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SHORT REPORT

Enhanced embodied response following ambiguous emotional processing

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Abstract It has generally been assumed that high-level cognitive and emotional processes are based on amodal conceptual information. In contrast, however, "embodied simulation" theory states that the perception of an emotional signal can trigger a simulation of the related state in the motor, somatosensory, and affective systems. To study the effect of social context on the mimicry effect predicted by the "embodied simulation" theory, we recorded the electromyographic (EMG) activity of participants when looking at emotional facial expressions. We observed an increase in embodied responses when the participants were exposed to a context involving social valence before seeing the emotional facial expressions. An examination of the dynamic EMG activity induced by two socially relevant emotional expressions (namely joy and anger) revealed enhanced EMG responses of the facial muscles associated with the related social prime (either positive or negative). These results are discussed within the general framework of embodiment theory.

Keywords Embodiment theory · Top-down regulation · Electromyography · Visual perception · Emotional facial expressions

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Introduction

As a theory of the human conceptual system, situated or grounded simulation theory possesses a dynamically evolving non-modular architecture characterized by modal representations, situated abstraction, and an organization based on an interface between actions and the environment (Barsalou 2003). This theory considers that there is a clear link between abstract concepts, physical experiences and anticipation and holds that action is central in the construction of representations. Nevertheless, this link still needs to be formalized, especially at the level of the physical variables involved in information coding. Smith et al. (2005) provided interesting results concerning one particular physical variable: space. Their idea was that emotional facial expressions (EFE) take the form of patterns of muscular activations that form orthogonal (non-correlated) visuospatial signals which are easy to decode. This could be the result of the coevolution of muscle movements, the repertory of EFEs, and categorization (Mermillod et al. 2010).

However, this form of emotional decoding based on perceptual analysis might also be influenced by the interaction of bottom-up and top-down processes (Kvegara et al. 2007). Our goal here was to gain at least a partial understanding of the extent to which the social dimensions of human beings have an influence on the (de-)coding of emotional information. Several studies of embodiment theory have observed facial mimicry in subjects after seeing another person expressing a facial emotion (e.g., Niedenthal 2007). Moreover, this mimicry process appears to be automatic and unconscious (Dimberg et al. 2002; Vermeulen et al. 2009a, b) that could facilitate the recognition of facial expressions (Dimberg et al. 2011). Within the general framework of top-down social influences on basic sensory-motor activity and, more particularly, the influence of social context on the embodied processing of emotional expressions, embodiment theory (Niedenthal et al. 2010) provides an interesting theoretical framework within which to address this issue. Working within a similar perspective, Likowski et al. (2008) have shown that attitudes concerning a person can modulate facial mimicry. Attitudes, like expectations, are a form of social prediction and can influence the perception of a social stimulus.

In order to investigate the effects of social valence contexts (positive, negative, or neutral) on the perception of EFE, we recorded the EMG activity of 6 facial muscles during an EFE categorization task. Embodiment theory predicts that we should observe the classical mimicry effect when EFE is not preceded by any valence information. We also expected the level of mimicry to be greater on the recognition of EFEs preceded by a congruent social context (e.g., joy expressed by an individual associated with a positive social prime) than in the opposite case (e.g., joy expressed by an individual associated with a negative social prime). In other words, congruent primes should increase embodiment processes (i.e., the muscles associated with the respective emotion should exhibit greater EMG activity).

Method

Participants

Twenty healthy participants (mean age $M = 20.8$, $SD = 2.26$) with normal or corrected-to-normal vision and audition completed this experiment, which lasted about 1 h.

Material and procedure

The participants saw seven categories of dynamic facial expressions, which either changed from an initial neutral stage to one of the six basic emotional expressions (i.e., anger, disgust, fear, happiness, sadness, surprise) or remained neutral. The pictures were of different faces (4 female and 6 male) and were taken from Ekman and Friesen (1976). These pictures had already been used in a similar neuroimaging/EMG study (Achaibou et al. 2008). However, Achaibou et al. (2008) did not investigate the impact of social context on embodiment effects. The dynamic change to the facial expressions was achieved using Benson and Perrett's morphing technique (Benson and Perett 1993). For each of the ten faces, this type of dynamic modification was performed for each emotional condition.

