Received: 23 June 2021 | Revised: 25 February 2022 | Accepted: 11 March 2022

DOI: 10.1111/psyp.14060

ORIGINAL ARTICLE

PSYCHOPHYSIOLOGY SPR WILEY

Adolescents and young adults differ in their neural response to and recognition of adolescent and adult emotional faces

Aislinn Sandre[1] | **Michele Morningstar**[2] | **Alison Farrell-Reeves**[1] | **Melanie Dirks**[1] | **Anna Weinberg**[1]

[1]Department of Psychology, McGill University, Montreal, Quebec, Canada

[2]Department of Psychology, Queen's University, Kingston, Ontario, Canada

Correspondence
Anna Weinberg, Department of Psychology, McGill University, 2001 McGill College Avenue, Montreal, Quebec H3A 1G1, Canada.
Email: anna.weinberg@mcgill.ca

Funding information
This work was supported by funding from the Natural Sciences and Engineering Research Council of Canada (RGPIN-2017-04329) awarded to Dr. Anna Weinberg, funding from the Social Sciences and Humanities Research Council of Canada (435–2014-0974) awarded to Dr. Melanie Dirks, and a Doctoral Training Award—Fonds de recherche du Québec-Santé (277215) awarded to Aislinn Sandre.

Abstract

Peer relationships become increasingly important during adolescence. The success of these relationships may rely on the ability to attend to and decode subtle or ambiguous emotional expressions that are common in social interactions. However, most studies examining youths' processing and labeling of facial emotion have employed adult faces and faces that depict emotional extremes as stimuli. In this study, 40 adolescents and 40 young adults viewed blends of angry-neutral, fearful-neutral, and happy-neutral faces (e.g., 100% angry, 66% angry, 33% angry, neutral) portrayed by adolescent and adult actors as electroencephalogram (EEG) was recorded. Participants also labeled these faces according to the emotion expressed (i.e., angry, fearful, happy, or neutral). The Late Positive Potential (LPP), an event-related potential (ERP) component that reflects sustained attention to motivationally salient information, was scored from the EEG following face presentation. Among adolescents, as peer-age faces moved from ambiguous (33%) to unambiguous (100%) emotional expression, the LPP similarly increased. These effects were not found when adolescents viewed emotional face blends portrayed by adult actors. Additionally, while both adolescents and young adults showed greater emotion labeling accuracy as faces increased in emotional intensity from ambiguous to unambiguous emotional expression, adolescent participants did not show greater accuracy when labeling peer-compared to adult-age faces. Together, these data suggest that adolescents attend more to subtle differences in peer-age emotional faces, but they do not label these emotional expressions more accurately than adults.

KEYWORDS
adolescents, adults, ambiguous, emotion, event-related potential, faces, late positive potential

1 | INTRODUCTION

Adolescence is a time of dramatic social re-orientation (Nelson et al., 2005). During this period, proximity to and reliance on parents wanes (Larson & Richards, 1991), and youths' interactions and relationships with peers become more frequent, intimate, and influential (Brechwald & Prinstein, 2011; Brown, 2004; Lam et al., 2014; Rice & Mulkeen, 1995; van Hoorn et al., 2016). This shift embeds youth in an increasingly complex social context in which they must develop and practice new interpersonal and emotional skills (Parker et al., 2006). Rapid and accurate perception and decoding of other youth's socioemotional signals are key for successful navigation of this social transition (Collin et al., 2013; Izard et al., 2001; Trentacosta & Fine, 2010).

In particular, facial expressions of emotion contain critical information in social interactions. The process of interpreting these expressions is complex and involves multiple steps: from allocating attentional resources to—and discriminating between—emotional displays, to retrieving representations of these displays from memory, to recognizing and accurately identifying the emotions expressed, to placing these emotions in the appropriate context (Frith & Frith, 2008, 2010). We focus here on early indices of attention to and identification of facial emotional expressions and their neural and behavioral correlates. Early attentional processes allow for rapid detection and encoding of emotional information from other's faces (Brosch et al., 2010; Leppänen & Nelson, 2009), and these processes initiate (or inhibit) subsequent steps involved in socioemotional processing. Accurate identification of others' emotional displays allows for the selection of appropriate behaviors in social situations (Adolphs, 2002a, 2002b; Crick & Dodge, 1994; Lemerise & Arsenio, 2000). Thus, simultaneous investigation of both processes may improve our understanding of how youth navigate this time of social transition.

A large body of work has sought to chart the normative developmental trajectory of socioemotional processing. Within the first year of life, infants can detect and discriminate between emotional expressions (Haviland & Lelwica, 1987; Leppänen & Nelson, 2009; Montague & Walker-Andrews, 2001), and gradual refinements in these abilities occur across childhood and adolescence and into early adulthood (Flannery et al., 2017; MacNamara et al., 2016; Monk et al., 2003; Posner et al., 2014). However, emerging work suggests that neural responses to facial affect associated with attention may not follow a linear trajectory across development (Somerville et al., 2011). In particular, adolescents' social re-orientation toward peers coincides with a period of substantial neural growth and plasticity in brain regions that support attention to socioemotional information (Casey et al., 2008; Pfeifer & Blakemore, 2012; Somerville et al., 2011), and activity in these regions appears to peak in response to facial affect during this period of life (Guyer et al., 2008; Hare et al., 2008; Ladouceur, 2012; Monk et al., 2003; Nelson et al., 2005; Somerville, 2013).

In contrast, studies of emotion recognition or labeling abilities support a linear and protracted developmental trajectory. For instance, the capacity to identify emotional content in facial expressions is evident in early childhood, and gradual improvements in speed and accuracy occur throughout and beyond childhood and adolescence (Camras & Allison, 1985; Gao & Maurer, 2010; Gross & Ballif, 1991; Harrigan, 1984; Herba & Phillips, 2004; Kolb et al., 1992; Morningstar et al., 2020; Odom & Lemond, 1972; Thomas et al., 2007; Tremblay et al., 1987).

However, the majority of neural and behavioral studies examining youths' attention to and accuracy in identifying facial emotion have relied on adult emotion face stimuli (Guyer et al., 2008; Herba et al., 2006; Kestenbaum & Nelson, 1992; Kujawa et al., 2012; Monk et al., 2003; Rodger et al., 2015; Somerville et al., 2011; Thomas et al., 2007; Yurgelun-Todd & Killgore, 2006), making it unclear whether facial expressions of same-age peers and adults recruit similar neural resources and are identified with equal accuracy during this developmental period. Because peers become increasingly relevant social interaction partners during adolescence (Brown & Larson, 2009), their facial displays of emotion may be particularly salient during this period. Consistent with this, the few studies that have used both peer- and adult-age faces as stimuli find that adolescents display heightened activation in socio-affective brain regions when viewing peer-compared to adult-age emotional faces (Marusak et al., 2013; Saxbe et al., 2015), suggesting that adolescents devote more attentional resources toward processing emotional faces portrayed by same-age peers than by adults. However, it is not clear whether this is a developmental effect. Instead, youth may devote more attentional resources toward processing emotional faces posed by same-age peers because these faces could be more *difficult* to decipher (e.g., Morningstar et al., 2018), suggesting an effect of stimulus or actor. It will therefore be important to investigate these potential effects in adolescent and adult samples, using faces of both adolescent and adult actors.

In addition, previous studies examining the neural and behavioral correlates of youths' attention to and labeling of emotional facial expressions have typically used faces that depict emotional extremes as stimuli (e.g., Guyer et al., 2008; Hare et al., 2008; Kujawa et al., 2012; Lawrence et al., 2015; Monk et al., 2003). However, emotional expressions in real-world social situations are often subtle and ambiguous (Calvo et al., 2014; Dols & Russell, 2017; Fridlund, 1994; Hassin et al., 2013), and the ability to track ambiguous peer expressions is likely important in guiding more flexible social interactions (van Hoorn et al., 2018). For instance, detecting and identifying subtle signs of anger in a peer's facial expression may allow youth to quickly execute behaviors that de-escalate conflict or rejection, as well as aggression and potential harm (e.g., Bublatzky et al., 2020; Kavcıoğlu et al., 2021; Pozzoli et al., 2017).

One method to investigate responses to more ecologically valid emotional expressions is to morph prototypical emotional faces with neutral faces, creating stimuli that depict varying degrees of facial affect (e.g., angry-to-neutral, happy-to-neutral; Duval et al., 2013; Gibb et al., 2009; Kavcıoğlu et al., 2021; Sandre et al., 2018; Thomas et al., 2007). Prior behavioral work that has used this method to compare adolescents' and adults' ability to accurately recognize adult emotional facial expressions, however, has shown mixed results. For instance, while some studies indicate that youth and adults perform comparably (Wiggins et al., 2016), other studies suggest that youth perform worse when identifying more ambiguous adult emotional expressions (Lee et al., 2019; Thomas et al., 2007).

Additionally, the few studies that have simultaneously examined adolescents' neural and behavioral responses when viewing ambiguous adult emotional faces suggest that youths' neural responses to ambiguous emotional expressions may not be reflected in their ability to identify these emotions accurately (Lee et al., 2019; Wiggins et al., 2016). For instance, some work suggests that adolescents show increased activity in neural regions associated with attention, but not improved emotion labeling accuracy, when viewing ambiguous adult emotional expressions (Wiggins et al., 2016). In order to understand whether a social reorientation toward peers in adolescence is accompanied by enhanced processing and recognition of ambiguous emotional expressions by peers, the present study compared youths' and adults' neural responses and emotion labeling accuracy when viewing ambiguous and unambiguous faces portrayed by adolescent and adult actors.

The neural measures we used were event-related brain potentials (ERP), which are well-suited to investigations of very early attentional allocation and provide an ideal complement to behavioral measures due to their excellent temporal resolution. In this study, we relied upon the late positive potential (LPP), a positive slow-wave ERP component that indexes sustained attention toward motivationally salient information (Cuthbert et al., 2000; Schupp et al., 2000; Weinberg & Hajcak, 2011). The LPP can be reliably measured across development (Hua et al., 2014; Kujawa et al., 2013; Moran et al., 2013), and tends to be maximal at central-parietal recording sites, beginning approximately 300 ms post-stimulus onset (Cuthbert et al., 2000). The component is also larger for emotional (appetitive or aversive) compared to neutral stimuli (Cuthbert et al., 2000; Foti et al., 2009; Hajcak et al., 2010; Pastor et al., 2008; Schupp et al., 2004; Weinberg & Hajcak, 2010), and this modulation continues for the full duration of stimulus presentation, and even following picture offset (Codispoti et al., 2007; Foti & Hajcak, 2008; Hajcak & Olvet, 2008).

Studies in youth and adults suggest that the magnitude of the LPP is related to activity in neural circuits that support attention to emotional content (e.g., visual cortices, amygdala, medial prefrontal cortex, and orbitofrontal cortex; Bunford et al., 2018; Liu et al., 2012; Sabatinelli et al., 2013). Importantly, the LPP is sensitive to subtle variation in emotional content, such that the component's amplitude varies as a function of the level of emotion expressed (Duval et al., 2013; Sandre et al., 2018). Together, these data suggest that the LPP may be useful in studies investigating the ways in which youth attend to subtle differences in peer-age emotional facial expression.

The goals of the present study, therefore, were to examine adolescents' attention to and recognition of ambiguous and unambiguous emotional peer- and adult-age faces. To that end, we collected adolescents' LPPs in response to ambiguous and unambiguous emotional faces posed by adolescent and adult actors. We also examined adolescents' ability to accurately label the emotions expressed by these faces. To determine whether adolescents are uniquely sensitive to subtle variation in peer-relative to adult-age faces, we compared adolescents' neural and behavioral responses to a sample of young adults who completed the same task. We had the following hypotheses:

1. The magnitude of the LPP in adolescent participants would track subtle differences in facial affect portrayed by adolescents more strongly than in adult actors, such that as adolescent faces increased from ambiguous (i.e., 33%) to unambiguous (i.e., 100%) emotional expression, the magnitude of the LPP in adolescent participants would similarly increase (Marusak et al., 2013; Morningstar et al., 2019; Saxbe et al., 2015);
2. This effect would be stronger for adolescent participants than for adult participants.
3. Adolescent participants' enhanced tracking of subtle differences in facial affect portrayed by adolescent actors would be accompanied by greater accuracy in labeling the emotions portrayed by adolescents compared to adult actor faces, consistent with theoretical models of socioemotional processing (Halberstadt et al., 2001; Lemerise & Arsenio, 2000).

2 | METHOD

2.1 | Participants

Forty-nine adolescent participants were recruited from a high school in Montreal and forty-two young adult participants were recruited from the McGill University psychology human participant pool. After reviewing the study protocol, written informed parental consent and assent was obtained for adolescent participants, and written informed consent was obtained for the young adult participants. As compensation for their participation in the study, adolescents received a $50 gift card and young adults received course credit. All procedures were approved by the Research Ethics Board at McGill University.

Among the adolescent participants, electroencephalogram (EEG) data from two participants was excluded due to poor-quality recordings (i.e., fewer than 4 artifact-free trials in at least one condition). Behavioral data from these two participants were retained in subsequent analyses. EEG and behavioral data from an additional seven adolescent participants were excluded due to either a technical error during recording ($N = 1$) or because their performance on the identification task was poor (i.e., less than 14% accuracy; $N = 6$). Among the young adult participants, EEG data from one participant were excluded due to poor-quality recordings (i.e., fewer than 4 artifact-free trials in at least one condition). Behavioral data from this participant were included in subsequent analyses. EEG and behavioral data from one young adult participant were also excluded because they terminated the task early. Therefore, 42 adolescents and 41 young adults were included in our behavioral analyses.

The final sample included in EEG analyses consisted of forty adolescents (25 females; age $M = 12.73$ years, $SD = 0.45$ years, range = 12–13 years) and forty young adult participants (36 females; age $M = 19.78$ years, $SD = 1.23$ years, range = 18–23 years). Of the adolescent participants, 90% were White, 5% were Caribbean, 3% were Hispanic, and 3% declined to answer. Of the young adult participants, 55% were White, 20% were Chinese, 8% were Arab/West Asian, 5% were Korean, 3% were Japanese, and 10% indicated they were another ethnicity/nationality. The adolescent and young adult samples significantly differed from each other in terms of gender, $\chi^2(1) = 8.35$, $p < .01$, and ethnicity, $\chi^2(8) = 25.38$, $p < .01$, such that the young adult sample included more female participants and fewer White participants than the adolescent sample.

