-rating relationship in a context of judgements about participants' own emotional state (self-rating, Experiment 1), and judgments about the emotional state of others (other-rating, Experiment 2). In both studies, we included expression stimuli that were either clear in their valence (happy/angry) or ambiguous (neutral/surprised). Additionally, we employed a heartbeat tracking task as a measure of body sensitivity, to test whether participants who were more sensitive to their bodily feedback might show a stronger relation between their muscle activation and their affective ratings. When asked to evaluate their own emotional reactions (Experiment 1), more smiling and less frowning predicted more positive ratings for clearly valenced pictures. Importantly, activity in both muscles measured could predict differences in rating of the same valence (e.g. differences between slightly more or less positive ratings related to happy faces). There was no consistent evidence for a general muscle-rating-relationship when participants were asked to judge the emotional state of the people presented to them (Experiment 2). For the corrugator, but not for the zygomaticus, this difference in the pattern of results was supported by a comparison between the two experiments. Note that while both experiments employed very similar designs (changing only the rating question), they were not conducted as a between-design experiment (e.g., no random assignment of participants to experimental groups took place). Thus, the results should be interpreted with caution. Future studies could attempt to combine both rating tasks, preferably in a within-subject design, in order to increase power (e.g., by varying the rating task between experimental blocks). The difference in results for the corrugator and the zygomaticus are in line with earlier studies that found that corrugator activation showed more pronounced affect-congruent reactions (Larsen, Norris, & Cacioppo, 2003; but see Moody & McIntosh, 2011). Measurements of the zygomaticus might tend to show lower signal-to-noise ratios (cf. Hess, 2009), for example because of this muscle's proximity to the very prominent jaw muscle. Since lower face muscles are more often involved in voluntary movements (e.g., speaking or social smiles), it is also possible that participants are more likely to inhibit spontaneous facial reactions depending on the experimental context.

As the current experiments relied on spontaneously occurring, subtle facial reactions, it is worth comparing the findings to studies that causally influenced facial activation by requesting voluntary, strong muscle movements. Whereas we found no clear evidence for a relation between spontaneous facial reactivity and evaluations of other people's emotions based on their facial expressions (Experiment 2), previous experiments that causally influenced facial muscle movements found that incongruent muscle movements (but not congruent ones) could impair the classification of matching facial expressions (Neal & Chartrand, 2011; Niedenthal et al., 2001; Oberman et al., 2007). This might suggest that facial activation needs to reach a certain intensity to influence the processing of emotional stimuli.

While Terasawa et al. (2014) found that people with higher scores on the heartbeat tracking task were better at identifying subtle emotions, our results suggest a stronger relationship between their corrugator activity and their interpretation of ambiguous expressions (Experiment 2). This would support the view that people with high body sensitivity are more likely to incorporate their bodily feedback when making judgments under uncertainty. Overall, our results are consistent with the idea that facial feedback is less relevant for the interpretation of others' expressions when a purely perceptual analysis might suffice (cf. Niedenthal et al., 2010).

Further research is needed to investigate the generalizability of the current findings. For example, it should be noted that it is still an open question as to how far sensitivity towards one specific bodily process is an accurate predictor of sensitivity towards other bodily signals (cf. Craig, 2003). While the heartbeat tracking task focuses on the perception of an interoceptive signal, it would be desirable in future studies to more directly measure sensitivity towards facial surface muscle (i.e., proprioceptive) feedback (e.g., by assessing the ability to perceive subtle electric stimulation on the face; for a comparable approach for measuring sensitivity on the hand see Lloyd, Mason, Brown, & Poliakoff, 2008). We chose the heartbeat tracking task because, as compared to other available measures of body sensitivity (cf. Mehling et al., 2009), it is a relatively well validated test that has been linked to sensitivity towards emotional influences in general (Herbert et al., 2011; Katkin, Wiens, &Öhman, 2001; Pollatos et al., 2005; Wiens, 2005) and to the identification of subtle facial expressions in particular (Terasawa et al., 2014).

To conclude, the current study investigated some of the conditions under which spontaneous facial reactions might be related to emotional evaluations of facial expressions. Overall, the current findings support the view that facial feedback should not be seen as a general mechanism for the interpretation of facial expressions, but that its relevance might be limited to specific types of evaluations and personality-dependent differences. Current psychological research has shown a great interest in the interplay between bodily and psychological processes, especially in relation to the processing of emotional information (e.g., Barrett & Lindquist, 2008; Damasio, 2000; Niedenthal, 2007). Specifying the boundary conditions and moderating factors of a relation between bodily states and psychological processes will be an important step in developing a clear understanding of the body’s role in emotional processes and evaluative decisions.

Chapter V: Prolonged priming with affective stimuli leads to opposite effects on facial reactions and behaviour

Abstract

According to theories of embodiment, emotion-related facial activity, such as smiling or frowning, can influence our processing of affective stimuli. This study investigated the possible role of facial muscle feedback in an affective priming procedure. Prolonged presentations of happy or angry prime faces were followed by target faces that participants had to classify as positive or negative. Primes led to congruent facial reactions in participants, i.e. happy prime faces, as compared to angry prime faces, led to increased smiling and decreased frowning in participants. As in previous studies, the prolonged prime presentation led to incongruent behavioural effects in both classification speed and tendency: Happy primes, as compared to angry primes, led to the faster identifications of negative targets, and to an increased likelihood of interpreting targets as negative. The effect of primes on target classification was not mediated by facial activation. Our finding that primes had opposite effects on facial and behavioural outcomes suggests that emotion-congruent influence of facial activation can be overridden by cognitive processes. Overall, our study supports the view that facial activation is not a necessary part of affective evaluations.

Introduction

Seeing someone smiling or frowning can affect us in many ways. Seeing facial expressions can induce behavioural priming effects in the observer (i.e., influence judgments and recognition times of subsequently or simultaneously displayed target stimuli; Stenberg, Wiking, & Dahl, 1998; Winkielman et al., 2005). Seeing facial expressions can also induce bodily priming effects in the observer, such as changes in his or her facial expressions (e.g., Dimberg & Thunberg, 1998; Sato, Fujimura, & Suzuki, 2008). According to theories of embodiment, changes in facial muscle tension can lead to cognitive and behavioural changes, such as our evaluations of affective stimuli (Barrett & Lindquist, 2008; Niedenthal et al., 2005). This would suggest that facial reactions towards emotional primes might partially be responsible for the primes' behavioural effect on target evaluations. The current study employed happy and angry facial expressions as primes and measured their influence on participants' facial muscles, as well as their behavioural effect on participants' evaluations of subsequently presented target faces. We tested whether the behavioural effect of the primes was mediated by facial reactions induced by the primes. Investigating the role of participants' facial reactions towards prime faces in their evaluations of target faces can help to elucidate both the assumption that affective priming effects might partially rely on bodily feedback (Foroni & Semin, 2011; Ito et al., 2006), and theories that our interpretations of facial expressions can be influenced by the state of our facial muscles (Hatfield et al., 1994; Niedenthal et al., 2010).

