What do facial expressions of emotion express in young children? The relationship between facial display and EMG measures

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Abstract

The present paper explored the relationship between emotional facial response and electromyographic modulation in children when they observe facial expression of emotions. Facial responsiveness (evaluated by arousal and valence ratings) and psychophysiological correlates (facial electromyography, EMG) were analyzed when children looked at six facial expressions of emotions (happiness, anger, fear, sadness, surprise and disgust). About EMG measure, corrugator and zygomatic muscle activity was monitored in response to different emotional types. ANOVAs showed differences for both EMG and facial response across the subjects, as a function of different emotions. Specifically, some emotions were well expressed by all the subjects (such as happiness, anger and fear) in terms of high arousal, whereas some others were less level arousal (such as sadness). Zygomatic activity was increased mainly for happiness, from one hand, corrugator activity was increased mainly for anger, fear and surprise, from the other hand. More generally, EMG and facial behavior were highly correlated each other, showing a "mirror" effect with respect of the observed faces.

Keywords: Facial expression of emotion; Psychophysiological measures; Arousal; Valence

1. Introduction

Emotional face production, recognition and understanding represent a primary social competence, because they contribute to social interactions and social management (Balconi & Lucchiari, 2006; Eisenberg, Eggum & Di Giunta, 2010). Bullock and Russell (1986) proposed a model in which children acquire a system to represent and classify emotions which is based on a limited number of wide categories. The most important of them are the two dimensional axes of the hedonic value and the arousal level. This model was tested by some empirical studies which found that at the first time children interpret facial expressions in terms of pleasure-displeasure (bipolar hedonic value) and intensity (arousal level). Only in a second time they use more articulated and wider conceptual categories (Balconi & Carrera, 2007; Widen & Russell, 2003). Indeed, in order to explain this developmental process, a first main factor related to decoding competences is the type of emotions children express and recognize (Bormann-Kischkel, Vilsmeier & Baude, 1995).

More specifically, about the ability to display emotions, in line with Russell's model of emotional experience, emotion fundamentally varies activation in centrally organized appetitive and aversive motivational systems that have evolved to mediate the wide range of adaptive behaviors necessary for an organism struggling to survive in the physical world (Bradley & Lang, 2007; Davidson, Ekman, Saron, Senulis & Friesen, 1990; Lang, Bradley & Cuthbert, 1990). Thus, a primary distinction among emotional events is whether they are appetitive or aversive, positive or negative, pleasant or unpleasant, which clearly relates to the motivational parameter of direction. Secondly, all agree that hedonically valenced expressions differ in the degree they arouse or engage action, which is related to intensity parameter. Emotional intensity reflects the strength of activation in motivational systems subserving appetitive and defensive behaviors and, as such, has impact on the type of physiological response. Thus, the two dimensions of pleasure and arousal explain the majority of the emotional experience, emotional expressions and subjective judgment on emotions (Balconi, 2012; Balconi & Pozzoli, 2005; Russell, 1980).

It should be noted that young subjects show to be competent in the encoding and decoding of the primary or simple emotions (e.g. happiness and anger), but they have more difficulties in processing secondary or complex emotions, such as pride and embarrassment dismay, and astonishment (Balconi & Lucchiari, 2005; Balconi & Pozzoli, 2003a; Capps, Yirmiya & Sigman, 1992). In parallel, Capps et al. (1992) suggested that the expression and comprehension is more difficult for emotions that imply the activation of some cognitive functions, such as mentalization and metarepresentation. Moreover, these competencies were partially impaired in some clinical groups, such as autistic children (Homer & Rutherford, 2008).

Recent study tried to explore the children competence to adequately respond to facial expression of emotions with coherent facial behavior, that was represented as a sort of "facial feedback" ability (Andrèasson & Dimberg, 2008; Balconi & Bortolotti, 2012a; 2013; Balconi & Canavesio, 2013a). This emotional skill was mainly explored by assessing the main facial patterns produced by children observing other people facial displays. As shown in adult sample, specific "action units" characterize some main emotional expression correlates. However, these measures were mainly focalized on a categorical model (Ekman and Friesen), and they did not take into account the "continuity" of facial expression along some relevant dimensions. At the light of the Russell's model, in fact, we may suppose that also the facial response by children may vary along a continuum determined by arousal and valence, when children see other emotional faces. In the present paper we tried to integrate the Ekman and Friesen's model to the Russell's orthogonal model, including the distinction between valence and arousal. Thus an ampler model should be adopted which was able to consider the facial feedback as a proper behavior that varies as a function of the emotional content that was displayed, it being regulated by the emotional valence and arousal of emotions.

