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A Negativity Bias for Ambiguous Facial Expression Valence during Childhood: Converging Evidence from Behavior and Facial Corrugator Muscle Responses

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Abstract

Interpretations of facial expressions with ambiguous valence, like surprised (which can be perceived as having positive or negative valence) reveal individual differences in positivity-negativity biases. Negative interpretations are first and fast, but this initial negativity default can be overridden by regulatory control processes that result in positive interpretations. We tested the initial negativity hypothesis by examining positivity-negativity biases during development. We hypothesized that during childhood, the default negativity mode would be more evident than in adulthood and, as a group, children would show a negativity bias when processing ambiguous facial expressions. We examined ratings of two ambiguous expressions, surprised and neutral expressions, from childhood through adolescence and recorded facial corrugator muscle activity, a physiological index of negative appraisals. Surprised faces were rated as conveying clear negative affect by younger participants as indexed by fast reaction times and negative ratings, and corrugator data showed a corresponding increase in activity to surprised faces. By adolescence, positive ratings of surprised faces became more frequent and reaction times slowed, suggesting that surprised faces were perceived as having more ambiguous meaning. Accordingly, corrugator activity also decreased during adolescence. Neutral faces also produced negative ratings by children, but were also rated as conveying negative affect by older participants. Accordingly, neutral faces also elicited high corrugator activity that was similar to that elicited by angry faces. These data show that early in life, ambiguous facial expressions are perceived as conveying negative meaning, adding support for an initial-negativity hypothesis.

The development of facial expression interpretation is a protracted process that can extend into the second decade of life (Herba & Phillips, 2004; L.A. Thomas, De Bellis, Graham, & LaBar, 2007). The emergence of expression processing is uneven, and as reviewed by both Herba & Phillips (2004) and Gross & Ballif (1991), children's abilities emerge gradually over time, with accuracy in happy faces emerging earlier than negative expressions, like angry, fear, and sad. This unevenness reflects the dynamic architecture of expression learning, where a few basic distinctions (e.g., good/bad) are learned initially, followed by a continual process of category narrowing and acquisition (Widen & Russell, 2003). Despite confusion between negative expressions, which may be infrequent and ambiguous early in life, very young children can nonetheless draw communicative meaning from facial

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expressions, often understanding the general tone of expressions (e.g., pleasant versus unpleasant; Russell & Bullock, 1985; Widen & Russell, 2003), and their errors rarely cross the positive/negative valence boundary. For example, a fearful face may be mislabeled as a sad face, but it is seldom mislabeled as a happy face. Therefore, the good-bad valence distinction, although simple, is fundamental to facial expression interpretation, and seems to develop quite early. When faced with an ambiguous expression, children must decide whether a face has positive or negative valence, and these decisions may be influenced by positivity/negativity biases that are present during normative development.

Unlike previous studies that have primarily examined children's knowledge of specific facial expression labels, the current study aimed to characterize the initial valence bias that contributes to the ability to ultimately label specific expressions. Characterizing this bias during development may aid in describing how facial expression interpretations are developmentally constructed. In the current study, we assessed positive/negative biases during development for faces that allow for multiple interpretations - that is, those with ambiguous interpretations like surprised and neutral faces. Unlike affectively anchored expressions, like happy and angry, which already have certain valence at an early age, faces like surprised and neutral can be interpreted as having positive or negative valence and maintain this ambiguity across development (Leppanen, Milders, Bell, Terriere, & Hietanen, 2004; Neta & Whalen, 2011; Said, Sebe, & Todorov, 2009; Somerville, Kim, Johnstone, Alexander, & Whalen, 2004). Therefore, ambiguous faces present an opportunity to examine positivity/negativity biases during development. The goal of the current study was to use these ambiguous faces as a probe to examine such biases during development.

Positivity/negativity biases for surprised faces have previously been studied in adulthood. Within adult samples, some individuals have a great tendency to interpret surprised faces as negative, while others have less of a tendency (and a greater tendency to indicate that they have positive valence) in forced-choice paradigms (Neta, Norris, & Whalen, 2009; Neta & Whalen, 2011). It has been argued that, even in adulthood, the initial default mode is to interpret surprised faces as negative (i.e., an *initial-negativity* hypothesis). That is, the face processing system is predisposed to interpret surprised faces as having negative valence. However, for some adults, surprised faces can be interpreted as positive, and this occurs when there is an overriding of this negativity default by an additional layer of regulatory influence (perhaps via activation of prefrontal cortical regions), which takes added processing time for a response (H. Kim, Somerville, Johnstone, Alexander, & Whalen, 2003; H. Kim et al., 2004; Neta & Whalen, 2011). Relative to adults, children may have less developed regulatory function (see Casey, Tottenham, Liston, & Durston, 2005; Nelson & Guyer, 2011; Nelson, Leibenluft, McClure & Pine, 2005; Steinberg, 2008 for reviews on the development of prefrontal cortex regulatory function), and therefore, examining good/bad appraisals during childhood may allow for an even greater likelihood of observing the negativity default. Although these interpretations were based largely on neuroimaging data, they motivate our predictions for behavior in children and adolescents. The current behavioral study tests the hypothesis that the potential for a negativity bias might be greater at early ages than at older ages.

Examination of surprised interpretations has not been as common as other expressions in young children, but existing evidence motivated our anticipation of a negativity bias in children. Although the concept of surprise (e.g., a surprise party) has positive connotations for children, their perception of surprised faces tends to be negative (Kestenbaum, 1992). As described earlier, there seems to be weak category boundaries between various non-happy expressions early in development, leading to children's labeling confusion between one static non-happy expression and another (Gao & Maurer, 2010; Herba & Phillips, 2004; Widen & Russell, 2003). Static surprised faces are commonly confused for negative expressions, like fear, during childhood (Gao & Maurer, 2010). Critically, the opposite is not true - fear faces are seldom misclassified as surprised faces. This unilateral association indicates that the surprised/fear confusion is not merely the result of a perceptual similarity (otherwise the association would be bidirectional), but rather a tendency for children to view surprised faces as having negative valence. With age, evidence suggests that the perception of surprised faces develops since it has been shown that 7-year-old children are twice as likely as adults to make this unilateral error (Gao & Maurer, 2010).