Previous studies found that the presentation of affective primes, such as facial expressions, can influence behavioural and evaluative tendencies. More specifically, the presentation of happy/angry faces can lead to a faster identification of positive/negative target stimuli (Aguado, García-Gutierrez, Castañeda, & Saugar, 2007; Stenberg et al., 1998). Additionally, happy faces, as compared to angry faces, can make it more likely that an observer interprets a target stimulus as positive, especially when this target stimulus is ambiguous concerning its valence (i.e., could be compatible with both a positive and a negative interpretation; Kouider et al., 2011; Winkielman et al., 2005; Wong & Root, 2003). These are examples of congruent priming, because participants' judgments of the target matches the valence of the prime.

Viewing facial expression can also lead to incongruent behavioural effects (Strobach & Carbon, 2013). For example, some studies have found that positive expressions, as compared to negative expressions, can lead to a *decreased* likelihood of classifying a subsequent target face as positive (Fox & Barton, 2007; Luo, Wang, Schyns, Kingdom, & Xu, 2015; Yang, Hong, & Blake, 2010). Since such incongruent effects have also been found for other visual features (e.g., the gender or identity of a face), this phenomenon has been linked to visual adaptation towards relevant stimulus categories that occurs after observing a stimulus for a longer period of time (Webster & MacLeod, 2011; Webster, 2015). Accordingly, it has been observed that short prime presentations are more likely to lead to congruent priming, while a prolonged presentation of prime faces (e.g., more than 1 s) is more likely to result in incongruent effects. There are, however, also cases where a relatively long prime presentation does result in congruent priming effects (Kouider et al., 2011), suggesting that the exact reasons for incongruent effects might be more complex (Klauer, Teige-Mocigemba, & Spruyt, 2009).

Seeing a facial expression often evokes automatic facial reactions in the observer. Most studies investigating this phenomenon have found that observers' reactions were congruent with the expression they saw (e.g., happy faces, as compared to angry faces, led to more smiling and less frowning; Dimberg & Thunberg, 1998; Sato, Fujimura, &Suzuki, 2008). Such congruent facial reactions have been found to emerge after approximately the first 500 ms of a facial expression's presentation (Dimberg & Petterson, 2000) and usually remain stable over the whole duration of the face presentation, with most studies showing effects on facial muscles for durations of one second or longer. In the context of a priming procedure, such reactions could be described as bodily priming effects.

Is there a relation between such automatic facial reactions and behavioural priming effects? According to some theories of embodiment, afferent signals from facial muscles (so-called *facial feedback*) might influence our interpretations of affective stimuli (Hatfield et al., 1993; McIntosh, 1996). Previous studies have found that when participants had to perform facial movements that either facilitated or blocked emotional expressions, such as smiling or frowning, they were either more likely or less likely to give expression-congruent ratings towards affective stimuli (Larsen et al., 1992; Dimberg & Söderkvist, 2011). Thus, it might be that behavioural effects of priming procedures are at least partially mediated by facial reactions towards prime faces. Consistent with this idea, one study found that a short presentation (~30 ms) of happy versus angry prime faces led to more positive ratings of target stimuli when participants were exposed to primes without any special intervention, while a motor task blocking their naturally occurring facial reactions suppressed this congruent behavioural priming effect (Foroni & Semin, 2011).

Previous studies investigating facial feedback effects often used artificial facial manipulations that led to strong and overt facial muscle movements. This is a suitable approach for investigating the possibility of facial feedback effects, since strong facial manipulations could be expected to maximize any facial muscle effect. Spontaneous facial reactions that people show in real life, however, are often subtle and do not necessarily result in overt expression changes (Tassinary & Cacioppo, 1992). Thus, only relying on strong facial manipulations for studying the impact of facial muscle tension on evaluations might overestimate its role in everyday life. The current study investigated the role of naturally occurring facial reactions in behavioural priming effects. We presented happy and angry prime faces, which were followed by targets that participants had to classify as positive or negative, and we measured changes in participants' smiling (zygomaticus) and frowning (corrugator) muscles evoked by the primes via electromyography (EMG; Tassinary, Cacioppo, & Vanman, 2000). This allowed us to test whether any behavioural prime effect was mediated by participants' facial reactions towards the primes.

While Foroni and Semin (2011) employed a very short presentation of prime faces (ca. 30 ms), we chose to present primes for a prolonged time (1500 ms). Based on previous studies, one could expect that the presentation of expressions for similar durations leads to congruent effects on facial activation (i.e., more smiling and less frowning after happy primes, as compared to after angry primes). Based on embodiment theories, one could assume that matching facial reactions lead to congruent evaluative and behavioural tendencies on the evaluations of subsequently presented targets. However, a prolonged prime presentation has sometimes been found to elicit incongruent behavioural effects. If such a mismatch between facial and behavioural effects was found, this would be directly relevant for assessing embodied interpretations of affective priming. Since theories of embodiment usually assume that facial feedback should have a congruent effect on affective processes (e.g., more smiling should facilitate positive evaluative tendencies; Niedenthal et al., 2005; Winkielman et al., 2015), such a finding would question the idea of direct link between facial expressions and evaluative tendencies. On the other hand, if both a congruent facial and behavioural effect were found, this would be consistent with the proposal that facial feedback might be partially involved in the affective priming effect.

As targets, we employed both facial expressions ambiguous in their valence value (e.g., expressions that have been found to be compatible with both a positive and a negative meaning, such as neutral faces or expressions of surprise; Neta, Norris, & Whalen, 2009; Noordewier, Topolinski, & Van Dijk, 2016) and clearly valenced expressions (clearly happy or angry faces). This was done to allow for a test of both rating tendency and classification speed. Since neutral and surprised expressions do not clearly communicate either a positive or negative emotion, one could expect them to be more amenable towards contextual influences (i.e., an effect on rating tendency might be more likely to emerge for these targets). On the other hand, clearly valenced expressions allowed us to test for facilitation effects of the primes on target identification speed (e.g., the possibility that targets are processed more quickly when they are congruent with the prime; e.g., Aguado et al., 2007) or participants' facial actions (Havas et al., 2007; Stel & Knippenberg, 2014).

Lastly, since people might differ in their susceptibility towards bodily feedback, we performed a heartbeat perception task with each participant prior to the main experiment (Garfinkel et al., 2015; Schandry, 1981). This task measured participants' ability to perceive their own bodily signals (in this case, the interoceptive signal from their heartbeats). It has been suggested that a higher performance on this test might indicate increased sensitivity towards bodily signals, especially when they are related to the processing of affective information (Domschke, Stevens, Pfleiderer, & Gerlach, 2010; Herbert & Pollatos, 2012; Terasawa et al., 2014). Accordingly, if facial feedback was mediating the priming effect, one could assume that the mediated effect would be higher for people with a better performance on this task.

