Generalizing Duchenne to Sad Expressions With Binocular Rivalry and Perception Ratings

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Discrete emotion theories emphasize the modularity of facial expressions, while functionalist theories suggest that a single facial action may have a common meaning across expressions. Smiles involving the Duchenne marker, eye constriction causing crow’s feet, are perceived as intensely positive and sincere. To test whether the Duchenne marker is a general index of intensity and sincerity, we contrasted positive and negative expressions with and without the Duchenne marker in a binocular rivalry paradigm. Both smiles and sad expressions involving the Duchenne marker were perceived longer than non-Duchenne expressions, and participants rated all Duchenne expressions as more affectively intense and more sincere than their non-Duchenne counterparts. Correlations between perceptual dominance and ratings suggested that the Duchenne marker increased the dominance of smiles and sad expressions by increasing their perceived affective intensity. The results provide evidence in favor of Darwin’s hypothesis that specific facial actions have a general function (conveying affect intensification and sincerity) across expressions.

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apparent sincerity of both positive and negative emotional expressions.

Smiles involving the Duchenne marker occur in more positive circumstances (Frank, Ekman, & Friesen, 1993) and are perceived as more positive than other smiles (Gunnery & Ruben, 2016; Krumhuber & Manstead, 2009). The Duchenne marker is also a component of adult pain expressions (Kappesser & Williams, 2002) and infant cry-face expressions (Mattson, Cohn, Mahoor, & Gangi, 2013). However, no study has tested whether the Duchenne marker intensifies the valence of both positive and negative adult expressions.

Likewise, a large body of literature has focused on the sincerity of smiles involving the Duchenne marker. Smiles with the Duchenne marker are associated with smile authenticity and are rated as more sincere than smiles without the Duchenne marker (e.g., Frank et al., 1993; Gunnery & Ruben, 2016; Krumhuber & Manstead, 2009). However, little is known about the perceived sincerity of negative expressions involving the Duchenne marker. In this study, we compare the perceived valence intensity of Duchenne and non-Duchenne expressions, as well as perceptions of their sincerity.

To investigate the perceptual basis of reactions to Duchenne and non-Duchenne expressions we employed a binocular rivalry paradigm. Binocular rivalry is characterized by spontaneous switches in conscious perception between monocularly presented images (Tong, Meng, & Blake, 2006), and indexes perceptual dominance and saliency during emotion processing (Bammerman, Milders, De Gelder, & Sahraie, 2008). The viewing time of an image when in competition with another image during binocular rivalry is its dominance duration. Dominance duration indexes an image’s perceptual strength or saliency (Bagby, 1957). More salient stimuli, like those with emotional content, have longer dominance durations than less salient stimuli, like neutral expressions (Yoon, Hong, Joormann, & Kang, 2009). During binocular rivalry, positive facial expressions tend to be perceived for longer than negative expressions (Yoon et al., 2009). However, there is no relevant research focused on the Duchenne marker. We hypothesized that Duchenne expressions represent more affectively intense stimuli which would be more perceptually salient and so more likely to dominate binocular rivalry than non-Duchenne expressions.

Motivated by a functionalist/dynamic perspective, we probed the general hypothesis that the Duchenne marker intensifies the perceived valence and sincerity of both positive and negative expressions. Specifically, we tested whether Duchenne smiles and Duchenne sad expressions are perceptually dominant during binocular rivalry relative to their non-Duchenne counterparts. Complementing binocular rivalry with participant ratings, we tested whether the Duchenne marker led smiles to be perceived as more positive, sad expressions to be perceived as more negative, and both smiles and sad expressions to be perceived as more sincere than identical non-Duchenne expressions. Finally, we anticipated that the perceptual dominance of Duchenne smiles and Duchenne sad expressions during rivalry would be associated with their valence intensity and sincerity ratings.

Method

Participants

Twenty-eight undergraduate students (18 females, 10 males; age range 19–34) with normal or corrected-to-normal vision took part in the experiment for course credit. Participants consented to study procedures prior to participation, and all procedures were approved by the McGill Research Ethics Boards.