Like static surprised faces, static neutral faces are affectively ambiguous and may be interpreted as slightly positive or slightly negative, even in adulthood (Leppanen et al., 2004; Said, et al., 2009; Somerville et al., 2004). Therefore, in addition to surprised faces, we also assessed interpretations of neutral faces to examine negativity biases that may exist for neutral faces during development. Previous research has shown that preschool aged children show low accuracy when labeling neutral faces. Often neutral faces are mislabeled as sad (when “happy, sad, mad or just OK” are the response options; Carlson, Felleman, & Masters, 1983), and this misinterpretation as a negative expression declines across age (Czerwon, Luttke, & Werheid, 2011). The addition of contextual cues increases children's accuracy in labeling neutral faces (Reichenbach & Masters, 1983), suggesting that early in development, in the absence of information other than from the face, there is a bias to interpret neutral faces as negative. Thus, we chose to test the negativity bias hypothesis using two different expressions, one with high arousal (surprised) and one with low (neutral; Russell & Bullock, 1985) rather than a single expression. If both expressions were to show a negativity bias during childhood, these findings would suggest that conclusions about negativity biases generalize across more than one expression, and perhaps extend across multiple expressions.

We examined interpretive biases across development using a paradigm developed by Neta and colleagues (2009), that assesses participants' interpretation of ambiguous faces. In Neta's study, which was with adults, responses to surprised faces were assessed. There was a wide spread in the ratings of surprised faces (from positive to negative), and those participants who indicated that surprised had negative valence also showed increased facial motor activity in the corrugator supercilii muscle. Several studies have shown that the corrugator muscle, which draws the brows together in expressions of displeasure, reflexively increases activity during viewing of unpleasant visual stimuli (Lang, Greenwald, Bradley, & Hamm, 1993; McManis et al., 2001). This effect of increased corrugator activity has also been observed in children as young as 7-years-old when viewing unpleasant material (e.g., IAPS images; McManis, Bradley, Berg, Cuthbert, & Lang, 2001). The ingenuity of the Neta et al., design was in its taking advantage of the corrugator's reflexive response to obtain a physiological index of an individual's appraisal of a valence-ambiguous stimulus. In the current study, we repeated Neta's study with a developing population and also measured corrugator activity concurrently during appraisals. Corrugator activity is useful in a sample including young children as it provides a non-verbal index of valence appraisal.

We expected that if ratings of ambiguous faces became less negative with age, associated physiologic responses would correspondingly decrease with age. We reasoned that if interpreting ambiguous faces as negative is a default response, then this negativity bias should be most evident early in life. Thus, we hypothesized that younger age would be associated with implicit negativity biases, which would be corroborated with quick reaction times and increased corrugator activity in response to ambiguous faces. We examined responses to surprised faces in children and adolescents in Experiment 1 and to neutral faces in Experiment 2. We chose to use static images of faces in both experiments. While static images of facial expressions are not an ideal ecological stimulus, they do allow us to address the aim of the current study, which was to assess initial negativity biases using rapidly presented ambiguous expressions.

Method

The ambiguous expressions of interest were surprised (for replication and extension of the Neta et al., 2009 study) and neutral. Responses to these expressions were examined in two separate experiments where most participants participated in both. Because most participants provided data in both experiments, we were able to compare findings from the two experiments in an analysis described at the end of the Results section.

Experiment 1 (Surprised, Angry, Happy)

Participants—88 (44 male/44 female; mean (SD) age = 12 (3.57) years old, range =6–17) typically developing participants participated with parental consent. Participants were recruited through advertisements in the community and state birth records. This wide age range was selected to be able to observe age-related change from childhood through adolescence. There were no *a priori* predictions about particular age cut-offs, but for the purposes of our statistical analyses, participants were divided evenly into the following 3 age groups: 1) Children (6–9 year olds; n=31; 17male/14 female; mean (SD) age=7.5(1.1)); 2) Early Adolescents (10–13 year olds; n=28; 16 male/12 female; mean (SD) age=11.8(1.1)); and 3) Adolescents (14–17 year olds; n=29; 11 male/18 female; mean(SD) age=15.7(1.1)). We chose to examine age in 3 equal groups because large variability was anticipated in the data (potentially masking age-related changes in behavioral and EMG data), although we also provided analyses that examined continuous age in years. Ethnicity was comprised of the following groups: 57% European-American; 27% Hispanic/Latino(a); 24% African-American; 15% Asian-American; 6% American Indian/Alaska Native; 1% Native Hawaiian/ Pacific Islander; 16% Other (note: some participants checked more than one category). All participants were free of behavioral or psychological concerns or learning disability as indicated by parent telephone screening (presence/absence of behavioral/ psychological/learning disability history) and had an average estimated IQ of 110 (SD=16) as measured by the WASI (Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999).

Average parent education was a four-year college degree, and modal household income level was between $150,000–$200,000.

All 88 participants provided complete behavioral data. Electrophysiological data were collected from the majority of participants. 16 children (9 male/7 female), 8 early adolescents (5 male/3 female), and 8 adolescents (2 male/6 female) did not provide electrophysiological analyses because of motion artifact or equipment reasons (e.g., sensor detachment or software issues). Participants excluded from the EMG analyses did not differ from those included in the EMG analyses on age group (chi-squared=2.85, p=.24) or participant sex (chi-squared=.03, p=.87). Therefore, a total of 56 participants provided usable electrophysiological data. There were no differences in surprised negativity ratings for those participants who provided usable electrophysiological data (mean(SD)= 59%(26)) and those who did not (mean(SD)= 62%(28); t(86)=.62, ns).

Stimuli: We used nearly identical methods employed by Neta et al., (2009) with a few minor modifications (i.e., we did not administer the additional “masked” presentations as Neta did, and therefore did not employ a 250 ms black-and-white pattern following each face, which was originally used as a retinal sweep; the presentation times in this study was 1500 ms, which is longer than the 1000 ms presentation in the Neta study). We selected 8 European- and African-American identities[1] (4 female, 4 male) from the NimStim Set of Facial Expressions (Tottenham, Tanaka et al., 2009) whose published validity ratings were very high (see footnote 1). Stimuli were randomly presented in a single run for a total of 48 face stimuli. An equal number surprised, angry, and happy expressions were presented for 1500 ms, with each face stimulus followed by a fixation that was presented for 200 ms.

Testing Session: Participants were seated in a room and accompanied by a female experimenter. They viewed grayscale images of faces on the computer in front of them. Prior to the task, the experimenter attached electrodes for recording facial electromyography (EMG). Faces were presented one at a time at the center of the screen (visual angle approximately 15°), on a black background. For each face presented, participants were asked to make a two alternative forced-choice decision as quickly and as accurately as possible indicating whether each face “felt good or felt bad”; this language has been used in previous work with similar age groups (Kestenbaum, 1992). Participants responded with their right index finger to indicate a “feels good” response and their left for a “feels bad” response, and the response buttons were counterbalanced across participants. In data analyses, the percent of times that a participant indicated that a particular expression “felt bad” was calculated (e.g., if a participant indicated that a surprised face “felt bad” on all trials, then his/her negative rating score for surprised faces would be 100%).