The continuity and modulation of facial displays was also confirmed by observing facial EMG variations in response to specific emotional patterns. In adults, it was observed that the psychophysiological responses to emotional pictures co-vary along continuous dimensions with system evaluation (pleasure/displeasure) and motive intensity (arousal) (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000; Lang, Greenwald, Bradley & Hamm, 1993; Balconi & Bortolotti, 2012b; Balconi, Falbo & Conte, 2012). It was underlined that emotion display and comprehension play a critical role in adaptive behavior, since they promote survival and guide human behavior by exerting a direct influence on brain responsiveness and autonomic activities. Psychophysiological responses are not directly observable, and they include cardiovascular, electrodermal, respiratory measures, etc. Between the others, facial action revealed by EMG measure (electromyogram), heart rate and skin conductance were observed to vary in concomitance of pleasure and displeasure reports while viewing of emotional patterns. Facial EMG (electromyographic) activity accompanies changes in appetitive (positive) and defensive (negative) activation (Balconi, Bortolotti & Gonzaga, 2011; Tassinary, Cacioppo & Geen, 1989). Facial EMG was revealed to be sensitive to the valence dimension, with increased corrugator activity in response to unpleasant patterns and zygomatic activity in response to pleasant patterns. Specifically, the corrugator muscle appears to be responsive to judgment of unpleasant event compared to neutral pictures (Lang et al., 1993). Many studies found a consistent significant relationship between corrugator and hedonic valence, with greater corrugator activity elicited when viewing the most unpleasant stimuli (Balconi, Brambilla & Falbo, 2009a; 2009b; Balconi & Canavesio, 2013b). Moreover, Bradley, Codispoti, Sabatinelli and Lang (2001) showed that pictures that produce disgust (for example mutilation), that were higher in arousal, prompt larger changes than other unpleasant pictures.

However, about these psychophysiological variations in response to emotions and facial stimuli, an important debate regards the presence of a coherent response by psychophysiological measures in childhood, as it was observed in adult subjects. Previous research found consistent patterns of psychophysiological activation in response to emotional stimuli also by children (Bernat, Cadwallader, Seo, Vizueta & Patrick, 2011; McManis, Bradley, Berg, Cuthbert & Lang, 2001). Two studies analyzed the EMG response to facial expression of emotions in young children, showing significant similarities between children' responses and adults' responses (de Wied, van Boxtel, Posthumus, Goudena & Matthys, 2009; Deschamps, Schutte, Kenemans, Matthys & Schutter, 2012). Nevertheless, to verify the coherence of these physiological measures in young people in response to facial emotional patterns, specific analysis should be conducted which included both arousal and valence parameters.

To summarize our main objectives, we decoded the spontaneous productions of children by classifying their facial behavior based on the orthogonal dichotomic variation of arousal and valence. Each emotional facial behavior was characterized by using a continuous measure of valence (positive vs. negative on 7-points scale) and arousal (high vs. low on 7-points scale). In addition, a preliminary analysis allowed to define the specific configuration of each emotional pattern based on Ekman's classification. Secondly, facial EMG was analyzed taking into account the continuous modulation of facial muscle (both zygomatic and corrugator muscle), based on valence and arousal, in response to different facial stimuli. No previous study has directly analyzed the relationship between these multilevel measures, which were spontaneous facial feedback and EMG behavior based on valence and arousal parameters. Finally, the present study was finalized to explore the convergence of these different measures by using a correlational approach.