To conclude, the current study investigated the role of facial feedback in affective priming, by measuring affective behavioural priming effects on both classification tendency and speed for ambiguous and clearly valenced target expressions. It was tested whether priming effects were mediated by participants' facial reactions, and whether such an effect might be stronger for people with a greater ability to perceive bodily feedback, as measured with the heartbeat perception test.

Method

Participants

Ninety students from Sussex University took part in the experiment, either for course credit or a financial reimbursement of £ 5. Data on two participants was excluded, in one case due to a measurement error, and in the other case due to the fact that the participant reported feeling tired and started falling asleep during the procedure. This resulted in a sample of 88 participants (63 female) with a mean age of 23.19 years (SD = 5.41 years).

Materials

Target stimuli were taken from the Karolinska Directed Emotional Faces Database (Lundqvist et al., 1998) and consisted of photos from 28 actors (half female/male), each with two clearly valenced (happy/angry) expressions and two ambiguous (neutral/surprised) expressions (i.e., 112 targets in total). Prime stimuli were photos of 14 actors (half female) taken from the NimStim database (Tottenham et al., 2009), with one happy and one angry expression for each of them. As the quality of expressions within any database varies (for previous ratings, see Lundqvist et al., 1998; Tottenham et al., 2009), using a different database for primes and targets made it easier to select a sufficient number of prototypical photos for each expression type. Primes were never used as targets (and vice versa), so that the employment of separate datasets for each would not create a confounding factor. All photos were matched in size and mean brightness.

Procedure

The experiment started with the administration of the heartbeat tracking task, following the procedure reported by Garfinkel, Seth, Barrett, Suzuki, and Critchley (2015). In six trials of varying lengths (from 25 to 50 seconds), participants were asked to count their own heartbeats from the point that the word START appeared on the screen, until the word STOP was shown. Participants were not allowed to touch their own bodies during the counting (e.g., in order to feel their own pulse). After each trial, they indicated the number of heartbeats counted via keyboard.

The main phase of the experiment consisted of two blocks, with each target face shown once per block, resulting in 224 trials overall. Each trial started with the presentation of a fixation cross for 1000 ms. Then a happy or angry prime face was shown for 1500 ms, followed by the presentation of the target face for 100 ms. The order of primes and targets, and the prime-target assignments were randomized for each participant and counterbalanced as follows: Half of the target faces of each emotion were preceded by a happy (angry) prime in the first block, and by the opposite expression in the second block. Primes and targets were always matched in gender, as a switch in gender between prime and target might have produced additional processing interference. Participants were instructed to identify whether the emotion of the target face was either positive or negative as quickly as possible by pressing the left/right arrow button on the keyboard, with the assignment of buttons to emotions counterbalanced between participants. The instructions emphasized that participants should observe both primes and targets, but only classify the latter. To ensure task adherence, participants went through a number of test trials (using primes and targets not employed in the main experiment) until they had correctly identified four nonambiguous target faces in a row. During the main trials, they did not receive any feedback about their decisions, except for a reminder on the screen to “please be quicker” if they took longer than 1.5 seconds on a trial to decide.

Measurement setup

During the heartbeat counting task, a photoplethysmogram transducer (Biopac SS4LA) on the left index finger measured participants’ actual heartbeat, in order to calculate the accuracy of their estimates. Facial EMG was measured with 4 mm AG/AG-Cl electrodes (Biopac EL254S) filled with conductive gel (Biopac GEL 100), positioned according to the recommendations of Fridlund and Cacioppo (1986). Nuprep skin preparation gel was used to lower resistance in the measurement regions. Both EMG and pulse signals were recorded with a Biopac MP36 measurement unit at a sample rate of 2000 Hz.

Results

Data preprocessing

Participants’ performance on the heartbeat counting test was calculated by comparing their heartbeat estimates with the actual number of heartbeats, employing the following formula for each of the test trials: 1 – (|$nbeats_{actual}$-

$nbeats_{estimate}|)/((nbeats_{actual}+nbeats_{estimate})/2)$ (cf. Garfinkel et al., 2015). The average score (with higher scores meaning more accurate guesses) of all trials was calculated and treated as a measure of participants' trait sensitivity towards their bodily signals.

For the main classification task, we excluded trials with markedly long reaction times (reaction times > 2.5 SD of a participant's average, 2.28%), since these were likely to reflect task-irrelevant influences (e.g., temporary inattentiveness; see Ratcliff, 1993).

To evaluate facial reactions evoked by the primes, we averaged the EMG activation for the corrugator and zygomaticus muscles for the last 500 ms of the prime presentation (i.e., the activation directly prior to target onset), and subtracted the baseline activation (i.e., the activation during the presentation of the fixation cross) from this value for each trial. To account for outliers due to movement artefacts, trials deviating more than 2.5 standard deviations from a participant's mean were excluded (4.83% of all trials).

Analysis procedure

A series of regression models was used to test for the following relations: the effect of prime type on zygomaticus and corrugator activation, the overall effect of prime type on classification tendency and speed (i.e., the total effect), and lastly, the effect of primes on behaviour mediated by facial activation (i.e., the mediated effect). To account for the clustering of our data (with several trials for each participant), we based our analysis on hierarchical regression. For analysis of the priming effect on classification tendency, logistic regression was used, since the outcome rating was a binary decision (coded as 0 = negative, 1 = positive). For all categorical predictors dummy coding was used. The binary predictor, prime type, was always coded as 0 =

negative and 1 = positive. Since we assumed that prime effects on classification tendency and reaction times could differ between clearly valenced and ambiguous targets, we included ambiguity (coded as 0 = clearly valenced, 1 = ambiguous), as well as the prime type x ambiguity interaction in the model in a separate step. In cases in which an interaction suggested a difference between these target types, we analysed the two target subgroups separately, also testing for a difference between the two face categories used in each case (for clearly valenced: happy/angry, for ambiguous: neutral/surprised), by including this factor and its interaction in the model in a separate step. The regression models were calculated with the lme4 package in R (Bates et al., 2015). Based on these models, we calculated estimates of the mediation effects with the R mediation library, which estimates the size of mediation effects and their confidence intervals (CI) based on a quasi-Bayesian Monte Carlo approximation (Imai, Keele, Tingley, & Yamamoto, 2010). A mediation effect significantly different from zero would indicate that priming influenced the target evaluations via changes in facial activation. We calculated separate models for corrugator and zygomaticus activation as potential mediators. Mediation effects were calculated both on average for all participants and for each participant independently. This allowed us to regress participants' individual estimates of their mediation effect on their performance scores in the heartbeat counting task, to test whether participants' heartbeat sensitivity predicted the estimated size of their mediation effect.

