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Generalizing Duchenne to Sad Expressions with Binocular Rivalry and Perception Ratings

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Abstract

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.

Keywords: Duchenne marker, smile, sad, valence, binocular rivalry

Generalizing Duchenne to Sad Expressions with Binocular Rivalry and Perception Ratings

Discrete emotion theory emphasizes the modularity and unique form of facial expressions (Ekman & Cordaro, 2011; Tracy & Randles, 2011). Functionalist and dynamic emotion theories suggest that a given facial action might have a single role across multiple facial expressions (Barrett, 2006). In fact, Darwin (1872/2009) observed the Duchenne marker in expressions of strong, genuine emotions—specifically smiles and grief. The Duchenne marker is produced by *orbicularis oculi pars lateralis*, which raises the cheeks, narrows the eyes, and causes wrinkling around the corners of the eyes (de Boulogne, 1990; Ekman, Friesen, & Hager, 2002). Here we test whether a specific facial action, the Duchenne marker, has a general function: increasing the perceptual salience, affective intensity, and 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, Ekman, & Friesen, 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 (Bannerman, Milders, De Gelder, & Sahrai, 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, Hong, Joormann, & Kang, 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, $.15 < \eta_p^2 < .34$ (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 (Levelt, 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 Modeller (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 and 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 supercilii*, *depressor supercilii*), and depression of the lateral portion of the brows (AU1, *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).

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, 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., Natick, MA) using the Psychophysics toolbox (Brainard, 1997). Stimuli were presented using a CRT monitor (*LaCie* Electro-n22blueIV, 40×30.5 cm, 1280×1024 pixel resolution, 75 Hz refresh rate; Portland, OR). The viewing distance was 35.6 cm. Participants viewed the stimuli through a mirror stereoscope so that each side of the screen was presented with a different stimulus, subtending 7.23°×8.03° of visual angle (Figure 1c). Experiments were performed in a dark room. A chin rest kept the participant's head stationary. Participants were asked to maintain fixation throughout each trial on a white fixation cross situated on the bridge of the identity's nose (i.e., the center of the face) (Figure 1b).

Each trial lasted 40 seconds. The first five seconds permitted the participant to discern which stimulus was being shown to which eye, and the last 35 seconds were analyzed. Throughout a trial, participants pressed the number "1" key of a keyboard when they perceived the face stimulus corresponding to the left eye, the number "3" when they perceived the right face stimulus, and the number "2" if a combination of both stimuli was perceived (Figure 1d). Participants were not asked to identify the facial expression they perceived, but simply to report whether they perceived the left or right face stimulus. The timing of when each key was pressed was recorded by MATLAB.

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).

<u>Analysis</u>

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 (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 are available at https://osf.io/xevs4/?view_only=c2f32266bd1040678220cdaf3ebdb8b2.

As preliminary analyses did not reveal significant interactions between identity and the Duchenne marker, $F(2,23) < 1.50$, $p > .243$, $\eta_p^2 < .12$, $\beta < .29$, we averaged mean dominance durations across identities. Mean dominance durations were subjected to repeated-measures analyses of covariance (ANCOVA). The ANCOVAS controlled for participant gender (Dimberg & Lundquist, 1990), participant dominant eye (Bartels, Vázquez, Schindler, Logothetis, 2011), and presentation eye (the eye to which a stimulus was presented), as well as interactions between these factors and the Duchenne marker.

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]), $F(1,24) = 26.37$, $p < .001$, $\eta_p^2 = .52$, β = .998 (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 (*M* = 7.83 sec, *CI* = [5.45, 10.21]) dominated non-Duchenne smiles (*M* = 1.18 sec, *CI* = [.65, 1.71]), $F(1,24) = 30.72$, $p < .001$, $\eta_p^2 = .56$, β = 1.00 (Figure 4a). Duchenne sad expressions (*M* = 7.22 sec, *CI* = [4.42,10.02]) dominated non-Duchenne sad expressions (*M* = .98 sec, *CI* = [.54, 1.42]), $F(1,24) = 19.89$, $p < .001$, $\eta_p^2 = .45$, β = .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, η_p^2s, 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 (*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 (*M* = 4.89, *CI* = [4.83, 4.95]) as more positive than non-Duchenne smiles (*M* = 4.01, *CI* = [3.99, 4.04]), $F(1,27) = 626.49$, $p < .001$, $\eta_p^2 = .96$, β

= 1.00 (Figure 5a). Duchenne sad expressions (*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, $p < .001$, $\eta_p^2 = .94$, β = 1.00 (Figure 5b). All participants reported higher ratings (greater valence intensity) for Duchenne smiles than for non-Duchenne smiles. Likewise, all participants reported lower ratings (greater valence intensity but in the opposite direction) for Duchenne sad expressions than for non-Duchenne sad expressions.