2.2 | Visual stimuli

Sixty-four photographs of sixteen adolescent actors (eight male and eight female; age range: 10–16 years) were selected from the NIMH Child Emotional Faces Picture Set (NIMH-ChEFS; Egger et al., 2011), and sixty-four photographs of sixteen adult actors (eight males and eight females; age range: 20–30 years) were selected from the Directed Emotional Faces database (KDEF; Lundqvist et al., 1998). These two data sets contain color and high-definition images of actors of the appropriate ages. Prototypical angry, fearful, happy, and neutral expressions, with a direct gaze, were selected for each actor. Within each actor, two prototypical images (either neutral and angry, neutral and fearful, or neutral and happy) were combined in different proportions (e.g., 100% angry/0% neutral, 66% angry/33% neutral, 33% angry/66% neutral, and 0% angry/100% neutral) using Fantamorph software (Abrosoft; http://www.abrosoft.com/). To do this, control points on the prototypical emotional face (i.e., either angry, fearful, or happy) and prototypical neutral face were identified (e.g., corners of the eyes, pupils, eyebrows, nostrils, outline of the mouth, circumference of the face). Each morphed image represents the distance between the identified points in the two images proportional to the percentage of emotion expressed (e.g., in a 66% angry photograph, the points are located 66% closer to the points on the prototypical angry face than on the neutral face); pixel intensity values are also blended according to the proportion of the emotion represented. Faces were then cropped so only facial expressions were visible and were presented against a black background. Specific images used in the study are listed in the Appendix. The use of these facial blends allowed us to examine participants' modulation of attention to varying degrees of emotional expression, ranging from ambiguous (low levels of emotional intensity, e.g., 33% and 66% emotion) to unambiguous expression (high levels of emotional intensity, e.g., 100% emotion) in faces posed by adolescent and adult actors.

All stimuli were presented on an Intel Core i7 computer using Presentation software (Neurobehavioral Systems, Inc.). Participants were seated approximately 70 cm from the screen.

2.3 | Procedure

Participants were seated, and EEG sensors were attached. All participants were instructed to view different faces of varying emotional quality and to identify the emotion of each face. Following these instructions, participants performed six practice trials, which consisted of prototypical facial expressions modeled by three adolescent and three adult actors not included in the actual task. The actual task consisted of 320 trials (160 adult faces and 160 adolescent faces), each presented once in a randomized order. Due to a coding error in the task, one trial, at random, was not recorded from the adolescent sample. Therefore, in this sample, a total of 319 trials per participant were available for subsequent EEG and behavioral analyses. Each trial consisted of a fixation point (random interval from 2000 to 3000 ms), followed by a centrally presented face (300 ms), followed by a fixation cross (1000 ms), followed by a screen that required the participant to indicate the emotion of the preceding face. Participants were asked to use the keyboard to indicate whether the face was happy (press 1), scared (press 2), angry (press 3), or neutral (press 4). After indicating the emotion, the next trial began. See Figure 1 for examples of adolescent and adult neutral-emotional face blend stimuli, as well as an example of a trial in the faces task.

All participants completed multiple computer tasks during the experiment. Other tasks completed by the adolescent participants included a social feedback task (Panier et al., 2022), a monetary reward task (described in Freeman et al., 2020), and a risk-taking task (also described in Freeman et al., 2020). Other tasks completed by the adult participants included a threat-generalization task (described in Bauer et al., 2020) and an emotional learning task. The order of the tasks was counterbalanced across participants, with the exception of the risk-taking task in the adolescent sample which was completed first. The results from other tasks administered during the same experimental session are presented elsewhere (e.g., Freeman et al., 2020). The magnitude of the LPP to adolescent and adult faces did not significantly differ based on the order of the faces task (i.e., second, third, or fourth; *ps* > .05) in the adolescent sample, nor did it significantly differ based on the order of the faces task (i.e., first, second, or third) in the young adult sample (*ps* > .05).

2.4 | Electroencephalographic recording and data processing

Continuous EEG was recorded using a 32-electrode cap and a BrainVision actiCHamp system (Brain Products, Munich, Germany) based on the standard 10/20 layout, with active Ag/AgCl sensors and a ground electrode at Fpz. Facial electrodes were placed approximately 1 cm above and below the left or right eye (VEO) and 1 cm outside the outer canthi of both eyes (HEO) to generate the electrooculogram (EOG). All electrode impedances were

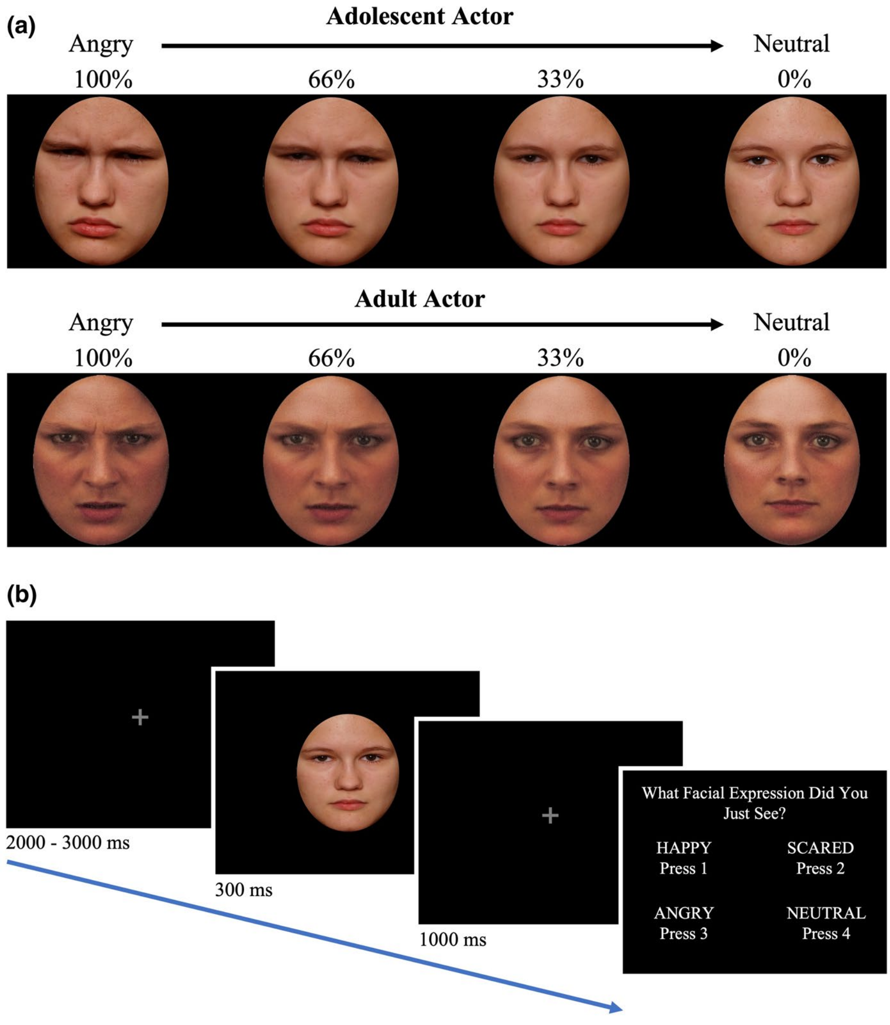

FIGURE 1 (a) Examples of adolescent and adult neutral-angry face blend (i.e., 0%, 33%, 66%, 100%) stimuli. (b) Example of a trial in the faces task. Adolescent actor face stimuli were selected from the NIMH Child Emotional Faces Picture Set (NIMH-ChEFS; Egger et al., 2011), and adult actor face stimuli were selected from Karolinska Directed Emotional Faces database (KDEF; Lundqvist et al., 1998)

kept below 10 kΩ, and data were recorded with a sampling rate of 1000 Hz. No online filter was used.

BrainVision Analyzer software (Brain Products, Munich, Germany) was used for offline analysis of EEG data. Continuous (non-segmented) data were band-pass filtered with low and high cut-offs of 0.01 and 30 Hz (24 dB/octave), respectively. Data were then referenced to an average of the left and right mastoids (TP9 and TP10), and eyeblink and ocular corrections were conducted per a modification of the algorithm published in Miller et al. (1988). The EEG was segmented into 1200 ms windows separately for each face type; these segments began 200 ms before stimulus onset and continued for 1000 ms.

A semi-automatic procedure was employed to detect and reject artifacts. The criteria applied were a voltage step of more than 50.0 μV between sample points, a voltage difference of 175 μV within a trial, and a minimum voltage difference of less than 0.50 μV within 100 ms intervals. These intervals were rejected from individual channels in each trial. Additional artifacts were identified and removed based on visual inspection. ERPs were constructed by separately averaging each of the ten stimulus types (i.e., 100% angry, 100% fearful, 100% happy, 66% angry, 66% fearful, 66% happy, 33% angry, 33% fearful, 33% happy, neutral) for adolescent and adult faces. The mean activity in a 200 ms window from −200 to 0 ms prior to picture onset served as the baseline and was subtracted from each data point.

Visual inspection of grand averages within the adolescent and adult samples confirmed that the LPP was maximal at site Pz, consistent with previous research in adolescent (Horndasch et al., 2018; Kujawa et al., 2012) and young adult samples (Bluntschli et al., 2015; Sandre et al., 2018). Therefore, the LPP was scored as the average activity at Pz between 400–1000 ms after picture onset. Independent sample t tests indicated that, at electrode Pz, the average percentage of data identified as artefactual did not significantly differ between the adolescent (adult faces: 2.60%; adolescent faces: 2.92%) and adult samples (adult faces: 1.56%; adolescent faces: 1.77%) for faces portrayed by adolescent ($t[78] = 0.81$, $p = .42$) and adult actors ($t[78] = 0.93$, $p = .36$). See Table S1 in the Supplemental Results for descriptive statistics of the number of artifact-free trials for each face type at electrode Pz within the adolescent and young adult samples. As indicated in Table S1, adolescent participants had an average of 15.03, 15.13, and 15.12 artifact-free trials across angry-neutral, fearful-neutral, and happy-neutral face blends portrayed by adolescent actors, respectively. Adolescent participants also had an average of 14.99, 15.09, and 14.94 artifact-free trials across angry-neutral, fearful-neutral, and happy-neutral face blends portrayed by adult actors, respectively. Adult participants had an average of 15.24, 15.41, and 15.47 artifact-free trials across angry-neutral, fearful-neutral, and happy-neutral face blends portrayed by adolescent actors, respectively. Additionally, adult participants had an average of 15.28, 15.51, and 15.33 artifact-free trials across angry-neutral, fearful-neutral, and happy-neutral face blends portrayed by adult actors, respectively. Paired sample t tests indicated that for adolescent participants, the number of artifact-free trials did not significantly differ between angry-neutral, fearful-neutral, and happy-neutral faces blends portrayed by adolescent and adult actors ($ps > .05$). In the adult sample, the number of artifact-free trials did not significantly differ between angry-neutral, fearful-neutral, and happy-neutral face blends portrayed by adolescent and adult actors ($ps > .05$). Additionally, independent t tests revealed that angry-neutral, fearful-neutral, and happy-neutral faces blends portrayed by adolescent and adult actors did not significantly differ in the number of artifact-free trials between adolescent and adult participants ($ps > .05$).

To examine the internal consistency (split-half reliability) of the LPP, we calculated the correlation between averages based on odd- and even-numbered trials for each face type within each participant age group. These estimates were corrected using the Spearman-Brown prophecy formula (Nunnally & Bernstein, 1994). Consistent with previous research on the psychometric properties of ERPs (Meyer et al., 2014; Moran et al., 2013; Pontifex et al., 2010), internal consistencies of the LPP in adolescents ranged from moderate to high for angry (100%, $r = .68$; 66%, $r = .53$; 33%, $r = .73$), fearful (100%, $r = .67$; 66%, $r = .50$; 33%, $r = .52$), happy (100%, $r = .64$; 66%, $r = .52$; 33%, $r = .56$), and neutral ($r = .57$) faces portrayed by adult actors, and from moderate to high for angry (100%, $r = .66$; 66%, $r = .55$; 33%, $r = .77$), fearful (100%, $r = .69$; 66%, $r = .59$; 33%, $r = .56$), happy (100%, $r = .75$; 66%, $r = .63$; 33%, $r = .59$), and neutral ($r = .74$) faces portrayed by adolescent actors. Internal consistencies of the LPP in adults ranged from moderate to high for angry (100%, $r = .60$; 66%, $r = .63$; 33%, $r = .57$), fearful (100%, $r = .70$; 66%, $r = .50$; 33%, $r = .62$), happy (100%, $r = .62$; 66%, $r = .58$; 33%, $r = .56$), and neutral ($r = .55$) faces portrayed by adult actors, and from moderate to high for angry (100%, $r = .51$; 66%, $r = .62$; 33%, $r = .55$), fearful (100%, $r = .67$; 66%, $r = .55$; 33%, $r = .66$), happy (100%, $r = .62$; 66%, $r = .65$; 33%, $r = .61$), and neutral ($r = .56$) faces portrayed by adolescent actors.

2.5 | Emotion recognition data

To examine adolescents' and adult's emotion recognition accuracy, we computed the proportion of times a participant selected each of the four possible responses (angry, fearful, happy, neutral) for each type of face participants saw in the task (e.g., adolescent 100% happy faces, adolescent 66% happy faces, etc.), by dividing the number of responses made for that label by the number of stimuli seen within each category. Values range from 0 to 1. Thus, a participant who identified 4 of the 16 adolescent 100% fearful faces as "angry" and 10 of the same faces as "fearful" would obtain a value of 0.25 for the "response type" of angry and a value of 0.625 for the "response type" of fearful. In other words, that participant answered "fearful" 62.5% of the time, and "angry" 25% of the time, when shown adolescent 100% fearful faces. This approach allowed us to examine both accurate responses (i.e., identifying a fearful face as conveying fear) *and* inaccurate responses (i.e., identifying it as angry) simultaneously.

