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BRIEF REPORT

Perceiving Facial Affective Ambiguity: A Behavioral and Neural Comparison of Adolescents and Adults

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The current study examined perceptual differences between adults and youth in perceiving ambiguous facial expressions. We estimated individuals' internal representation for facial expressions and compared it between age groups (adolescents: $N = 108$, $M_{age} = 13.04$ years, 43.52% female; adults: $N = 81$, $M_{age} = 31.54$, 65.43% female). We found that adolescents' perceptual representation for facial emotion is broader than that of adults', such that adolescents experience more difficulty in identifying subtle configurational differences of facial expressions. At the neural level, perceptual uncertainty in face-selective regions (e.g., fusiform face area, occipital face area) were significantly higher for adolescents than for adults, suggesting that adolescents' brains more similarly represent lower intensity emotional faces than do adults'. Our results provide evidence for age-related differences concerning psychophysical differences in perceptual representation of emotional faces at the neural and behavioral level.

Keywords: face emotion perception, adolescents, uncertainty, MVPA, fMRI

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The ability to recognize and decode others' facial expressions is an essential feature of social interaction (Adolphs, 2002). Emotion perception is incredibly complex, requiring the individual to both distinguish fine-grained differences in facial configuration and understand complicated, nuanced social context rules (Barrett, Lindquist, & Gendron, 2007). Although there is a robust connection between a confined set of prototypical facial configurations and emotional states (i.e., the "discrete emotions" perspective; Ekman, 1999, p. 45), face emotion perception is not always determined by specific physical features of facial configurations, such that various external and internal factors can change an observer's emotion perception even for the same facial configuration (e.g., Kim et al., 2004; Lee, Choi, & Cho, 2012). Furthermore, emotional expressions are often subtle, ambiguous, and uncertain in everyday social interactions (Fridlund, 2014). Such ambiguity poses particular challenges to adolescents as they learn to identify and appropriately respond to seemingly ambiguous emotional states. Indeed, incorporation of various social cues to interpret others' emotional states develops in conjunction with improvements in youths' perceptual abilities (Barrett et al., 2007). Therefore, facial affect perception can be challenging for youth (Gross & Ballif, 1991; McClure, 2000) as perceptual learning of emotions is still developing (Pollak, Messner, Kistler, & Cohn, 2009).

Although evidence to date has indicated that adolescents' perception of others' affect differs from adults' perceptions, studies have largely utilized overt facial affect recognition tasks that are not designed to capture the often ambiguous nature of real-world situations (i.e., ambiguous expressiveness; e.g., Batty & Taylor, 2006; Thomas et al., 2001). Furthermore, much of the research base has focused on clinical populations (e.g., autism spectrum; Critchley et al., 2000), where affective processing is clearly sub-optimal. Studying the normative development of facial emotion

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perception is integral to improving the understanding of how affective processing normatively changes over the life span. In the only known study to date to examine developmental differences in ambiguous facial affect (Wiggins et al., 2016), adolescents recruited face-processing networks significantly less than did adults when the emotional intensity of the face was unclear (i.e., ambiguous; e.g., 50% intensity of a fearful face), indicating adolescents' perceptions of subtle facial expressions may be comparatively underdeveloped. This study suggests that activation in the ventral stream is a likely neural candidate reflecting the maturation of systems for perceiving facial affect.

Building upon this work (Wiggins et al., 2016), we sought to examine the internal representation of perceptual uncertainty for emotional faces between adolescents ($N = 108$) and adults ($N = 81$) by fitting behavioral and neural data to a psychophysics model (see Figure 1A; Calder, Jenkins, Cassel, & Clifford, 2008; Clifford, Mareschal, Otsuka, & Watson, 2015; Lynn et al., 2016; Mareschal, Calder, Dadds, & Clifford, 2013; Wang et al., 2017). In the present study, we focused on neural pattern similarities between emotional faces as a form of multivoxel pattern approach to directly fit neural patterns to a psychophysics model. To generate emotionally ambiguous facial expressions, we used happy and angry faces morphed with neutral faces ranging from 15% to 75% intensity levels (see Figure 1B). We hypothesized that adolescents would be less sensitive to ambiguous facial emotions. In other words, compared with adults, adolescents would be more likely to perceive ambiguous facial expressions as nonemotional, or "neutral," thereby demonstrating broader representations of nonemotional faces.