Physiological Data Treatment: The skin was first cleaned with alcohol. Facial EMG was measured using Ag-AgCl 4 mm TP electrodes filled with Biopac 250 G - GEL 100 electrode gel, which were placed bipolarly over the right corrugator supercilli muscle region (Fridlund

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[1] Models included in this study were (validity ratings for angry, happy, and surprised, respectively, in parentheses based on Tottenham et al., 2009 findings): 01 (99%, 99%, 80%), 06 (71%, 96% 75%), 11 (90%, 99%, 91%), 13 (87%, 99%, 74%), 20 (99%, 96%, 62%), 22 (99%, 99%, 90%), 38 (83%, 99% 73%) & 40 (72%, 97%, 90%).

et al., 1986). Tape was applied to the electrodes leads to reduce movement artifact. Recordings began 5 minutes after electrode placement to allow for gel absorption. Data were visually examined for signal quality. Poor quality data points were deleted prior to analysis.

Offline, EMG data were submitted to a DC restore to center the signal at a zero point, a 60-Hz filter to reduce 60 Hz of noise present in the testing room, a 30-Hz high-pass filter to reduce movement and blink-related artifact, then fully rectified. Data were then subjected to a square-root transformation. Responses were averaged across a period of 1,000 ms after stimulus onset and a baseline of 500 ms before the stimulus onset was subtracted for each trial, producing a change score for each trial. These scores were averaged for each condition.

Results

Negative Ratings—A repeated measures ANCOVA was performed on the dependent variable of percent negative ratings (percent of faces in each condition rated as negative) with the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Angry, Happy, Surprised), controlling for participant sex and mean accuracy on angry and happy. We chose to control for participant sex because of previous findings of sex differences in facial emotion processing (see the meta-analysis of McClure, 2000). We chose to control for overall accuracy on expressions with clear valence (angry, happy) because we were primarily interested in developmental changes in ratings for surprised faces, and to minimize the chance that developmental changes in general performance (that is errors in button pressing) would mask the changes in surprise ratings, we added a control variable that accounted for performance on these anchored expressions (angry, happy). The literature shows angry and happy expressions are already well-associated with appropriate valence and expression label at ages younger than those tested here (Widen & Russell, 2003).

As anticipated, there was a strong main effect for emotion ($F(2,168)=11.01$, $p<.0001$, partial $\eta^2=.12$), such that negative ratings for surprised faces were intermediate to those for happy and angry faces. As seen in Figure 1A, angry was rated as negative the majority of the time (mean(SD)=90%(1%)) and happy was rarely rated as negative (mean(SD)=12% (1%)) by all participants. In contrast to the uniform ratings for angry and happy, there was large variation in negative ratings for surprised faces (based on visual inspection of Figure 1A).

Critically, there was an interaction between Emotion and Age Group ($F(4,168)=3.49$, $p<.01$, partial $\eta^2=.08$), which post-hoc tests showed was the result of surprised ratings becoming more positive over development ($F(2,84)=3.12$, $p<.05$, partial $\eta^2=.07$). One-sampled t-tests comparing ratings to the 50% negative line revealed that surprised faces were rated as negative (that is, more than 50% of the time) for the children ($t(30)=2.21$, $p<.05$, $d=.4$) and early adolescents ($t(27)=3.87$, $p<.005$, $d=.75$). As shown in Figure 1B, it was only the oldest group, the adolescents, who showed an indication of ambivalence – with average responses not differing from chance (that is, at the group level, adolescents rated surprised faces as positive 50% of the time, and they rated surprised faces as negative 50% of the time)($t(28)=.68$, ns, $d=.13$). There were no other main effects or interactions. In addition to this analysis, we included the following supplemental analyses. If the same ANCOVA was performed without controlling for general accuracy, the findings remained (Emotion: F(4,168)=34.42 $p<10^{-13}$ & EmotionXAgeGroup: F(2,168)=3.46, p<.01). Similarly, if the same ANCOVA was performed examining age continuously in years, the findings remained, F(2,168)=3.99, p<.025). These rating data show that during childhood and early adolescence, surprised faces are more likely to be rated as conveying negative valence than positive valence.

Reaction time—A repeated measures ANCOVA was performed with the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Angry, Happy, Surprised) on the dependent variable of correct reaction time (normed using each participant's mean reaction time), controlling for participant sex. We chose to calculate reaction times during those trials when participants identified angry as "feeling bad", happy as "feeling good", and surprised faces as either "good" or "bad" because these faces can be interpreted either way. Since mean reaction time can decrease significantly with age and we were interested in reaction times relative to each expression, we analyzed normed reaction time.

There was a main effect of emotion (F(2,168)=4.77,p<.01, partial η^2= .05), an EmotionXAgeGroup interaction (F(4,168)=5.78, p<.001, partial η^2=.12) and an EmotionXSex interaction (F(2,168)=5.73, p<.004, partial η^2= .06). Across all participants, reaction time was slowest to surprised and fastest to happy faces. Additionally, tests for linear trends revealed that reaction time to happy (p<.005) and angry (p<.0002) faces became faster with age, whereas, in contrast, reaction time to surprised faces showed a trend towards becoming slower across increasing age groups (p=.056)(Figure 1C). The adolescent group had reaction times to surprised faces that were significantly slower than those for happy ($p<10^{-5}$) and angry ($p<10^{-5}$) faces, as has been shown previously in adults (Neta & Whalen, 2009). Additionally, post hoc tests showed that female subjects were slower to responding to surprised faces than males (p<.025).

In addition to this analysis, we included the following supplemental analyses. If the same ANCOVA was performed using raw reaction times, the findings remained, AgeGroupXEmotion: F(4,168)=5.72, p<.001. The only difference between using raw versus normed reaction time was in age-related baseline decreases in general reaction time (i.e., there was a main effect of age using raw reaction times such that reaction time became faster with increasing age, F(2,84)=6.70,p<.002). Similarly, if the same ANOVA was performed examining age continuously in years, the findings remained, AgeXEmotion: F(2,170)=11.18, p<.001). Taken together, these reaction time data show that decisions about surprised faces are relatively quick for children and become slower decisions during adolescence. We tested the possible correlation between normed reaction time to surprised faces and negative ratings for surprised faces, and there was no association (r(86)=.006, ns).

Corrugator Activity—A repeated measures ANCOVA was performed on the dependent variable of corrugator muscle EMG activity with the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Angry, Happy, Surprised), controlling for participant sex. Additionally, because some participants rated surprised faces as positive and some as negative, we created a bias score for each participant (coded based on group median split: 1=S_positive if participant was unlikely (less than median score) to rate surprised faces as negative and 2=S_negative if participant was likely to rate surprised faces as negative); this bias score was added as a control variable.

