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Similar facial electromyographic responses to faces, voices, and body expressions

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Observing facial expressions automatically prompts imitation, as can be seen with facial electromyography. To investigate whether this reaction is driven by automatic mimicry or by recognition of the emotion displayed we recorded electromyograph responses to presentations of facial expressions, face-voice combinations and bodily expressions, which resulted from happy and fearful stimuli. We observed emotion-specific facial muscle activity (zygomaticus for happiness, corrugator for fear) for all three

stimulus categories. This indicates that spontaneous facial expression is more akin to an emotional reaction than to facial mimicry and imitation of the seen face stimulus. We suggest that seeing a facial expression, an emotional body expression or hearing an emotional tone of voice all activate the affect program corresponding to the emotion displayed. *NeuroReport* 18:369–372
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Introduction

The close link between emotion and motor activity has been a constant theme in the emotion literature since at least Darwin's time [1]. Yet many different interpretations of it have been offered over time and the nature of the relation is far from clear. This might be partly due to the fact that many of the current insights about the perception of emotions are based on investigations of facial expressions. Recent findings, however, have drawn attention to the importance of voice cues and body language in emotion perception. Comparing the reactions these emotional signals evoke in the observer may add new dimensions to the understanding of human emotions and its neurobiological basis. Here we address this issue by investigating whether spontaneous mimicry of facial expressions is stimulus specific. This mimicry was recently linked to imitation in the observer of the facial expression, shown under the assumption that this imitation reflects activation in the mirror neuron system generated by observation of the specific facial expression.

Previous research has shown that presentation of facial expressions can generate subtle changes in an observer's muscle activity, which are seldom visible to the naked eye but can be reliably detected by electromyography (EMG). Specifically, viewing happy faces elicits increased zygomaticus major activity, whereas negative expressions (e.g. angry faces) evoke increased corrugator supercilii activity [2]. Corrugator supercilii moves the brows down into a frown and zygomaticus major elevates the cheeks and pulls the corners of the mouth back and upwards into a smile. Facial

EMG activity is also observed when participants are not aware they see a facial expression, because it may have been shown very briefly or rendered subjectively invisible by a mask [3]. The similarity between the EMG measures obtained for normal and masked presentation indicates that automatic mimicry rather than intentional imitation is at the basis of this reaction.

Faces, however, are not unique in evoking an automatic reaction in the observer. Older studies on facial EMG activity have established that an emotional facial reaction is observed in response to auditory stimuli [4–6]. These findings suggest that emotional stimuli, rather than faces *per se*, trigger facial motor behavior in the observer, and that this reaction is therefore not strictly an instance of mimicry of the stimulus.

To elaborate on these findings, this study investigated the hypothesis that perception of an emotional stimulus triggers an emotional reaction in the observer based not on mimicry but on recognition of the emotion. We want, therefore, to extend this well-known paradigm to the domain of multi-sensory integration (MSI) of emotions, and to the perception of body language. Several studies now indicate the importance of rapid processing of multiple emotional cues, which have reciprocal effects on successful social communication. The perception of emotions in the face is, for instance, influenced by the emotion displayed in the tone of voice. This MSI is found in behavioral response facilitations in audiovisual (AV) emotion processing [7], and has, furthermore, been shown to occur in the earliest stages of

processing [8]. One approach to evaluating MSI is to compare AV-congruent with AV-incongruent emotional information: a difference in the responses to these stimuli is seen as a signature effect of MSI.

Additionally, normal observers are very adept at reading the emotional meaning of body language [1]. So far, no direct comparison has been made between EMG responses to emotional faces and to body gestures. However, a reason exists to believe that seeing body expressions will lead to a facial reaction specifically attuned to the emotion expressed in the stimulus. Recently, de Gelder and her colleagues [9] used functional MRI to investigate the reaction of the brain to visual cues of fearful body postures. A network of brain structures corresponding to a mechanism of automatic fear contagion is activated when observers view fearful body images. Importantly, brain areas and structures prominently involved in seeing fearful bodies are the visual and temporal areas, as well as the premotor and motor structures [10].