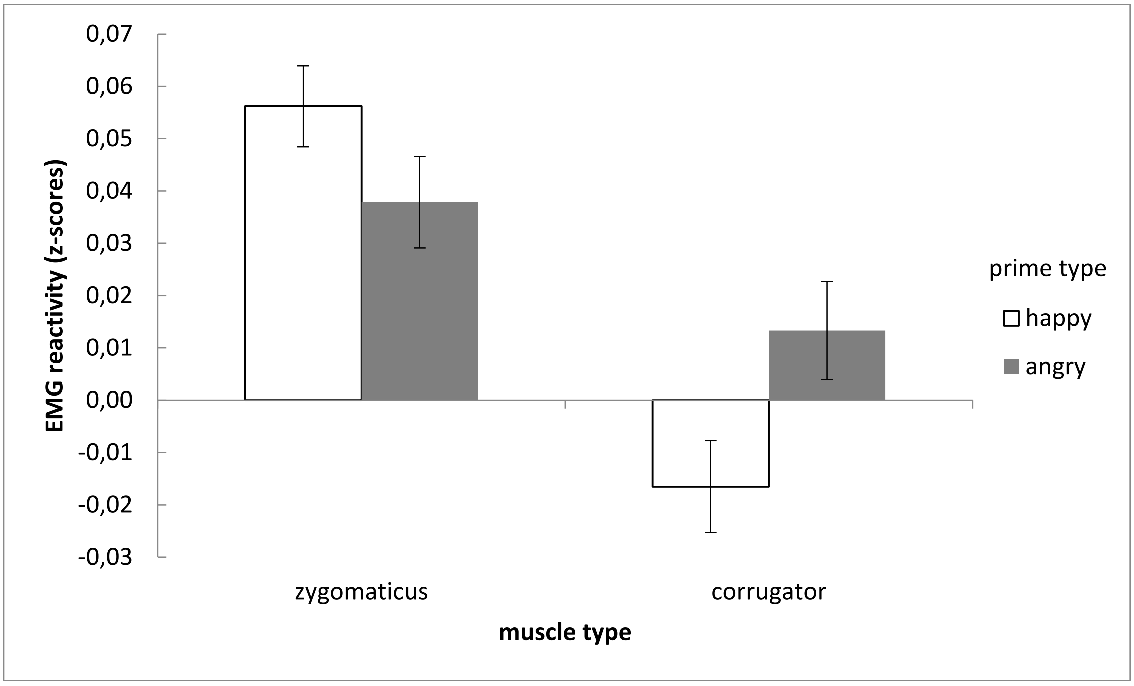

Figure 5.1. Mean reactivity of zygomaticus ('smiling') and corrugator ('frowning') muscles towards happy and angry primes (+/- 1 standard error represented by error bars). Values represent standardized changes in EMG signals towards baseline.

Effect of prime type on facial activation

Our regression models revealed that happy primes, as compared to angry primes, predicted more zygomaticus activation, b = 0.016, SE = 0.006, $t(18250) = 2.71$, $p < .01$, and less corrugator activation, b = -0.031, SE = 0.011, $t(18250) = -2.74$, $p < .01$ (see Figure 5.1 for means and standard errors). Thus, the prime faces evoked congruent facial effects.

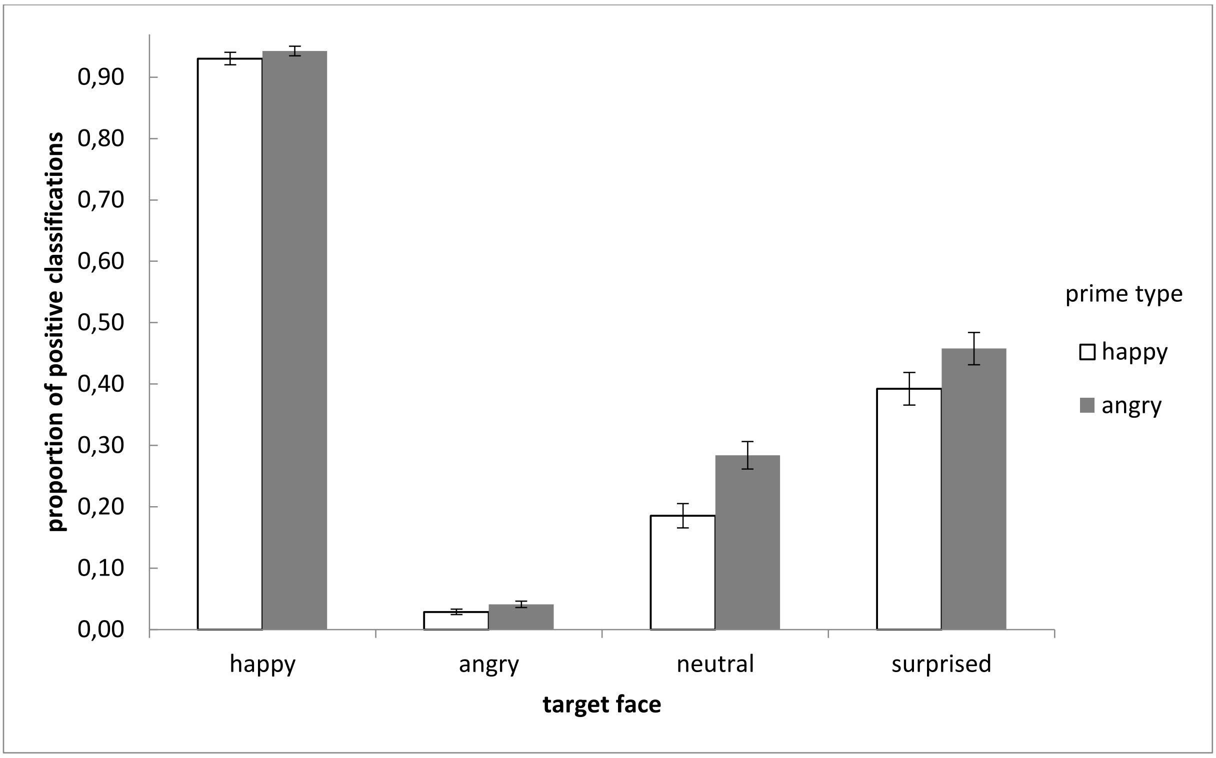

Figure 5.2. Mean classification tendency of target faces (+/- 1 standard error represented by error bars) depending on prime type, expressed as the proportion of positive classifications.