The sample size was chosen based on effect sizes reported in previous investigations utilizing emotion stimuli in similar paradigms. Yoon and colleagues (2009) compared 38 participants’ perceptions of positive (happy), negative (disgust), and neutral expressions during binocular rivalry and observed a very large effect size, $t(37) = 4.61$, $p < .001$, $d = .82$, in favor of emotion expressions when compared to neutral expressions and of positive expressions when compared to negative expressions. Bolzani-Dinehart and colleagues (2005) investigated ratings of positive and negative infant expressions with and without the Duchenne marker in 95 participants. Effect sizes, indicating greater valence for expressions with the Duchenne marker in these infant expressions, were large, $15 < R^2 < .34$ (i.e., $.84 < d < 1.44$).

Based on these effect sizes, estimates of the projected power of Duchenne marker effects conducted, using G*Power Version 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) with an alpha level of .05, yielded power estimates from .85 to .99 for both positive and negative expressions.

Stimuli

Previous binocular rivalry studies of emotion expressions employed black and white photographs or schematic drawings as rivaling stimuli and did not control for their sensory salience (i.e., brighter or higher contrast)—a predictor of dominance durations (Levitt, 1965). We employed software-generated, naturalistic facial stimuli, matched for contrast and luminance. We created three naturalistic base facial identities of similar skin tone (i.e., three identities; luminance levels 8.76–10.56 cd/m$^2$) with FaceGen Modeler (v3.1.2, Singular Inversions, Toronto, ON) software, which creates recognizable expressions with a naturalistic appearance (Krumhuber & Scherer, 2016). Stimuli were manipulated with the FACSGen Animation Software (v2.0, University of Geneva, Affective Sciences, Geneva, CH) to create expressions validated with the Facial Action Coding System (FACS; Krumhuber, Tamarit, Roesch, & Scherer, 2012). FACS describes expressions based on their smallest distinguishable features, referred to as action units (AUs; Ekman & Friesen, 1976). Smiles and sad expressions were generated with and without the Duchenne marker (AU6, cheek raiser) that constricts the eyes, creating wrinkles lateral to the eyes (Figure 1a). Smiles involved oblique raising of the lip corners (AU12, zygomaticus major). Sad expressions involved depression of the lip corners (AU15, depressor anguli oris), elevation of the middle portion of the forehead and brows (AU4, corrugator supercili, depressor supercili), and depression of the lateral portion of the brows (AU11, frontalis, pars medialis). Together with a neutral (no AU) expression, yielded five expressions (or stimuli) for each of the three facial identities: Duchenne smile, non-Duchenne smile, neutral expression, non-Duchenne sad expression, and Duchenne sad expression (Figure 1b).$^1$

For each identity, 10 rivalry conditions were generated in which all five stimuli were paired (e.g., Duchenne smile with non-Duchenne smile, neutral expression, non-Duchenne sad expression). 

$^1$ An additional 12 identities conveying non-Duchenne smile, neutral, and non-Duchenne sad expressions were used to familiarize participants with the procedure.
sion, and Duchenne Sad expression; non-Duchenne smile with neutral expression, non-Duchenne sad expression, and Duchenne sad expression; neutral expression with non-Duchenne sad expression and Duchenne sad expression; and non-Duchenne sad expression with Duchenne sad expression). Counterbalancing the eye to which stimuli were presented (e.g., Duchenne smile to the right eye and non-Duchenne smile to the left eye, and then the reverse) yielded 20 conditions. Each of these was presented twice, in each of the three identities, yielding 120 trials presented in random order.

Our focal analyses involved the 24 trials per participant that rivaled Duchenne and non-Duchenne smile and Duchenne and non-Duchenne sad expressions. The 12 trials rivaling non-Duchenne smile and non-Duchenne sad expressions were also analyzed to verify whether positive expressions dominated negative expressions. In an independent experiment, five expressions of one facial identity were inverted (Figure S1a) and presented using the paradigm detailed above (see Figure S1b and S1c for results).

**Procedure**

**Binocular Rivalry**

The presentation of stimuli and management of participant data were programmed in MATLAB® (R2012b, The MathWorks, Inc., 2012).
Stimuli Ratings

After performing the binocular rivalry experiments, the facial expressions were presented individually in random order on the computer screen. Participants were instructed to rate naturalness, valence intensity, and sincerity on separate 5-point Likert scales (see Table S1 for the ratings of each participant).

Participants first rated the naturalness of only the neutral expressions for the three facial identities, responding to the query: “How natural looking do you find the face?” (1 = not natural looking/cartoon-like, 5 = very natural looking/realistic). All facial expressions—Duchenne smile, non-Duchenne smile, neutral expression, non-Duchenne sad expression, and Duchenne sad expression—were then rated on (a) valence intensity, “How negative/positive do you find the stimulus?” (1 = very negative, 5 = very positive), and (b) sincerity, “How sincere do you find the expression?” (1 = not at all, 5 = very).