2.6 | Data analytic approach

All statistical analyses were conducted using SPSS General Linear Model Software (Version 23).

To identify effects of face type on modulation of the LPP, a mixed-model repeated-measures analysis of variance (ANOVA) was conducted with the factors of participant age (between-subjects variable, 2 levels: adolescent participant, adult participant), actor age (within-subjects variable, 2 levels: adolescent face, adult face), emotion (within-subjects variable, 3 levels: angry, fearful, happy), and intensity (within-subjects variable, 3 levels: 33%, 66%, 100%).

To understand factors associated with the selection of each response type for each type of stimuli, a mixed-model repeated-measures ANOVA was conducted to examine the effect of participant age (between-subjects variable, 2 levels: adolescent participant, adult participant), actor age (within-subjects variable, 2 levels: adolescent face, adult face), emotion (within-subjects variable, 3 levels: angry, fearful, happy), and intensity (within-subjects variable, 3 levels: 33%, 66%, 100%), on the proportion of responses for each response type (within-subjects variable, 4 levels: angry, fearful, happy, neutral). Importantly, including "response type" as a factor allows us to compare the different accurate and inaccurate responses made to each stimulus category within one model, rather than computing separate ANOVAs for each type of response. However, this then removes all variance for main effects of factors related to stimulus characteristics (actor age, emotion, intensity) and the main effect of participant age: the overall proportion of responses made did not differ by actor age, for instance, as an equal number of responses are given to adolescent versus adult faces in the task. Instead, effects of interest pertain to how these factors may interact with response type—or, in other words, whether the proportion of times you select "angry" is associated with particular characteristics of the stimuli (such as its emotional intensity, or whether the actor is an adult or not) or your age group. As such, *F*-statistics were generated for the main effect of response type, as well as interactions of response type with all other factors.

Because neutral faces do not vary in intensity as the other expressions do, neutral was not included in the analyses above. Effects of participant age and actor age on modulation of the LPP and emotion recognition accuracy to neutral faces are reported in the Supplemental Results.

For both emotion recognition and LPP analyses, when assumptions of sphericity were violated (Mauchly, 1940), the Greenhouse–Geisser statistic was used to adjust the degrees of freedom (using estimated epsilon, ε). Effect sizes are reported as partial eta-squared (η_p^2; $SS_{effect}/[SS_{effect}+SS_{error}]$). In the Results section below, we focus on reporting interactions between face type and participant age and their associations with the LPP and emotion recognition responses. Results for main effects and interactions not discussed in the manuscript are presented in the Supplemental Results.

3 | RESULTS

3.1 | Effects of actor age, emotion, intensity, and participant age on the LPP

Table 1 displays means and standard deviations of the LPP to each face type and participant group. Figure 2 displays grand-average stimulus-locked ERPs in response to angry, fearful, and happy blends (i.e., 100%, 66%, 33%) portrayed by adolescent actors for each participant age group, and Figure 3 displays grand-average stimulus-locked ERPs in response to angry, fearful, and happy face blends (i.e., 100%, 66%, 33%) portrayed by adult actors for each participant age group. Topographic maps depicting voltage across the scalp for angry, fearful, and happy face blends (i.e., 100%, 66%, 33%) portrayed by adolescent and adult actors for each participant age group are presented in Figure 4.

Table 2 depicts the full model results from the mixed-model repeated-measures ANOVA examining the effects of participant age and face type on modulation of the LPP. As indicated in Table 2, we observed a significant three-way interaction of actor age x intensity x participant age on modulation of the LPP. To understand the actor age x intensity x participant age interaction, within each participant age sample, we conducted an actor age (within-subjects variable, 2 levels: adolescent face, adult face) by intensity (within-subjects variable, 3 levels: 33%, 66%, 100%)

TABLE 1 Means and standard deviations of adolescents' and adults' late positive potentials (μV) to angry, fearful, and happy face blends (i.e., neutral, 33%, 66%, 100%) portrayed by adolescent and adult actors

Actor age	Emotion	Intensity	Adolescent participants M (SD)	Adult participants M (SD)
Adult faces	Happy	33%	13.36 (5.83)	6.15 (3.20)
		66%	13.54 (5.70)	6.50 (3.78)
		100%	12.82 (6.37)	6.43 (3.84)
	Fearful	33%	13.05 (5.73)	7.56 (4.83)
		66%	12.70 (6.54)	7.17 (4.71)
		100%	13.59 (7.23)	8.03 (4.71)
	Angry	33%	13.52 (7.14)	6.49 (5.04)
		66%	14.48 (5.64)	7.54 (3.92)
		100%	13.37 (7.43)	7.29 (4.96)
	Neutral	0%	13.21 (7.65)	8.23 (3.90)
Adolescent faces	Happy	33%	8.67 (7.65)	7.35 (4.42)
		66%	14.98 (6.06)	10.12 (5.05)
		100%	15.40 (8.26)	11.42 (4.24)
	Fearful	33%	14.68 (7.58)	11.47 (4.80)
		66%	15.08 (6.70)	11.87 (5.10)
		100%	17.32 (7.85)	12.10 (4.87)
	Angry	33%	15.69 (6.94)	12.36 (4.47)
		66%	16.90 (7.83)	12.77 (3.90)
		100%	18.92 (9.08)	13.34 (4.88)
	Neutral	0%	14.77 (8.83)	13.29 (4.55)

Abbreviations: *M*, mean; *SD*, standard deviation.

repeated-measures ANOVA, collapsing across emotion types (e.g., across 66% happy, fearful, and angry faces, for one 66% variable). Within the adolescent participant sample, we observed significant main effects of actor age, $F(1, 39) = 6.83$, $p < .05$, $\eta_p^2 = .15$, and intensity, $F(2, 78) = 7.27$, $p = .001$, $\eta_p^2 = .16$, as well as a significant interaction between actor age and intensity, $F(2, 78) = 11.53$, $p < .001$, $\eta_p^2 = .23$. To decompose the interaction between actor age and intensity, we conducted two three-level (intensity: 100%, 66%, 33%) repeated-measures ANOVAs, one using faces portrayed by adolescents and one using faces portrayed by adults. When adolescent participants viewed adolescent faces, we observed a significant main effect of intensity, $F(2, 78) = 17.05$, $p < .001$, $\eta_p^2 = .30$. A significant linear trend was found for the effect of intensity for adolescent faces, such that, as faces portrayed by adolescents increased in intensity from ambiguous (i.e., 33%) to unambiguous emotional expression (i.e., 100%), the LPP in adolescent participants similarly increased, $F_{lin}(1, 39) = 38.36$, $p < .001$, $\eta_p^2 = .50$. In contrast, when adolescent participants viewed adult faces, we did not observe a significant main effect of intensity, $F(2, 78) = .12$, $p = .89$, $\eta_p^2 = .003$. These effects are depicted in Figure 5, which shows the mean amplitude of the LPP in response to emotional face blends portrayed by adolescents and adults within the adolescent sample.

We subsequently examined the effects of actor age and intensity on the LPP collected from the adult participant sample. We again observed a significant main effect of actor age, $F(1, 39) = 91.17$, $p < .001$, $\eta_p^2 = .70$, on the magnitude of the LPP, such that adolescent faces ($M = 11.42$, $SE = 0.53$) elicited a larger LPP compared to adult faces ($M = 7.02$, $SE = 0.43$; $t(39) = 9.55$, $p < .001$, 95% CI [3.47, 5.34]). There was also a significant main effect of intensity, $F(2, 78) = 7.68$, $p < .001$, $\eta_p^2 = .16$, on the magnitude of the LPP, such that faces at 100% intensity ($M = 9.77$, $SE = 0.46$) elicited a larger LPP than faces at 33% intensity ($M = 8.56$, $SE = 0.47$; $t(39) = 3.37$, $p = .002$, 95% CI [0.48, 1.92]), and faces at 66% intensity ($M = 9.33$, $SE = 0.43$) elicited a larger LPP than faces at 33% intensity among adult participants ($t(39) = 2.59$, $p = .01$, 95% CI [0.17, 1.36]; the LPP to faces at 100% and 66% intensity did not significantly differ, ($t(39) = 1.60$, $p = .12$, 95% CI [−0.12, 1.00]). A significant linear trend was found for the effect of intensity for adolescent and adult faces, such that, as the faces increased in intensity from

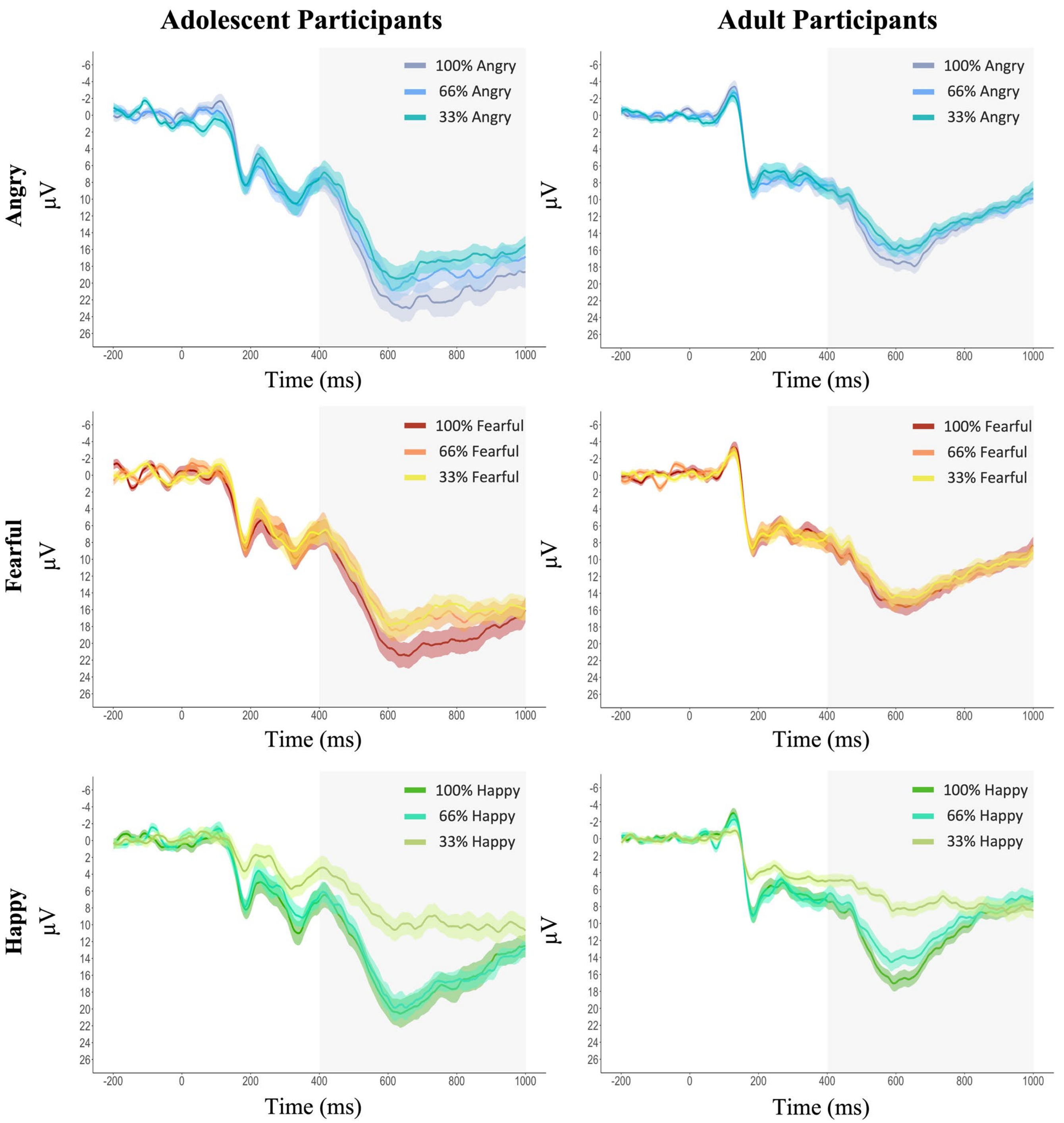

FIGURE 2 Stimulus-locked event-related potential (ERP) waveforms at electrode site Pz in response to angry, fearful, and happy face blends (i.e., 33%, 66%, 100%) portrayed by adolescent actors for the adolescent (left) and adult (right) samples. Face stimulus offset occurred at 300 ms. The late positive potential was scored from 400 to 1000 ms. Per ERP convention, negative is plotted up. Shading around waveforms represents standard error of the mean across participants at each timepoint

ambiguous to unambiguous emotional expression, the LPP in adult participants similarly increased, $F_{\text{lin}}(1, 39) = 11.39$, $p = .002$, $\eta_p^2 = .23$. However, in the adult participants, we did not observe a significant interaction between actor age and intensity on the magnitude of the LPP, $F(2, 78) = 1.90$, $p = .16$, $\eta_p^2 = .05$. These effects are depicted in Figure 5, which shows the mean amplitude of the LPP in response to emotional face blends portrayed by adolescents and adults within the adult participant sample. For further discussion of the LPP results presented in Table 2, see the Supplemental Results.