The trials were structured as follows. First, a fixation cross was presented for 500–1,000 ms. Next, a social prime appeared for 1,500 ms. For half of the participants, a specific individual was associated with a positive social prime (i.e., humanitarian doctor), whereas he or she was associated with a negative social prime for the other half of the participants (i.e., recurrent rapist). The social valence of the prime was therefore counterbalanced across participants. After this, 18 frames depicting one of the faces expressing increasing emotional intensity were presented in the center of the screen. The first 17 prime frames were displayed for 40 ms each and followed by the last frame (the target) for 2,000 ms. A second fixation cross then appeared for 500–1,000 ms after which the participant was asked to indicate on a continuous scale varying from 0 to 100 pixels the valence and emotions *perceived* on the EFE. Immediately after rating the perceived EFE, the participants were asked to rate the valence and emotion *felt* after exposure to this EFE in order to extend the focus to their own emotional processes. The order of presentation of the different dynamic changes was randomized. E-Prime software (Psychology Software Tools, http://www.pstnet.com) was used for stimulus presentation.

Data acquisition

Six pairs of electrodes were attached to the following six muscle regions of the face: the frontalis pars medialis, the corrugator supercilii, the orbicularis occuli pars orbitalis, the levator labii superioris, the zygomaticus major, and the orbicularis oris inferior. This choice was inspired by the method used by Fridlund and Cacioppo (1986). The EMG signal was recorded using bipolar electrodes and amplified using a Multi-Channel Bio Amps GT201 (ADInstruments equipment, ML880 Powerlab 16/30). A band pass filter of 10–1,000 Hz was used. The EMG data were collected and averaged for a period of 5,000 ms after target onset. In order to remove a general effect of the prime on EMG activity, the average baseline (recorded during the presentation of the fixation cross, 500 ms before the target)

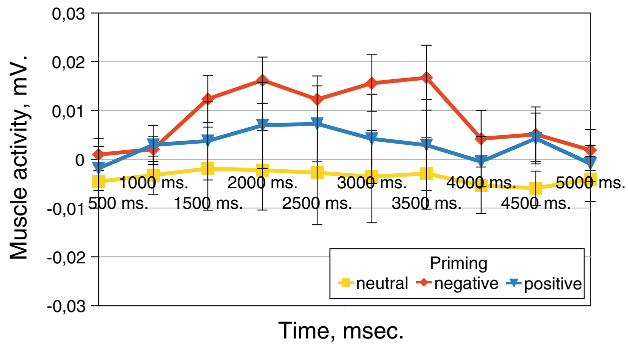

Fig. 1 Mean EMG activity of the corrugator supercilii after exposure to the emotion of anger for each type of social valence (priming) as a function of time. Standard errors of the means are illustrated by *error bars*

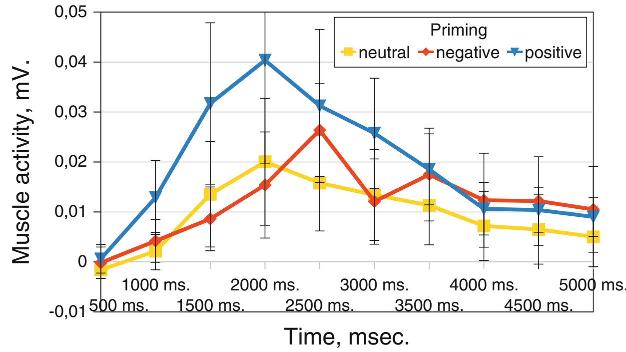

Fig. 2 Mean EMG activity of the zygomaticus major after exposure to happiness for each type of social valence (priming) as a function of time. Standard errors of the means are illustrated by *error bars*

was subtracted from the mean activity. This difference constituted our dependent variable.