Method and Analysis

Participants

An emotion-labeling task was presented to 189 participants during a functional magnetic resonance imaging (fMRI) scan; 108 adolescents (M_{age} = 13.04 years, SD = .90, range = 12–15;

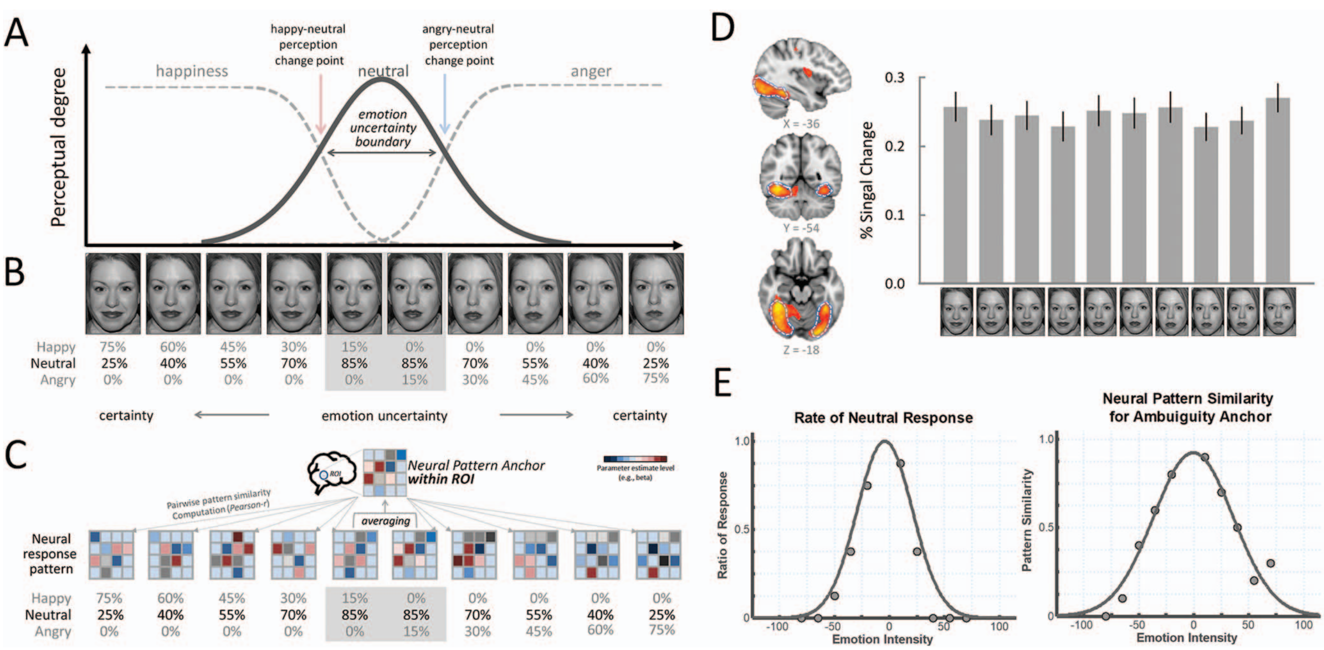

Figure 1. Panel A: The schematic psychophysical model, showing a perceptual representation for emotion perception and perceptual criteria between perceiving emotion (either happy or angry) and nonemotion (neutral) as two perception-change points (red arrow [vertical arrow left of center] and blue arrow [vertical arrow right of center]) become closer. The observer has more keen criteria in perceiving emotionality from subtle facial expressions as the uncertainty boundary gets smaller. Panel B: An example of face stimuli used in the current study. Panel C: Neural pattern similarity estimation within the region of interest (ROI) as a function of emotion intensity (NimStim available at http://www.macbrain.org; Tottenham et al., 2009). Using a neural pattern anchor averaged across lowest emotion intensities in both happy and angry faces, we computed pattern similarities between neural pattern anchor and each intensity using Pearson r (Fisher's z−transformed), then fitted them into the emotion perception model. The matrices (4 × 4) are just for a schematic illustration of the pattern within the ROI mask. Panel D: Group activation map responding to all face stimuli versus baseline during the observe round. The stimuli robustly activated regions along the ventral visual pathway. The bar plots show activation strength in those regions on the affect-label round as a function of emotion intensity across participants. Note that there was no significant difference for happy and angry stimuli at corresponding stimulus levels (e.g., 75% happy and angry; all $ps > .09$). Error bars indicate standard errors. Panel E: Representative participant's fitted curves for behavioral and neural data, showing the perceptual boundary representation as a function of facial emotion intensity. The fitting values on average were .87 and .56 for behavioral and neural data, respectively. See the online article for the color version of this figure.

43.52% female) and 81 adults (M_{age} = 31.54, *SD* = 12.47, range = 19–54; 65.43% female) participated. The adult sample included younger adults (*N* = 39; college students) as well as older adults, some of whom were the parent of an adolescent in the sample (*N* = 33). Data from eight individuals were excluded due to motion (three adolescents; mean FD = 1.10 mm, DVARS = 51.52) and technical failure (four adolescents and one adult). The remaining participants for fMRI data analysis (*N* = 181) did not have any motion issues (mean FD = .11 mm, DVARS = 29.69; adolescents: FD = .14 mm, DVARS = 30.27; adults: FD = .08 mm, DVARS = 29.10). All participants provided informed consent and were remunerated for their participation. The study was approved by the Institutional Review Board of the University of Illinois at Urbana–Champaign.

