Research Article

The Nonlinear Development of Emotion Differentiation: Granular Emotional Experience Is Low in Adolescence

Erik C. Nook [1], Stephanie F. Sasse[1], Hilary K. Lambert[2],
Katie A. McLaughlin[2], and Leah H. Somerville[1]
[1]Department of Psychology, Harvard University, and [2]Department of Psychology, University of Washington

Abstract
People differ in how specifically they separate affective experiences into different emotion types—a skill called *emotion differentiation* or *emotional granularity*. Although increased emotion differentiation has been associated with positive mental health outcomes, little is known about its development. Participants ($N = 143$) between the ages of 5 and 25 years completed a laboratory measure of negative emotion differentiation in which they rated how much a series of aversive images made them feel angry, disgusted, sad, scared, and upset. Emotion-differentiation scores were computed using intraclass correlations. Emotion differentiation followed a nonlinear developmental trajectory: It fell from childhood to adolescence and rose from adolescence to adulthood. Mediation analyses suggested that an increased tendency to report feeling emotions one at a time explained elevated emotion differentiation in childhood. Importantly, two other mediators (intensity of emotional experiences and scale use) did not explain this developmental trend. Hence, low emotion differentiation in adolescence may arise because adolescents have little experience conceptualizing co-occurring emotions.

Keywords

People differ in how specifically they experience emotions, a phenomenon known as *emotion differentiation* or *emotion granularity* (Barrett, Gross, Christensen, & Benvenuto, 2001; Kashdan, Barrett, & McKnight, 2015). Some people naturally differentiate their emotions into specific types and know when they are feeling, for example, angry but not sad. Other people struggle to differentiate their emotions so specifically. Strong emotion differentiation—especially of negative emotions—is important to psychological well-being. High negative emotion differentiation is associated with increased use of adaptive emotion regulation strategies, reduced use of alcohol to cope, and reduced aggression (Barrett et al., 2001; Kashdan, Ferssizidis, Collins, & Muraven, 2010; Pond et al., 2012). Low negative emotion differentiation has been documented in adolescents and adults with depression, social anxiety disorder, borderline personality disorder, and autism spectrum disorder (Demiralp et al., 2012; Erbas, Ceulemans, Boonen, Noens, & Kuppens,

2013; Kashdan & Farmer, 2014; Lennarz, Lichtwarck-Aschoff, Timmerman, & Granic, 2018; Starr, Hershenberg, Li, & Shaw, 2017; Suvak et al., 2011).

Although stronger emotion differentiation has been associated with better mental health for adolescents and adults, the development of this affective skill remains unknown. Understanding the trajectory through which adults arrive at their level of emotion differentiation—and the mechanisms that explain that trajectory—would grant insight into the nature of emotional experience across development and potentially clarify factors that predispose people to mental illness. Extant research could support two different developmental trajectories for emotion differentiation: a linear increase from

Corresponding Author:
Erik C. Nook, Department of Psychology, Harvard University, William James Hall, 33 Kirkland St., Cambridge, MA 02138
E-mail: enook@g.harvard.edu

childhood to adulthood and a nonlinear trajectory in which emotion differentiation is low in adolescence.

One possibility is that emotion differentiation increases monotonically from childhood to adulthood. Converging evidence indicates that children represent their own and others' emotions within a broad positive versus negative dichotomy and thus may struggle to make fine-grained distinctions between emotions within each valence. Research on the development of *emotion perception* (i.e., how people label others' emotions) demonstrates that young children around age 3.5 categorize facial expressions into two groups ("positive" and "negative") and learn to provide more specific emotion labels over the following years (Widen, 2013). Young children's *emotion experiences* (i.e., how they label their own emotions) may be similarly dichotomized. Children tend to report feeling either positive or negative emotions at any given time and only report mixes of positive and negative emotions around age 8 (Larsen, To, & Fireman, 2007). In fact, children's *emotion concepts* (i.e., the internal semantic representations that they use to categorize their own and others' emotions; Barrett, 2006) are strongly focused on valence, and this focus shifts to other dimensions (i.e., arousal) through adolescence and into adulthood (Nook, Sasse, Lambert, McLaughlin, & Somerville, 2017). This increasing complexity in emotion representation might contribute to greater emotion differentiation with age. These findings motivate the hypothesis that emotion differentiation may increase from childhood to adulthood as emotion representations shift from a broad valence dichotomy to more specific emotion concepts that are differentiated from each other.