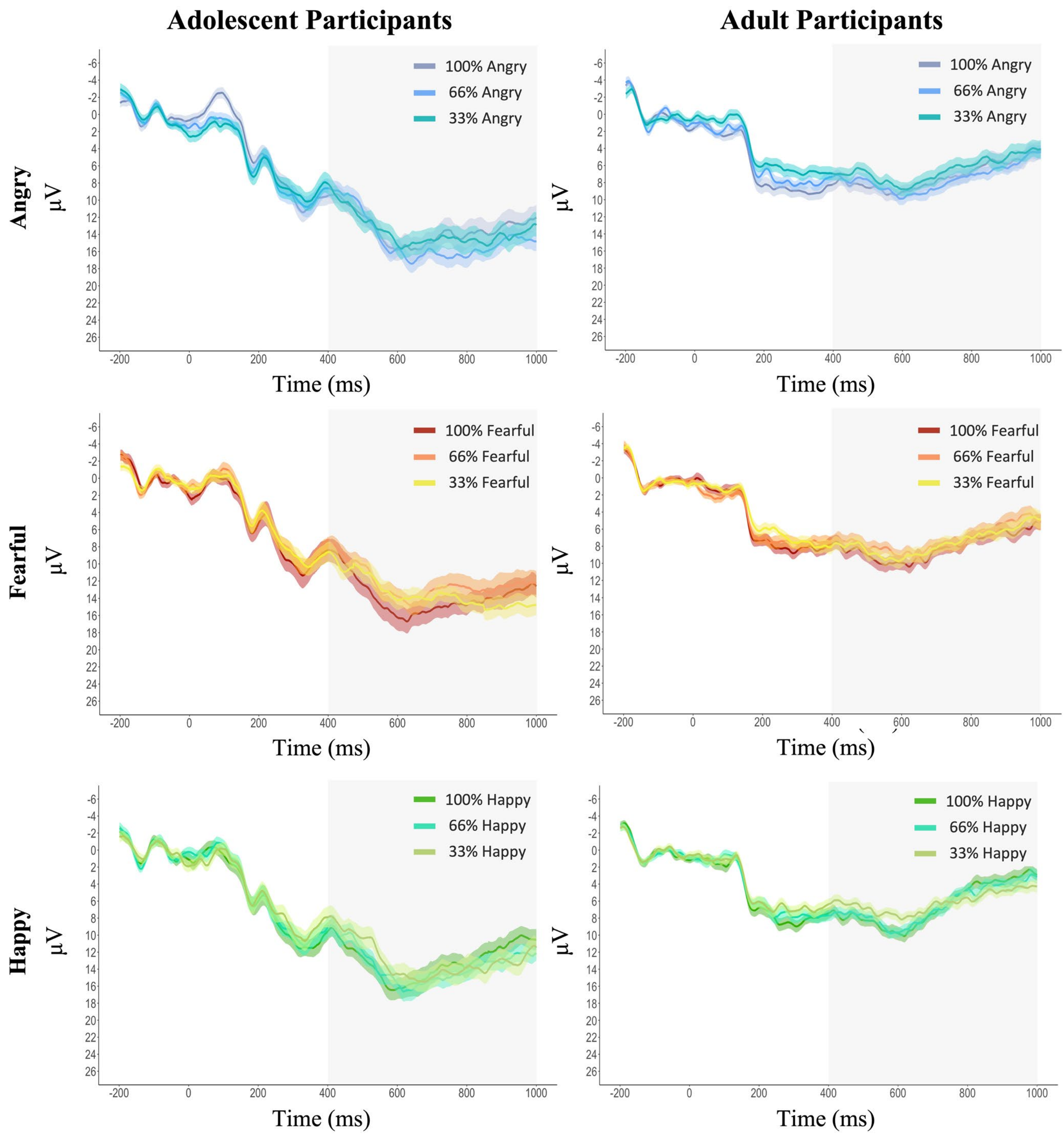

FIGURE 3 Stimulus-locked event-related potential (ERP) waveforms at electrode site Pz in response to angry, fearful, and happy face blends (i.e., 33%, 66%, 100%) portrayed by adult actors for the adolescent (left) and adult (right) samples. Face stimulus offset occurred at 300 ms. The late positive potential was scored from 400 to 1000 ms. Per ERP convention, negative is plotted up. Shading around waveforms represents standard error of the mean across participants at each timepoint

3.2 | Effects of actor age, emotion, intensity, and participant age on emotional recognition

Table 3 displays means and standard deviations of adolescents' and adults' emotion recognition responses to each face type.

Table 2 depicts the full model results from the mixed-model repeated-measures ANOVA examining the effects of participant age and face type on emotion recognition responses. As indicated in Table 2, we observed a significant four-way interaction of actor age × emotion × response type × participant age on emotion recognition

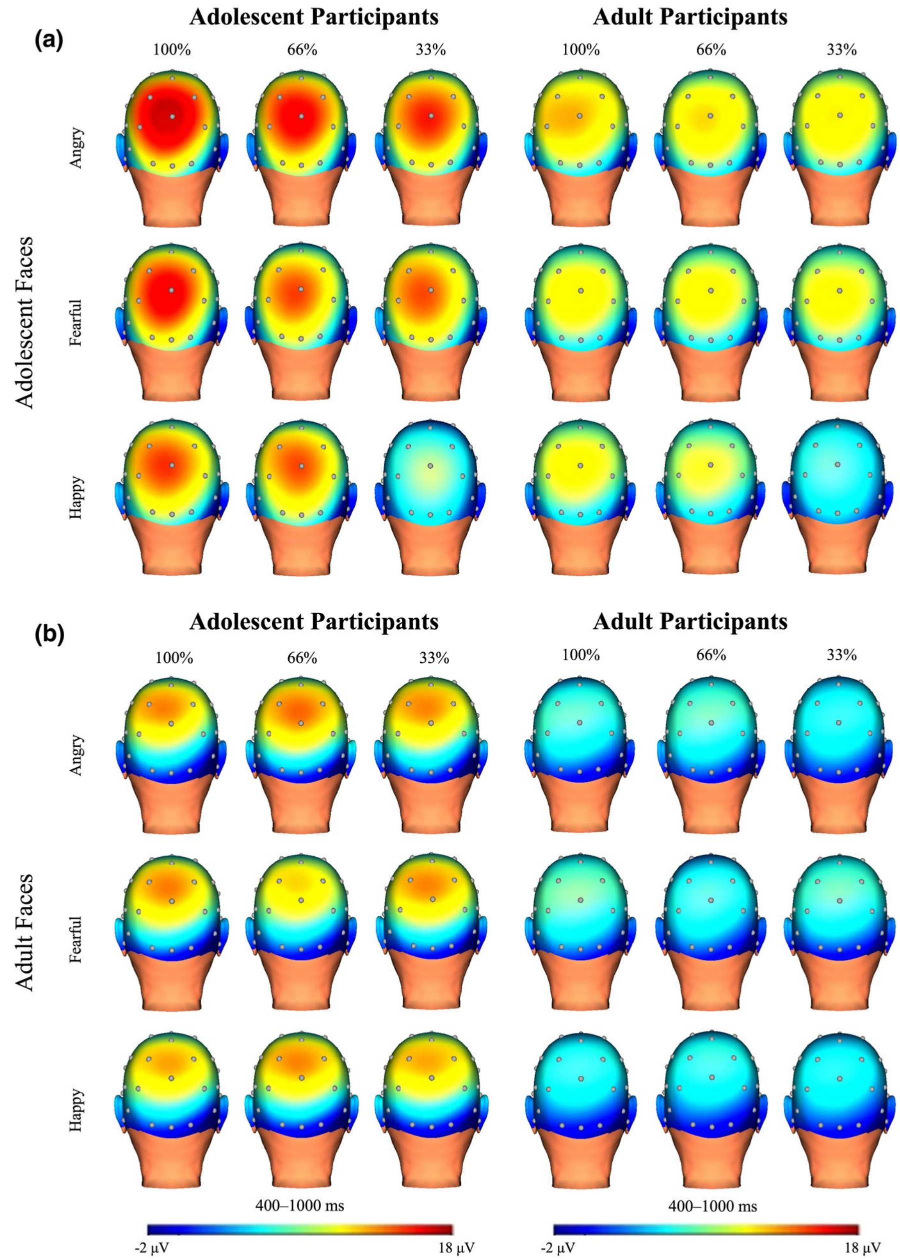

FIGURE 4 Topographic maps depicting voltage across the scalp for angry, fearful, and happy face blends (i.e., 33%, 66%, 100%) portrayed by adolescent (panel a) and adult actors (panel b) for the adolescent and adult samples

responses. When seeing happy adult faces, adolescent participants were less likely to select the correct response of "happy" (M = 0.85, SE = 0.01; t(81) = 4.00, p < .001, 95% CI [−0.11, −0.04]) and more likely to select "fearful" (M = 0.03, SE = 0.01; t(81) = 2.45, p = .02, 95% CI [0.003, 0.03]) or "neutral" (M = 0.09, SE = 0.01; t(81) = 3.12, p < .01, 95% CI [0.02, 0.07]) as a response than were adult participants (happy, M = 0.92, SE = 0.01; fearful, M = 0.02, SE = .004; neutral, M = 0.05, SE = 0.01). When seeing angry adult faces, adolescent participants were less likely to select the correct response of "angry" (M = 0.66, SE = 0.02; t(81) = 2.88, p = .01, 95% CI [−0.13, −0.02]) and more likely to choose "fearful" (M = 0.12, SE = 0.01; t(81) = 2.29, p = .02, 95% CI [0.01, 0.07]) as a response than were adult participants (angry, M = 0.74, SE = 0.02; fearful, M = 0.09, SE = 0.01). Lastly, adolescent participants were more likely to erroneously identify adolescent angry faces as "fearful" (M = 0.05, SE = 0.01; t(81) = 2.08, p = .04, 95% CI [0.001, 0.04]) than were adult participants (fearful, M = 0.03, SE = 0.00). For all other types of faces, adolescents and adults did not differ significantly in their responses (ps > .09). These effects are depicted in Figure 6, which shows emotion recognition responses for angry, happy, and fearful faces portrayed by adolescent and adult actors within the adolescent and adult samples.

PSYCHOPHYSIOLOGY

TABLE 2 Full factorial results for the late positive potential and emotion recognition responses

	Late positive potential				Emotion recognition responses				
Effect	***df***	***F***	η_p^2	***p***	**Effect**	***df***	***F***	η_p^2	***p***
–	–	–	–	–	Response Type	(2.29, 185.14)	79.55	0.5	<.001
Actor Age	(1, 78)	53.38	0.41	<.001	Response Type × Actor Age	(3.87, 209.31)	118	0.59	<.001
Emotion	(2, 156)	30.63	0.28	<.001	Response Type × Emotion	(2.81, 227.89)	3269.81	0.98	<.001
Intensity	(2, 156)	13.7	0.15	<.001	Response Type × Intensity	(2.24, 181.15)	776.08	0.91	<.001
Participant Age	(1, 78)	38.34	0.33	<.001	Response Type × Participant Age	(2.29, 185.17)	2.69	0.03	.06
Actor Age × Participant Age	(1, 78)	8.33	0.1	.01	Response Type × Actor Age × Participant Age	(2.58, 185.17)	3.96	0.05	.01
Actor Age × Emotion	(2, 156)	10.83	0.12	<.001	Response Type × Actor Age × Emotion	(4.18, 338.41)	43.55	0.35	<.001
Actor Age × Intensity	(2, 156)	12.32	0.14	<.001	Response Type × Actor Age × Intensity	(3.93, 318.34)	93.12	0.54	<.001
Emotion × Intensity	(4, 312)	3.77	0.05	.01	Response Type × Emotion × Intensity	(4.22, 342.12)	412.5	0.84	<.001
Actor Age × Intensity × Participant Age	(2, 156)	3.19	0.04	.04	Response Type × Actor Age × Intensity × Participant Age	(3.93, 370.33)	0.56	0.01	.69
Actor Age × Emotion × Intensity	(3.63, 283.46)	4.47	0.05	.002	Response Type × Actor Age × Emotion × Intensity	(6.55, 530.66)	47.91	0.37	<.001
Actor Age × Emotion × Participant Age	(2, 156)	1.02	0.01	.36	Response Type × Actor Age × Emotion × Participant Age	(4.18, 370.33)	2.56	0.03	.04
Emotion × Participant Age	(2, 156)	1.03	0.01	.36	Response Type × Emotion × Participant Age	(2.81, 370.33)	3.39	0.04	.02
Intensity × Participant Age	(2, 156)	1.03	0.01	.36	Response Type × Intensity × Participant Age	(2.24, 370.33)	0.59	0.01	.58
Emotion × Intensity × Participant Age	(4, 312)	0.63	0.01	.64	Response Type × Emotion × Intensity × Participant Age	(4.22, 740.66)	1.14	0.01	.34
Actor Age × Emotion × Intensity × Participant Age	(4, 312)	0.61	0.01	.66	Response Type × Actor Age × Emotion × Intensity × Participant Age	(6.55, 740.66)	1.46	0.02	.18

Abbreviation: η_p^2, partial eta squared.

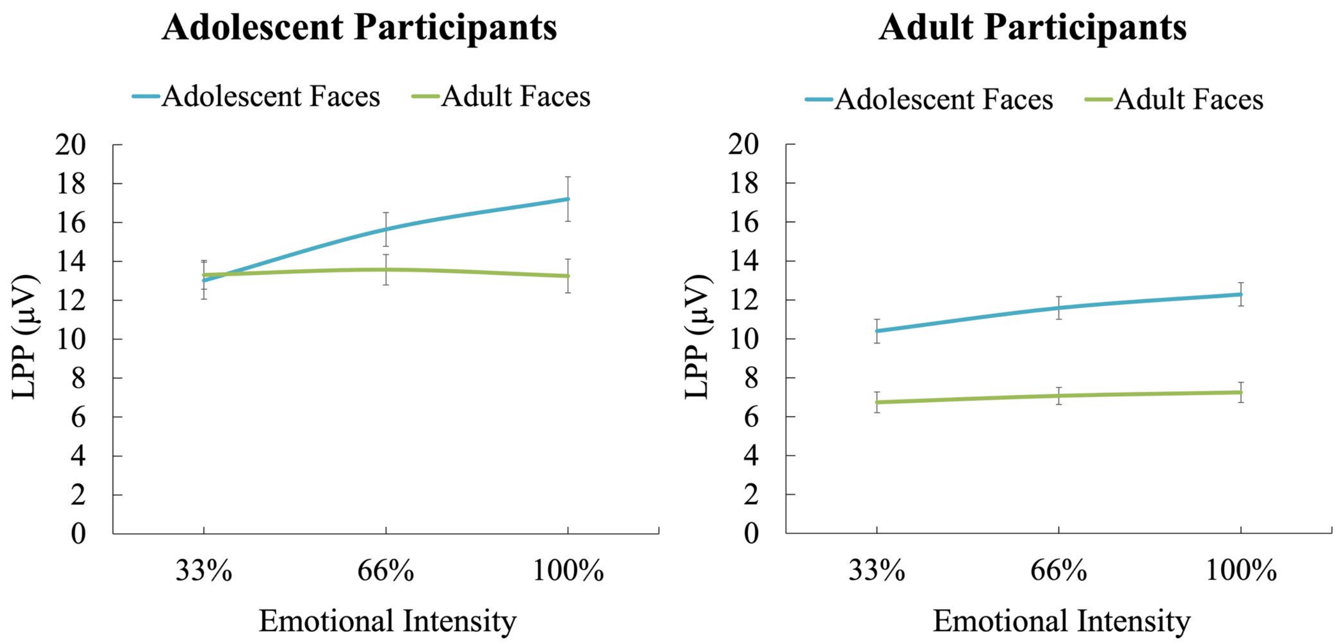

FIGURE 5 Mean amplitude of the late positive potential (LPP; in μV) to emotional face blends (i.e., 33%, 66%, 100%) portrayed by adolescents and adults within the adolescent (left) and adult (right) samples from 400–1000 ms. Error bars indicate standard error of the mean

For further discussion of the emotion recognition results presented in Table 2, see the Supplemental Results.