Effect of prime type on classification tendency

Figure 5.2 shows the average classifications for each expression type, expressed as the rate of positive classifications. Regressing classifications on prime type, target ambiguity, and (separately added to the model) the prime x ambiguity interaction, we found a significant effect for prime type, $b = -0.199$, $SE = 0.031$, $z = -6.41$, $p < .01$, and ambiguity, $b = -0.684$, $SE = 0.031$, $z = -21.88$, $p < .01$, and a significant prime x ambiguity interaction, $b = -0.354$, $SE = 0.063$, $z = -5.67$, $p < .01$. The negative predictor for prime type suggests that positive primes were more likely to lead to a *negative* rating of target faces. The prime x ambiguity interaction indicates that this incongruent effect of primes was stronger for ambiguous targets. For clearly valenced targets, there was a significant main effect of prime, $b = -0.284$, $SE = 0.098$, $z = -2.89$, $p < .01$, and target (coded as happy = 1, angry = 0), $b = 6.393$, $SE = 0.118$, $z = -53.96$, $p < .01$, but no significant prime x target interaction, $b = -0.180$, $SE = 0.206$, $z = -0.87$, $p = .38$. Happy targets, as compared to angry targets, were more likely to be classified as positive. Happy primes, as compared to angry primes, were more likely to lead to negative classifications, with no significant difference in prime effect between the two target types. For ambiguous targets, there was a significant main effect of prime, $b = -0.461$, $SE = 0.050$, $z = -9.14$, $p < .01$, and target (coded as surprised = 1, neutral = 0), $b = 1.058$, $SE = 0.051$, $z = 20.57$, $p < .01$, as well as a significant prime x target interaction, $b = 0.323$, $SE = 0.102$, $z = 3.16$, $p < .01$. Surprised targets, as compared to neutral targets, were more likely to be rated as positive. Happy primes, as compared to angry primes, led to more negative classifications for ambiguous faces. The prime x target interaction indicates that this negative priming effect was stronger for neutral faces. Thus, overall, the primes did influence classifications for both clearly valenced and ambiguous targets in an incongruent way, with happy primes, as compared to angry primes, leading to more negative target classifications. This priming effect was significantly stronger for ambiguous targets.

Table 5.1

Estimations of the effect of prime type on ratings mediated by muscle activation (mediated effect) and the effect not mediated by the muscles (direct effect) with 95% CI. Exponential notation was used for very small effects.

	Mediator: Zygomaticus		Mediator: Corrugator	
	Direct	Mediated	Direct	Mediated
Happy	-0.012 [-0.026, 0.006]	0.8×10^{-6} [-0.005, 0.006]	-0.012+ [-0.025, 0.002]	0.013 [-0.043, 0.16]
Angry	-0.013* [-0.025, -0.002]	0.0006 [-0.016, 0.005]	-0.013* [-0.025, -0.003]	0.0001 [-0.011, 0.012]
Neutral	-0.097*** [-0.121, -0.072]	-0.0003 [-0.002, 0.001]	-0.097*** [-0.121, -0.071]	0.001 [-0.005, 0.007]
Surprised	-0.067*** [-0.094, -0.041]	0.6×10^{-6} [-0.003, 0.003]	-0.066*** [-0.090, -0.014]	0.0004 [-0.001, 0.003]

+ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Mediation of classification tendency via facial activation

For the effect of prime type on classifications, the average mediation effect of both facial muscles was not significant for clearly valenced faces, zygomaticus: b = 0.0001, 95% CI [-0.0075, 0.0079], p = .85, corrugator: b = 0.0004, 95% CI [-0.0103, 0.0160], p = .88, or for ambiguous faces, zygomaticus: b < 0.0001, 95% CI [-0.0006, 0.0010], p = .94, corrugator: b = -0.0004, 95% CI [-0.0025, 0.0010], p = .50. We report both estimates of direct effects (i.e., the effect of the prime on classification, independent of facial activation) and mediated effects for all individual face categories in Table 5.1. As can be seen, in no case did we find evidence for a mediation of the behavioural effect by either corrugator or zygomaticus activation. This suggests that the priming effect on classification tendency did not depend on facial reactions. Participants' sensitivity scores (M= 0.47, SD = 0.31) did not predict the size of their mediation effect for either clearly valenced targets or for ambiguous faces (all p-values > .2). Thus, there was no evidence that more sensitive participants showed a stronger mediation effect.

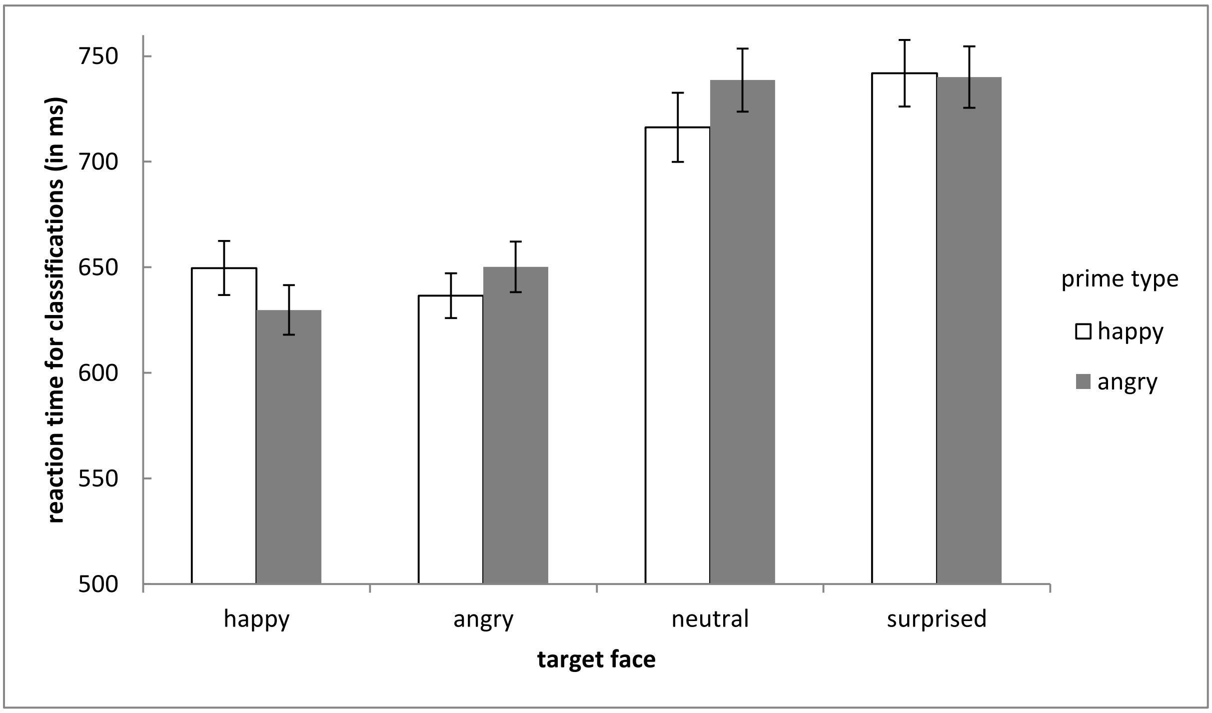

Figure 5.3. Mean reaction time towards target faces (+/- 1 standard error represented by error bars) depending on prime type. Note that the Y-axis starts at 500 ms to allow for easier visibility of the interaction effect (see text for statistical analysis).