A competing hypothesis is that emotion differentiation follows a quadratic trajectory such that it reaches a nadir in adolescence. This hypothesis is based on the finding that children not only report an absence of mixed emotions, they also struggle to understand that any emotions can co-occur (Harter & Buddin, 1987; Wintre & Vallance, 1994). For example, children expect people to feel either angry or sad, not both angry and sad. Interestingly, reporting only one emotion at a time is one route to high emotion differentiation, as it involves specifically identifying one individual emotion. For example, children would experience sadness and anger as discrete and differentiated experiences, precisely because they do not co-occur. Hence, childhood may be a period of high emotion differentiation.

As a result, emotion differentiation may decrease from childhood to adolescence as children shift away from experiencing emotions as mutually exclusive. Adolescence would be a period of low emotion differentiation in which emotions co-occur at greater frequency (Harter & Buddin, 1987; Wintre & Vallance, 1994).

However, because emotion concepts continue to become more refined from adolescence to adulthood (Nook et al., 2017), emotion differentiation may rise within this period as young adults learn to separate coexperienced emotions using increasingly defined emotion concepts. Hence, adults may also have high emotion differentiation but through a different route than children (i.e., because they can specifically identify emotions, even those that occur simultaneously). These two developmental processes (i.e., reduced single emotion experience from childhood to adolescence and increased familiarity parsing coexperienced emotions from adolescence to adulthood) would ultimately result in a quadratic relationship between age and emotion differentiation.

Other mechanisms beyond single emotion experiences could also produce a nonlinear relationship between age and emotion differentiation. We investigated two inspired by prior work: emotional intensity and extreme scale use. Daily reports of experienced negative affect increase from age 10 to 18 (Larson, Moneta, Richards, & Wilson, 2002), and adolescents seek higher levels of negative affect in daily life compared with children and adults (Riediger, Schmiedek, Wagner, & Lindenberger, 2009). Given that emotional intensity and emotion differentiation have correlated negatively in prior work (Erbas, Ceulemans, Lee Pe, Koval, & Kuppens, 2014), increased emotional intensity in adolescence could produce a quadratic developmental trajectory. In addition, children's ratings are more likely to be at the extreme ends of the scales compared with those of older participants (Chambers & Johnston, 2002), so extreme scale use could also affect emotion differentiation.

This study investigated the development of negative emotion differentiation using a standardized emotion-differentiation laboratory task in a sample of individuals between the ages of 5 and 25. In addition to adjudicating between the linear and nonlinear trajectories outlined above, we assessed three potential mechanisms that could explain age-related changes in emotion differentiation: single emotion experience, average emotional intensity, and extreme scale use. Insight into the development of this critical affective skill elucidates the nature of emotional experiences across development.

Method

Participants

Data for this research were drawn from a larger study of emotional development. One hundred ninety-nine participants between the ages of 4 and 25 years completed all tasks related to the present study. Thirty participants (primarily young children) were unusable

because they did not pass a screening process (i.e., an emotion vocabulary test) that ensured they understood the terms used in the negative-emotion-differentiation task. An additional 26 participants were excluded because they did not understand or comply with task instructions ($n = 13$), because their scores on any of the four dependent variables were statistical outliers (> 2.5 *SD* from the sample mean; $n = 8$), or because they reported feeling no emotion for at least half of the trials ($n = 5$). Even though doing so did not affect the significance of any results, we excluded participants who did not report feeling any emotion on at least half of the trials to ensure the measure of negative emotion differentiation included situations in which participants actually experienced negative affect. Statistical outliers were also excluded to normalize distributions and optimize statistical estimates, but doing so did not affect the significance of results.