4 | DISCUSSION

The present study examined adolescents' and young adults' neural responses to and labeling of ambiguous and unambiguous facial affect posed by youth and adult actors. We found that adolescents allocated more neural resources to subtle differences in peer-age relative to adult-age facial affect, such that as the intensity of peer-age faces increased from ambiguous (i.e., 33%) to unambiguous (i.e., 100%) emotional expression, the magnitude of the LPP in adolescents similarly increased. In contrast, the magnitude of the LPP in adults increased as emotional expressions became less ambiguous across both adolescent and adult faces, but this pattern did not significantly differ between youth and adult displays of facial affect. These results are consistent with evidence that adolescence may be characterized by enhanced attention to subtle changes in peer emotional faces—an effect that likely reflects the shift in importance of peer socioemotional cues during this social transition period (Nelson et al., 2005).

These data highlight that peer-age facial displays of emotion are salient and socially significant cues during adolescence (Morningstar et al., 2019; Nelson et al., 2005; Saxbe et al., 2015), a period during which the relevance of peers as interaction partners increases dramatically and when establishing oneself within peer networks becomes increasingly important (Steinberg & Morris, 2001). Increased attention to subtle or more ambiguous emotional displays of peers may support youths' ability to flexibly adjust behavior in ways that promote and maintain positive social exchanges and relationships, as well as prevent harmful interactions with peers (Crone & Dahl, 2012; Nelson & Guyer, 2011; Pfeifer & Allen, 2012; van Hoorn et al., 2018). Future work is necessary to determine whether neural correlates of attention to ambiguous and unambiguous peer-age emotional expression in adolescents are associated with behaviors that support social success across different peer contexts (e.g., initiating a friendship, peer provocation and rejection). Additionally, because we focused on ambiguous and unambiguous angry, fearful, and happy faces portrayed by adolescent and adult actors, it will be important to replicate the present study's results using a broader range of emotional expressions (e.g., sadness, disgust, surprise).

Interestingly, adolescents' increased neural responses to peer-age emotional expressions, as measured by the LPP, was not reflected in their ability to label these faces more accurately than adults. Prior research suggests that by about 10 years of age, children show adult-like performance when labeling subtly varying happy, angry, and fearful faces portrayed by adult actors (Gao & Maurer, 2009, 2010). In our study, while youth demonstrated comparable accuracy as adults when labeling some adolescent face types (i.e., fearful and happy adolescent faces), they showed worse accuracy for others (i.e., angry adolescent faces). However, angry adolescent faces were also the

TABLE 3 Means and standard deviations of adolescents' and adults' emotional recognition responses to angry, fearful, and happy face blends (i.e., neutral, 33%, 66%, 100%) portrayed by adolescent and adult actors

			Adult faces		Adolescent faces	
			Adolescent participants	Adult participants	Adolescent participants	Adult participants
Emotion	**Intensity**	**Response type**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Happy	33%	Happy	.67 (.21)	.80 (.20)	.34 (.16)	.36 (.16)
		Fearful	.06 (.07)	.04 (.05)	.08 (.11)	.07 (.06)
		Angry	.04 (.08)	.03 (.06)	.09 (.09)	.07 (.09)
		Neutral	.23 (.19)	.13 (.15)	.49 (.21)	.50 (.19)
	66%	Happy	.93 (.07)	.98 (.04)	.95 (.08)	.97 (.05)
		Fearful	.03 (.05)	.01 (.03)	.01 (.03)	.01 (.02)
		Angry	.01 (.02)	.00 (.01)	.01 (.03)	.00 (.01)
		Neutral	.03 (.04)	.01 (.03)	.03 (.07)	.02 (.05)
	100%	Happy	.96 (.06)	.99 (.03)	.97 (.05)	.99 (.04)
		Fearful	.01 (.04)	.00 (.00)	.01 (.03)	.00 (.02)
		Angry	.01 (.03)	.00 (.01)	.00 (.01)	.00 (.01)
		Neutral	.02 (.04)	.01 (.02)	.02 (.04)	.01 (.03)
Fearful	33%	Happy	.03 (.06)	.03 (.05)	.03 (.07)	.03 (.07)
		Fearful	.48 (.17)	.44 (.15)	.38 (.18)	.38 (.16)
		Angry	.06 (.07)	.07 (.08)	.06 (.06)	.07 (.07)
		Neutral	.43 (.17)	.46 (.15)	.53 (.17)	.52 (.18)
	66%	Happy	.01 (.03)	.01 (.03)	.02 (.05)	.02 (.05)
		Fearful	.87 (.11)	.89 (.08)	.80 (.11)	.81 (.12)
		Angry	.05 (.06)	.06 (.07)	.08 (.07)	.09 (.08)
		Neutral	.07 (.07)	.04 (.05)	.10 (.07)	.08 (.08)
	100%	Happy	.01 (.03)	.02 (.03)	.04 (.08)	.02 (.04)
		Fearful	.90 (.09)	.91 (.09)	.85 (.14)	.87 (.09)
		Angry	.06 (.07)	.06 (.07)	.09 (.09)	.09 (.08)
		Neutral	.03 (.04)	.01 (.03)	.02 (.04)	.02 (.03)
Angry	33%	Happy	.03 (.06)	.02 (.03)	.02 (.05)	.02 (.03)
		Fearful	.13 (.12)	.10 (.08)	.05 (.07)	.02 (.04)
		Angry	.37 (.18)	.45 (.20)	.34 (.18)	.35 (.20)
		Neutral	.47 (.20)	.43 (.20)	.59 (.20)	.61 (.21)
	66%	Happy	.02 (.04)	.02 (.03)	.02 (.04)	.01 (.04)
		Fearful	.12 (.10)	.08 (.07)	.05 (.08)	.04 (.06)
		Angry	.79 (.15)	.86 (.10)	.75 (.14)	.77 (.15)
		Neutral	.07 (.09)	.04 (.06)	.18 (.11)	.18 (.12)
	100%	Happy	.01 (.06)	.01 (.02)	.01 (.04)	.01 (.02)
		Fearful	.12 (.10)	.07 (.09)	.05 (.07)	.02 (.05)
		Angry	.82 (.14)	.91 (.11)	.86 (.12)	.91 (.10)
		Neutral	.05 (.07)	.01 (.03)	.08 (.08)	.06 (.07)
Neutral	0%	Happy	.03 (.05)	.03 (.05)	.02 (.04)	.02 (.03)
		Fearful	.10 (.10)	.05 (.07)	.07 (.09)	.02 (.04)
		Angry	.12 (.12)	.11 (.12)	.11 (.11)	.10 (.10)
		Neutral	.75 (.19)	.81 (.15)	.80 (.17)	.86 (.12)

Notes: Values represent the proportion of times a particular response was selected for each face type in the task, expressed as (number of times this response was selected)/(number of times this face type was seen).

Abbreviations: *M*, mean; *SD*, standard deviation.

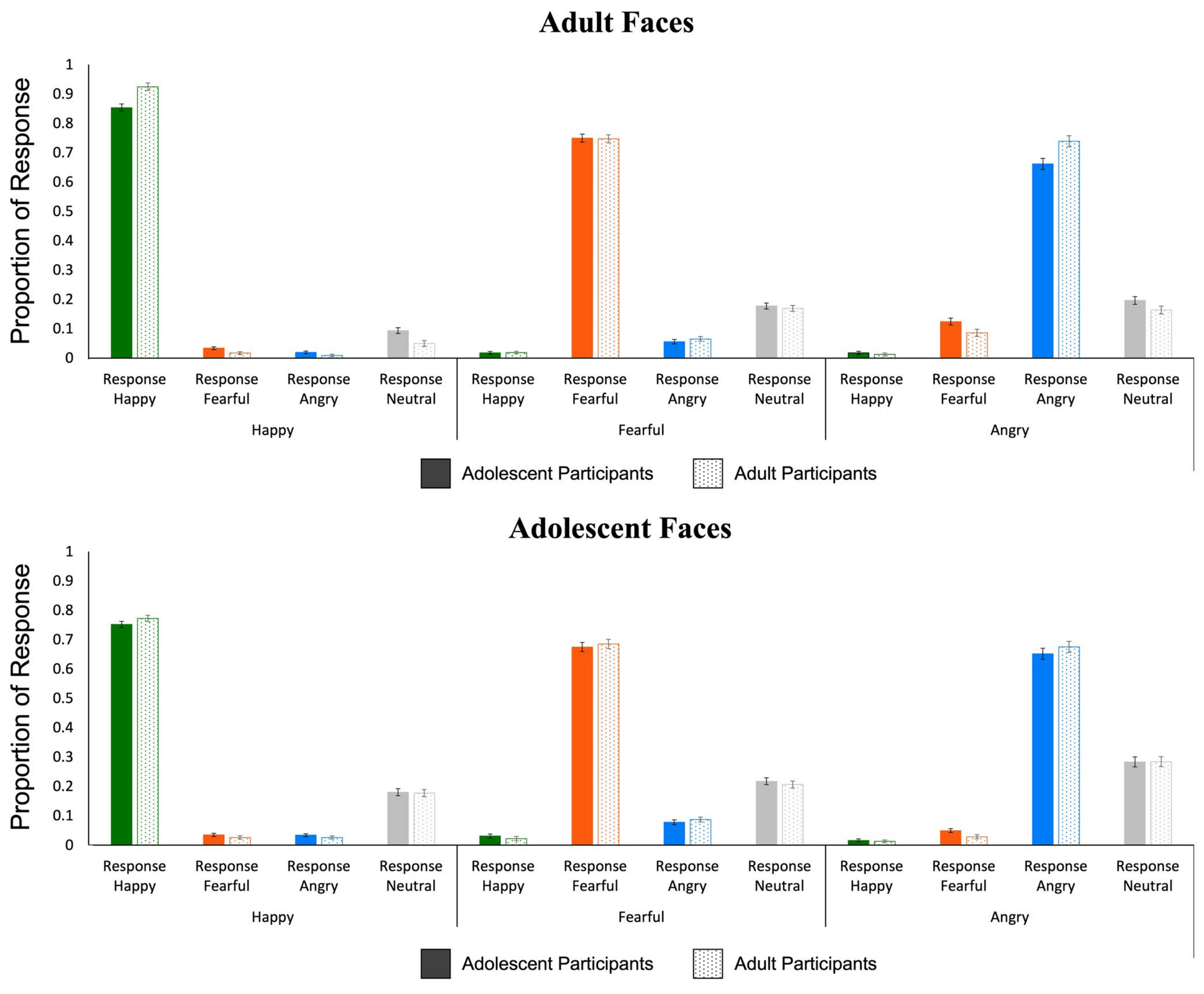

FIGURE 6 Emotion recognition responses by participant age, actor age, and emotion. The *y*-axis is the proportion of times a specific response (happy, fearful, angry, or neutral) was selected in response to the different types of stimuli, computed as (number of times the response was selected)/(number of times the stimulus type was seen). Error bars represent the standard error of the mean

faces that elicited the largest neural response in the adolescent participants. These results are surprising and raise questions about what the function of youths' increased attention to peer-age faces might be, given that that these faces are not more easily understood. It is possible that increased neural correlates of attention to peer-age faces may be an early-emerging ability in adolescents' social transition that sets the stage for the later specialization of downstream socioemotional processes, such as labeling (e.g., Marusak et al., 2013). Additionally, the processes between attending to a face and the behavioral response elicited by the face are numerous, complex, and may follow different developmental trajectories (Somerville et al., 2011; Thomas et al., 2007). As such, patterns of attention to and labeling of facial affect may not align at different points in development. Future longitudinal research with a broader age range of adolescents and young adults will be needed to substantiate these hypotheses.

These findings also suggest that peer-age facial affect may modulate youths' attention and emotional labeling in distinct ways, underscoring the fact that attention and emotion labeling reflect independent aspects of socioemotional processing and should not necessarily be expected to converge. Consistent with this, inconsistencies between neural indices of attention and behavioral correlates of emotion recognition are common in both adolescent and adult samples (Fölster & Werheid, 2016; Frühholz et al., 2011; Lee et al., 2019; Marusak et al., 2013; Wiggins et al., 2016). Future research will be necessary to understand why these differences in attention and emotion labeling exist in youth, and how these processes relate to real-world social behavior in peer and adult interactions.

Our results may have important implications for understanding youths' socioemotional functioning in peer contexts. In particular, attending more to the emotional facial expressions of peers without the attendant ability to *identify* the emotions expressed by these faces accurately likely poses challenges, and may contribute to some of the social and emotional difficulties that are common during adolescence (Kessler et al., 2007; Klomek et al., 2007; Laird et al., 2001; Roberts et al., 1998; Rudolph, 2002). Future research with larger samples will be needed to replicate these effects, and to determine whether both increased attention to and difficulties labeling peer-age facial affect may have meaningful effects on adolescents' social and emotional functioning in peer contexts.

