Facial EMG as a Tool for Inferring Affective States

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ABSTRACT
In this presentation, I will give a concise overview of several important methodological aspects of recording facial EMG signals as an index of affective states. In addition, several strengths and weaknesses of this technique during practical applications will be emphasized.

Author Keywords
Facial EMG, EMG recording, EMG signal processing, emotion.

INTRODUCTION
The human face may be considered the richest source of information for revealing someone's affective state. Healthy persons during daily life automatically recognize affective facial expressions quite well. For scientific purposes, affective facial expressions can be quantitatively analyzed by trained experts coding elementary facial actions, or by automated systems recognizing facial expressions through visual analysis of facial movements. Another method is recording electromyographic (EMG) signals of specific facial muscles. Both visual and EMG methods have their strengths and weaknesses. I will present a concise overview of several advantages and disadvantages of EMG signals as a tool for inferring affective states.

RECORDING AND ANALYSIS OF FACIAL EMG

Electrodes
Facial EMG is generally recorded bipolarly with small surface electrodes (contact area diameter ≤ 4 mm) located close to each other. EMG activity is frequently recorded from specific muscles playing a prominent role in the expression of elementary emotions, like happiness, surprise, anger, sadness, fear, and disgust (Figure 1). Although affective facial EMG responses may show bilateral differences in individual subjects, group results generally do not show systematic differences between both sides of the face during spontaneous emotional expressions [3].

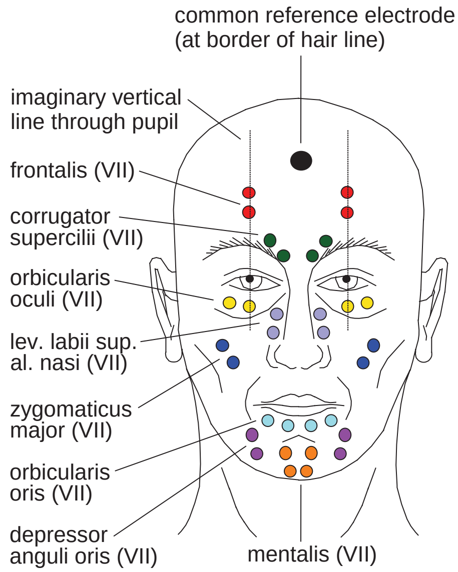

Figure 1. Electrode locations for measuring facial EMG activity.

Conditioning of EMG Signals
Following amplification, the EMG signal must be bandpass filtered within the frequency range 20-500 Hz, being the predominant frequency range of facial EMG signals. Effective high-pass filtering at 20 Hz is essential because of the strong influence of low-frequency artifacts such as motion potentials, eye movements, eyeblinks, activity of neighboring muscles, respiration, swallowing, etc. [12]. If not removed, low-frequency artifacts may dominate the real facial EMG potentials (which under natural circumstances are often small; see Figure 2) and may thus strongly affect the estimation of real EMG activity. In most practical applications occurring outside an electrically-shielded laboratory, it may also be necessary to remove 50-Hz power line interference by applying 50-Hz notch filtering.

Quantification of EMG Amplitude
The EMG is a signal with random properties. Its amplitude can be quantified by calculating the mean rectified EMG amplitude during a fixed time interval on the basis of the rectified, or rectified and smoothed (low-pass filtered), EMG signal (Figure 3). The duration of the optimal analysis epoch depends on the purpose of the study. A longer interval may be necessary if one is interested in relatively