Hence, primary analyses included data from 143 participants (age range = 5.78–25.91 years, *M* = 15.55, *SD* = 5.11; 54.55% female; 60.14% Caucasian, 3 did not disclose race). Note that although we recruited a sample between the ages of 4 and 25, our final usable set of participants included participants between the ages of 5 and 25. Because no prior work has investigated the development of emotion differentiation, an a priori power analysis was not possible. However, post hoc power simulations (e.g., Green & MacLeod, 2016) confirmed that we had sufficient power to detect small to medium effect sizes and larger (power ≥ 87% for βs ≥ 0.23) with 143 participants (see the Supplemental Material available online for details of power simulations). All participants were native English speakers who were compensated for their time and recruited from communities surrounding Harvard University and the University of Washington. Participants provided informed written consent, and minor participants received written permission for their participation from a parent or legal guardian. The Committee on the Use of Human Subjects at Harvard University and the University of Washington Institutional Review Board approved all research procedures. Data and analysis code for this study can be accessed at https://osf.io/8yufm/.

Emotion vocabulary assessment

We adapted previous methods (Baron-Cohen, Golan, Wheelwright, Granader, & Hill, 2010) to assess participants' understanding of 27 emotion terms, 5 of which were later used in the negative emotion differentiation task (i.e., angry, disgusted, sad, scared, and upset). Thus, this test screened participants to ensure they understood words used in that task. The experimenter said each emotion word aloud, showed the participant a card with that emotion word written on it, and asked the participant to define the word. Responses were audio-recorded. Similar to a Wechsler vocabulary test (Wechsler, 1999), trained experimenters assigned each definition a score of 0 (*no understanding*), 1 (*some understanding*), or 2 (*full understanding*). Full details of this task and scoring system are described in the Supplemental Material and in Nook et al. (2017).

For primary analyses, we excluded participants who did not fully understand one or more of the five emotion words used in the negative-emotion-differentiation task (i.e., they did not receive perfect scores of 2 for the emotions angry, disgusted, sad, scared, and upset). We present analyses that relax this criterion and include an additional 21 participants who demonstrated partial comprehension of these emotion words (i.e., they received at least 1 point for each emotion term) in the Supplemental Material.

Negative-emotion-differentiation task

We adapted laboratory-based assessments (Erbas et al., 2014) to quantify how specifically participants parse their own emotions (see Figs. 1 and 2). Participants viewed a set of 20 negative images drawn from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) and online websites. Images were selected to depict a wide variety of negative scenes that would be tolerable even to young children. On each trial, participants viewed a fixation cross for 2 s and then an image for 6 s. A series of five emotion ratings—angry, disgusted, scared, sad, and upset—then appeared sequentially under the image. Participants moved a sliding bar along the scale using the mouse to indicate how much they felt each emotion while looking at the image (0 = *not [emotion adjective] at all*, 100 = *very [emotion adjective]*). Ratings were self-paced and quantified as a percentage of the scale (i.e., distance between the leftmost point and their rating/total length of the scale). Both image and emotion order were randomized.