We would also note here that our results do not suggest that youth allocated more attentional resources toward processing emotional faces posed by same-age peers because these faces were more difficult to decipher. In fact, adolescent participants showed comparable accuracy to adults when labeling *most* emotional faces portrayed by adolescent actors (i.e., ambiguous and unambiguous happy and fearful adolescent faces). This suggests that faces portrayed by adolescent actors were not more difficult for adolescent participants to label, and that the LPP in adolescent participants was not influenced by emotion labeling difficulty. To our knowledge, few studies have examined whether emotional faces portrayed by youth are more difficult to identify than emotional faces portrayed by adults. Nonetheless, there is some evidence that difficulties discriminating between target stimuli in auditory and visual oddball tasks, as well as difficulties discriminating the valence of emotional words, may influence the magnitude of the LPP (Delaney-Busch et al., 2016; Twomey et al., 2015). Thus, an important direction for future research is to examine whether emotional faces portrayed by youth actors are more difficult for adolescents and adults to label (e.g., by using a wider variety of actors of each age group, and measuring reaction time alongside accuracy), and whether this difficultly influences the magnitude of the LPP to faces portrayed by adolescent actors.

There are several limitations to the current study that lend themselves directly to suggestions for future research. First, there were fewer female participants in our adolescent sample compared to our adult sample. Females have been found to show increased emotion recognition accuracy compared to males across development (McClure, 2000). Because our sample was insufficiently powered to examine potential gender differences, it will be important to replicate the present results in a larger sample of youth and young adults and to examine potential influences of gender in attending and labeling peer- and adult-age facial affect.

Second, our faces task required participants to label the emotion expressed by adolescent and adult faces, and not the emotional intensity of these faces. Instead, we chose to use a relatively simple task where discrete emotion label choices were displayed on each trial in order to reduce task length and participant fatigue. However, it remains unclear whether adolescents and adults show comparable accuracy when more fine-grained emotional labels are available, such as those capturing the emotional intensity of faces (e.g., Sandre et al., 2018). Although the use of discrete emotion labels are common in research focused on understanding the development of attention to and labeling of emotional expressions (Lee et al., 2019; Thomas et al., 2007; Wiggins et al., 2016), it will be important for future studies to compare youths' and adults' labeling of adolescent and adult emotion expressions using both discrete emotion and emotion intensity labels, and with different tasks (e.g., Vicari et al., 2000).

Third, the number of trials included in each face type condition was low (16 trials in each condition); our condition averages of the LPP were therefore based on a small number of artifact-free trials (i.e., an average of 15 artifact-free trials in each condition for adolescent and adult participants). This may have reduced signal-to-noise ratios and consequently impacted the internal consistency reliability of the LPP, as well as the strength of the within- and between-subjects effects we observed (Klawohn et al., 2020; Sandre et al., 2020). Prior work suggests that at least eight trials are needed to obtain a reliable LPP (Moran et al., 2013). In our study, most adolescent participants (95%) and all adult participants had eight or more trials across all conditions. Internal consistency (split-half) estimates of the LPP fell within moderate to high thresholds (i.e., *r*s ranged between .50 to .77), consistent with prior work on the LPP in adolescent and adult samples (i.e., *r*s range between .43 to .81; Auerbach et al., 2016; MacNamara et al., 2019; Moran et al., 2013; Mulligan et al., 2020). We would also note here that we designed our task to include faces of different ages, faces expressing a range of emotions, as well as faces that varied across levels of ambiguity. On the one hand, this allowed us to compare adolescents' and adults' neural responses to more developmentally relevant and ecologically valid stimuli. On the other hand, this resulted in a total of 20 different conditions and subsequently increased the length of the task. To decrease participant fatigue and minimize the potential for data loss, which is an especially important consideration in developmental samples (DeBoer et al., 2005), we designed our faces task to include fewer trials in each condition. Nonetheless, there is a need for future research to design tasks that use more ecologically valid face stimuli and that are scalable across development to better understand trajectories of socioemotional processing.

Fourth, while the present data are cross-sectional and therefore cannot speak directly to developmental trajectories of socioemotional processing, they do indicate that adolescents allocate their attention differently depending on whether the social target is a peer or an adult. In particular, when using stimuli that may be more socially salient (peer-age faces) and ecologically valid (morphed emotional faces), developmental trends in attention to facial affect may vary from commonly assumed linear trajectories (e.g., Burnett et al., 2011; Monk et al., 2003; Somerville et al., 2011). As such, our results highlight the importance of considering developmentally relevant stimuli when examining socioemotional processing in adolescent samples (Del Piero et al., 2016). Future longitudinal work will be needed to clarify typical trajectories of socioemotional processing using both peer- and adult-age faces.

The current study's results may also inform future work focused on understanding the development and maintenance of psychopathology in youth. Adolescence is a period of peak vulnerability for psychopathology (Kessler et al., 2007), and abnormalities in attention to and recognition of both prototypical and morphed facial displays of emotion portrayed by adults have been demonstrated in youth with and at risk for internalizing and externalizing disorders (Bunford et al., 2017; Cservenka et al., 2014; Dan & Raz, 2018; Hankin et al., 2010; Jacobs et al., 2011; Ladouceur et al., 2006; Lopez-Duran et al., 2013; Roy et al., 2008; Schepman et al., 2012). Thus, there is a critical need to characterize developmental trajectories of socioemotional processing in clinical samples using peer- and adult-age facial affect, and to establish whether abnormalities in attending and labeling adult portrayals of emotion generalize to those displayed by same-age peers.

In sum, the present study indicates developmental variation in attention to and labeling of peer- and adult-age emotional expressions which may inform our understanding of how socioemotional processing unfolds in adolescence. Our results suggest that adolescence is uniquely associated with increased attention to subtle differences in peer-age emotional expression, an effect that may reflect the social relevance of these faces during this developmental period (Steinberg & Morris, 2001). Moreover, youths' enhanced attention to peer-age facial affect did not coincide with greater accuracy in labeling the emotion of these faces relative to young adults, highlighting that continued work is needed to understand how discrete stages of socioemotional processing may contribute to variation in adolescents' social functioning. Accurate characterization of normative trajectories of socioemotional processing will likely involve the use of developmentally relevant stimuli, multi-method measures of attention and labeling, and consideration of whether these measures are modulated by peer and parental experiences.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest to disclose.

AUTHOR CONTRIBUTIONS

Aislinn Sandre: Conceptualization; formal analysis; investigation; methodology; project administration; visualization; writing – original draft; writing – review and editing. **Michele Morningstar:** Conceptualization; data curation; formal analysis; investigation; methodology; visualization; writing – review and editing. **Alison Farrell-Reeves:** Investigation; project administration; writing – review and editing. **Melanie Dirks:** Conceptualization; funding acquisition; project administration; resources; supervision; writing – review and editing. **Anna Weinberg:** Conceptualization; funding acquisition; investigation; methodology; project administration; resources; supervision; writing – review and editing.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Aislinn Sandre https://orcid.org/0000-0003-2317-0929

REFERENCES

Adolphs, R. (2002a). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169–177. https://doi.org/10.1016/s0959-4388(02)00301-x

Adolphs, R. (2002b). Recognizing emotion from facial expressions: Psychological and neurological mechanisms. *Behavioral and Cognitive Neuroscience Reviews*, *1*(1), 21–62. https://doi.org/10.1177/1534582302001001003

Auerbach, R. P., Bondy, E., Stanton, C. H., Webb, C. A., Shankman, S. A., & Pizzagalli, D. A. (2016). Self-referential processing in adolescents: Stability of behavioral and ERP markers. *Psychophysiology*, *53*(9), 1398–1406. https://doi.org/10.1111/psyp.12686

Bauer, E. A., MacNamara, A., Sandre, A., Lonsdorf, T. B., Weinberg, A., Morriss, J., & van Reekum, C. M. (2020). Intolerance of uncertainty and threat generalization: A replication and extension. *Psychophysiology*, *57*(5). e13546. https://doi.org/10.1111/psyp.13546

Bluntschli, J. R., Maxfield, M., Grasso, R. L., & Kisley, M. A. (2015). The last word: A comparison of younger and older adults' brain responses to reminders of death. *The Journals of Gerontology: Series B*, *73*(4), 555–563. https://doi.org/10.1037/e514472015-528

Brechwald, W. A., & Prinstein, M. J. (2011). Beyond homophily: A decade of advances in understanding peer influence processes. *Journal of Research on Adolescence*, *21*(1), 166–179. https://doi.org/10.1111/j.1532-7795.2010.00721.x

Brosch, T., Pourtois, G., & Sander, D. (2010). The perception and categorisation of emotional stimuli: A review. *Cognition &*

Emotion, *24*(3), 377–400. https://doi.org/10.1080/02699930902975754

Brown, B. B., Larson, J. (2009). Peer relationships in adolescents. In Steinberg, R. M. L. (Ed.), *Handbook of adolescent psychology, Contextual influences on adolescent development* (Vol. *2*, 3rd ed., pp. 74–103). John Wiley & Sons.

Brown, B. B. (2004). Adolescents' relationships with peers. In R. M. Lerner & L. Steinberg (Eds.), *Handbook of adolescent psychology* (pp. 363–394). John Wiley & Sons Inc.. https://doi.org/10.1002/9780471726746

Bublatzky, F., Kavcıoğlu, F., Guerra, P., Doll, S., & Junghöfer, M. (2020). Contextual information resolves uncertainty about ambiguous facial emotions: Behavioral and magnetoencephalographic correlates. *NeuroImage*, *215*, 116814. https://doi.org/10.1016/j.neuroimage.2020.116814

Bunford, N., Kujawa, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2018). Convergence of BOLD and ERP measures of neural reactivity to emotional faces in children and adolescents with and without anxiety disorders. *Biological Psychology*, *134*, 9–19. https://doi.org/10.1016/j.biopsycho.2018.02.006

Bunford, N., Kujawa, A., Swain, J. E., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2017). Attenuated neural reactivity to happy faces is associated with rule breaking and social problems in anxious youth. *European Child & Adolescent Psychiatry*, *26*(2), 215–230. https://doi.org/10.1007/s00787-016-0883-9

Burnett, S., Sebastian, C., Kadosh, K. C., & Blakemore, S. J. (2011). The social brain in adolescence: Evidence from functional magnetic resonance imaging and behavioural studies. *Neuroscience & Biobehavioral Reviews*, *35*(8), 1654–1664. https://doi.org/10.1016/j.neubiorev.2010.10.011

Calvo, M. G., Gutiérrez-García, A., Fernández-Martín, A., & Nummenmaa, L. (2014). Recognition of facial expressions of emotion is related to their frequency in everyday life. *Journal of Nonverbal Behavior*, *38*(4), 549–567. https://doi.org/10.1007/s10919-014-0191-3

Camras, L. A., & Allison, K. (1985). Children's understanding of emotional facial expressions and verbal labels. *Journal of Nonverbal Behavior*, *9*(2), 84–94. https://doi.org/10.1007/bf00987140

Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review*, *28*(1), 62–77. https://doi.org/10.1016/j.dr.2007.08.003

Codispoti, M., Ferrari, V., & Bradley, M. M. (2007). Repetition and event-related potentials: Distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience*, *19*(4), 577–586. https://doi.org/10.1162/jocn.2007.19.4.577

Collin, L., Bindra, J., Raju, M., Gillberg, C., & Minnis, H. (2013). Facial emotion recognition in child psychiatry: A systematic review. *Research in Developmental Disabilities*, *34*(5), 1505–1520. https://doi.org/10.1016/j.ridd.2013.01.008

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social information-processing mechanisms in children's social adjustment. *Psychological Bulletin*, *115*(1), 74–101. https://doi.org/10.1037/0033-2909.115.1.74

Crone, E. A., & Dahl, R. E. (2012). Understanding adolescence as a period of social–affective engagement and goal flexibility. *Nature Reviews Neuroscience*, *13*(9), 636–650. https://doi.org/10.1038/nrn3313

Cservenka, A., Fair, D. A., & Nagel, B. J. (2014). Emotional processing and brain activity in youth at high risk for alcoholism. *Alcoholism: Clinical and Experimental Research*, *38*(7), 1912–1923. https://doi.org/10.1111/acer.12435

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, *52*(2), 95–111. https://doi.org/10.1016/S0301-0511(99)00044-7

Dan, O., & Raz, S. (2018). Response patterns to emotional faces among adolescents diagnosed with ADHD. *Journal of Attention Disorders*, *22*(12), 1123–1130. https://doi.org/10.1177/1087054715606215

DeBoer, T., Scott, L. S., & Nelson, C. A. (2005). Event-related potentials in developmental populations. In T. C. Handy (Ed.), *Methodological handbook for research using event-related potentials* (pp. 263–297). The MIT Press.