Task and Stimuli

Face stimuli consisted of angry, happy, and neutral expressions. To vary emotional intensity parametrically, we morphed happy and angry faces with neutral faces in 15% increments (e.g., 15%, 30%, 45%, 60%, and 75%, where the percentage indicates the emotional intensity [happy or angry] of each category). Eighty total stimuli constituted these emotion-intensity categories (40 happy and 40 angry faces with intensity variations). Participants completed two different variants of the task: *affect label* and *observe* rounds. During the affect-label round, participants were instructed to match the facial emotion of the stimuli displayed with one of three labels (*Happy, Neutral,* or *Angry*), displayed across the bottom of the screen, using their index, middle, and ring fingers, respectively. During the observe rounds, participants were asked to press their thumb for each face instead of making an effort to label the emotion of the face (Please see the online supplemental materials for more details). This observe round was designed to serve as a main-task independent localizer for face-selective voxels (see Figure S1 in the online supplemental materials) with the assumption that it reflects simple face perception without recruiting affective resources explicitly (see the reaction time results in Figure S2 in the online supplemental materials).

Data Acquisition and Preprocessing

T1-MPRAGE and T2*-weighted echoplanar images were collected using a 3T-Siemens Trio MRI scanner with a 32-channel matrix coil. Preprocessing was carried out using FMRIB Software Library (FSL) 5.0.10 (Smith et al., 2004; Please see the online supplemental materials for more details).

Analysis of Behavioral Response

We defined *perceptual uncertainty* for the proportion of trials labeled as *Neutral* as a function of facial emotion intensity (see Figure 1A). The more neutral judgments across face emotion intensities represented more perceptual uncertainty for the face emotion. To quantify this perceptual uncertainty level, we computed the proportions of *Neutral* responses (i.e., indicating no emotion perception for a given emotional intensity) for each intensity of face stimuli, and fitted them into the psychophysics model using a Gaussian function representing the perceptual uncertainty boundary in sensory representation (see Figure 1A; Clifford et al., 2015; Jun, Mareschal, Clifford, & Dadds, 2013; Mareschal et al., 2013):