There was a significant interaction between Age Group and Emotion, $F(4,102)=3.65$, $p<.05$, partial $\eta^2= .13$. There were no other main effects or interactions. Planned contrasts revealed that corrugator activity in response to surprised faces was very high for the two youngest groups (Figure 1D), resembling their level of activity in response to angry faces and significantly different from happy faces, and then fell to a near-zero value in the oldest group, similar to happy and significantly different from angry faces ($p<.025$). There were no age group effects for angry ($p=.84$) or happy faces ($p=.68$). In addition to this analysis, we also examined age continuously in years as a supplemental analysis. When age was examined continuously in years, there was no AgeXEmotion interaction, $F(2,104)=1.29$, ns. As Figure 1D shows, this lack of interaction is likely due to the non-linear age-related change in EMG response to surprised faces. Taken together, these data show that in childhood and early adolescence, corrugator activity to surprised faces is very high resembling responses to angry faces, and by adolescence, it decreases response to a level comparable to that for happy faces.

Association between Surprised Ratings and Corrugator Activity—In adults (Neta et al., 2009), it has been shown that corrugator activity reflect participants' biases in rating surprised faces. In other words, adult participants who tended to rate surprised faces as negative showed increased corrugator activity to surprised faces, whereas those who tended to rate surprised as positive showed decreased activity. We sought to examine this association between negative bias and corrugator activity within the current developmental sample. We used the bias score based on group median split described above (1=S_positive if participant was unlikely (less than group median score) to rate surprised faces as negative and 2=S_negative if participant was likely to rate surprised faces as negative) to create two groups of participants and used this variable (S_positive vs. S_negative) as an independent variable in a repeated measures GLM examining corrugator EMG activity. To examine EMG activity, we calculated a change scores for angry and surprised from the happy condition. EMG responses to happy faces did not differ from zero (and there was no significant difference for corrugator activity to happy between groups, $p=.78$). We calculated for each participant, a change score for angry EMG minus happy EMG and surprised EMG minus happy EMG, thus producing two change scores, which were entered into the 2(Group: S_positive, S_negative)×2(Angry EMG change score, Surprised EMG change score) repeated measures ANCOVA, controlling for age group and participant sex. As shown in Figure 2, there was a main effect for group, such that across participants, S_negative individuals showed greater corrugator activity to both angry and surprised faces than S_positive individuals ($F(1,51)=4.28$, $p<.05$, partial $\eta^2=.08$). Thus, S_negative individuals tended to show greater EMG activity to both surprised and angry faces.

An additional analysis using partial correlations controlling for age group and sex revealed a positive correlation between negativity ratings and corrugator activity as measured by EMG for surprised faces ($r_p(52)=.34$, $p<.05$). That is, even when controlling for age group and sex, more negative ratings of surprised faces were associated with increased corrugator activity across participants. There was only a trend association between corrugator activity and reaction times to surprised faces ($r_p(52)=-.23$, $p=.095$), where higher corrugator response was associated with faster normed reaction times to surprised faces. Taken together, these analyses suggest that, as in adults, an individual child or adolescent's corrugator activity is associated with his/her ratings of facial expressions.

Interim Discussion

These data show that children and early adolescents show a negativity bias when viewing ambiguous facial expressions, like surprised. The results from the adolescent group (i.e., the oldest group in this study) largely replicate the findings from the Neta et al., 2009 study with adults. That is, unlike angry and happy faces, which showed evidence of being heavily anchored to one valence across participants, ratings of surprised faces ranged widely so that calculating the average negative rating across participants resulted in a value no different from chance (50%). Reaction times to surprised faces in the adolescent group were slowest compared to other expressions, again consistent with the Neta et al., study, supporting the hypothesis that surprised faces are more ambiguous with respect to valence. Importantly, there was an AgeGroupXEmotion interaction, such that in contrast to the adolescent group, children and early adolescents showed evidence of a negative bias when interpreting surprised faces. Ratings of angry and happy were similar across age groups, indicating that the two youngest groups could perform the task. Unlike the adolescent group, negative ratings of surprised faces were above 50% (i.e., surprised faces were likely to be rated as having negative valence) in the two youngest groups, and reaction times for these responses were rapid as shown in the AgeGroupXEmotion interaction. Using the logic that longer reaction times are indicative of ambiguity, the fast reaction times of children and early adolescents support the hypothesis that at young ages, surprised faces are unambiguously negative in valence. We also observed a sex difference in reaction times, where female subjects were slower when responding to surprised faces than males. Given the repeated findings that female children show more mature facial expression processing (McClure, 2000), these slower reaction times to surprised faces of female subjects may be an indication of females demonstrating a more mature (i.e., like adults) response to surprised faces.

The hypothesis that surprised faces are unambiguously negative early in life and then become increasingly ambiguous in valence with development was additionally supported by the corrugator data. Corrugator activity, which is an objective measure of valence, was associated with ratings of surprised faces, such that individuals with a negative behavioral bias (S_negative) for surprised faces showed a greater increase in corrugator EMG activity, even when controlling for age. This activity was a general increase across both angry and surprised faces, in contrast to Neta et al. (2009), who only observed the increase for surprised faces, which may indicate a negative bias that generalizes across multiple expressions during development. Additionally, we observed an association between corrugator response to surprised faces and negative ratings to surprised faces, suggesting again that the corrugator reflects the negative interpretation of surprised faces. Importantly, there was an AgeGroupXEmotion interaction where corrugator activity to surprised faces was significantly greater in the two youngest age groups, who provided the most negative ratings of surprised.

The negative ratings, fast reaction time, and high corrugator response to surprised faces in children and early adolescents are consistent with the hypothesis that there is a greater negative bias for ambiguous facial expressions, like surprised, during development than has previously been observed in adulthood. In Experiment 2, we used the same design and data analysis strategy as in Experiment 1 to examine responses to neutral, another ambiguous expression.

Experiment 2 (Neutral, Fear, Happy)

Method

Participants—78 (35 male/43 female; mean (SD) age = 12 (3.54) years old, range =6–17) typically developing participants participated with parental consent. Participants were recruited through advertisements in the community and state birth records. As in Experiment 1, participants were divided into the following 3 age groups for statistical analysis based on the groupings from Experiment 1: 1) Children (6–9 year olds; n=29; 16 male/13 female; mean (SD) age=7.7(1.1)); 2) Early Adolescents (10–13 year olds; n=23; 11 male/12 female; mean (SD) age=11.8(1.1)); and 3) Adolescents (14–17 year olds; n=26; 8 male/18 female; mean(SD) age=15.7(1.1)). We chose to examine age in the same age groupings as Experiment 1 because of the large variability anticipated in the data (potentially masking age-related changes in behavioral and EMG data), although we also provided analyses that examined continuous age in years. Participants in Experiment 2 largely overlapped (n=75) with the participants from Experiment 1, and an additional 3 participants (1 African-American/European-American 8-year-old male, 1 Asian-American/European-American 8-year old male, and 1 European-American 8-year-old female) provided data for Experiment 2, who did not participate in Experiment 1. Average estimated IQ was 110 (SD=17) as measured by the WASI (Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999). Average parent education was a four-year college degree, and modal household income level was between $150,000–$200,000.