Both Duchenne smiles (*M* = 4.14, *CI* = [3.86, 4.43]), *F*(1,27) = 72.20, $p < .001$, $\eta_p^2 =$ .73, β = 1.00 (Figure 5c) and Duchenne sad expressions (*M* = 3.73, *CI* = [3.39, 4.07]), *F*(1,27) = 60.12, $p < .001$, $\eta_p^2 = .69$, β = 1.00 (Figure 5d) were perceived as more sincere than their non-Duchenne counterparts. Of the 28 participants, 26 rated Duchenne smiles as more sincere than non-Duchenne smiles, and 27 rated Duchenne sad expressions as more sincere than non-Duchenne sad expressions.

Overall, both smiles and sad expressions containing the Duchenne marker were perceived as more affectively intense and sincere than expressions without the marker. Effect sizes, η_p^2s, indicated that more than two-thirds of the variance in ratings was explained by the Duchenne effect. In addition, there was striking inter-individual 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, *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, *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, *CI* = [.18, .62], $p = .001$, and Duchenne sad expressions, r = .37, *CI* = [.12, .58], $p =.005$. These results indicate that the longer dominance durations of Duchenne expressions found during binocular 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 (Matsumoto, 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, Ekman, & Friesen, 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 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.

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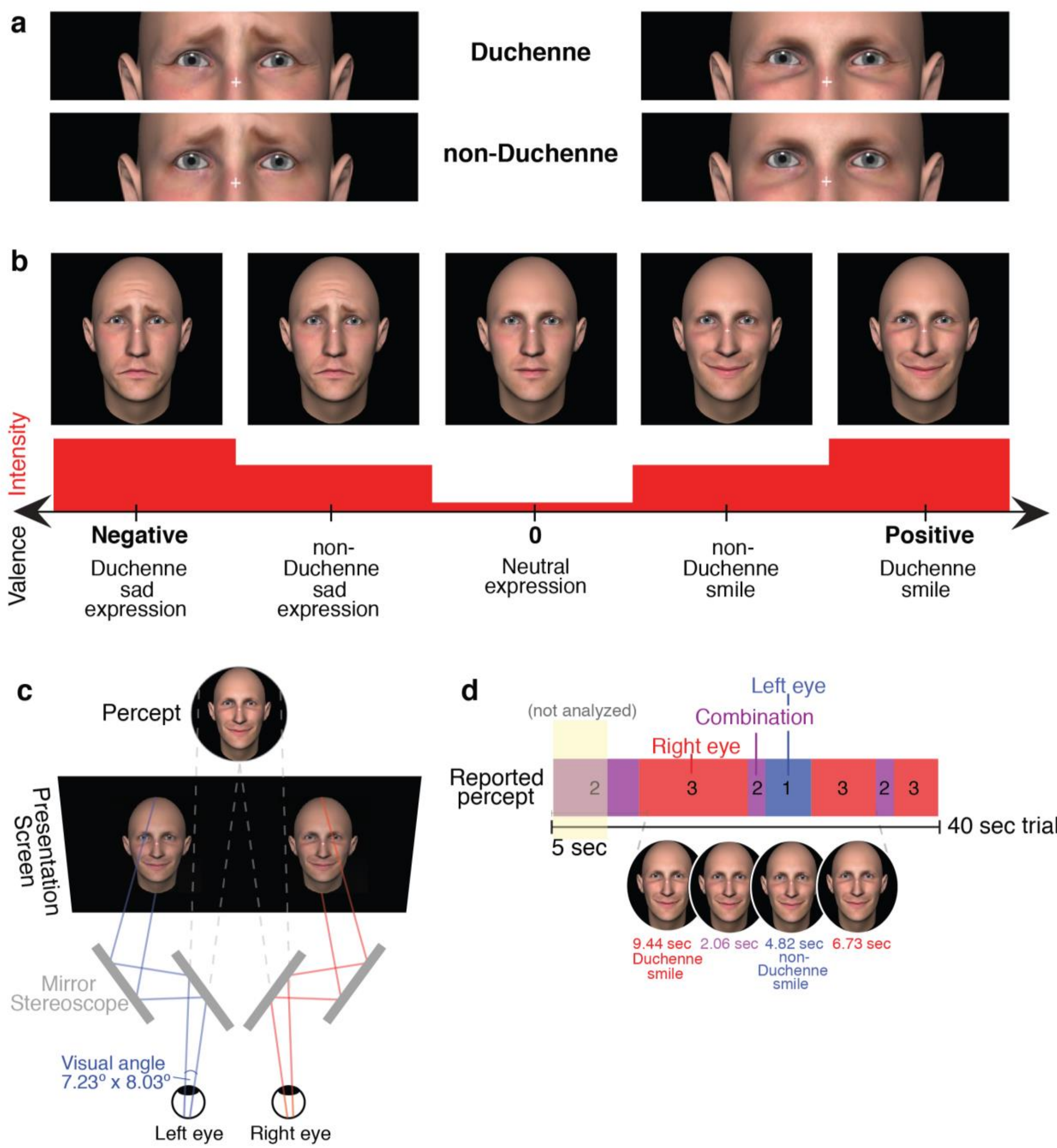