Here we investigated facial EMG to emotional expressions in faces, face-voice combinations, and emotional expressions of the whole body. We hypothesized that the perceived emotions, expressed by emotionally congruent AV stimulus combinations and by whole-body gestures, evoke emotion-congruent facial muscle activity. In the first experiment, facial EMG responses were measured during the presentation of face-voice stimulus pairs. We hypothesized that for the congruent (voice and face expressing the same emotion) stimulus pairs, happy AV trials lead to increased zygomatic activity and fearful AV trials to increased corrugator activity. The second experiment measured facial EMG reactions to happy and fearful faces and body expressions to test whether viewing fear in either faces or body postures similarly increases corrugator activity, and whether viewing happiness, instead, also similarly increases zygomatic activity.

Method

Experiment 1: Facial electromyograph to happy and fearful face-voice pairs

Participants

Thirteen healthy, native Dutch-speaking men (12 right-handed, one left-handed; average age 23.0 years and $SD=2.9$) participated in this study. They all had normal or corrected-to-normal vision. Written informed consent was obtained from each participant before the session, according to the Declaration of Helsinki (2000). They were paid for their participation.

Materials and procedure

Stimuli consisted of AV-stimulus pairs with either a congruent or an incongruent affective content. Visual stimuli consisted of six happy and six fearful faces (equally matched between men and women) taken from the Ekman series [11]. Auditory stimuli consisted of spoken sentence fragments with a neutral content, which were pronounced in either a happy or fearful tone of voice (the Dutch sentence fragment 'met het vliegtuig' meaning 'by plane'). Combinations were always of the same sex, and the same actors participated in the happy and fearful stimulus combinations. Stimuli are described in more detail in [12]. Each visual stimulus was combined with a spoken fragment, resulting in 12 congruent and 12 incongruent stimulus pairs.

The size of the portraits was 19 cm height \times 13 cm width, which at the mean viewing distance of 80 cm corresponds to a visual angle of $13.5 \times 9.2^\circ$. The mean luminance of the pictures was 38 cd/m^2 on a 2.5 cd/m^2 background. The mean duration of the auditory stimuli was 1022 ms (ranging from 900 to 1100 ms); the mean level for sound was 60 dB(a) delivered over one loudspeaker placed directly below the screen.

A trial started with the presentation of the face. After 900 ms, the auditory stimulus was presented, whereas the face remained on screen until the end of the voice fragment. This delay was introduced to be able to analyze the visual and the AV EMG responses separately. The six resulting stimulus categories were as follows: visual happy, visual fear, congruent AV happy, congruent AV fear, incongruent auditory happy-visual fear and incongruent auditory fear-visual happy.

Participants were comfortably seated in chairs in a soundproof experimental chamber. They were instructed to judge the sex of each stimulus pair, by pushing one of two designated buttons on a response box. To avoid any response-related components in the ongoing EMG signal, they were instructed not to respond until after the visual stimulus was withdrawn. Intertrial interval was chosen randomly between 1000 and 1500 ms, immediately after the participant's response. During this interval, a central fixation cross was presented on the screen. Stimuli within a total of eight blocks of 24 AV trials (equal amount of congruent and incongruent stimuli) were presented randomly.

Recordings

Electrode placement followed the guidelines given by Fridlund and Cacioppo [13]. Electrodes were placed on the left side of the face, in accordance with higher sensitivity on the left half of the face half [14]. On each facial muscle (zygomaticus major and corrugator supercilii), two Ag/AgCl flat-type active electrodes (BIOSEMI, Amsterdam, The Netherlands), each with a contact area of 2 mm and casing of 11 mm diameter, were placed in a direction parallel to the muscle and with a distance of 15 mm between the electrode centers.

During the recording, EMG signals were filtered (DC-134 Hz, -3 dB) at a sample rate of 512 Hz. Subsequently, EMG signals were filtered offline (high-pass 20 Hz, 48 dB/octave), full-wave rectified and checked for gross movement associated with irrelevant activities. The raw data were segmented into epochs for visual and AV categories separately. The two visual-stimulus categories consisted of a 500-ms prestimulus baseline condition and a 900-ms visual stimulus condition. The four AV-stimulus categories consisted of similar 500-ms prestimulus and 900-ms visual-stimulus conditions, and an extra 900-ms AV-stimulus condition. For the two visual-stimulus categories, mean rectified EMG amplitudes were calculated for the 900-ms visual-stimulus conditions. The AV categories contained mean rectified-EMG amplitudes for the 900-ms AV stimulus conditions. Subsequently, these data points were depicted as a percentage of the mean prestimulus baseline amplitude.