Analysis

Binocular Rivalry

In brief, binocular rivalry was operationalized as mean dominance duration—a comparison of the mean duration of button presses for the Duchenne to those for the non-Duchenne expressions (see Figure 2). Specifically, each pairing of a Duchenne and non-Duchenne expression occurred over four trials. In two trials, the Duchenne expression was presented to the left eye and the non-Duchenne expression to the right; in two trials, presentation to the left and right eyes was reversed. For each trial, we calculated the mean duration of Duchenne button presses and non-Duchenne button presses. Dominance durations were then calculated over the two trials for each pairing of expression and eye presented to (e.g., Duchenne expressions presented to the right eye) and then averaged. These mean dominance durations were the participant level data used in binocular rivalry analyses. Dominance duration data

Results

Binocular Rivalry

We first investigated emotion valence effects on binocular rivalry using the non-Duchenne expressions to confirm the dominance of positive expressions over negative ones. Non-Duchenne smiles (mean \( M = 7.16 \) sec, confidence intervals (CI) \([5.03, 9.29]\)) dominated non-Duchenne sad expressions (\( M = 1.56 \) sec, CI \([1.14, 1.98]\)), \( F(1, 24) = 26.37, p < .001, \eta^2_p = .52, \beta = .998 \) (see Figure 3). There were no interactions between this valence effect and gender, dominant eye, or presentation eye; nor were there any significant higher-order interactions (Table S2).

We next tested whether Duchenne expressions dominated binocular rivalry relative to non-Duchenne expressions. Duchenne smiles (mean \( M = 7.83 \) sec, CI \([5.45, 10.21]\)) dominated non-Duchenne smiles (\( M = 1.18 \) sec, CI \([.65, 1.71]\)), \( F(1, 24) = 30.72, p < .001, \eta^2_p = .56, \beta = 1.00 \) (Figure 4a). Duchenne sad expressions (mean \( M = 7.22 \) sec, CI \([4.42,10.02]\)) dominated non-Duchenne sad expressions (\( M = .98 \) sec, CI \([.54, 1.42]\)), \( F(1, 24) = 19.89, p < .001, \eta^2_p = .45, \beta = .99 \) (Figure 4b). There were no interactions between these Duchenne effects and gender, dominant eye, or presentation eye for either smiles or sad expressions, nor were there higher-order interactions (Table S3). All participants showed a mean dominance duration that was longer for Duchenne smiles than non-Duchenne smiles. Of the 28 participants, 26 showed a mean dominance duration that was longer for Duchenne sad expressions than for non-Duchenne sad expressions. These results indicate that both Duchenne smiles and Duchenne sad expressions are perceptually dominant relative to their respective non-Duchenne variants. Effect sizes, \( \eta^2_p \), indicated that approximately half the variance in mean dominance duration was explained by the Duchenne effect, which characterized the perceptions of almost every participant.

Stimuli Ratings

Neutral expressions were rated as naturalistic (mean \( M = 4.08, CI \([3.92, 4.25]\)) on the 5-point Likert scale, supporting the ecological validity of the stimuli.

Participants perceived Duchenne smiles (mean \( M = 4.89, CI \([4.83, 4.95]\)) as more positive than non-Duchenne smiles (mean \( M = 4.01, CI \([3.99, 4.04]\)), \( F(1, 27) = 626.49, p < .001, \eta^2_p = .96, \beta = 1.00 \) (Figure 5a). Duchenne sad expressions (mean \( M = 1.05, CI \([0.99, 1.11]\)) were perceived as more negative than non-Duchenne sad expressions (\( M = 1.95, CI \([1.88, 2.02]\)), \( F(1, 27) = 406.13, p < .001, \eta^2_p = .94, \beta = 1.00 \) (Figure 5b). All participants reported higher
sincere than the homolog non-Duchenne expressions. Interindividual consistency such that almost all participants perceived Duchenne marker were perceived as more affectively intense and sincere than expressions without the marker. Effect sizes, \( r \), indicated that more than two thirds of the variance in ratings was explained by the Duchenne effect. In addition, there was striking interindividual consistency such that almost all participants perceived Duchenne expressions as more affectively intense and sincere than the homolog non-Duchenne expressions.