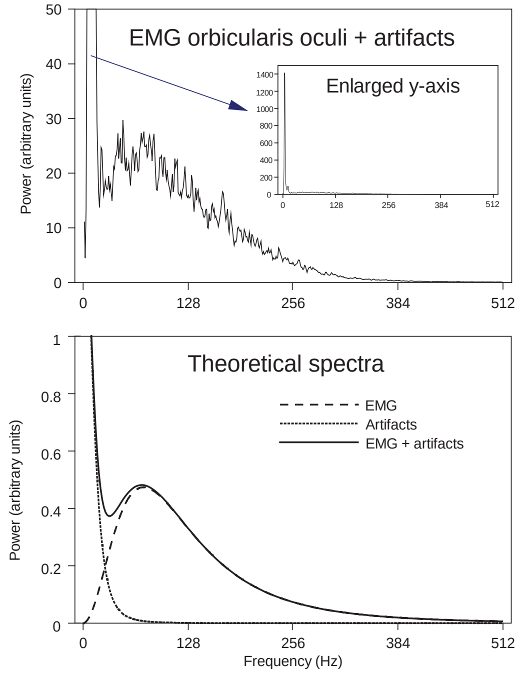

Figure 2. Empirical EMG power spectrum (above) and theoretical power spectrum (below). The low frequency range (< 20 Hz) is dominated by large frequency components caused by artifacts.

steady emotional states, such as a subject's mood state [9]. A shorter interval will be required if one is interested in dynamic changes in emotional responses, for example short-lived facial mimicry responses [1]. Using a shorter interval, temporal resolution becomes better but random error also increases, with negative consequences for reliability. In my experience, the optimal analysis interval for tracking fast dynamic changes in facial expression, while avoiding large effects of random error, has a duration in the order of magnitude of 100 ms (Figure 4).

Standardization of EMG Responses

Baseline EMG amplitudes and affective EMG response magnitudes strongly vary between individuals, not only because of differences in affective processes but also due to anatomical and biophysical differences. This implies that, when determining group means, individual contributions will strongly differ in weight. An adequate method to standardize individual results, and making them comparable between individuals, is expressing EMG response magnitudes as a proportion of an adequate baseline value. As EMG amplitudes are measured on a ratio scale, expressing them as a proportion of baseline level is preferred rather than expressing them as difference scores between baseline and response levels. This standardization also enables a direct comparison of affective responses in different muscles within the same person. It also provides a solution for the problem that EMG amplitudes of a certain person may considerably vary over repeated measurement sessions, even when precautions have been taken to place

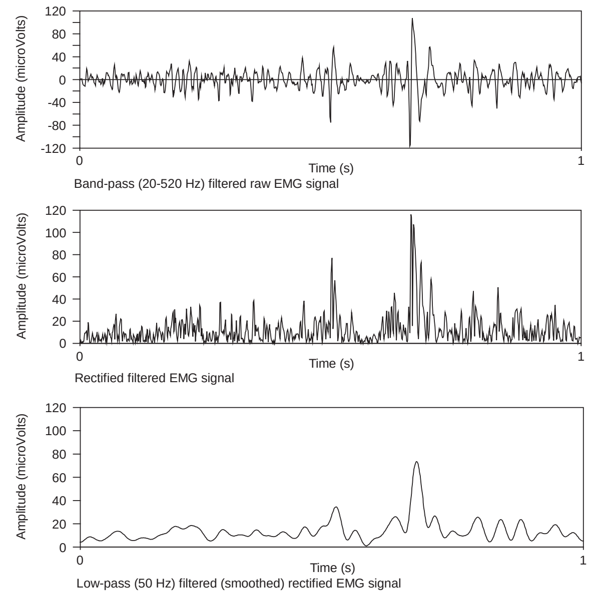

Figure 3. Raw EMG signal (upper frame), rectified raw EMG signal (middle frame), and smoothed rectified EMG signal (lower frame).

electrodes on exactly the same locations. Relatively minor changes in location may have strong effects on absolute signal amplitude [7].

An even better standardization method would be expressing EMG activity of a specific muscle as a proportion of the EMG level during maximal voluntary contraction of that muscle [4,14]. Theoretically, this leads to a better compatibility between different subjects or different measurement sessions from the same subject. However, in practice this procedure is somewhat complicated since it requires training the subject to perform selective maximal contractions of specific muscles.