Statistical analysis

The data were analyzed over the time course of presentation from 0 to 5,000 ms at intervals of 500 ms. Analyses were computed for each muscle and each emotion. The results for rapid activity (from 500 to 2,500 ms) are presented below. The EMG data were analyzed as a function of emotion (7 levels: neutral, anger, sadness, happiness, disgust, surprise, fear) and social label (3 levels: positive, negative or without a prime). In order to test our hypothesis that the electrical activity recorded at the muscle after priming with a congruent social label would be significantly enhanced compared to the no-priming or incongruent social-label conditions, we performed pairwise comparisons specifically addressing this issue. Due to the deviations from normal distributions, pairwise comparisons were made using paired-sample Wilcoxon's tests. In order to compare our current results with previous data reported by Achaibou et al. (2008), we focused on the emotions of anger and joy. For each emotion, we therefore analyzed the EMG activity of the specific muscle related to it (i.e., the corrugator supercilii for anger and the zygomaticus major for happiness).

As shown in Fig. 1, negative primes produced greater corrugator activation than neutral primes 1,500 ms after exposure to angry faces ($W = -2.20$, $N = 20$, $p < 0.05$). The difference between positively induced emotions and the no-prime condition was not significant ($p > 0.1$).

We observed a similar effect of social prime after exposure to happiness (Fig. 2), which showed that the activity of the zygomaticus was enhanced (1,500 ms after stimulus exposure) in the positive priming condition compared to the control condition ($W = -2.24$, $N = 20$, $p < 0.05$). There was no significant difference between negatively induced emotions and the no-prime condition ($p > 0.1$).

Discussion

First of all, the fact that the neutral condition was characterized by low muscle activity compared with the positive and negative conditions leads us to suggest that mimicry is substantially reduced in the absence of social utility. Conversely, the presence of a relevant social object seems to greatly increase the level of embodiment. These results considerably extend those reported by Achaibou et al. (2008) and are consistent with those of Likowski et al. (2008), who suggest that attitude, as a top-down guess selector, not only serves as a modulator of facial emotion recognition but, by enhancing the relevance of embodied processes, is also a prior condition for mimicry. Therefore, unlike a purely cognitive process (without social valence) in which prior knowledge modulates the perception of an object, a social context may add a socially relevant dimension and permit modulation of EMG activity. This hypothesis is compatible with the results of Hess and Bourgeois (2010), who considered that mimicry is due to an affiliative activation of facial muscles, with the role of social norms being paramount.

Second, as far as the modulation by top-down social information is concerned, we observed that the effect of social prime was not systematic but highly dependent on the target emotion. It seems that a kind of selection occurred at a very early stage, thus indicating some ecological relevance. For example, it is more important to recognize anger in an enemy than anger in a friend (in light of the finding that mimicry in response to this negative and aggressive emotion (anger) occurred only after negative priming). Conversely, the presence of an affiliative function probably results in a higher level of mimicry (at the level of the zygomaticus major) in response to happiness exhibited by an individual having a positive (compared to a negative) social label. This confirms the function of mimicry as theorized by Niedenthal et al. (2010). Their model postulates that the simulation of a facial expression activates brain areas involved in the construction of the meaning of the expression on the basis of the subject's previous experience. This is precisely what is shown by the current results. Moreover, our results also extend the theory proposed by Smith et al. (2005), who suggest that the spatial configurations of the perceptual signals resulting from EFE have evolved to maximize differences between the various EFE. Our current results suggest that top-down processes probably also have a significant impact on the musculoskeletal facial movements related to complex social interactions (group effects, affiliations, etc.) Further analyses will need to be conducted in order to determine whether this congruency effect between the facial muscle related to this social valence that we observed in the case of the emotions reported by Achaibou et al. (2008) can be generalized to all emotional expressions.

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