Two separate multivariate analyses of variance (MANOVA) were performed (visual and AV) for each muscle region. MANOVA analyses for the visual EMG consisted of one within-participant factor for emotions at

two levels (happy vs. fear). In the AV conditions, we tested – separately for corrugator and zygomaticus – whether the EMG activities in response to congruent and incongruent AV stimuli differed from each other, using the within-participant factors – Emoface (happy vs. fear) and Emovoice (happy vs. fear). A significant interaction between the two variables can be decomposed into the specific contrast effects in which the effect of congruency is tested.

Results

We found increased corrugator activity when participants were confronted with fearful faces (mean \pm SE: 103.8% \pm 0.9), compared with the corrugator response to happy faces [(101.7% \pm 0.6), $F(1,12)=5.10$, $P<0.05$]. Viewing happy faces evoked significantly greater zygomatic muscle activity (99.0% \pm 0.9) than viewing fearful faces [(96.3% \pm 1.0), $F(1,12)=5.67$, $P<0.05$].

Facial EMG responses of the corrugator muscle to AV stimuli revealed no significant effect of Emoface and a marginally significant effect of Emovoice, [$F(1,12)=3.86$, $P=0.07$]. The interaction between the two variables was significant [$F(1,12)=5.46$, $P<0.05$]. Congruent fearful AV interactions evoked increased corrugator activity, [$F(1,12)=5.02$, $P<0.05$], compared with the condition where a happy voice was added to a fearful face (Table 1). Presentation of a fearful voice did not evoke corrugator activity when added to a happy-face, ($F<1$).

Concerning the AV-EMG responses of the zygomaticus muscle, MANOVA analyses revealed no significant effect of Emoface and a marginally significant effect of Emovoice, [$F(1,12)=3.99$, $P=0.07$]. Again, the interaction between the two variables was significant, [$F(1,12)=10.19$, $P<0.01$]. Congruent happy AV trials elicited increased zygomatic activity, [$F(1,12)=14.34$, $P<0.01$], when compared with incongruent happy-face-fearful-voice. Similarly, zygomaticus muscle activity was not increased when a happy voice was presented together with a fearful face, ($F<1$).

Method

Experiment 2: Facial electromyograph to happy and fearful body postures

Participants

Thirteen healthy, native Dutch-speaking new students, 9 women and 4 men (11 right-handed, two left-handed; average age 20.9 years, $SD=3.6$) participated in the study. They all had normal or corrected-to-normal vision. Written informed consent was obtained from each participant before the session, according to the Declaration of Helsinki (2000). They all received course credits for participation.

Table 1 EMG activity to congruent and incongruent happy and fearful face-voice pairs: depicted is the percentage of muscle activity compared with baseline

	Corrugator		Zygomaticus	
	Fearful face (SE)	Happy face (SE)	Fearful face (SE)	Happy face (SE)
Fearful voice	108.1 (3.6)*	102.4 (1.0)	94.9 (1.7)	93.3 (1.8)
Happy voice	102.7 (1.5)	102.4 (0.8)	95.4 (2.2)	100.4 (1.8)*

EMG, electromyograph.

*Significant P -values ($P<0.05$).

Materials and procedure

Stimuli consisted of pictures of eight happy and eight fearful faces (equally matched between men and women) taken from [11], and whole bodies of eight women who each adopted a fearful and a happy posture. To minimize face processing during the presentation of bodies, the faces on the photographs were masked with an opaque gray patch. The mean size of the body pictures was equal to that of the face pictures, with a mean height of 19 cm and width of 13 cm. At a mean viewing distance of 80 cm, these sizes correspond to a visual angle of $13.5 \times 9.2^\circ$. The mean luminance of the pictures was 38 cd/m² on a 2.5 cd/m² background. Further details of body pictures can be found in [9].

A total of 32 images (eight happy bodies, eight fearful bodies, eight happy faces, eight fearful faces) was selected and randomly shown within a total of three consecutive blocks. The stimulus duration was 2000 ms, followed by an intertrial interval varying randomly between 1000 and 3000 ms. Stimulus presentation was preceded by a central fixation cross with a random duration of between 500 and 1500 ms. Participants were instructed to pay attention to the images, but no behavioral data were collected to avoid any response-related components in the ongoing EMG. Afterwards, participants were given a short recognition task. Here, a total of 32 images (16 bodies, 16 faces) were randomly shown: 20 images were in the actual experiment, 12 were not. The task was to judge whether they recognized the images from the experiment.