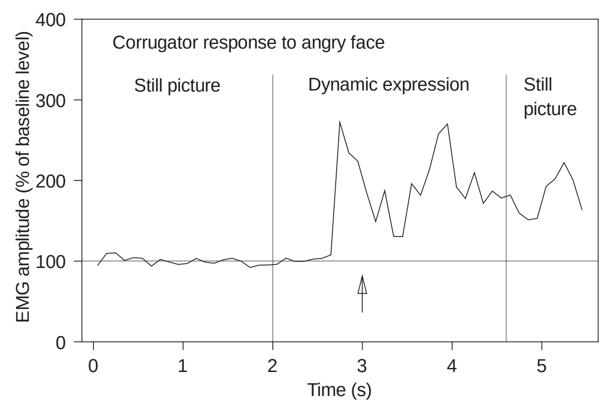

Figure 4. Dynamic corrugator EMG response with a time resolution of 100 ms to a brief film clip showing a dynamic facial expression of anger [1]. The arrow indicates the apex of the dynamic angry expression.

ADVANTAGES AND DISADVANTAGES OF FACIAL EMG AS AN INDEX OF AFFECTIVE STATES

Sensitivity

A basic problem associated with systems relying on the analysis of observable facial motions is that weak or moderate affective responses may be accompanied by visually undetectable facial actions [11]. Using EMG techniques, even the weakest responses, remaining under the visual detection threshold, can be detected, especially since most facial muscles are located at close distance from the surface electrodes. Besides their great sensitivity in the amplitude domain, EMG signals also have a good time resolution so that rapid changes in activity can be reliably measured. Using techniques relying on observable facial movements, small dynamic transitions in activity may be less well observed since they may be masked by the stiffness of overlying cutaneous and subcutaneous tissues. Good dynamic response properties are a prerequisite, among others, for accurate measurement of response latencies to affective stimuli or rapid changes in emotional state during social interactions (e.g., emotional mimicry).

Selectivity

An important application of facial EMG activity may be discriminating between different elementary emotions.

Elementary emotions	Muscles involved	Produced actions
Happiness	• Orbicularis oculi • Zygomaticus major	Closing eyelids Pulling mouth corners upward and laterally
Surprise	• Frontalis • Levator palpebrae superioris	Raising eyebrows Raising upper eyelid
Fear	• Frontalis • Corrugator supercilii • Levator palpebrae superioris	Raising eyebrows Lowering eyebrows Raising upper eyelid
Anger	• Corrugator supercilii • Levator palpebrae superioris • Orbicularis oculi	Lowering eyebrows Raising upper eyelid Closing eyelids
Sadness	• Frontalis • Corrugator supercilii • Depressor anguli oris	Raising eyebrows Lowering eyebrows Depressing lip corners
Disgust	• Levator labii superioris • Levator labii superioris alaeque nasi	Raising upper lip Raising upper lip and wrinkling nasal skin

Table 1. Predominant facial actions during the expression of elementary emotions according to Ekman and Friesen [2].