All 78 participants provided complete behavioral data. Electrophysiological data were collected from the majority of participants. 17 children (11 male/6 female), 13 early adolescents (6 male/7 female), and 17 adolescents (6 male/11 female) did not provide electrophysiological analyses because of motion artifact or equipment reasons (e.g., sensor detachment or software issues). Participants excluded from the EMG analyses did not differ from those included in the EMG analyses on age group (chi-squared=.41, p=.81) or participant sex (chi-squared=.02, p=.89). Therefore, a total of 47 participants provided usable electrophysiological data. There were no differences in neutral negativity ratings for those participants who provided usable electrophysiological data (mean(SD)= 83%(15)) and those who did not (mean(SD)= 86%(25); t(62)=.70, ns).

Procedure—Stimuli and testing session were identical to Experiment 1 except that the face images selected from the NimStim Set of Facial Expressions were 8 fear, happy, and neutral. We chose to use these three expressions based on their wide co-occurrence in the face expression literature (Johnstone et al., 2005; M.J. Kim et al. (2010); Nelson et al., 2003; Pérez-Edgar et al., 2007; Yang et al., 2002). We selected 8 European- and African-American identities (4 female, 4 male) from the NimStim Set of Facial Expressions (Tottenham, Tanaka et al., 2009) whose published validity ratings were very high[2].

Negative Ratings—A repeated measures ANCOVA was performed on the dependent variable of percent negative ratings (percent of faces in each condition rated as negative). We used the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Fear, Happy, Neutral), controlling for participant sex and overall accuracy on fear and happy. (We chose to control for overall accuracy on expressions with clear valence (fear, happy) because we were primarily interested in developmental changes in ratings for neutral faces. To minimize the chance that developmental changes in general performance (e.g., errors in button pressing) would mask the changes in neutral ratings, we added a control variable that accounted for performance on the anchored expressions. The literature shows happy and fear are already well-associated with appropriate valence at ages younger than those tested here (Widen & Russell, 2003)).

As shown in Figure 3A/B, there was a main effect of Emotion ($F(2,146)=16.08$, $p<.0001$, partial $\eta^2= 18$). Negativity ratings for neutral faces were highly negative, with negativity ratings significantly higher than the 50% negativity mark ($t(77)=15.23$, $p<10^{-6}$, $d=1.72$). These ratings did not show the same spread in negative ratings that surprised did. Neutral ratings did not different from fear ($p=.17$) but were significantly different from happy faces ($p<10^{-46}$). There were no other main effects or interactions. In addition to this analysis, we included the following as supplemental analyses. When the same ANCOVA was performed without controlling for general accuracy, the findings remained, main effect of emotion: $F(2,148)=58.07$, $p<10^{-18}$). Similarly, when the same ANCOVA was performed examining age continuously in years, the findings remained, main effect of emotion: $F(2,148)=18.03$, $p<.0001$. These rating data show that neutral was rated as negatively as fear was across all age groups.

Reaction Time—A repeated measures ANCOVA was performed on the dependent variable of correct reaction time (normed using each participant's mean reaction time) with the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Fear, Happy, Neutral), controlling for participant sex. There was an interaction of AgeGroupXEmotion ($F(4,148)=5.07$, $p<.001$, partial $\eta^2= .12$). There were no other main effects or interactions. As Figure 3C shows, test for linear trends revealed that reaction time to fear ($p<.0005$) and happy ($p<.05$) both decreased with increasing age group, but reaction to neutral faces did not show any significant decline with age, and trended towards slower reaction times for the adolescent group ($p=.13$).

In addition to this analysis, we included the following as supplemental analyses. If the same ANCOVA was performed examining raw reaction time, the findings remained, AgeGroupXEmotion $F(4,148)=3.95$, $p<.005$. Additionally, we observed age-related baseline

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[2] Models included in this study were (validity ratings for fear, happy, and neutral, respectively, in parentheses based on Tottenham et al., 2009 findings): 05 (77%, 99%, 98%), 07 (74%, 100%, 95%), 12 (67%, 10%, 63%), 14 (90%, 99%, 93%), 21 (68%, 99%, 96%), 23 (58%, 99%, 95%), 39 (93%, 99%, 89%), 41 (73%, 100%, 95%).

decreases in general reaction time (i.e., there was a main effect of age using raw reaction times such that reaction time became faster with increasing age, F(2,74)=6.70,p<.025) and a main effect of emotion (F(2,148)=3.36, p<.05), such that reaction time to happy was significantly faster than fear and neutral, an effect that was only at the trend level when using normed values, F(2,148)=2.28, p=.11. Similarly, if the same ANCOVA was performed examining age continuously in years, the findings remained, AgeXEmotion F(2,150)=9.17, p<.005. Additionally, we observed a main effect of emotion (F(2,150)=3.51, p<.05), such that reaction time to happy was significantly faster than fear and neutral, an effect that was only at the trend level when using age groups, F(2,148)=2.28, p=.11. These reaction time data show that unlike fear and happy reaction times, reaction times to neutral faces do not become faster with increasing age group and, if anything, trend towards a relative slowing. We tested the possible correlation between normed reaction time to neutral faces and negative ratings for neutral faces, and there was no association (r(76)=−.10, ns).

Corrugator Activity—A repeated measures ANCOVA was performed on the dependent variable of corrugator muscle EMG activity with the between subjects factor of AgeGroup (children, early adolescents, adolescents) and the within subjects factor of Emotion (Fear, Happy, Neutral), controlling for participant sex. Unlike Experiment 1, we chose not to control for negative bias for neutral faces, since neutral was overwhelmingly rated as negative across all participants. There was a main effect for emotion (F(2,82)=3.70, p< .05, partial η^2= .08). There were no other main effects or interactions. As shown in Figure 3D, corrugator activity was greatest for the neutral face condition, which was significantly different from the happy face condition (p<.007), but was not different from the fear face condition (p=.14). In summary, neutral faces resulted in the greatest corrugator EMG activity across participants and were more similar to the responses to fear faces than happy faces.

To test for associations between EMG and behavioral data, partial correlations were used controlling for age group and sex. There was no association between negativity ratings and corrugator activity as measured by EMG for neutral faces (r_p(43)=−.01, ns), and there was a trend-level association between corrugator activity and normed reaction times to neutral faces (r_p(43)=−.27, p=.07), where higher corrugator response was associated with faster normed reaction times to surprised faces.