$$f(x) = \alpha e^{\frac{-(x-\mu)^2}{2\sigma^2}} \quad (1)$$

where α represents peak amplitude of responses (i.e., the height of the curve's peak), μ specifies the position of the center of the peak (i.e., face emotion intensity in which faces were judged as neutral), and σ is the bandwidth (i.e., standard deviation of the curve). The bandwidth parameter, σ, was used as the primary metric for the degree of perceptual uncertainty (Calder et al., 2008; Clifford et al., 2015; Mareschal et al., 2013) because wider curves (larger σs) suggest participants had greater neutral responses in emotion judgment to changes in emotional intensity. That is, participants were less perceptively sensitive to subtle emotional changes in the faces and vice versa for narrower curves (smaller σs). The fitting values on average were .87 and .56 for behavioral and neural data, respectively.

Analysis of Neural Pattern

To fit the neural data on the psychophysics model depicted in Figure 1A, we performed a neural pattern similarity analysis (e.g., Kriegeskorte, Mur, & Bandettini, 2008; Lee, Qu, & Telzer, 2017) by estimating single-trial activation patterns for each emotional intensity based on least-squares-single methods (Mumford, Turner, Ashby, & Poldrack, 2012). We then extracted standardized voxelwise pattern activity (i.e., *z* map) for each emotion intensity within the region of interest (ROI) on each individual space and computed the similarity values (i.e., Fisher's *z*−transformed Pearson correlation coefficients) across each vector between the neural pattern anchor (Wang et al., 2017) and the other vectors in each emotional intensity (see Figure 1C). The neural pattern anchor was created by averaging the neural patterns of 15% angry and 15% happy faces, and thus the anchor pattern should show high similarity with both neural patterns of 15% happy and angry faces, respectively. Finally, we fitted pattern similarity metrics of each intensity into the psychophysical model. Higher pattern similarities for the anchor indicate neural encoding for a given face is more likely to be perceived as neutral (Please see the online supplemental materials for more details).

ROI Selection

For the face-sensitive ROI selection, we performed a standard two-stage univariate GLM analysis for the observe rounds as an orthogonal functional localizer (Poldrack, 2007). An individual-level GLM estimated brain activation for faces regardless of their intensities contrasted to the baseline (e.g., Bishop, Aguirre, Nunez-Elizalde, & Toker, 2015; Thielscher & Pessoa, 2007), and then group-level random effects were estimated (clusters-corrected $z > 2.3$, $p = .05$, one-tailed; FLAME 1+2; see Table S1 in the online supplemental materials). Finally, we selected voxels that fell within the previously defined functional parcels (available at http://web.mit.edu/bcs/nklab/GSS.shtml) for face-sensitive voxels (Julian, Fedorenko, Webster, & Kanwisher, 2012). No clear superior temporal sulcus (STS) cluster activation was observed, and this may be due to our current approach (contrasted with baseline instead of face minus other categorical stimulus such as places). However, it does not suggest that the STS is not a face-selective region; hence our final ROI mask included the fusiform face area (FFA) and occipital face area (OFA; $k = 2{,}104$ voxels; see Figure 1D). Given that previous studies have shown that the amygdala also plays a role in encoding emotion parametrically (Wang et al., 2017), we also selected voxels ($k = 432$) within the bilateral amygdala atlas (Harvard-Oxford Atlas, 50% threshold; Desikan et al., 2006).

Results

Each participant's neutral responses were fitted to the psychophysics model to estimate the uncertainty boundary (i.e., σ).[1] An independent-samples t test indicated that perceptual uncertainty levels were significantly higher for adolescents ($M = 45.82$, $SD = 8.25$, $SE = .82$) than for adults ($M = 43.37$, $SD = 7.49$, $SE = .83$), $t(177) = 2.09$, $p = .037$, 95% confidence interval (CI) [.14, 4.68], Cohen's $d = .31$ (see Figure 2A). This indicates that adolescents' face emotion perception is less sensitive to changes in expression intensities compared to adults, and therefore adolescents are more likely to perceive subtle expressions as neutral or not indicative of increasing emotional intensity. In contrast, adults' perceptual ability is more finely tuned, enabling them to recognize subtler expressions with only minor observed affective changes.[2]