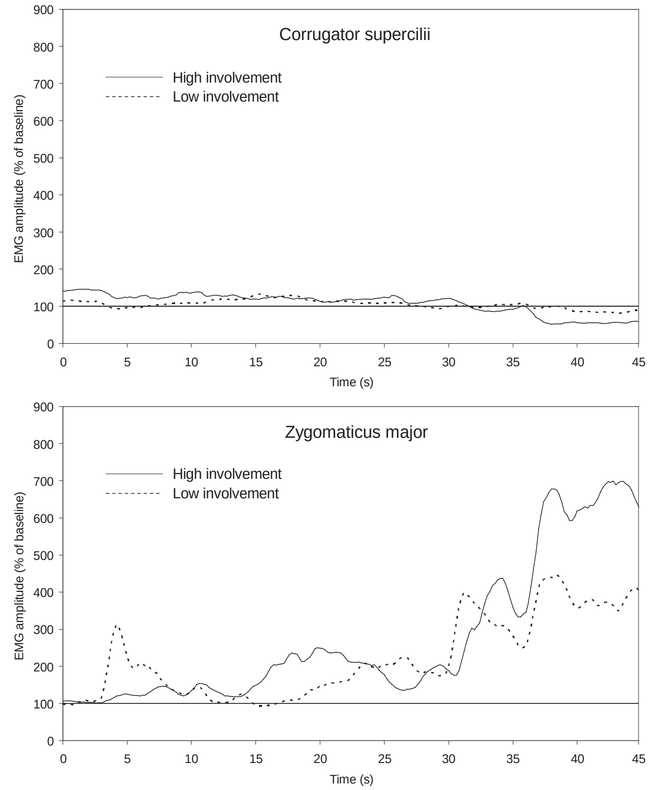

Figure 5. Time course of corrugator and zygomaticus EMG activity while watching a humorous TV-commercial with a climax toward the end of the film clip. The attention of the participants was experimentally manipulated (high vs. low involvement).

These emotions are characterized by specific configurations of facial actions [2] (see Table 1). There is some interindividual variability in these patterns which, at least partly, may be due to interindividual differences in the morphology of the facial musculature. A robust, and often replicated, finding is that positive and negative affective states can be reliably distinguished on the basis of corrugator and zygomaticus responses, corrugator responses showing a negative linear relationship with emotional valence and zygomaticus responses showing a positive curvilinear relationship [8]. Corrugator activity is not only facilitated during negative emotional states but is also inhibited during positive emotions [1,8] (see also Figure 5).

A challenging application would be discriminating between elementary emotions on the basis of the pattern of EMG responses of different muscles. Multivariate analysis of EMG response patterns may be a useful technique for this purpose. Subjecting facial EMG response patterns to discriminant analysis, a reasonably accurate identification could be made of (a) elementary mood states induced by mental imagery, and (b) posed expressions of elementary emotions (happiness, fear, anger, sadness) [4].

However, reliable discrimination between specific positive or negative emotions on the basis of facial EMG response patterns remains complex as yet. There are two important factors contributing to this problem. First, recordings of EMG activity from different muscles are less selective than desirable. The major reason for this disadvantage is crosstalk, that is, the phenomenon that electrical activity generated by a specific muscle spreads to adjacent areas through volume conduction. This activity, at least partly, will be detected by electrodes located on muscles in the vicinity of the target muscle. However, using a high-density grid of surface electrodes, estimations of real facial EMG activity could be considerably improved [6]. Another impeding factor is that emotional experiences under natural circumstances often consist of a mixture of elementary emotions which, in addition, may rapidly change so that EMG response patterns may thus be a function of such undetermined or dynamic emotional states.

Confounding Factors

A limitation of EMG recordings (but also of all other techniques analyzing facial movements) as an index of emotional processes is that the human face does not only display affective responses but also produces a large variety of activities unrelated to emotional processes like speech, mental effort or mental fatigue, task involvement or performance motivation, anticipation of sensory stimuli, preparation of motor responses, orienting responses, and startle reflexes [10,13,15,16,17]. In experimental studies, we can try to control for such disturbing influences but during practical applications outside the laboratory this will be much more difficult. Anyhow, the influence of such ubiquitous factors should be carefully evaluated to avoid invalid conclusions regarding a person's affective state.

Obtrusiveness

A basic limitation of using facial EMG recording in practical applications is the obtrusiveness of this technique. The extensive preparation being required and the connection with the recording equipment through electrode leads may interfere with spontaneous, natural behavior. Although the tactile sensations associated with the presence of skin electrodes generally quickly habituate during the absence of facial movements, strong dynamic facial movements may generate tactile sensations due to the high density of sensitive mechanoreceptors in the facial skin [5]. This may particularly occur when a large array of closely spaced electrodes is used.

Conclusion

EMG recording may be considered a sensitive technique for inferring subjective mood states or affective responses. However, it has limitations for many applications under natural life circumstances due to its obtrusiveness and the fact that facial activity is influenced by many other, nonaffective, behavioral factors. Also, methodological improvements are necessary to enhance its effectiveness as a tool for reliable differentiation between specific emotions.

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