Comparisons of Emotions across Experiments 1 & 2—Because the majority of participants completed both Experiments 1 and 2, we were able to compared corrugator EMG responses across experiments. We performed a 3 (Age Group: children, early adolescents, adolescents) × 6 (Emotion: angry, happy (Exp 1), surprised, fear, happy (Exp 2), neutral) repeated measures ANCOVA on the dependent measure of corrugator EMG response, controlling for sex. There was a main effect of emotion (F(5,180)=4.08, p<.005, partial η^2= .10). As can be seen in Figure 4, corrugator was greatest for angry faces, followed by neutral, surprised, fear, and finally, by the happy conditions from the two experiments, which did not differ from 0 (p=.76, Exp 1 & p=.34, Exp 2). Post hoc tests were performed with the extracted unstandardized predicted values from the GLM. T-tests showed that the two happy conditions (one from Experiment 1 and one from Experiment 2) did not significantly differ from each other (p=.8) and neither did neutral and angry faces (p=.1). All other expressions were significantly different from each other as presented in rank order in Figure 4.

Interim Discussion

Neutral faces were rated as having negative valence by all age groups, as shown by the main effect of emotion in the absence of an interaction with age group, and negative ratings for neutral faces were as frequent as those for fear faces. Although there was no developmental change for valence ratings of neutral faces, the reaction time data suggest, nonetheless, that there is some developmental change in perception of neutral faces. The AgeGroupXEmotion interaction showed that relative to reaction times to fear and happy, which became faster with age, neutral faces did not show the drop in reaction time and if anything, showed a trend towards slowing as age increased. This pattern of reaction times suggests that although ratings may remain negative in adolescence, there is an increasing ambiguity surrounding the decision of whether neutral faces are positive or negative as individuals age. Corrugator EMG data are consistent with the negative ratings of neutral faces in that neutral faces resulted in the significant increases in corrugator activity, suggesting again that neutral faces are perceived as having negative valence. In support of this assertion, an examination of EMG responses across both experiments showed that EMG responses to angry and neutral faces were equivalent and higher than for any other emotional expression tested.

General Discussion

Emotionally ambiguous facial expressions, which can be interpreted as having either positive or negative valence, can reveal positivity-negativity biases. Such expressions have previously revealed *individual* differences in negativity biases in adulthood (Neta et al., 2009), and in the current study, we used them to reveal *developmental* differences in negativity biases. We tested the hypothesis that childhood would be associated with more negative appraisals of emotionally ambiguous facial expressions, a hypothesis generated from findings in adults showing an initial negativity for interpretations of surprised faces. We found support for our developmental hypothesis such that, both children and early adolescents showed a negativity bias when interpreting surprised faces and when interpreting neutral faces. The reaction time data, which can be used as an index for ambiguity (Neta et al., 2009), suggests that young participants are not ambivalent about their negative ratings – that is, surprised and neutral faces are unambiguously negative at early ages.

Corrugator EMG data added support for the developmental negativity hypothesis. Typically in adults, the corrugator muscle increases activity in response to perception of negative expressions, like angry, (Neta et al., 2009), and its activity increases in parallel to amygdala reactivity (Lapate et al., 2011) and electrical stimulation of the amygdala (Lanteaume et al., 2007). Thus, corrugator EMG activity is often used as an objective measure of valence perception. Importantly, adult participants who perceive surprised faces as negative are those who show increased corrugator activity to surprised faces (Neta et al., 2009). In the current study, children exhibited the largest corrugator EMG responses for surprised faces (activity that declined with increasing age). Corrugator EMG activity has been shown to decrease in response to deliberate regulation of affect in adulthood (Lapate et al., 2011), suggesting that regulatory processes influence EMG activity. Thus, in the current data, maturation of regulatory control mechanisms may, in part, explain some of the age-related decline in corrugator EMG activity observed in response to surprised faces. EMG responses to neutral faces also paralleled the behavioral data; neutral faces were rated as having negative valence by all participants, and EMG activity was correspondingly high for all participants in response to neutral faces. In conjunction with the rapid and negative ratings in the young groups, these data suggest that the observed corrugator activity, a reflexive response that indexes negative appraisals, reflects a negative evaluation of surprised and neutral faces in childhood. Taken together, the behavioral and physiologic data in response to these faces support the hypothesis that a negativity bias is present early in life when interpreting emotionally ambiguous facial expressions.

Our data replicate the findings with adults (Neta et al., 2009) in several ways. First, we showed large variation in ratings of surprised faces relative to angry and happy (based on visual inspection of Figure 1A). Second, reaction times slowed as ratings became more positive, suggesting that positive evaluations required more processing time than negative evaluations. Third, corrugator activity decreased as ratings became more positive, suggesting that surprised faces were more likely to be interpreted as negative for participants who increased corrugator activity when viewing surprised faces. However, in the current study with children and adolescents, the variation in ratings was attributable to developmental differences, whereas in adults, it was attributable to individual differences during adulthood (Neta et al., 2009).

In addition to the surprised-angry-happy trio tested in the Neta et al., 2009 study, we added a neutral-fear-happy trio since these are three commonly co-occurring expressions in the literature, and neutral faces, like surprised, are emotionally ambiguous. Also like surprised, it is an expression resulting very low recognition accuracy during childhood because it is often confused with negative expressions (Gross et al., 1991). The results from the current study suggest that the low accuracy rates for neutral faces is in part attributable to the negative bias that children have when interpreting neutral faces. All age groups showed a negative bias for neutral faces, although there was some suggestion in the reaction time data of developmental change towards ambiguity. This finding is important because neutral faces have been used as the control for many studies of facial emotion processing, and perhaps not surprisingly, neuroimaging studies have often found that neutral faces elicit amygdala activity (often an index of negative affect) in children that is comparable to the types of activity elicited by negatively valenced faces in adults (Lobaugh, Gibson, & Taylor, 2006; K. M. Thomas et al., 2001; Tottenham et al., 2011). The current behavioral ratings provide some insight into why children in previous studies exhibited high amygdala activity to neutral faces. Neutral faces, when posed by an adult stranger with direct eye-contact may not be an emotionally neutral stimulus to children, but may instead be perceived as possessing negative valence. These data would suggest that future neuroimaging studies consider this possibility when interpreting brain activity.