Consistent with the behavioral findings, an independent-samples t test on the neural parameter indicated that perceptual uncertainty levels in face-selective regions (see the ROI Selection section) were significantly higher for adolescents ($M = 56.74$, $SD = 28.88$, $SE = 2.87$) than for adults ($M = 45.31$, $SD = 19.68$, $SE = 2.18$), $t(175) = 3.17$, $p = .002$, 95% CI [4.71, 18.61], Cohen's $d = .46$ (see Figure 2B), suggesting that adolescents more similarly represent lower intensity emotional faces than do adults. In other words, subtle intensities in facial expression are less finely represented in adolescents at the neural level, and therefore, adolescents need more intense emotional facial expressions to perceive facial emotion at the neural level, whereas adults perceived more emotionality even from subtle facial expressions. The bandwidth parameter from the neural data showed a modest yet significant positive correlation with the bandwidth from the behavioral data across participants, $r(179) = .195$, $p = .022$, 95% CI [.02, .32]. Additional correlation analyses separately for each group, however, did not reveal significant relationships between the behavioral and neural parameters (for adolescents, $p = .792$; for adults, $p = .139$), implying that there was no explicit convergent evidence between behavioral and neural measures within each age group. Last, we estimated the bandwidth metric with the amygdala voxels identified from the same ROI contrast, but no age-related differences in the bandwidth parameter emerged, $t(180) = 1.46$, $p = .270$, 95% CI [.56, 25.51].

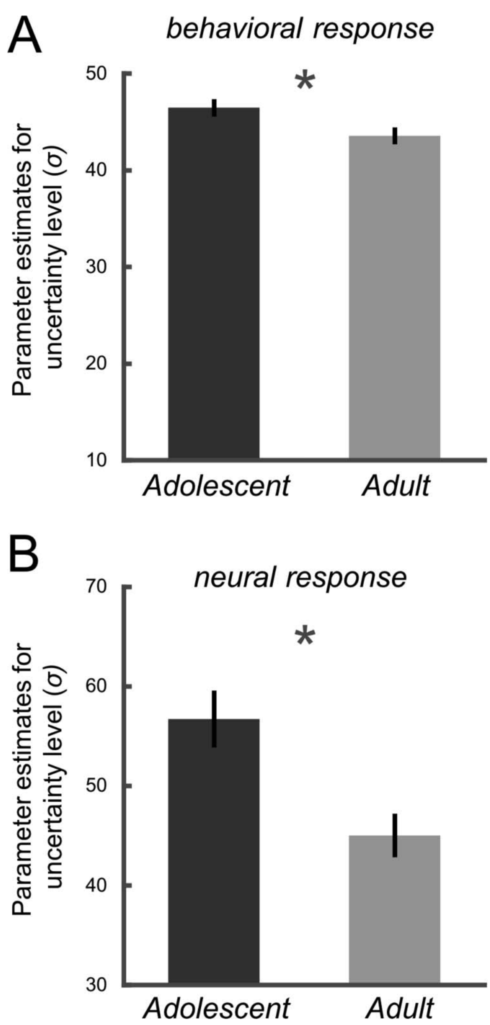

Figure 2. Averaged perceptual uncertainty parameter (σ) based on behavioral response (Panel A) and neural pattern similarity (Panel B) as a function of age. Error bars represent $\pm SEM$. Asterisks denote statistical significance at the 95% confidence interval level based on bootstrapping resampling ($n = 9{,}999$).

Discussion

Youth have less experience with emotion as a function of age, with some difficulty recognizing and interpreting others' facial affect, particularly when expressed in subtle or ambiguous ways. The current study was designed to provide a more nuanced analysis of the perceptual differences between adults and youth by comparing internal representations of emotional faces between the age groups. We provide evidence for age-related differences in perceptual representation of emotional faces by fitting the behavioral and neural data to a psychophysics model of emotion perception.