In particular, we explored the facial responsiveness and physiological reactivity (facial EMG) in response to different facial expressions of emotions. Thus, the purpose of this study was to verify the attended psychophysiological and facial feedback to emotion variation, and, secondly, to show that these processes were related to valence/arousal parameters. These objectives may be strengthened by the following hypotheses:

1. A coherent "facial feedback" was attended in response to emotional facial expressions, taking into account both the behavioral (facial configurations) and EMG variables.
2. Facial feedback should induce a significant modulation in facial expression of emotions by children who should coherently respond to facial configurations by showing analogous facial patters. Moreover it was supposed that these modulations should be sensitive to variations in valence and arousal.
3. More negative or positive valenced faces with higher arousal should elicit more intense responses, being the subjects more engaged with the stimulus, whereas neutral stimuli should be less able to induce intense responses. The interaction effect of these two parameters (i.e. valence and arousal) is also expected. This would suggest that effects due to emotional arousal should be greater for unpleasant and pleasant relevant stimuli.
4. EMG measures should show a significant variation in correlation with emotionally relevant, higher arousal and pleasant or unpleasant stimuli. We supposed that subjects might be more emotionally involved by a high-arousal negative or positive stimulus than neutral or low-arousal pictures, and that they might have a more intense psychophysiological activation while viewing a negative or positive than a neutral pattern. This should produce an increased facial EMG effect and it should be differentiated as a function of the emotional valence, with specific responsiveness by corrugator and zygomatic muscle, respectively for negative and positive emotions.

2. Method

2.1. Participants

The sample included 28 normal children. Ages varied from 6 to 11 (M = 8.75; SD = 0.78; range = 6-11.5; 15 females and 13 males). All these children attend the primary school at Milan or the province. None of them presented cognitive or linguistic deficits. With regard to cognitive competences, children presented a middle-high or high functioning cognitive profile (IQ: M = 93; range = 80-120). The presence of other deficits on the perceptive or cognitive levels was excluded. Children' parents gave informed written consent to participate into the study by their sons, and the research was approved by the local Ethics Committee of the Department of Psychology, Catholic University of Milan.

2.2. Materials

The facial stimuli (cardboards black and white 10 cm × 10 cm) consisted of an emotional face of a young boy/girl showing six emotions (happiness, sadness, anger, fear, disgust and surprise) and one neutral face. The stimulus material was selected by Ekman and Friesen database (1976). We have opted for a young actor aged similarly to the experimental subjects, in order to facilitate the identification process, which would make easier the recognition task (Figure 1).

First time stimuli were presented simultaneously, in order to allow familiarization with the material. In a second assessment, they were presented one at time, in a random sequence, varying the order of the stimulus across the participants. The subjects were required to accurately observe the facial expressions which were presented on the monitor, without other explicit indications about the emotional content of the stimuli.

Figure 1. Examples of facial expression stimuli

2.3. Procedure

FACSAID (Facial Action Coding System Affect Interpretation Dictionary) and EMFACS (Emotional Facial Action Coding System) (Friesen & Ekman, 1983) were used to code each facial expression. Each expression was evaluated immediately after the emotional stimulus was displayed on the video. Each subject was videotaped during the entire experimental session and the encoding procedure was applied on the specific initial registered frame of the subject's response at the onset of facial display appearance on the video. The main results of this coding procedure allowed to define the following categories as emotional expression: happiness: 6 + 12; surprise: 1 + 2 + 5B + 26; sadness: 1 + 4 + 15; fear: 1 + 2 + 4 + 5 + 20 + 26; anger: 4 + 5 + 7 + 23; disgust: 9 + 15 + 16. These results were also compared with the classical FACS analysis (Ekman & Friesen, 1976), allowing to support the homogeneity of facial profiles.

Secondly twelve judges evaluated the subjects' facial expressions by using a nine-point scale taking into account the hedonic value (positive/negative) and the arousal value (more/less arousal) of the emotional content expressed by the subjects' faces (Balconi, 2012; Balconi, Amenta & Ferrari, 2012). The same initial frame used to apply FACSAID and EMFACS was used to evaluate the arousal/valence parameters. An inter-reliability value was calculated between the judges for each emotional type and rating scale. Cronbach's alpha was calculated for anger (arousal 0.84, and valence 0.83), fear (0.94, 0.88), surprise (0.88, 0.91), disgust (0.86, 0.89), happiness (0.84, 0.83), sadness (0.82, 0.86), and neutral (0.84, 0.89).