Age-related change in behavior and electrophysiological variables was examined by comparing children (6–9 years old), early adolescents (10–13 years old), and adolescents

(14–17 year olds). There were no *a priori* hypotheses motivating these groupings. Because of the wide age range included in this study and our anticipation of high variability in the data, we created three groups by evenly dividing the larger sample into thirds. Similar groupings have been used previously to show developmental change in face emotion processing (Thomas et al., 2007). Both behavioral and electrophysiological data did not significantly differ between children and early adolescents, perhaps suggesting that there is an important developmental change between early and later adolescence, a time that has previously been associated with significant transitions in emotional face processing (Herba, Landau, Russell, Ecker, & Phillips, 2006; reviewed in Herba & Phillips, 2004).

Limitations: We chose a simple experimental design to assess the development of interpretive biases, and chose to rely on the labels “good” or “bad” to avoid the developmental changes in access to linguistic labels. We used language that has previously been applied to similar age groups (Kestenbaum, 1992). Although this language was selected to be appropriate and accessible for all ages tested, it is possible that the forced-choice format used in these two experiments was confusing for the youngest children when faced with an ambiguous stimulus. However, even if this format was confusing for children, it is interesting that as a group, the average overall decision was negative and responses were rapid. Additionally, the high corrugator EMG activity to surprised faces in children suggests that the affective appraisals were valid (since EMG has been shown to index negative valence; Lanteaume et al., 2007). We did not ask children to explicitly label each expression, which if we did might have provided additional insight into their negative ratings (e.g., is it possible that children confused surprised faces with fear?). It is possible that at young ages, surprised faces were mistaken for fear faces although the ratings of fear were more negative for surprised faces. Additionally, as described in the introduction, this confusion, which has been shown in young children, is unilateral such that fear faces are seldom confused for surprised faces (Gao & Maurer, 2010), suggesting that the confusion may in part be due to the negative interpretation of surprised faces rather than simple perceptual similarity.

This study cannot address how children and adolescents appraise surprised and neutral faces when they occur in an ecologically valid manner (e.g., dynamic, contextualized, 3-dimensional, etc.). Instead, this study was focused on assessing an initial negativity bias during development and used static images of surprised and neutral faces as an experimental probe. Future work could better inform how these initial negativity biases operate when expressions are contextualized and dynamic. For example, morphing faces into other expressions, changing eye-contact, and making context clues available would interact with an initial negativity bias in ways that would significantly influence the interpretation of these ambiguous faces across development.

We cannot say why appraisals for surprised faces become less negative with age. These effects may be caused by differential experience with ambiguous expressions across development. For example, it may be that static, non-happy faces are initially viewed as negative by everyone and that with experience, individuals learn that certain expressions sometimes reflect a positive emotion (which might lead to increased response times that accompany increased contemplation). Interestingly, the rating data for neutral faces were almost uniformly negative, whereas ratings for surprised faces varied widely. Although speculative, static neutral faces, more than surprised faces, may “necessitate” contextual information to be interpreted as positive and, in its absence, neutral will be perceived as negative. In fact, the ratings of neutral were as negative as those for angry (Experiment 1) and fear (Experiment 2). In contrast, the wide spread of ratings for surprised may reflect individual differences in experiences with surprised faces that accumulate with age and allow for the positive interpretation of surprised faces in the absence of contextual information. Perhaps training studies that alter subjects' affective experience with such faces could add insight into the source of developmental change.

Additionally, these changes in appraisals may be the result of neurodevelopmental changes in amygdala and prefrontal cortex development. Neuroimaging data collected with adult subjects show that negative appraisals of surprised are associated with high amygdala response and decreased prefrontal cortex activity (H. Kim et al., 2003; 2004), which may index a neuroregulatory influence over the amygdala. The human amygdala is an early developing structure (Tottenham, Hare et al., 2009) and predates the development of the prefrontal regulatory regions. While amygdala has been shown to be functionally reactive to facial emotion during childhood (Baird et al., 1999; K.M. Thomas et al., 2001), prefrontal cortex undergoes a protracted development in humans that extends through the early adulthood period (see Casey et al., 2005; Nelson & Guyer, 2011; Nelson, Leibenluft, McClure & Pine, 2005; Steinberg, 2008 for reviews). Thus, a negativity bias may arise from a developmental lag in prefrontal cortex developmental relative to the amygdala early in life, and the pattern of brain activity in children in response to ambiguous faces may more closely resemble that of the adults who appraise ambiguous as conveying negative emotion (that is, high amygdala activity, low prefrontal cortex activity). The hypothesis predicts that as age increases and prefrontal cortex continues to develop, some individuals will show greater inhibitory influence from prefrontal regions over amygdala activity that will result in a positivity bias in adulthood. In support of this hypothesis, high amygdala reactivity has been observed in response to neutral faces during childhood (K.M. Thomas et al., 2001), and in a separate cross-sectional study, children and adolescents showed progressively greater modulation of amygdala activation by the prefrontal cortex with increasing age (Killgore, Oki, & Yurgelun-Todd, 2001). Future studies that employ fMRI designs to examine amygdala versus prefrontal regulatory activity in response to ambiguous expressions, like studies performed with adult samples (H. Kim 2003; 2004), would be useful in constraining interpretations regarding age-related change in ambiguous expression interpretations. Of course these possibilities are not mutually exclusive, and increasing experience with faces might be an important agent of change in the development of brain responses associated with processing of ambiguous faces.

What are the implications, then, for how a *developmental-initial-negativity* influences the developmental construction of expression recognition? The current findings generate the hypothesis that after the initial discrimination between happy and other faces, all non-happy faces are initially perceived to be negative. Perhaps through mounting experiences with facial expressions throughout development, the finer discriminations between non-happy faces become possible. Increased contextualized experiences with facial expressions in conjunction with concurrent neurodevelopment, in particular connectivity between the amygdala and the prefrontal cortex, may influence appraisals to allow for increased affect regulation and contemplation and/or enhanced delineation between facial expression categories.

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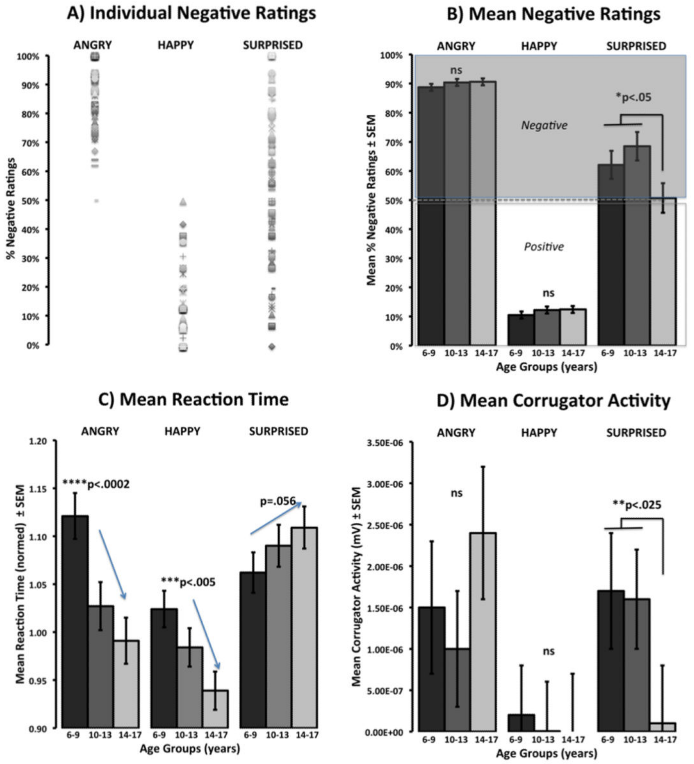

Figure 1.