[1] We observed violations of equal variance assumption (Levene's test; all $ps < .049$). This violation is possibly due to group size difference and/or higher variability in our adolescent sample. Accordingly and unless otherwise noted, we employed Welch's t test (adjusting degrees of freedom) for mean difference between groups, as well as nonparametric correlation coefficients (i.e., Spearman's rho; Bishara & Hittner, 2012) between age and curve fit parameter combined with the bootstrap random sampling ($n = 9{,}999$; with replacement) at a 95% confidence level to reduce the possible impact of data heteroscedasticity.

[2] Although our primary interest was perceptual uncertainty level (i.e., curve bandwidth, σ), we additionally compared the peak amplitude (i.e., α), and its location (i.e., μ) and found no age group differences (95% CI [−1.57, 1.62] and 95% CI [−.02, .03], respectively), indicating that adolescents and adults showed similar height of the curve's peak and face emotion intensity in which faces were judged as neutral or having no emotion. Therefore, we focused our remaining analyses on σ.

Our work expands upon previous findings (Wiggins et al., 2016) that the ventral stream system may provide a neural index for the ability to perceive ambiguous facial expressions and maturation of fine-tuned internal perceptual representations for ambiguity in developing youth. More specifically, our results suggest that adolescents show less perceptual sensitivity in the ventral stream system to perceive changes of facial expression, such that adolescents' perceptual representation for neutral expression is broader than is adults. In other words, adolescents have more uncertainty for emotion than do adults, leading adolescents to be more likely to perceive subtle facial expressions of emotion as nonemotional, consistent with previous interpretations of the broader curve in the perception model (Calder et al., 2008; Clifford et al., 2015; Mareschal et al., 2013).

Our work provides support that adolescents perceive ambiguous facial affect as being less emotionally salient than do their adult counterparts. However, some limitations exist in our design. Given our recruitment of teens and adults specifically, we were not able to speak to how this facial affect processing develops in early childhood, a critical developmental period for learning about affect (Sroufe, 1997). Additionally, given the cross-sectional design, we were unable to examine these changes in vivo. Future work is necessary to study the progression of affect processing across development, because this will provide greater insight into how these processes are shaped normatively and how they may be impacted by life experiences. Another constraint on generalizability may be the lack of attention paid toward how adolescents express emotions relative to adults (McLaughlin, Garrad, & Somerville, 2015). It may be that adolescents are generally less expressive, perhaps complicating the interpretations of the current study. Finally, we did not address individual differences, such as anxiety (e.g., Bishop et al., 2015), or physiological reactivity (e.g., McManis, Bradley, Berg, Cuthbert, & Lang, 2001), which may play an important modulatory role in affect processing. For example, social−emotional competency may moderate how well one perceives or attributes emotional states, particularly in subtle or ambiguous presentations (e.g., Mayer & Geher, 1996). Future examinations should test whether individual differences, such as arousal reactivity, moderate perceptual differences in developing populations or whether the same individual differences that predict adult perception can be linked to adolescents' affect perception. Last, we used relatively short interstimulus intervals between faces (range = 3.17–4.54 s, based on Gaussian distribution), which may be suboptimal compared to a fully stimulus-spaced design with long stimulus onset asynchronies (e.g., 12 s). Thus, it is possible the neural estimation for each trial may be less specific and more influenced by a close trial, because model fitting for neural data was not as high as behavior-based values. Although, we found that there is a consistency in findings across age groups for both neural and behavioral data as we hypothesized, future work is necessary to have more optimal parameters in the design to increase the specificity of neural pattern estimation.

Extending previous work (Batty & Taylor, 2006; Gross & Ballif, 1991; McClure, 2000; Thomas et al., 2001; Wiggins et al., 2016), the present study adds to the knowledge about age-related differences in facial emotion perception. Our findings provide direct evidence that internal perceptual criteria in representing others' emotional expressions is still developing during adolescence. Compared with adults, adolescents exhibited a broader bandwidth for neutral face perception, indicating that they may be less sensitive to subtle features of emotional expression and are more likely to perceive others' subtle expressions as nonemotional or neutral.