Effect of prime type on classification speed

Figure 5.3 shows the average classifications for each expression type in milliseconds. Reaction times on individual trials were analysed to see if prime faces facilitated faster identification of the target faces. As for the assessment of speed effects on target identification trials with incorrect classifications (i.e., trials in which participants incorrectly classified clearly valenced happy/angry targets as negative/positive) were less informative, these were excluded from the reaction time analysis (2.47% of all trials). No ambiguous target trials were excluded, since in these cases there was no a priori correct or incorrect classification.

Regressing reaction times on prime type, target ambiguity, and the prime x ambiguity interaction, we found no significant main effect of prime, b = -3.96, SE = 2.45, *t*(17801) = -1.62, p = .11, but a significant main effect of ambiguity, b = 93.89, SE = 2.45, *t*(17801) = 38.27, p < .01, and a significant prime x ambiguity interaction, b = -12.52, SE = 4.90, *t*(17755) = -2.55, p = .01. This indicates that classification tended to take longer for ambiguous targets. The interaction indicates that the effect of the primes on classification speed differed between clearly valenced and ambiguous targets. For clearly valenced targets, there was no main effect of prime, b = 2.41, SE = 2.89, *t*(8774) = 0.83, p = .40, and a marginally significant effect of target, b = 4.91, SE = 2.89, *t*(8774) = 1.70, p = .09. Both effects were qualified by a significant prime x target interaction, b = -31.50, SE = 5.77, *t*(8757) = -5.46, p < .01, indicating a difference in prime effect for happy and angry faces. For happy targets, happy primes, as compared to angry primes, predicted *slower* classification times, b = 18.76, SE = 4.10, *t*(4270) = -5.46, p < .01. For angry targets, happy primes, as compared to angry primes, predicted *faster* classification times, b = -13.06, SE = 3.95, *t*(4410) = -3.31, p < .01. For ambiguous targets, there was a significant main effect of prime, b = -10.19, SE = 3.83, *t*(8938) = -2.66, p = .01, a significant main effect of target, b = 13.21, SE = 3.84, *t*(8938) = 3.45, p < .01, both qualified by a significant prime x target interaction, b = 24.80, SE = 7.66, *t*(8939) = 3.24, p < .01. Happy primes, as compared to angry primes, predicted faster reactions towards neutral targets, b = -22.86, SE = 5.33, *t*(4449) = -4.29, p < .01, but not towards surprised targets, b = 2.06, SE = 5.45, *t*(4396) = 0.38, p = .71.

Table 5.2

Estimations of the effect of prime type (0 = negative, 1 = positive) on classification time (in ms) mediated by muscle activation (mediated effect) and the effect not mediated by the muscles (direct effect) with 95% CI. Exponential notation was used for very small effects.

	Mediator: Zygomaticus		Mediator: Corrugator	
	Direct	Mediated	Direct	Mediated
Happy	18.968*** [10.757, 26.799]	-0.6×10^{-6} [-0.0003, 0.0001]	19.049*** [11.129, 27.493]	-0.0002 [-0.0008, 0.0002]
Angry	-13.751*** [-21.284, -6.097]	-0.3×10^{-8} [-0.0003, 0.0003]	-13.990*** [-21.911, -6.051]	-0.5×10^{-6} [-0.006, 0.002]
Neutral	-21.925*** [-32.145, -11.842]	-0.0002 [-0.0011, 0.0003]	-22.342*** [-32.728, -11.630]	-0.4×10^{-7} [-0.0003, 0.0003]
Surprised	2.151 [-8.678, 12.066]	0.2×10^{-8} [-0.0039, 0.0020]	1.546 [-9.021, 11.568]	0.0005 [-0.099, 0.090]

+ p< .10, * p < .05, ** p < .01, *** p < .001

Mediation of classification speed via facial activation

Using the same procedure as for the test of mediation of classification tendency, we tested whether the corrugator or zygomaticus mediated the effect of prime on target classification speed. Estimates of direct and mediated effects for each individual face category are shown in Table 5.2. In no case did we find any evidence for a mediation via facial muscles (all p-values > .4). As for classification tendency, we regressed participants' individual estimates of mediation effects on their heartbeat sensitivity scores. Participants' sensitivity did not predict the size of their mediation scores (all p-values > .2). Overall, this indicates that the primes' influence on classification speed occurred independently of participants' facial activation.

Role of facial activation after target onset

Since we were interested in the role of the facial activation elicited by the primes in the behavioural effect, we chose to analyse facial activation directly prior to target onset. We assumed that facial activation after target onset might be less representative of the primes' impact, since several non-affective influences due to the presentation of a new stimulus could influence the signal here, such as increased processing effort related to the appearance of the target stimulus (Topolinski & Strack, 2015) and elicitation of motor movements for the classification. However, one could argue that, for interpreting the target faces, facial activation after target onset is more likely to be relevant. We thus repeated our main analysis, but instead of 500 ms directly prior to target onset, we chose the first 500 ms after target onset as the region of interest for the EMG data. Happy primes, as compared to angry primes, predicted significantly higher zygomaticus activation, b = 0.012, SE = 0.006, $t(18260) = 1.96$, p = .0495, and lower corrugator activation, b = -0.026, SE = 0.011, $t(18270) = -2.28$, p = .02. This indicates that congruent facial activation elicited by the primes was still present during the target face presentation. Neither for classification decisions nor classification times did activation after target onset mediate the effect on clearly valenced or ambiguous targets (all p-values > .10). Thus, facial activation both directly before and during the target presentation showed a congruent priming effect, and neither showed any involvement in the incongruent behavioural priming effect.

Discussion

The current study investigated the role of spontaneously occurring facial activation in an affective priming procedure. As found previously, happy primes, as compared to angry primes, induced congruent facial effects (i.e., increased smiling and decreased frowning). Consistent with some previous studies, the presentation of primes for a prolonged duration led to incongruent behavioural effects in both classification decisions and reaction times: Happy primes, as compared to angry primes, led to an increased likelihood of classifying target expressions as negative, with ambiguous targets being influenced more strongly. Additionally, clearly happy targets, as compared to angry targets, were identified more quickly after angry prime faces. For none of these behavioural priming effects did we find any evidence for a mediation by participants' facial activation. This was true independently of the level of participants' individual performances on a heartbeat counting task.