Recordings

Recordings were as described for Experiment 1, except that the raw data were segmented into epochs of 2500 ms, including a 500-ms prestimulus interval and a 2000-ms stimulus condition period. We used a separate MANOVA for each muscle group. These consisted of the within-participant factors: stimulus with two levels (face vs. body) and emotion with two levels (happiness vs. fear).

Results

Analyzing the MANOVA of the corrugator response to happy and fearful faces and bodies revealed a significant main effect of emotion, [$F(1,12)=9.35$, $P<0.01$], indicating increased activity to fearful stimuli (103.3% \pm 1.2) compared with happy stimuli (97.9% \pm 1.3). Furthermore, we found a significant effect in the case of stimulus, [$F(1,12)=22.70$, $P<0.001$], meaning that the percentage of average corrugator activity was higher in response to bodies than faces. No significant interaction effect was seen between the variables emotion and stimulus, [$F(1,12)=1.35$, $P=NS$].

For the zygomaticus response to happy and fearful faces and bodies, we also again found a significant main effect in the case of emotion, [$F(1,12)=8.53$, $P<0.05$]. Here, zygomaticus activity was more pronounced in response to happy stimuli (101.9% \pm 0.9), compared with fearful stimuli (97.6% \pm 1.0). We found a marginally significant effect for stimulus [$F(1,12)=4.52$, $P=0.055$], which was represented by increased activity in response to faces rather than with bodies. Again, there was no interaction between the two independent variables [$F(1,12)=1.76$, $P=NS$].

Results from the behavioral recognition tasks presented afterwards indicate that the mean rate of recognition of the stimuli was 92% correct (range 84–100%).

General discussion

Our goal was to investigate whether emotional facial muscle activity as measured by facial EMG is obtained in response to presentation of happy or fearful facial expressions, face-voice combinations and bodily expressions. On the basis of the emotions we selected for the present study, we measured facial EMG to zygomaticus major and corrugator supercilii, as pleasant stimuli typically elicit greater activity in the zygomatic muscle whereas unpleasant stimuli evoke more corrugator activity.

The main result from Experiment 1 is that congruent AV pairs increased emotion-specific facial muscle activity, that is, congruent fearful AV pairs increased corrugator activity, whereas congruent happy presentations increased zygomaticus major activity compared with emotionally incongruent AV pairs. Experiment 2 revealed that fearful body expressions produced increased corrugator activity in the observer, and zygomaticus major activity was more pronounced in response to happy than to fearful body expressions.

The observed response similarity when perceiving facial expressions, face-voice combinations and body postures argues against the view that the EMG reaction is strictly based on mimicry initiated in motor neurons and as such constitutes evidence for motor simulation as the basis of emotion perception, as suggested by mirror neuron theorists [15]. Instead, the results are compatible with the notion that the perception of emotions triggers recognition of the emotion, which in turn activates motor structures in the brain. This is consistent with the view that emotions processed through face, voice and bodily expressions share an overlapping representation of emotion-specific affect programs [16]. A growing amount of research points to the amygdala as a brain structure that is particularly involved in this process [17,10].

Emotion-specific facial reactions are evident in all the stimulus categories investigated. In some stimulus categories, the EMG response was not increased in comparison with the prestimulus baseline activity. Similar results have already been described by Dimberg and colleagues [3], and were explained by the fact that these effects are influenced by anticipatory activity during baseline, preventing absolute increases in comparison with the prestimulus interval. Anticipatory responses are unavoidable when there is high certainty about the moment of stimulus presentation. These might be weakened by introducing larger variations in intertrial interval. Note that in Experiment 2 we find a significant Stimulus effect, meaning that body stimuli elicited more corrugator and less zygomatic activity than facial stimuli. A plausible explanation of this phenomenon is that stimulus characteristics other than the emotional content influenced facial muscle activity during the experiment. Again, these differences do not obscure the effects related to the emotion displayed in the stimulus.

Conclusion

Facial EMG activity is similarly observed in response to happy and fearful faces, emotionally congruent face-voice combinations and body expressions. Our results plead in favor of a perceptual process in which emotion recognition, and not mimicry, triggers the motor activity, as the latter is triggered interchangeably by all three stimulus categories.

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