Del Piero, L. B., Saxbe, D. E., & Margolin, G. (2016). Basic emotion processing and the adolescent brain: Task demands, analytic approaches, and trajectories of changes. *Developmental Cognitive Neuroscience*, *19*, 174–189. https://doi.org/10.1016/j.dcn.2016.03.005

Delaney-Busch, N., Wilkie, G., & Kuperberg, G. (2016). Vivid: How valence and arousal influence word processing under different task demands. *Cognitive, Affective, & Behavioral Neuroscience*, *16*(3), 415–432. https://doi.org/10.3758/s13415-016-0402-y

Dols, J. M. F., & Russell, J. A. (2017). *The science of facial expression*. Oxford Scholarship Online. https://doi.org/10.1093/acprof:oso/9780190613501.001.0001

Duval, E. R., Moser, J. S., Huppert, J. D., & Simons, R. F. (2013). What's in a face?: The late positive potential reflects the level of facial affect expression. *Journal of Psychophysiology*, *27*(1), 27–38. https://doi.org/10.1027/0269-8803/a000083

Egger, H. L., Pine, D. S., Nelson, E., Leibenluft, E., Ernst, M., Towbin, K. E., & Angold, A. (2011). The NIMH child emotional faces picture set (NIMH-ChEFS): A new set of children's facial emotion stimuli. *International Journal of Methods in Psychiatric Research*, *20*(3), 145–156. https://doi.org/10.1002/mpr.343

Flannery, J. E., Giuliani, N. R., Flournoy, J. C., & Pfeifer, J. H. (2017). Neurodevelopmental changes across adolescence in viewing and labeling dynamic peer emotions. *Developmental Cognitive Neuroscience*, *25*, 113–127. https://doi.org/10.1016/j.dcn.2017.02.003

Fölster, M., & Werheid, K. (2016). ERP evidence for own-age effects on late stages of processing sad faces. *Cognitive, Affective, & Behavioral Neuroscience*, *16*(4), 635–645. https://doi.org/10.3758/s13415-016-0420-9

Foti, D., & Hajcak, G. (2008). Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *Journal of Cognitive Neuroscience*, *20*(6), 977–988. https://doi.org/10.1162/jocn.2008.20066

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology*, *46*(3), 521–530. https://doi.org/10.1111/j.1469-8986.2009.00796.x

Freeman, C., Dirks, M., & Weinberg, A. (2020). Neural response to rewards predicts risk-taking in late but not early adolescent females. *Developmental Cognitive Neuroscience*, *45*, 100808. https://doi.org/10.1016/j.dcn.2020.100808

Fridlund, A. J. (1994). *Human facial expression: An evolutionary view*. Academic Press.

Frith, C., & Frith, U. (2008). Implicit and explicit processes in social cognition. *Neuron*, *60*(3), 503–510. https://doi.org/10.1016/j.neuron.2008.10.032

Frith, U., & Frith, C. (2010). The social brain: Allowing humans to boldly go where no other species has been. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1537), 165–176. https://doi.org/10.1098/rstb.2009.0160

Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011). Time course of implicit processing and explicit processing of emotional faces and emotional words. *Biological Psychology*, *87*(2), 265–274. https://doi.org/10.1016/j.biopsycho.2011.03.008

Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of Experimental Child Psychology*, *102*(4), 503–521. https://doi.org/10.1016/j.jecp.2008.11.002

Gao, X., & Maurer, D. (2010). A happy story: Developmental changes in children's sensitivity to facial expressions of varying intensities. *Journal of Experimental Child Psychology*, *107*(2), 67–86. https://doi.org/10.1016/j.jecp.2010.05.003

Gibb, B. E., Schofield, C. A., & Coles, M. E. (2009). Reported history of childhood abuse and young adults' information-processing biases for facial displays of emotion. *Child Maltreatment*, *14*(2), 148–156. https://doi.org/10.1177/1077559508326358

Gross, A. L., & Ballif, B. (1991). Children's understanding of emotion from facial expressions and situations: A review. *Developmental Review*, *11*(4), 368–398. https://doi.org/10.1016/0273-2297(91)90019-k

Guyer, A. E., Monk, C. S., McClure-Tone, E. B., Nelson, E. E., Roberson-Nay, R., Adler, A. D., Fromm, S. J., Leibenluft, E., Pine, D. S., & Ernst, M. (2008). A developmental examination of amygdala response to facial expressions. *Journal of Cognitive Neuroscience*, *20*(9), 1565–1582. https://doi.org/10.1162/jocn.2008.20114

Hajcak, G., Macnamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: An integrative review. *Developmental Neuropsychology*, *35*(2), 129–155. https://doi.org/10.1080/87565640903526504

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion*, *8*(2), 250–255. https://doi.org/10.1037/1528-3542.8.2.250

Halberstadt, A. G., Denham, S. A., & Dunsmore, J. C. (2001). Affective social competence. *Social Development*, *10*(1), 79–119. https://doi.org/10.1111/1467-9507.00150

Hankin, B. L., Gibb, B. E., Abela, J. R. Z., & Flory, K. (2010). Selective attention to affective stimuli and clinical depression among youths: Role of anxiety and specificity of emotion. *Journal of Abnormal Psychology*, *119*(3), 491–501. https://doi.org/10.1037/a0019609

Hare, T. A., Tottenham, N., Galvan, A., Voss, H. U., Glover, G. H., & Casey, B. J. (2008). Biological substrates of emotional reactivity and regulation in adolescence during an emotional go-nogo task. *Biological Psychiatry*, *63*(10), 927–934. https://doi.org/10.1016/j.biopsych.2008.03.015

Harrigan, J. A. (1984). The effects of task order on children's identification of facial expressions. *Motivation and Emotion*, *8*(2), 157–169. https://doi.org/10.1007/bf00993071

Hassin, R. R., Aviezer, H., & Bentin, S. (2013). Inherently ambiguous: Facial expressions of emotions, in context. *Emotion Review*, *5*(1), 60–65. https://doi.org/10.1177/1754073912451331

Haviland, J. M., & Lelwica, M. (1987). The induced affect response: 10-week-old infants' responses to three emotion expressions. *Developmental Psychology*, *23*(1), 97–104. https://doi.org/10.1037/0012-1649.23.1.97

Herba, C., Landau, S., Russell, T., Ecker, C., & Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry*, *47*(11), 1098–1106. https://doi.org/10.1111/j.1469-7610.2006.01652.x

Herba, C., & Phillips, M. (2004). Annotation: Development of facial expression recognition from childhood to adolescence: Behavioural and neurological perspectives. *Journal of Child Psychology and Psychiatry*, *45*(7), 1185–1198. https://doi.org/10.1111/j.1469-7610.2004.00316.x

Horndasch, S., Kratz, O., Van Doren, J., Graap, H., Kramer, R., Moll, G. H., & Heinrich, H. (2018). Cue reactivity towards bodies in anorexia nervosa–common and differential effects in adolescents and adults. *Psychological Medicine*, *48*(3), 508–518. https://doi.org/10.1017/s0033291717001994

Hua, M., Han, Z. R., Chen, S., Yang, M., Zhou, R., & Hu, S. (2014). Late positive potential (LPP) modulation during affective picture processing in preschoolers. *Biological Psychology*, *101*, 77–81. https://doi.org/10.1016/j.biopsycho.2014.06.006

Izard, C., Fine, S., Schultz, D., Mostow, A., Ackerman, B., & Youngstrom, E. (2001). Emotion knowledge as a predictor of social behavior and academic competence in children at risk. *Psychological Science*, *12*(1), 18–23. https://doi.org/10.1111/1467-9280.00304

Jacobs, R. H., Pine, D. S., Schoeny, M. E., Henry, D. B., Gollan, J. K., Moy, G., Cook, E. H., & Wakschlag, L. S. (2011). Maternal depressive history, teen 5HTTLPR genotype, and the processing of emotional faces: Exploring mechanisms of risk. *Behaviour Research and Therapy*, *49*(1), 80–84. https://doi.org/10.1016/j.brat.2010.10.004

Kavcıoğlu, F. C., Bublatzky, F., Pittig, A., & Alpers, G. W. (2021). Instructed threat enhances threat perception in faces. *Emotion*, *21*(2), 419–429. https://doi.org/10.1037/emo0000708

Kessler, R. C., Amminger, G. P., Aguilar-Gaxiola, S., Alonso, J., Lee, S., & Ustun, T. B. (2007). Age of onset of mental disorders: A review of recent literature. *Current Opinion in Psychiatry*, *20*(4), 359–364. https://doi.org/10.1097/yco.0b013e32816ebc8c

Kestenbaum, R., & Nelson, C. A. (1992). Neural and behavioral correlates of emotion recognition in children and adults. *Journal of Experimental Child Psychology*, *54*(1), 1–18. https://doi.org/10.1016/0022-0965(92)90014-w

Klawohn, J., Meyer, A., Weinberg, A., & Hajcak, G. (2020). Methodological choices in event-related potential (ERP) research and their impact on internal consistency reliability and individual differences: An examination of the error-related negativity (ERN) and anxiety. *Journal of Abnormal Psychology*, *129*(1), 29–37. https://doi.org/10.1037/abn0000458

Klomek, A. B., Marrocco, F., Kleinman, M., Schonfeld, I. S., & Gould, M. S. (2007). Bullying, depression, and suicidality in adolescents. *Journal of the American Academy of Child & Adolescent*

Psychiatry, *46*(1), 40–49. https://doi.org/10.1097/01.chi.0000242237.84925.18

Kolb, B., Wilson, B., & Taylor, L. (1992). Developmental changes in the recognition and comprehension of facial expression: Implications for frontal lobe function. *Brain and Cognition*, *20*(1), 74–84. https://doi.org/10.1016/0278-2626(92)90062-q

Kujawa, A., Klein, D. N., & Hajcak, G. (2012). Electrocortical reactivity to emotional images and faces in middle childhood to early adolescence. *Developmental Cognitive Neuroscience*, *2*(4), 458–467. https://doi.org/10.1016/j.dcn.2012.03.005

Kujawa, A., Klein, D. N., & Proudfit, G. H. (2013). Two-year stability of the late positive potential across middle childhood and adolescence. *Biological Psychology*, *94*(2), 290–296. https://doi.org/10.1016/j.biopsycho.2013.07.002

Ladouceur, C. D. (2012). Neural systems supporting cognitive-affective interactions in adolescence: The role of puberty and implications for affective disorders. *Frontiers in Integrative Neuroscience*, *6*, 1–11. https://doi.org/10.3389/fnint.2012.00065

Ladouceur, C. D., Dahl, R. E., Williamson, D. E., Birmaher, B., Axelson, D. A., Ryan, N. D., & Casey, B. J. (2006). Processing emotional facial expressions influences performance on a go/NoGo task in pediatric anxiety and depression. *Journal of Child Psychology and Psychiatry*, *47*(11), 1107–1115. https://doi.org/10.1111/j.1469-7610.2006.01640.x

Laird, R. D., Jordan, K. Y., Dodge, K. A., Pettit, G. S., & Bates, J. E. (2001). Peer rejection in childhood, involvement with antisocial peers in early adolescence, and the development of externalizing behavior problems. *Development and Psychopathology*, *13*(2), 337–354. https://doi.org/10.1017/s0954579401002085

Lam, C. B., McHale, S. M., & Crouter, A. C. (2014). Time with peers from middle childhood to late adolescence: Developmental course and adjustment correlates. *Child Development*, *85*(4), 1677–1693. https://doi.org/10.1111/cdev.12235

Larson, R., & Richards, M. H. (1991). Daily companionship in late childhood and early adolescence: Changing developmental contexts. *Child Development*, *62*(2), 284–300. https://doi.org/10.2307/1131003

Lawrence, K., Campbell, R., & Skuse, D. (2015). Age, gender, and puberty influence the development of facial emotion recognition. *Frontiers in Psychology*, *6*, 761. https://doi.org/10.3389/fpsyg.2015.00761

Lee, T.-H., Perino, M. T., McElwain, N. L., & Telzer, E. H. (2019). Perceiving facial affective ambiguity: A behavioral and neural comparison of adolescents and adults. *Emotion*, *20*(3), 501–506. https://doi.org/10.1037/emo0000558

Lemerise, E. A., & Arsenio, W. F. (2000). An integrated model of emotion processes and cognition in social information processing. *Child Development*, *71*(1), 107–118. https://doi.org/10.1111/1467-8624.00124

Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience*, *10*(1), 37–47. https://doi.org/10.1038/nrn2554

Liu, Y., Huang, H., McGinnis-Deweese, M., Keil, A., & Ding, M. (2012). Neural substrate of the late positive potential in emotional processing. *Journal of Neuroscience*, *32*(42), 14563–14572. https://doi.org/10.1523/jneurosci.3109-12.2012

Lopez-Duran, N. L., Kuhlman, K. R., George, C., & Kovacs, M. (2013). Facial emotion expression recognition by children at familial risk for depression: High-risk boys are oversensitive to sadness. *Journal of Child Psychology and Psychiatry*, *54*(5), 565–574. https://doi.org/10.1111/jcpp.12005

Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska directed emotional faces—KDEF [CDROM]*. Department of Clinical Neuroscience, Psychology section, Karolinska Institute.