Children show a negative bias for Surprised Faces. A) A scatter plot representing each participant's responses shows that angry faces are rated consistently as negative, happy faces are rated consistently as positive. In contrast, there was significant variation in ratings of surprised faces. B) At the group level, younger age groups (children, and early adolescents) were more likely to indicate that surprised faces had negative valence than they were to indicate that they had positive valence. C) At the group level, reaction time for rating surprised faces was quick in children and, unlike reaction times for angry and happy, became increasingly slow with age. This pattern suggests that surprised faces become more ambiguous with increasing age. Significance indicates between-group differences. D) At the group level, surprised faces elicited maximal corrugator supercilii activity in children and early adolescents, which decreased with age.

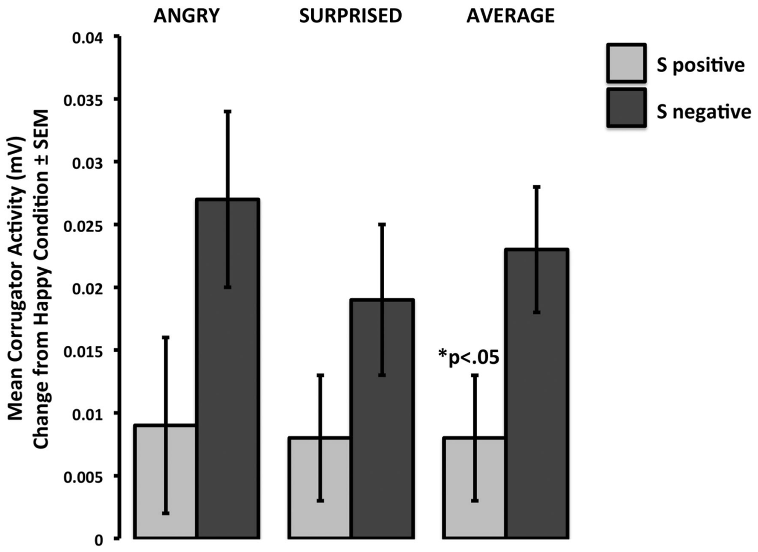

Figure 2.

Individual difference in corrugator supercilii activity in response to facial expressions. S negative participants showed a greater change in corrugator activity to surprised and angry faces relative to happy faces.

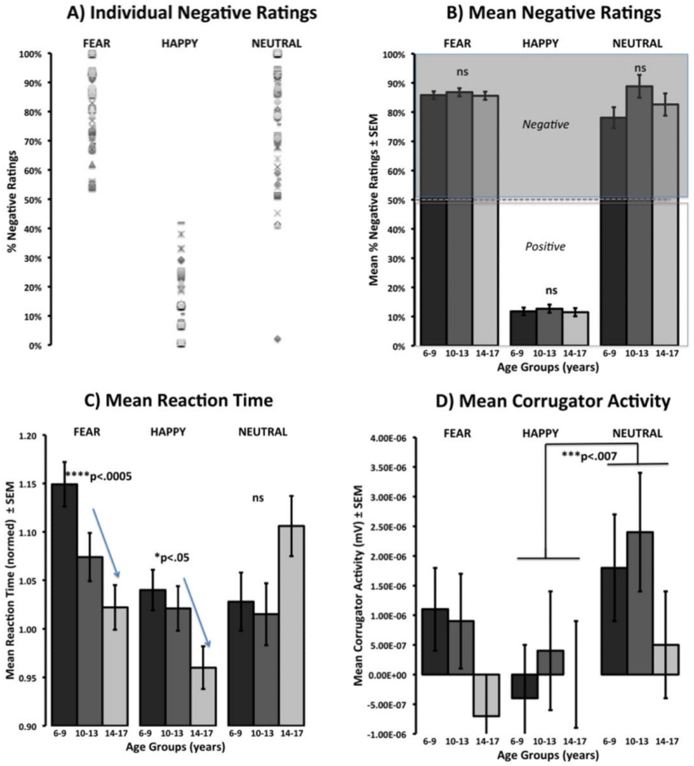

Figure 3.

Youths show a negative bias for Neutral Faces. A) A scatter plot representing each participant's responses shows that fear faces are rated consistently as negative, happy faces are rated consistently as positive. Additionally, neutral faces are rated as negative by the majority of the participants. B) At the group level, all participants rate neutral as conveying as much negative valence as fear faces. C) At the group level, neutral faces do not show the same age related decline in reaction time that fear and happy faces do. D) At the group level, corrugator supercilii activity is highest for neutral faces.

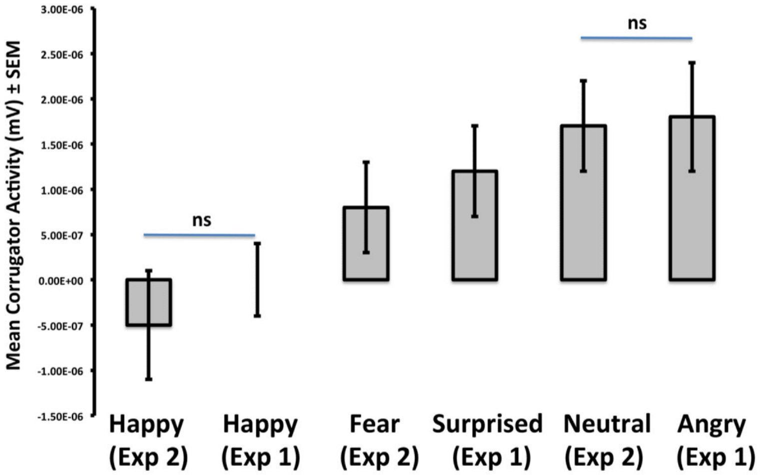

Figure 4.

Comparison of corrugator supercilii activity across Experiments 1 & 2. Across participants, angry and neutral faces (which did not differ from each other) resulted in the greatest corrugator activity, followed by surprised, fear, and then the two happy conditions.