2.4. EMG data reduction

Facial electromyographic (EMG) activity in the zygomaticus major and corrugators supercilii muscle regions were considered. The electrodes (4 mm diameter Ag/AgCl electrodes), filled with Surgicon electrolyte paste, were positioned over the corrugators and zygomatic muscles in accordance with guidelines for psychophysiological recording (Blumenthal et al., 2005; Fridlund & Cacioppo, 1986; Biofeedback 2000, version 7.01). Frequencies of interest generally ranged from 20 to 400 Hz. Corrugator and zygomatic EMG responses were successively scored as the difference between the mean rectified corrugators/zygomatic signals present during the presentation of the stimuli and the mean rectified signals in the 1 s prior to stimulus presentation (baseline measure). A positive value indicates that the corrugators/zygomatic measures were greater during the experimental phase than during the baseline phase.

3. Results

3.1. Behavioral measures

Type I errors associated with inhomogeneity of variance were controlled by decreasing the degrees of freedom using the Greenhouse-Geiser epsilon.

About the valence attribution, ANOVA showed a significant emotion effect ($F[6, 27] = 8.16$, $p \leq .01$, $\eta^2 = .36$). Post-hoc comparisons (contrast analysis, with Bonferroni corrections for multiple comparisons) showed increased negative valence attribution for anger, fear, surprise, disgust and sadness in comparison with happiness and neutral face. Moreover, happiness was considered as more positive than the other stimuli (all comparisons $p \leq .01$) (Figure 2).

About the arousal attribution it was found a significant emotion effect ($F[6, 27] = 10.60$, $p \leq .01$, $\eta^2 = .41$). Post-hoc comparisons showed increased arousal attribution for anger, fear, disgust and surprise in comparison with happiness and sadness. Moreover anger, fear, and surprise were rated as higher arousal level than disgust (all paired comparisons $p \leq .01$). Finally, all the emotional stimuli were considered higher in arousal than neutral faces (all paired comparisons $p \geq .01$).

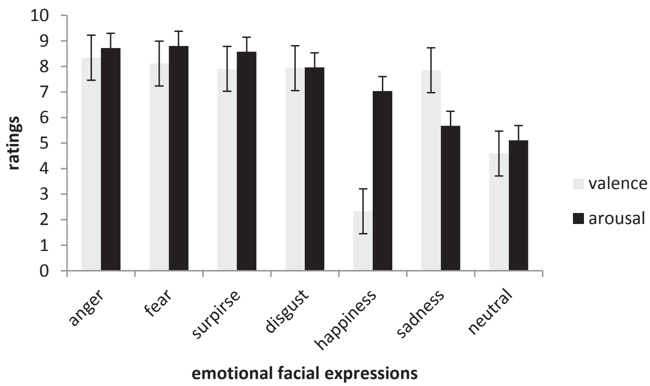

Figure 2. Mean rating values for valence and arousal in response to different emotions

3.2. EMG measures

Successively, two repeated measure ANOVAs (with an independent factor, emotion) were applied to each dependent autonomic EMG measures of the zygomatic and corrugator muscle.

Zygomatic EMG activity revealed significant differences as a function of emotion ($F[6, 27] = 9.08$, $p \leq .01$, $\eta^2 = .40$). As shown by contrast effects, EMG activity was enhanced in response to positive stimuli in comparison with negative and neutral faces (all comparisons $p \leq .01$). Contrarily, corrugator EMG activity was increased for negative emotions, respectively for anger, fear, disgust and surprise in comparison with happiness, sadness and neutral stimuli (Figure 3). Moreover anger, fear and surprise revealed a higher corrugator activity increasing when compared with disgust (all comparisons $p \leq .01$).

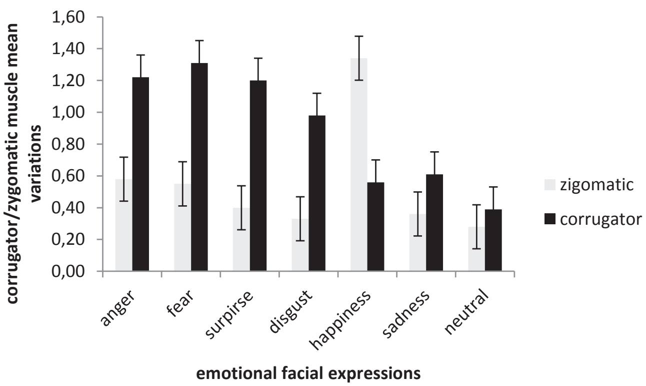

Figure 3. Mean zygomatic and corrugator modulations in response to different emotions

3.3. Correlational analysis between valence, arousal ratings and EMG measures

Distinct correlational analyses (Pearson coefficient) between each psychophysiological measure and valence/arousal rating for each emotion were performed. We report in Table 1 the coefficients.