Figure 1. Stimuli and binocular rivalry schematic. (a) A close-up distinction of the Duchenne marker, at the top with eye constriction, and non-Duchenne marker, at the bottom, for both the sad expressions (left) and smiles (right). (b) An example of the stimuli for one of the three identities with five expressions whose hypothesized valence (black arrow) and intensity (red [dark gray] bars) scale are displayed. (c) Binocular rivalry paradigm illustrates a condition in

which the non-Duchenne smiles of one identity was presented to the left eye and the Duchenne smiles of the same identity to the right eye through a mirror stereoscope. (d) Participants reported the stimulus they observed via key presses ("1" for stimulus in left eye, "3" for right eye, and "2" for combination); an example trial of reported dominance durations.

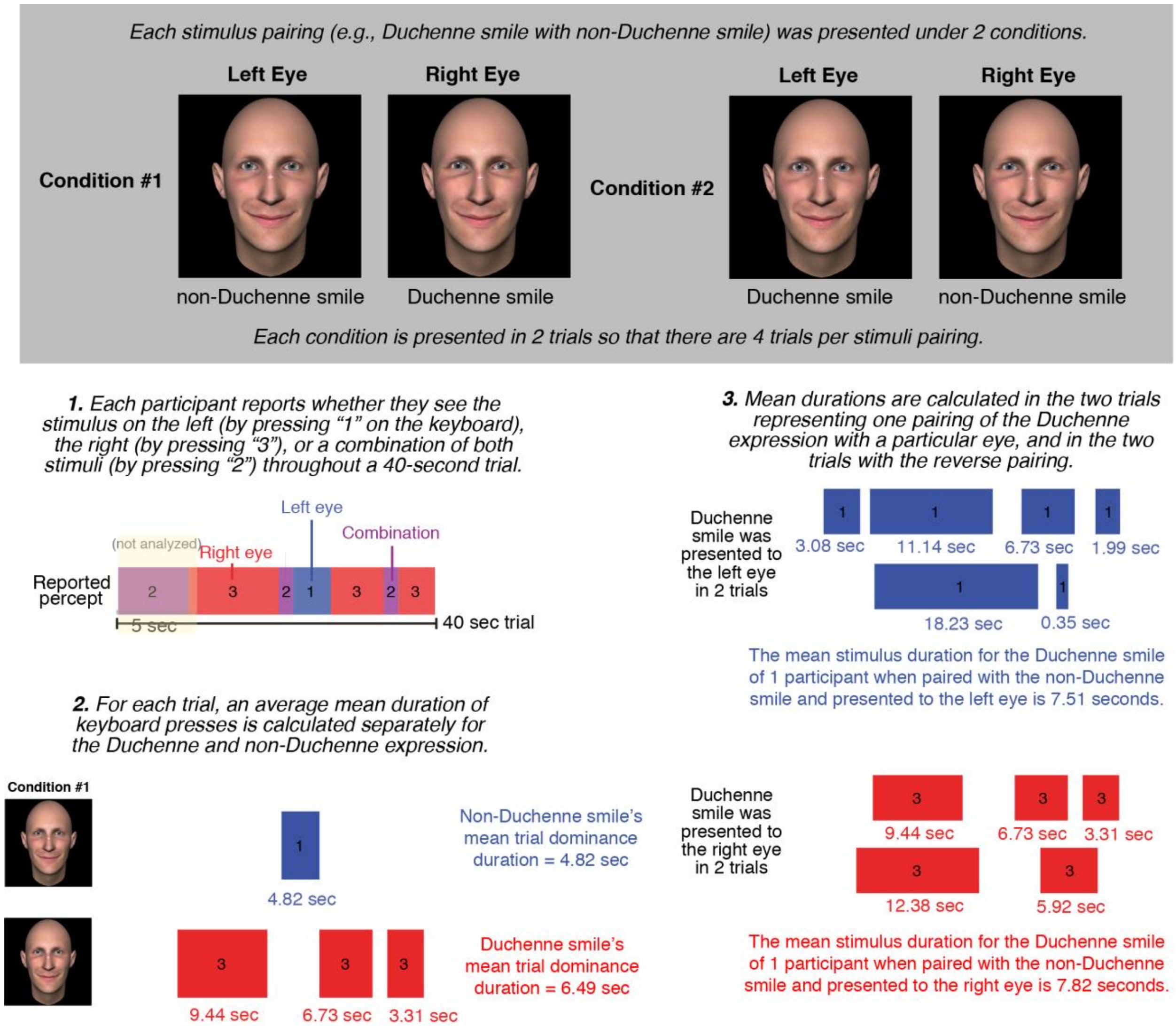

Figure 2. Calculation of mean dominance durations.

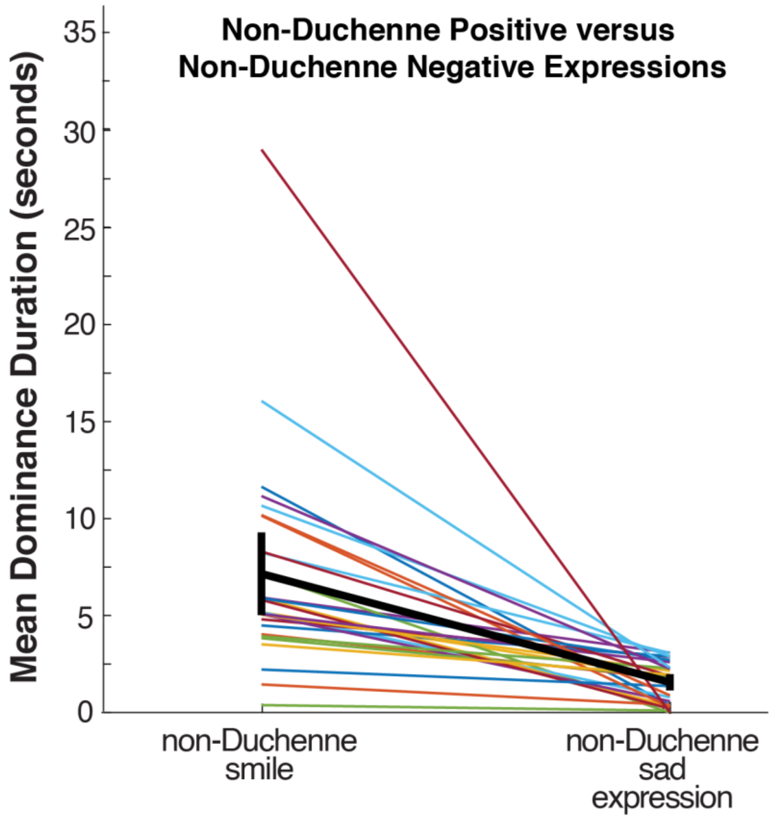

Figure 3. Dominance durations of non-Duchenne smiles when rivaled against non-Duchenne sad expressions for each participant (colored lines [varying colors along the grayscale palette]) and the mean across participants (thick black line). Error bars represent 95% confidence intervals.