References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology, 12,* 169–177. http://dx.doi.org/10.1016/S0959-4388(02)00301-X

Barrett, L. F., Lindquist, K. A., & Gendron, M. (2007). Language as context for the perception of emotion. *Trends in Cognitive Sciences, 11,* 327–332. http://dx.doi.org/10.1016/j.tics.2007.06.003

Batty, M., & Taylor, M. J. (2006). The development of emotional face processing during childhood. *Developmental Science, 9,* 207–220. http://dx.doi.org/10.1111/j.1467-7687.2006.00480.x

Bishara, A. J., & Hittner, J. B. (2012). Testing the significance of a correlation with nonnormal data: Comparison of Pearson, Spearman, transformation, and resampling approaches. *Psychological Methods, 17,* 399–417. http://dx.doi.org/10.1037/a0028087

Bishop, S. J., Aguirre, G. K., Nunez-Elizalde, A. O., & Toker, D. (2015). Seeing the world through non rose-colored glasses: Anxiety and the amygdala response to blended expressions. *Frontiers in Human Neuroscience, 9,* 152. http://dx.doi.org/10.3389/fnhum.2015.00152

Calder, A. J., Jenkins, R., Cassel, A., & Clifford, C. W. (2008). Visual representation of eye gaze is coded by a nonopponent multichannel system. *Journal of Experimental Psychology: General, 137,* 244–261. http://dx.doi.org/10.1037/0096-3445.137.2.244

Clifford, C. W., Mareschal, I., Otsuka, Y., & Watson, T. L. (2015). A Bayesian approach to person perception. *Consciousness and Cognition, 36,* 406–413. http://dx.doi.org/10.1016/j.concog.2015.03.015

Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C., Van Amelsvoort, T., Robertson, D. M., . . . Murphy, D. G. (2000). The functional neuroanatomy of social behaviour: Changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain: A Journal of Neurology, 123,* 2203–2212. http://dx.doi.org/10.1093/brain/123.11.2203

Desikan, R. S., Ségonne, F., Fischl, B., Quinn, B. T., Dickerson, B. C., Blacker, D., . . . Albert, M. S. (2006). An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. *Neuroimage, 31,* 968–980.

Ekman, P. (1999). Basic emotions. In T. Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 45–60). New York, NY: John Wiley & Sons Ltd.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48,* 384–392. http://dx.doi.org/10.1037/0003-066X.48.4.384

Fridlund, A. J. (2014). *Human facial expression: An evolutionary view*. San Diego, CA: Academic Press.

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

Julian, J. B., Fedorenko, E., Webster, J., & Kanwisher, N. (2012). An algorithmic method for functionally defining regions of interest in the ventral visual pathway. *NeuroImage, 60,* 2357–2364. http://dx.doi.org/10.1016/j.neuroimage.2012.02.055

Jun, Y. Y., Mareschal, I., Clifford, C. W., & Dadds, M. R. (2013). Cone of direct gaze as a marker of social anxiety in males. *Psychiatry Research, 210,* 193–198. http://dx.doi.org/10.1016/j.psychres.2013.05.020

Kim, H., Somerville, L. H., Johnstone, T., Polis, S., Alexander, A. L., Shin, L. M., & Whalen, P. J. (2004). Contextual modulation of amygdala responsivity to surprised faces. *Journal of Cognitive Neuroscience, 16,* 1730–1745. http://dx.doi.org/10.1162/0898929042947865

Kriegeskorte, N., Mur, M., & Bandettini, P. (2008). Representational similarity analysis—Connecting the branches of systems neuroscience. *Frontiers in Systems Neuroscience, 2,* 4.