In embodied theories of affective processing, it is often assumed that facial feedback would have a congruent effect on affective processes (e.g., more smiling or less frowning would be related to more positive evaluative tendencies; McIntosh, 1996; Niedenthal et al., 2005; Winkielman et al., 2015). Thus, the fact that we observed both a significant congruent effect on facial activation and a significant incongruent effect on behaviour seems to directly contradict the idea that affective priming does rely on facial feedback. However, note that our data can only speak to the role of facial feedback in the case of incongruent behavioural effects after a prolonged prime presentation. This leaves open the possibility that facial activation mediates effects for congruent priming (which often uses short prime presentations; e.g., Winkielman & Zajonc & Norbert Schwarz, 1997; Wong & Root, 2003). In line with this idea, a previous study found that a motor task blocking spontaneous facial reactions also blocked a behavioural affective congruent priming effect (Foroni & Semin, 2011). This might suggest that changes in facial activation can only influence evaluations that take place within a very short time window after prime onsets. Future studies could investigate the role of prime duration by varying it as a between-subject factor and testing whether prime duration changes the relation between facial and behavioural effects. We chose a prolonged prime presentation, since the possibility of congruent facial and incongruent behavioural prime effects seems especially relevant for exploring the boundaries of possible facial feedback effects. More specifically, the mismatch between facial and behavioural effects in the current study seems to suggest that any possible influence of facial feedback can be overridden relatively easily by other perceptual or cognitive mechanisms (for cognitive models of incongruent priming effects, see, for example, Clifford et al., 2007; Klauer et al., 2009).

Several studies found evidence that affective evaluations can be influenced by facial feedback (Dimberg & Söderkvist, 2011; Meeten et al., 2015; Strack et al., 1988). In this respect, it would be worth considering for embodiment theories why participants apparently discount facial actions in the context of incongruent affective priming. For example, the current results are in line with studies that suggest that facial feedback is not used as a possible source of information when tasks can be fulfilled more easily by non-embodied processes (Maringer et al., 2011; Niedenthal et al., 2009). In the current experiment, it might have been more convenient for participants to make their decisions based on a cursory analysis of visual features rather than attempting to integrate the state of their facial muscles. As the significant effects on participants' behaviour show, participants still integrated some emotion-relevant contextual factors (i.e., the type of prime) in their evaluations.

Cognitive accounts of emotional phenomena have often been criticized for discounting the importance of bodily states in affective processing (Barrett & Lindquist, 2008; Briñol & Petty, 2008; Niedenthal et al., 2009; Winkielman et al., 2015). While embodiment theories often mention that both cognitive and bodily processes can influence our behaviour, they are not always very specific about the factors that determine when bodily changes, such as facial muscle activation, can be expected to influence a behavioural outcome. On the one hand, it might be that bodily signals are an essential part of such processes, while on the other hand, facial activation could be relevant only under special circumstances (cf. Meier, Schnall, Schwarz, & Bargh, 2012). Our results suggest that in order to fully understand the processing of affective stimuli, hybrid models that account for both bodily and cognitive influences, as well as for the factors that determine their relative importance in specific evaluations, are more appropriate. Overall, the current study found that prolonged affective priming led to congruent facial reactions, but to incongruent behavioural consequences. This seems to indicate that the potential influence of facial feedback is not necessarily integrated in evaluative processes. This would support more restricted versions of embodiment theories, according to which bodily feedback is one possible source of information, which can be discounted when the decision in question can be reached more easily by cognitive or inferential means.

Chapter VI: Overall Discussion

In the first chapter of this thesis, common theories and findings were presented that would suggest that proprioceptive feedback from our facial muscles might influence affective evaluations. The so-called facial feedback hypothesis generally assumes that facial activation can influence affective processes, usually without making specific predictions about the boundary conditions of this phenomenon (e.g., McIntosh, 1996). Additionally, Chapter I introduced some examples of contemporary embodiment theories that make suggestions concerning the factors that might make reliance on bodily activation more likely: the somatic marker theory (Damasio, 2000), primitive emotion contagion theory (Hatfield et al., 1993), and the *simulation of smiles* model (SIMS; Niedenthal, Mermillod, Maringer, & Hess, 2010). All of these theories have in common that they identify bodily feedback with more intuitive judgments, for example, in contexts in which decisions based on purely cognitive reasoning might not be possible or practical(e.g., 'gut feelings' decisions).

The assumption that facial activation might influence affective evaluations was investigated in a number of empirical studies. Chapter II tested whether strong overt facial actions could influence participants' interpretations of sentences describing everyday scenarios. A facial feedback effect was found for participants who were aware that they were enacting emotional expressions, but not for those who were unaware. Note that it is usually assumed that facial feedback does not rely on conscious reflection (Rutledge & Hupka, 1985; Strack et al., 1988). The results for aware participants could be explained as demand or expectancy effects. Chapter III found that a nonconscious priming procedure led to subtle changes in facial activation, but this change in facial activation did not predict participants' ratings of subsequently presented ambiguous stimuli (Chinese characters for participants not familiar with this language). That is, there was no evidence that subtle facial activation leads to a change in rating tendency. Chapter IV investigated the possible role of facial activation in the interpretation of others' facial expressions. Generally, facial activation predicted participants' ratings of their own emotional reactions, but not their ratings of the expressions senders' feelings. Only participants with higher scores on a heartbeat counting task showed a relation between their facial activation and the evaluation of ambiguous facial expressions. These findings would not be consistent with the idea that we generally rely on facial feedback to interpret others' expressions, but they could suggest that a reliance on facial activation is only relevant for more ambiguous social signals, and only present for highly body-sensitive people. Chapter V reported a study in which participants had to quickly classify facial expressions according to their valences. These expressions were preceded by affective primes (prime faces that were either happy or angry). While the priming led to a congruent effect on participants' facial activation, it led to an incongruent effect on their ratings. Such a mismatch does not seem to be in line with the idea of affect-relevant feedback from facial muscles.

The results of this thesis would suggest that the lack of specificity often found in discussions of the idea of facial feedback (such as in the general facial feedback hypothesis) concerning its boundary conditions is problematic. Additionally, even when theories mention potential boundary conditions for feedback effects, these tend to be underspecified in many formulations (which their authors usually acknowledge; see, for example, Niedenthal, Mermillod, Maringer, & Hess, 2010). For example, the question in how far it might be considered easier to reach a decision with embodied or non-embodied means in specific cases is often hard to decide a priori, since it is usually a matter of degree whether a situation might allow for more or less inferential means.

Overall, if one looked at the results of this thesis in isolation, critics of embodiment theories might find it hard to justify that facial feedback should be considered a relevant influence on affective evaluations at all. Especially in the light of several published reports that found effects of facial feedback, drawing such a conclusion might be unwarranted. However, it is worth noting that studies reporting null findings are less likely to be published or submitted for publication in the first place (Ferguson & Heene, 2012). Thus, the number of previous experiments not supporting the idea of facial feedback effects is likely to be underreported (but see Reisenzein & Studtmann, 2007). Shortly before the submission of this thesis, the results of a registered replication report of a classic facial feedback study (Strack, Martin, & Stepper, 1988) were published (Wagenmakers et al., in press). Strack et al. was the first study to employ the so-called pen method (s. Chapter I), and is an often-cited example for the facial feedback effect. This cooperative replication project of 17 different research groups (with an overall sample size of approximately 1,700 participants) found overwhelming support for the null hypothesis (i.e., no effect of facial activation on participants' evaluations of cartoons). Further replications of other previous facial feedback studies might be warranted to develop a more balanced picture of the possibility of facial feedback effects. For example, the results from Chapter II suggest that an involuntary inclusion of task-aware participants in some experiments might have led to artificially increased effects in some previously published studies.