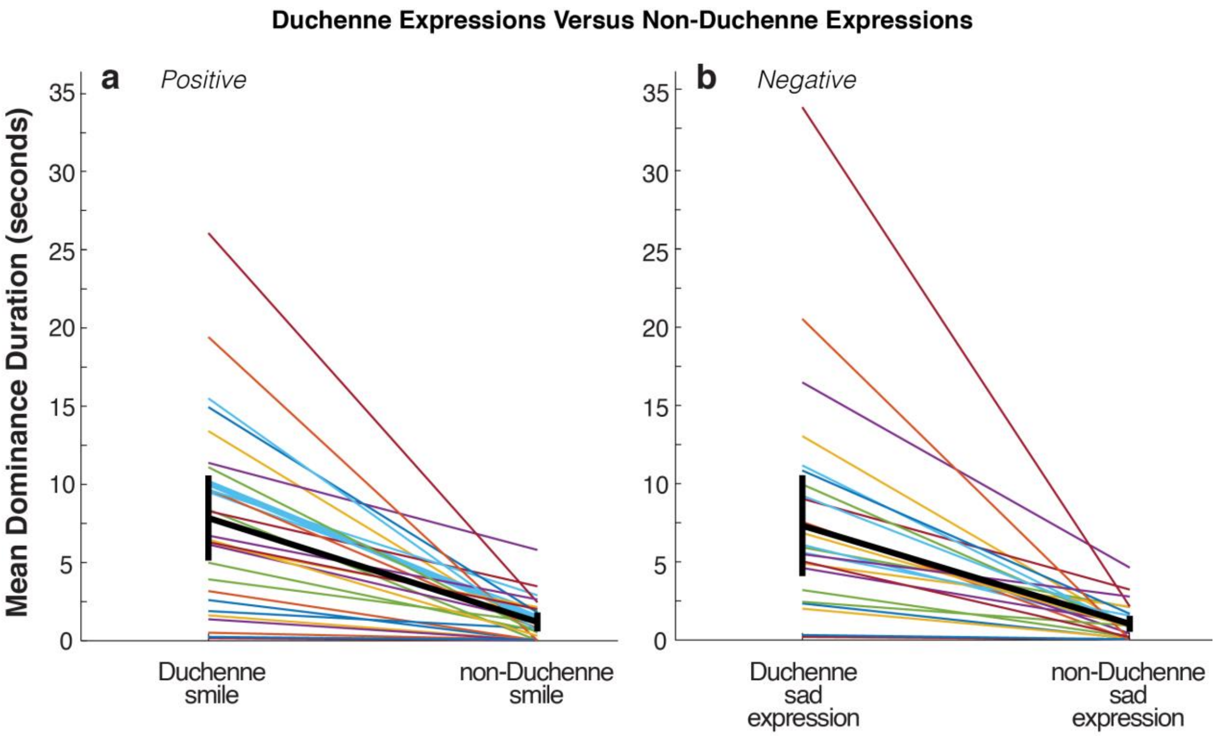

Figure 4. Dominance durations of rivaled Duchenne and non-Duchenne smiles (a) and rivaled Duchenne and non-Duchenne sad expressions (b) for each participant (colored lines [varying colors along the grayscale palette]) and the mean across participants (thick black line). Error bars represent 95% confidence intervals.