Table 1. Correlational values (Pearson coefficients) between EMG activity (zygomatic and corrugator muscle) and arousal and valence rating for the different emotions

	Corrugator	Zygomatic
	Anger	
arousal	**.457****	.123
valence	**.543****	.176
	Fear	
arousal	**.511****	.134
valence	**.523****	-.123
	Surprise	
arousal	**.432***	-.119
valence	**.498****	.189
	Disgust	
arousal	.234	.129
valence	**.419***	.165
	Sadness	
arousal	.229	.123
valence	-.170	.229
	Happiness	
arousal	.119	**-.459****
valence	.189	**-.511****
	Neutral	
arousal	.167	.172
valence	.139	.155

* $p = .05$; ** $p = .01$

As shown in Table 1, arousal and valence measures were significantly correlated with zygomatic muscle activity for happiness, whereas arousal and valence ratings were correlated with the corrugator muscle responsiveness for anger, fear and surprise.

On the contrary, in response to disgust, only the valence was significantly correlated with the corrugator muscle. No significant correlation was observed for sadness and neutral stimuli.

4. Discussion

The present study allowed to elucidate some important points in relationship with the facial emotion behavior in young children in response to different facial expressions of emotion. Significant results were found taking into account both the behavioral measures rated on a dichotomic axe (the valence and arousal) and the EMG psychophysiological responsiveness as a function of the zygomatic/corrugator muscle activity. Moreover, their intrinsic relationship was verified, showing a consonant profile between the autonomic and the behavioral measures. This point allowed to confirm the coherence of these two different levels in children emotional encoding. Finally, some emotional patterns (anger, fear, happiness and surprise) were better expressed by considering both the facial behavior and the autonomic responsiveness.

4.1. Arousal and valence effect on facial expressions

As hypothesized by the dimensional approach to emotion (Balconi & Pozzoli, 2003b; Ellsworth & Scherer, 2003; Russell, 1980), the two axes of valence and arousal characterized the emotional patterns. Specifically children were able to express each pattern as a function of high (for anger, fear, disgust, surprise and happiness) vs. low (sadness and neutral faces) arousal feature, and as a function of positive (happiness) vs. negative (anger, fear, disgust, surprise) valence feature. In particular, the negative emotions were also expressed with a higher arousal level if compared with other emotions (i.e. happiness). In fact, the positive emotion of happiness was positively connoted with a significant arousal level, but in general it was less intensely expressed in comparison with other negative emotions. Therefore a first main result of the present study was that the dichotomy pleasure/displeasure and high/low arousal was coherently adopted by the subjects, confirming their significant role in emotion encoding and decoding, as indicated by previous researches (Balconi, 2004; Balconi & Pozzoli, 2003a; Ellsworth & Scherer, 2003). In fact, from one hand, not only the hedonic category was useful to represent the entire pattern of facial expressions, but it was continuously declined in expressing the emotional correlates in terms of negativity/positivity. On the other hand, arousal rating can be considered a predictive cue of the ability to express and differentiate emotional correlates. Indeed, it was crucial to characterize the emotional encoding process in children.

As regard to more negative and high-arousal emotions (fear, anger and surprise) some recent study revealed also high rates of recognition, that the researcher attributes to the central adaptive function of these negative high-arousal emotions (Balconi & Carrera, 2007; Bernat, Bunce & Shevrin, 2001; Castelli, 2005). The prominence of specific category of emotion (more negative and high-arousal) may suggest their central role in emotion acquisition in comparison with other less relevant (and less-arousal) emotions in childhood. Indeed, they have a main role for the individual safeguard, both on an ontogenetic and a phylogenetic level. They may be represented as a cue in order to detect unfavorable environmental conditions (Balconi, 2004; Balconi & Pozzoli, 2003a). Accordingly to the functional model (Frijda, 1994; Lazarus, 1999), these emotional expressions represent a response to a particular event, significant in terms of costs and benefits for people. Specifically, the expression of anger and fear represents the perception of a threat for the personal safeguard and, therefore, it requires a greater investment of attentional resources.