**Correlations Between Ratings and Binocular Rivalry Dominance Durations**

We examined correlations between the mean dominance durations of each expression (from the binocular rivalry pairings of Duchenne and non-Duchenne smiles and sad expressions) and the rated valence intensity and sincerity of those expressions using Pearson correlations. There were strong correlations between the mean dominance durations of smiles (non-Duchenne and Duchenne) and their valence intensity ratings, \( r = .57, \text{CI} [.36, .72], p < .001 \). Likewise, there were strong negative correlations between the mean dominance durations of sad expressions (non-Duchenne and Duchenne) and their valence intensity ratings, \( r = -.48, \text{CI} [-.66, -.25], p < .001 \). That is, smiles that exhibited greater perceptual dominance were perceived as more positive. Sad expressions that exhibited greater perceptual dominance were perceived as more negative. Greater perceptual dominance was also associated with greater sincerity for both Duchenne smiles, \( r = .43, \text{CI} [.18, .62], p = .001 \), and Duchenne sad expressions, \( r = .37, \text{CI} [.12, .58], p = .005 \). These results indicate that the longer dominance durations of Duchenne expressions found during binocular rivalry were associated with greater valence intensity and sincerity of those expressions.
ocular rivalry are associated with participants’ perceptions of these expressions’ valence intensity and sincerity.

Discussion

Discrete emotion theory posits a one-to-one correspondence between specific emotions and their facial expressions (Ekman & Cordaro, 2011; Tracy & Randles, 2011). However, Darwin held that the Duchenne marker may signal a more intense and genuine expression in multiple expressive contexts (Darwin, 1872/2009). As predicted, the current binocular rivalry results indicate that the Duchenne marker rendered both positive and negative expressions perceptually dominant. Expressions involving the Duchenne marker were also rated as more emotionally intense (smiles appeared more positive and sad expressions appeared more negative) and more sincere. Finally, ratings of expressions’ valence intensity and sincerity were associated with their binocular dominance, suggesting a correspondence between perceptual strength and ratings.

As in prior ratings of Duchenne and non-Duchenne smiles, the current results indicate that eye constriction contributes to the intensity of adult positive facial expressions (Gunnery & Ruben, 2016; Krumhuber & Manstead, 2009). Here, we show for the first time that the Duchenne marker also intensifies the emotional valence of sad expressions. It should be noted, however, that the Duchenne marker may not increase intensity in all negative expressions (Susskind, Lee, Cusi, Feiman, Grabski, & Anderson, 2008). In fear, for example, eye opening rather than eye constriction, may be associated with increased affective intensity (Matsunoto, 1989).

This study indicates that Duchenne expressions are perceived as more sincere than their non-Duchenne counterparts. Duchenne smiles are associated with ratings of extraversion, likeableness, and trustworthiness (Frank et al., 1993; Johnston, Miles, & Macrae, 2010), but this is the first demonstration that the Duchenne marker contributes to the perceived sincerity of sadness as well.

The longer mean dominance durations of Duchenne expressions during binocular rivalry suggest these expressions are more perceptually salient than identical expressions without the

Figure 3. Dominance durations of non-Duchenne smiles when rivaled against non-Duchenne sad expressions for each participant (colored lines [varying colors along the grayscale palette]) and the mean across participants (thick black line). Error bars represent 95% confidence intervals. See the online article for the color version of this figure.

Figure 4. Dominance durations of rivaled Duchenne and non-Duchenne smiles (a) and rivaled Duchenne and non-Duchenne sad expressions (b) for each participant (colored lines [varying colors along the grayscale palette]) and the mean across participants (thick black line). Error bars represent 95% confidence intervals. See the online article for the color version of this figure.
Duchenne marker. For both smiles and sad expressions, the magnitude of mean dominance durations was associated with ratings of both affective intensity and sincerity. This suggests that the greater salience of Duchenne smile and Duchenne sad expressions indexes a propensity to view these expressions as both sincere and affectively intense. This predilection to perceive Duchenne expressions suggests the importance of detecting genuine and intense emotional signals in conspecifics.

Overall, the Duchenne marker intensified the perceptual salience as well as the affective valence and sincerity of both smiles and sad expressions. The results suggest that a single facial action may have general functions across multiple expressions—in the case of the Duchenne marker, intensifying valence and increasing perceptions of sincerity. These findings, which depart from and expand functional theories of emotional expressions, are a step toward understanding the more general question of why facial expressions contain the specific facial actions they do.

References