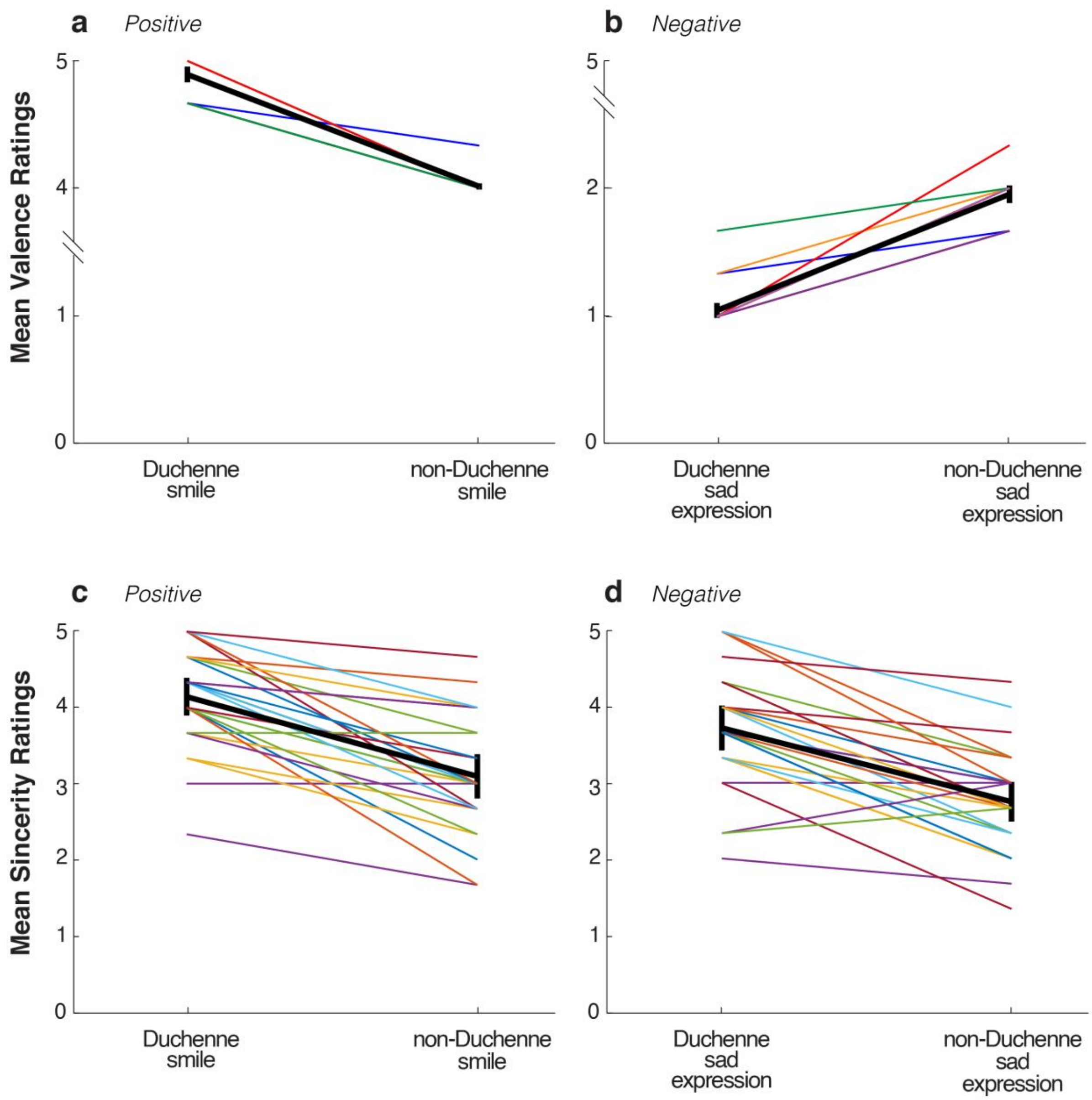

Figure 5. Ratings based on a 5-point Likert for the valence intensity (1=very negative, 5=very positive) of (a) positive expressions and (b) negative expressions for each participant (colored lines [varying colors along the grayscale palette]) and the mean across participants (thick black line). All participants rated Duchenne smiles more positively than non-Duchenne smiles, and rated Duchenne sad expressions more negatively than non-Duchenne sad expressions. The actual number of rating pairs through which this occurred (the number of lines displayed) was limited.

Ratings of the sincerity (1=not at all, 5=very) of (c) Duchenne smiles and non-Duchenne smiles and (d) Duchenne sad expressions and non-Duchenne sad expressions. All but two participants rated Duchenne smiles as more sincere than non-Duchenne smiles, and all but one rated Duchenne sad expressions as more sincere than non-Duchenne sad expressions. Error bars represent 95% confidence intervals.

Content Footnotes

[1]An additional 12 identities conveying non-Duchenne smile, neutral, and non-Duchenne sad expressions were used to familiarize participants with the procedure.