Lee, T.-H., Choi, J.-S., & Cho, Y. S. (2012). Context modulation of facial emotion perception differed by individual difference. *PLoS ONE, 7*(3), e32987. http://dx.doi.org/10.1371/journal.pone.0032987

Lee, T.-H., Qu, Y., & Telzer, E. H. (2017). Love flows downstream: Mothers' and children's neural representation similarity in perceiving distress of self and family. *Social Cognitive and Affective Neuroscience, 12,* 1916–1927. http://dx.doi.org/10.1093/scan/nsx125

Lynn, S. K., Ibagon, C., Bui, E., Palitz, S. A., Simon, N. M., & Barrett, L. F. (2016). Working memory capacity is associated with optimal adaptation of response bias to perceptual sensitivity in emotion perception. *Emotion, 16,* 155–163. http://dx.doi.org/10.1037/emo0000111

Mareschal, I., Calder, A. J., Dadds, M. R., & Clifford, C. W. (2013). Gaze categorization under uncertainty: Psychophysics and modeling. *Journal of Vision, 13,* 18. http://dx.doi.org/10.1167/13.5.18

Mayer, J. D., & Geher, G. (1996). Emotional intelligence and the identification of emotion. *Intelligence, 22,* 89–113. http://dx.doi.org/10.1016/S0160-2896(96)90011-2

McClure, E. B. (2000). *A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents*. Washington, DC: American Psychological Association.

McLaughlin, K. A., Garrad, M. C., & Somerville, L. H. (2015). What develops during emotional development? A component process approach to identifying sources of psychopathology risk in adolescence. *Dialogues in Clinical Neuroscience, 17,* 403–410.

McManis, M. H., Bradley, M. M., Berg, W. K., Cuthbert, B. N., & Lang, P. J. (2001). Emotional reactions in children: Verbal, physiological, and behavioral responses to affective pictures. *Psychophysiology, 38,* 222–231. http://dx.doi.org/10.1111/1469-8986.3820222

Mumford, J. A., Turner, B. O., Ashby, F. G., & Poldrack, R. A. (2012). Deconvolving BOLD activation in event-related designs for multivoxel pattern classification analyses. *NeuroImage, 59,* 2636–2643. http://dx.doi.org/10.1016/j.neuroimage.2011.08.076

Poldrack, R. A. (2007). Region of interest analysis for fMRI. *Social Cognitive and Affective Neuroscience, 2,* 67–70. http://dx.doi.org/10.1093/scan/nsm006

Pollak, S. D., Messner, M., Kistler, D. J., & Cohn, J. F. (2009). Development of perceptual expertise in emotion recognition. *Cognition, 110,* 242–247. http://dx.doi.org/10.1016/j.cognition.2008.10.010

Smith, S. M. (2002). Fast robust automated brain extraction. *Human Brain Mapping, 17,* 143–155. http://dx.doi.org/10.1002/hbm.10062

Smith, S. M., Jenkinson, M., Woolrich, M. W., Beckmann, C. F., Behrens, T. E., Johansen-Berg, H., . . . Niazy, R. K. (2004). Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage, 23,* S208–S219.

Sroufe, L. A. (1997). *Emotional development: The organization of emotional life in the early years*. New York, NY: Cambridge University Press.

Thielscher, A., & Pessoa, L. (2007). Neural correlates of perceptual choice and decision making during fear-disgust discrimination. *Journal of Neuroscience, 27,* 2908–2917. http://dx.doi.org/10.1523/JNEUROSCI.3024-06.2007

Thomas, K. M., Drevets, W. C., Whalen, P. J., Eccard, C. H., Dahl, R. E., Ryan, N. D., & Casey, B. J. (2001). Amygdala response to facial expressions in children and adults. *Biological Psychiatry, 49,* 309–316. http://dx.doi.org/10.1016/S0006-3223(00)01066-0

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry research, 168,* 242–249.

Wang, S., Yu, R., Tyszka, J. M., Zhen, S., Kovach, C., Sun, S., . . . Rutishauser, U. (2017). The human amygdala parametrically encodes the intensity of specific facial emotions and their categorical ambiguity. *Nature Communications, 8,* 14821. http://dx.doi.org/10.1038/ncomms14821

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

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