More generally, we found that children were highly responsive to facial stimuli, by adopting a sort of "facial feedback" modality, since they used facial configurations similar to which were displayed by the pictures (consonant behavior), as a function of the positive/negative and high/low arousal modulation (Balconi & Bortolotti, 2012a). This important result allowed to point out the adequacy of children' skills about the emotional facial encoding and the variability of facial expressions as a function of the dimensional axes proposed by Russell (1980).

4.2. Psychophysiological correlates of emotional faces

A relevant main result of the present research was related to the psychophysiological measures which were shown to vary in concomitance to the type of stimuli, mainly related to the valence and arousal parameters. In fact, children revealed a coherent psychophysiological behavior in response to the emotions and it was shown that EMG activity was modulated as a function of the two main axes of valence and arousal. In parallel, the psychophysiological behavior replicates of the produced facial display, with an increased "positive" (zygomatic) facial expression for happiness, from one hand; an increased "negative" (corrugator) facial expression mainly for anger, fear and surprise, from the other hand. We discuss these main points in the following paragraph.

Firstly, it was observed an increasing of mimic activity in case of some emotional conditions: the different emotions evoked distinct facial EMG response patterns, with increased zygomatic muscle activity to positive patterns and increased corrugator muscle activity to negative patterns, whereas both the corrugator and the zygomatic muscle response patterns were less pronounced in sadness and neutral condition. More generally, corrugator muscle activity was increased in response to more negative and high-arousal stimuli, mainly for fear, anger, and surprise.

These variations may mark a significant response in case of a high arousal displays, since facial patterns rated with more arousal level seem to produce and reinforce a coherent autonomic behavior, for both the two positive and negative emotional categories. Contrarily, it was observed a reduced arousal level for sadness and partially for disgust, fact that may explain the concomitant reduced EMG values. Thus, high arousal faces showed a perfect consonance between behavioral display and psychophysiological measures. More generally the modulation of psychophysiological measures was mainly related to arousal level more than to valence, since, independently from the valence, faces rated as high arousal (anger, fear, surprise and happiness) were able to induce a more significant and coherent EMG response.

In addition, correlational analysis confirmed these results. Both arousal and valence ratings were significantly related with the psychophysiological variations: arousal and valence were correlated with the corrugator modulation in response to the negative emotions, whereas they were related with the zygomatic muscle in response to positive emotions (happiness). These results support the existence of a strength relationship between the facial behavior and the autonomic measures as they were revealed by EMG. The estimated coherence between these two levels and their relevance with respect of the valence and arousal parameters allow to support the usability of both these measures to test the emotional encoding skills in children. Secondly, we may state that the autonomic variables may function as significant marker of the emotional behavior of young people and that they may be predictive of their displayed behavior.

Thirdly, in general psychophysiological measures may be interpreted as functional mechanism of "mirroring" the emotional condition displayed by the observed facial stimuli, where "sharing" similar emotional responses may facilitate a direct form of understanding and recognize emotion by a sort of simulation process. In other words, children replicate the facial behavior and autonomic activity observed in both positive vs. negative conditions (Andrèasson & Dimberg, 2008; Balconi & Bortolotti, 2012a). More specifically, emotional facial patterns which children observe may ingenerate a consonant useful response, since they firstly recognizes and secondly "mimic" (by face and autonomic behaviour) the somatic markers related to the observed emotions (Balconi & Bortolotti, 2012b).

5. Conclusion

To summarize, behavioral measures were replicated by psychophysiological level, that showed to vary coherently in relationship with different emotions. Children revealed a consonant and adequate behavior in terms of facial display and psychophysiological responsiveness. However, a clear advantage was observed for some specific emotions, those rated as higher arousal and negative (fear, anger and surprise). It was suggested these emotions may be central to people safeguard and they may be priority developed by children (Balconi, Bortolotti & Gonzaga, 2011). Arousal attribution was considered as the most critical parameter to explain the emotion encoding process and the psychophysiological behavior. Contrarily, sadness and disgust were less prominent in terms of both arousal and valence.

However, future research may explore more directly the intrinsic effect induced by facial expression of emotion taking into account also gender effect. Indeed previous research found significant differences between male/female children in response to the emotional type. Secondly, the arousal effect we found in the present study should be better considered in relationship with different emotional valence taking into account a wider range of facial expressions which may cover the ample orthogonal axes low/high arousal positive/negative valence.

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