MacNamara, A., Jackson, T. B., Fitzgerald, J. M., Hajcak, G., & Phan, K. L. (2019). Working memory load and negative picture processing: Neural and behavioral associations with panic, social anxiety, and positive affect. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(2), 151–159. https://doi.org/10.1016/j.bpsc.2018.04.005

MacNamara, A., Vergés, A., Kujawa, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2016). Age-related changes in emotional face processing across childhood and into young adulthood: Evidence from event-related potentials. *Developmental Psychobiology*, *58*(1), 27–38. https://doi.org/10.1002/dev.21341

Marusak, H. A., Carré, J. M., & Thomason, M. E. (2013). The stimuli drive the response: An fMRI study of youth processing adult or child emotional face stimuli. *NeuroImage*, *83*, 679–689. https://doi.org/10.1016/j.neuroimage.2013.07.002

Mauchly, J. W. (1940). Significance test for sphericity of a normal n-variate distribution. *The Annals of Mathematical Statistics*, *11*(2), 204–209. https://doi.org/10.1214/aoms/1177731915

McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. *Psychological Bulletin*, *126*(3), 424–453. https://doi.org/10.1037/0033-2909.126.3.424

Meyer, A., Bress, J. N., & Proudfit, G. H. (2014). Psychometric properties of the error-related negativity in children and adolescents. *Psychophysiology*, *51*(7), 602–610. https://doi.org/10.1111/psyp.12208

Miller, G. A., Gration, G., & Yee, C. M. (1988). Generalized Implementation of an Eye Movement Correction Procedure. *Psychophysiology*, *25*(2), 241–243. https://doi.org/10.1111/j.1469-8986.1988.tb00999.x

Monk, C. S., McClure, E. B., Nelson, E. E., Zarahn, E., Bilder, R. M., Leibenluft, E., Charney, D. S., Ernst, M., & Pine, D. S. (2003). Adolescent immaturity in attention-related brain engagement to emotional facial expressions. *NeuroImage*, *20*(1), 420–428. https://doi.org/10.1016/s1053-8119(03)00355-0

Montague, D. P. F., & Walker-Andrews, A. S. (2001). Peekaboo: A new look at infants' perception of emotion expressions. *Developmental Psychology*, *37*(6), 826–838. https://doi.org/10.1037/0012-1649.37.6.826

Moran, T. P., Jendrusina, A. A., & Moser, J. S. (2013). The psychometric properties of the late positive potential during emotion processing and regulation. *Brain Research*, *1516*, 66–75. https://doi.org/10.1016/j.brainres.2013.04.018

Morningstar, M., Grannis, C., Mattson, W. I., & Nelson, E. (2019). Associations between adolescents' social re-orientation towards peers over caregivers and neural response to teenage faces. *Frontiers in Behavioral Neuroscience*, *13*, 108. https://doi.org/10.3389/fnbeh.2019.00108

Morningstar, M., Ly, V. Y., Feldman, L., & Dirks, M. A. (2018). Mid-adolescents' and adults' recognition of vocal cues of emotion and social intent: Differences by expression and speaker age. *Journal of Nonverbal Behavior*, *42*(2), 237–251. https://doi.org/10.1007/s10919-0180274-7

Morningstar, M., Mattson, W. I., Singer, S., Jr., Venticinque, J. S., & Nelson, E. E. (2020). Children and adolescents' neural response to emotional faces and voices: Age-related changes in common regions of activation. *Social Neuroscience*, *15*(6), 613–629. https://doi.org/10.1080/17470919.2020.1832572

Mulligan, E. M., Infantolino, Z. P., Klein, D. N., & Hajcak, G. (2020). Developmental trajectory of the late positive potential: Using temporal-spatial PCA to characterize within-subject developmental changes in emotional processing. *Psychophysiology*, *57*(2), 1–11. https://doi.org/10.1111/psyp.13478

Nelson, E. E., & Guyer, A. E. (2011). The development of the ventral prefrontal cortex and social flexibility. *Developmental Cognitive Neuroscience*, *1*(3), 233–245. https://doi.org/10.1016/j.dcn.2011.01.002

Nelson, E. E., Leibenluft, E., McClure, E. B., & Pine, D. S. (2005). The social re-orientation of adolescence: A neuroscience perspective on the process and its relation to psychopathology. *Psychological Medicine*, *35*(2), 163–174. https://doi.org/10.1017/s0033291704003915

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill Education.

Odom, R. D., & Lemond, C. M. (1972). Developmental differences in the perception and production of facial expressions. *Child Development*, *43*(2), 359–369. https://doi.org/10.2307/1127541

Panier, L. Y. X., Ethridge, P., Punturieri, C., Farrell-Reeves, A., Dirks, M. A., & Weinberg, A. (2022). Associations between peer victimization and distinct neural responses to acceptance and rejection in early adolescence. Manuscript submitted for publication.

Parker, J. G., Rubin, K. H., Erath, S. A., Wojslawowicz, J. C., & Buskirk, A. A. (2006). Peer relationships, child development, and adjustment. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Theory and method* (pp. 419–493). John Wiley & Sons Inc.

Pastor, M. C., Bradley, M. M., Löw, A., Versace, F., Moltó, J., & Lang, P. J. (2008). Affective picture perception: Emotion, context, and the late positive potential. *Brain Research*, *1189*, 145–151. https://doi.org/10.1016/j.brainres.2007.10.072

Pfeifer, J. H., & Allen, N. B. (2012). Arrested development? Reconsidering dual-systems models of brain function in adolescence and disorders. *Trends in Cognitive Sciences*, *16*(6), 322–329. https://doi.org/10.1016/j.tics.2012.04.011

Pfeifer, J. H., & Blakemore, S. J. (2012). Adolescent social cognitive and affective neuroscience: Past, present, and future. *Social Cognitive and Affective Neuroscience*, *7*(1), 1–10. https://doi.org/10.1093/scan/nsr099

Pontifex, M. B., Scudder, M. R., Brown, M. L., O'Leary, K. C., Wu, C., Themanson, J. R., & Hillman, C. H. (2010). On the number of trials necessary for stabilization of error-related brain activity across the life span. *Psychophysiology*, *47*(4), 767–773. https://doi.org/10.1111/j.1469-8986.2010.00974.x

Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2014). Developing attention: Behavioral and brain mechanisms. *Advances in Neuroscience*, *2014*, 1–9. https://doi.org/10.1155/2014/405094

Pozzoli, T., Gini, G., & Altoè, G. (2017). Associations between facial emotion recognition and young adolescents' behaviors in bullying. *PLoS One*, *12*(11), e0188062. https://doi.org/10.1371/journal.pone.0188062

Rice, K. G., & Mulkeen, P. (1995). Relationships with parents and peers: A longitudinal study of adolescent intimacy. *Journal of Adolescent Research*, *10*(3), 338–357. https://doi.org/10.1177/0743554895103003

Roberts, R. E., Attkisson, C. C., & Rosenblatt, A. (1998). Prevalence of psychopathology among children and adolescents. *American Journal of Psychiatry*, *155*(6), 715–725. https://doi.org/10.1037/0096-1523.7.2.275

Rodger, H., Vizioli, L., Ouyang, X., & Caldara, R. (2015). Mapping the development of facial expression recognition. *Developmental Science*, *18*(6), 926–939. https://doi.org/10.1111/desc.12281

Roy, A. K., Vasa, R. A., Bruck, M., Mogg, K., Bradley, B. P., Sweeney, M., Bergman, R. L., McClure-Tone, E. B., & CAMS Team. (2008). Attention bias toward threat in pediatric anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, *47*(10), 1189–1196. https://doi.org/10.1097/chi.0b013e3181825ace

Rudolph, K. D. (2002). Gender differences in emotional responses to interpersonal stress during adolescence. *Journal of Adolescent Health*, *30*(4), 3–13. https://doi.org/10.1016/s1054-139x(01)00383-4

Sabatinelli, D., Keil, A., Frank, D. W., & Lang, P. J. (2013). Emotional perception: Correspondence of early and late event-related potentials with cortical and subcortical functional MRI. *Biological Psychology*, *92*(3), 513–519. https://doi.org/10.1016/j.biopsycho.2012.04.005

Sandre, A., Banica, I., Riesel, A., Flake, J., Klawohn, J., & Weinberg, A. (2020). Comparing the effects of different methodological decisions on the error-related negativity and its association with behaviour and gender. *International Journal of Psychophysiology*, *156*, 18–39. https://doi.org/10.1016/j.ijpsycho.2020.06.016

Sandre, A., Ethridge, P., Kim, I., & Weinberg, A. (2018). Childhood maltreatment is associated with increased neural response to ambiguous threatening facial expressions in adulthood: Evidence from the late positive potential. *Cognitive, Affective, & Behavioral Neuroscience*, *18*(1), 143–154. https://doi.org/10.3758/s13415-017-0559-z

Saxbe, D., Del Piero, L., Immordino-Yang, M. H., Kaplan, J., & Margolin, G. (2015). Neural correlates of adolescents' viewing of parents' and peers' emotions: Associations with risk-taking behavior and risky peer affiliations. *Social Neuroscience*, *10*(6), 592–604. https://doi.org/10.1080/17470919.2015.1022216

Schepman, K., Taylor, E., Collishaw, S., & Fombonne, E. (2012). Face emotion processing in depressed children and adolescents with and without comorbid conduct disorder. *Journal of Abnormal Child Psychology*, *40*(4), 583–593. https://doi.org/10.1007/s10802-011-9587-2

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*(2), 257–261. https://doi.org/10.1111/1469-8986.3720257

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, *41*(3), 441–449. https://doi.org/10.1111/j.1469-8986.2004.00174.x

Somerville, L. H. (2013). The teenage brain: Sensitivity to social evaluation. *Current Directions in Psychological Science*, *22*(2), 121–127. https://doi.org/10.1177/0963721413476512

Somerville, L. H., Fani, N., & McClure-Tone, E. B. (2011). Behavioral and neural representation of emotional facial expressions across the lifespan. *Developmental Neuropsychology*, *36*(4), 408–428. https://doi.org/10.1080/87565641.2010.549865

Steinberg, L., & Morris, A. S. (2001). Adolescent development. *Annual Review of Psychology*, *52*(1), 83–110. https://doi.org/10.1146/annurev.psych.52.1.83

Thomas, L. A., De Bellis, M. D., Graham, R., & LaBar, K. S. (2007). Development of emotional facial recognition in late childhood and adolescence. *Developmental Science*, *10*(5), 547–558. https://doi.org/10.1111/j.1467-7687.2007.00614.x

Tremblay, C., Kirouac, G., & Dore, F. Y. (1987). The recognition of adults' and children's facial expressions of emotions. *The Journal of Psychology*, *121*(4), 341–350. https://doi.org/10.1080/00223980.1987.9712674

Trentacosta, C. J., & Fine, S. E. (2010). Emotion knowledge, social competence, and behavior problems in childhood and adolescence: A meta-analytic review. *Social Development*, *19*(1), 1–29. https://doi.org/10.1111/j.1467-9507.2009.00543.x

Twomey, D. M., Murphy, P. R., Kelly, S. P., & O'Connell, R. G. (2015). The classic P300 encodes a build-to-threshold decision variable. *European Journal of Neuroscience*, *42*(1), 1636–1643. https://doi.org/10.1111/ejn.12936

van Hoorn, J., McCormick, E. M., & Telzer, E. H. (2018). Moderate social sensitivity in a risky context supports adaptive decision making in adolescence: Evidence from brain and behavior. *Social Cognitive and Affective Neuroscience*, *13*(5), 546–556. https://doi.org/10.1093/scan/nsy016

van Hoorn, J., van Dijk, E., Meuwese, R., Rieffe, C., & Crone, E. A. (2016). Peer influence on prosocial behavior in adolescence. *Journal of Research on Adolescence*, *26*(1), 90–100. https://doi.org/10.1111/jora.12173

Vicari, S., Reilly, J. S., Pasqualetti, P., Vizzotto, A., & Caltagirone, C. (2000). Recognition of facial expressions of emotions in school-age children: The intersection of perceptual and semantic categories. *Acta Paediatrica*, *89*(7), 836–845. https://doi.org/10.1111/j.1651-2227.2000.tb00392.x

Weinberg, A., & Hajcak, G. (2010). Beyond good and evil: The time-course of neural activity elicited by specific picture content. *Emotion*, *10*(6), 767–782. https://doi.org/10.1037/a0020242

Weinberg, A., & Hajcak, G. (2011). The late positive potential predicts subsequent interference with target processing. *Journal of Cognitive Neuroscience*, *23*(10), 2994–3007. https://doi.org/10.1162/jocn.2011.21630

Wiggins, J. L., Adleman, N. E., Kim, P., Oakes, A. H., Hsu, D., Reynolds, R. C., Chen, G., Pine, D. S., Brotman, M. A., & Leibenluft, E. (2016). Developmental differences in the neural mechanisms of facial emotion labeling. *Social Cognitive and Affective Neuroscience*, *11*(1), 172–181. https://doi.org/10.1093/scan/nsv101

Yurgelun-Todd, D. A., & Killgore, W. D. S. (2006). Fear-related activity in the prefrontal cortex increases with age during adolescence: A preliminary fMRI study. *Neuroscience Letters*, *406*(3), 194–199. https://doi.org/10.1016/j.neulet.2006.07.046

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Sandre, A., Morningstar, M., Farrell-Reeves, A., Dirks, M. & Weinberg, A. (2022). Adolescents and young adults differ in their neural response to and recognition of adolescent and adult emotional faces. *Psychophysiology*, 00, e14060. https://doi.org/10.1111/psyp.14060

APPENDIX A

Adolescent faces used in the study:

F38AS_9388, F38FS_9375, F38HS_9328, F38NS_9318, F36AS_8598, F36FS_8556, F36HS_8502, F36NS_8495, F5AS_3827, F5FS_3793, F5HS_3759, F5NS_3749, F18AS_6263, F18FS_6229, F18HS_6186, F18NS_6177, F12AS_5068, F12FS_5036, F12HS_5000, F12NS_4986, F32AS_8075, F32FS_8041, F32HS_7996, F32NS_7990, F15AS_5771, F15FS_5750, F15HS_5694, F15NS_5687, F22AS_6722, F22FS_6701, F22HS_6659, F22NS_6649, M16AS_8698, M16FS_8676, M16HS_8633, M16NS_8625, M4AS_4958, M4FS_4935, M4HS_4862, M4NS_4853, M7AS_5550, M7FS_5530, M7HS_5497, M7NS_5485, M8AS_5893, M8FS_5869, M8HS_5817, M8NS_5807, M9AS_6138, M9FS_6104, M9HS_6054, M9NS_6041, M17AS_8816, M17FS_8783, M17HS_8732, M17NS_8725, M3AS_4811, M3FS_4775, M3HS_4695, M3NS_4688, M5AS_5223, M5FS_5188, M5HS_5134, M5NS_5126.

Adult faces used in the study:

AF01ANS, AF01AFS, AF01HAS, AF01NES, AF09ANS, AF09AFS, AF09HAS, AF09NES, AF11ANS, AF11AFS, AF11HAS, AF11NES, AF14ANS, AF14AFS, AF14HAS, AF14NES, AF22ANS, AF22AFS, AF22HAS, AF22NES, AF26ANS, AF26AFS, AF26HAS, AF26NES, AF27ANS, AF27AFS, AF27HAS, AF27NES, AF29ANS, AF29AFS, AF29HAS, AF29NES, AM01ANS, AM01AFS, AM01HAS, AM01NES, AM09ANS, AM09AFS, AM09HAS, AM09NES, AM14ANS, AM14AFS, AM14HAS, AM14NES, AM21ANS, AM21AFS, AM21HAS, AM21NES, AM23ANS, AM23AFS, AM23HAS, AM23NES, AM31ANS, AM31AFS, AM31HAS, AM31NES, AM34ANS, AM34AFS, AM34HAS, AM34NES, AM35ANS, AM35AFS, AM35HAS, AM35NES.