Nevertheless, given the current amount of evidence for facial feedback effects in the published literature, it might be more appropriate to conclude from this thesis that facial feedback is probably not a general factor in our affective evaluations, but might only play a role under very specific circumstances. If that was the case, then facial feedback theories would have to specify what these circumstances are. While several factors that might explain individual results have been discussed in each chapter, this last section briefly highlights some potential mechanisms that might warrant closer investigation in the future.

One issue that has been highlighted in Chapter I was that many studies finding facial feedback effects employed intense and long-lasting face manipulations, as opposed to more subtle and natural muscle activation. For example, one could argue that Chapter III did not find a muscle-rating relationship for the evaluations of Chinese characters, since primed effects on facial muscle activation were too weak. Generally, the results of this thesis would be consistent with the assumption that more subtle facial activation is not sufficient for inducing facial feedback effects. Since Chapter II did not find an effect for expression-unaware participants, despite relying on strong facial manipulations, it cannot be said that the intensity of facial activation alone is the deciding factor for the emergence of such effects.

As discussed in Chapter I, it might be reasonable to assume that participants' evaluative decisions are especially likely to be related to their facial activation when having to judge ambiguous stimuli, as these do not contain sufficient information concerning their affective value on their own. Since all of the studies reported in thesis employed some form of ambiguous stimuli, one might argue that based on the theoretical accounts discussed in Chapter I, one could predict a relation between facial activation and evaluations, at least for this type of stimuli in all of the studies reported here. However, apart from Chapter III (where facial activation partially predicted ratings of ambiguous expressions for more sensitive participants), this assumption was not confirmed. This emphasizes the fact that ambiguity resolution can potentially be achieved by many other non-embodied means (which were not under investigation in this thesis) rather than via reliance on facial muscle activation.

Chapter IV and Chapter V explored the possibility that facial activation was more relevant for people with higher trait body sensitivity, which was operationalized with the heartbeat counting task. Chapter IV showed a partial relation between facial activation and ratings for potentially more body-sensitive people during the evaluation of ambiguous stimuli (based on a correlational design). However, Chapter V did not find any comparable effect for highly sensitive participants, even though the same target stimuli as in Chapter IV were employed. Given that the findings reported here cannot consistently confirm that increased scores on the heartbeat counting task led to increased muscle-evaluations relations, it is not possible to draw firm conclusions concerning the role of trait body sensitivity for this phenomenon. Future research interested in the role of trait body sensitivity could probably profit from establishing measures more closely related to the bodily phenomenon in question (i.e., in this case, sensitivity towards muscle tension) and/or ways to manipulate body sensitivity experimentally.

It is possible that the difference in muscle-rating relationship between Chapter IV and Chapter V is due to the specifics of the rating task. For example, while Chapter IV asked participants for ratings on a quasi-continuous scale (which might encourage more subtle distinctions), Chapter V used a speeded decision task with a binary positive/negative choice (which could encourage ad hoc judgments). Such an interpretation would be consistent with the idea that more subtle distinctions are more likely to profit from facial feedback as an additional source of information (Hess & Blairy, 2001). It might be possible that the employment of a fine-grained scale for evaluative ratings encourages the accessing of additional resources to ‘fine-tune’ evaluative decisions, and that more body-sensitive people were more likely to access facial feedback in this case. Note that a priori, it would have also been possible to argue that speeded decisions, as in Chapter V, are more likely to encourage intuitive evaluations, since less time for a judgement is available. If it was true that embodiment is particularly relevant for fine-grained evaluations as compared to for more broad distinctions between positive and negative stimuli (cf. Chapter IV and V), then the question would be exactly how granular a judgement must be to trigger a reliance on bodily feedback. Future research could explore these issues by experimentally manipulating relevant dimensions of the evaluation tasks in multiple steps (e.g., by comparing the relation between facial activation and evaluative decisions between rating scales of different granularities).

As can be seen by the many qualifications made in this discussion concerning possible overall conclusions, it might be the case that only a relatively complex interaction of several factors determines the reliance on facial feedback. To put this in another way, facial feedback effects might be a very rare phenomenon.

It should be noted that the findings in this thesis leave open the possibility that the evaluations tested were embodied with respect to bodily processes other than facial activation. For example, it might be that internal visceral bodily sensations are more important for evaluative decisions (cf. Bechara & Damasio, 2005; Wiens, 2005). While review literature discussing the embodiment of emotions suggests the potential involvement of a wide range of bodily activations in affective processes, experiments in this area have usually focussed on isolated measurements of specific aspects. For example, literature concerning the somatic marker theory seems to suggest that potentially all aspects of bodily emotional reactivity might play a role in creating evaluative outcomes. In practice, apart from a few exceptions (e.g., Arminjon et al., 2015) studies referring to this theory rely on the measurement of electrodermal activity. Since emotional reactions can produce relatively complex bodily changes, studies investigating the relevance of bodily feedback might profit from simultaneous measurements of different bodily signals (cf. Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). This would allow researchers to identify the relative contributions of individual internal or external bodily signals towards affective evaluations.

The current findings do not address the possibility of body-related brain activation or ‘as-if loops’ influencing affective processing. Instead of directly perceiving input from their facial muscles, it might be that affective decisions are influenced by activation in brain regions that have been identified as especially relevant for processing body signals. Several discussions of embodiment theories explicitly mention that such brain processes could effectively function as a simulation of actual bodily activation (e.g., Damasio, 1996; Niedenthal et al., 2010; Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015). For example, with respect to facial muscles, it has been found that disruption of the somatosensory cortex (relevant for processing feedback from skeletal muscles) can impair the ability to process others’ facial expressions of emotions (Pitcher, Garrido, Walsh, & Duchaine, 2008). As has been noted in Chapter I, embodiment theories are usually not very clear about the factors that determine under which circumstances body-related simulations in the brain should be expected to be more relevant than direct bodily feedback for psychological phenomena. One possibility might be that affective evaluations more commonly only rely on body-related brain activation, while actual peripheral feedback is only accessed when evaluative decisions are especially difficult to reach. Simultaneous measurements of brain and peripheral activation are needed to investigate the relative importance of these factors.

To conclude, the current thesis investigated the role of facial activation in affective evaluations of environmental stimuli, particularly the relevance for zygomaticus (‘smiling’) and corrugator (‘frowning’) activation for ratings of valence. The results seem to suggest that if facial activation can influence evaluations (as suggested by previous findings), this is less likely to be a regular or particularly important part of such affective judgements. Given that facial feedback is a popular example of the role of embodiment in emotional processes, emphasizing the potential limitations of this concept is arguably an important step in clarifying the role of our bodies in emotions.

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