For each participant, we tabulated ratings of each emotion experienced in response to each image. Following prior work (Kashdan et al., 2010; Pond et al., 2012; Tugade, Fredrickson, & Barrett, 2004), we computed the intraclass correlation (ICC) with absolute agreement for each participant's emotion ratings across all trials. A high ICC would indicate that ratings for different emotion types were strongly correlated. This would suggest that participants experienced all of the emotions in similar ways across trials and did not make fine-grained distinctions between emotion types (i.e., low emotion differentiation). By contrast, a low ICC would indicate that participants' emotion ratings were not strongly correlated with each other. This would
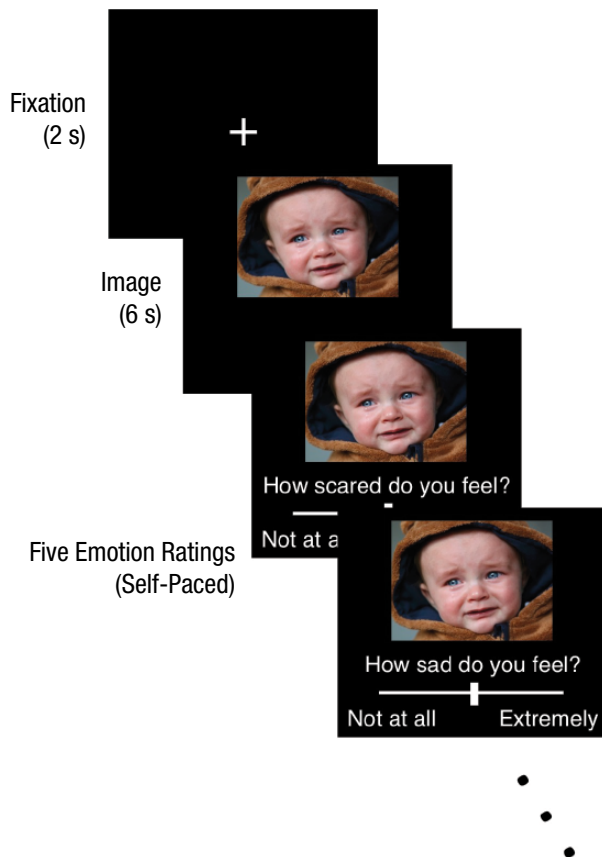
Fig. 1. Design of the negative-emotion-differentiation task. Following a 2-s intertrial interval with a fixation cross, participants viewed a negative image for 6 s. Participants then rated how angry, disgusted, sad, scared, and upset they felt while viewing the image (only two of the five emotion ratings are displayed in the figure). Emotion scales were presented in random order, and ratings were self-paced.

suggest that they experienced each emotion as a unique type across trials and thus were able to make fine-grained distinctions between emotions (i.e., high emotion differentiation). Hence, we computed each participant's negative emotion-differentiation score by reverse-scoring their ICC value (i.e., 1 − ICC) so that a larger value corresponded to greater differentiation.

Potential mediators

We investigated three potential mediating variables that could explain age-related changes in emotion differentiation (Fig. 2). First, we assessed participants' tendency to feel only one emotion at a time, a quality that prior work suggests is elevated in childhood (Harter & Buddin, 1987; Wintre & Vallance, 1994). We produced a measure of *single emotion experience* for each participant by computing the average distance between the highest rated emotion on each trial and the other

four emotion ratings. For each trial, we identified the highest rated emotion, subtracted the rating for the other four emotions from the rating for this emotion, and found the average of these four distances. We then averaged these values across all 20 trials within each participant. Higher values on this measure indicated that participants were more likely to give a high rating for one emotion and low ratings for other emotions. Second, we produced a measure of each participant's *average emotion intensity* by computing the average rating they provided for how strongly they experienced all emotions across all trials, following prior work (Demiralp et al., 2012; Erbas et al., 2014; Starr et al., 2017). Third, given prior evidence that children use the ends of scales more than adults (Chambers & Johnston, 2002), we produced a measure of *extreme scale use* by computing the average distance of participants' ratings from the midpoint of the scale. To generate this score, we computed the absolute value of the difference between every emotion rating and the scale's midpoint (50) and averaged these distances for all emotions across all trials within each participant.

Clarifying statistical and conceptual relations between single emotion experience and emotion differentiation

As described above, emotion differentiation was conceptualized as the ability to specifically identify what emotion (or emotions) one is feeling, and it was quantified by reverse-scoring the ICC between emotion ratings across trials (Fig. 2a). Elevated single emotion experience (i.e., the tendency to feel only one emotion at a time; Fig. 2b) is one route to high emotion differentiation. At the conceptual level, labeling one's emotions as only a single emotion type demonstrates understanding that emotion types differ from each other and is thus one way of specifically identify one's emotions. At the statistical level, singling out one's emotions on each trial (provided different emotions are selected across trials) would also reduce the ICC between emotion ratings and therefore increase emotion-differentiation scores.

However, single emotion experience is not the only route to high emotion differentiation. At the conceptual level, people can demonstrate that they have a specific understanding of emotions (even if they are coexperienced) by demonstrating that different situations make them feel each emotion to different degrees. In other words, high emotion differentiation involves demonstrating that one understands how each emotion type is unique and thus does not consistently covary with
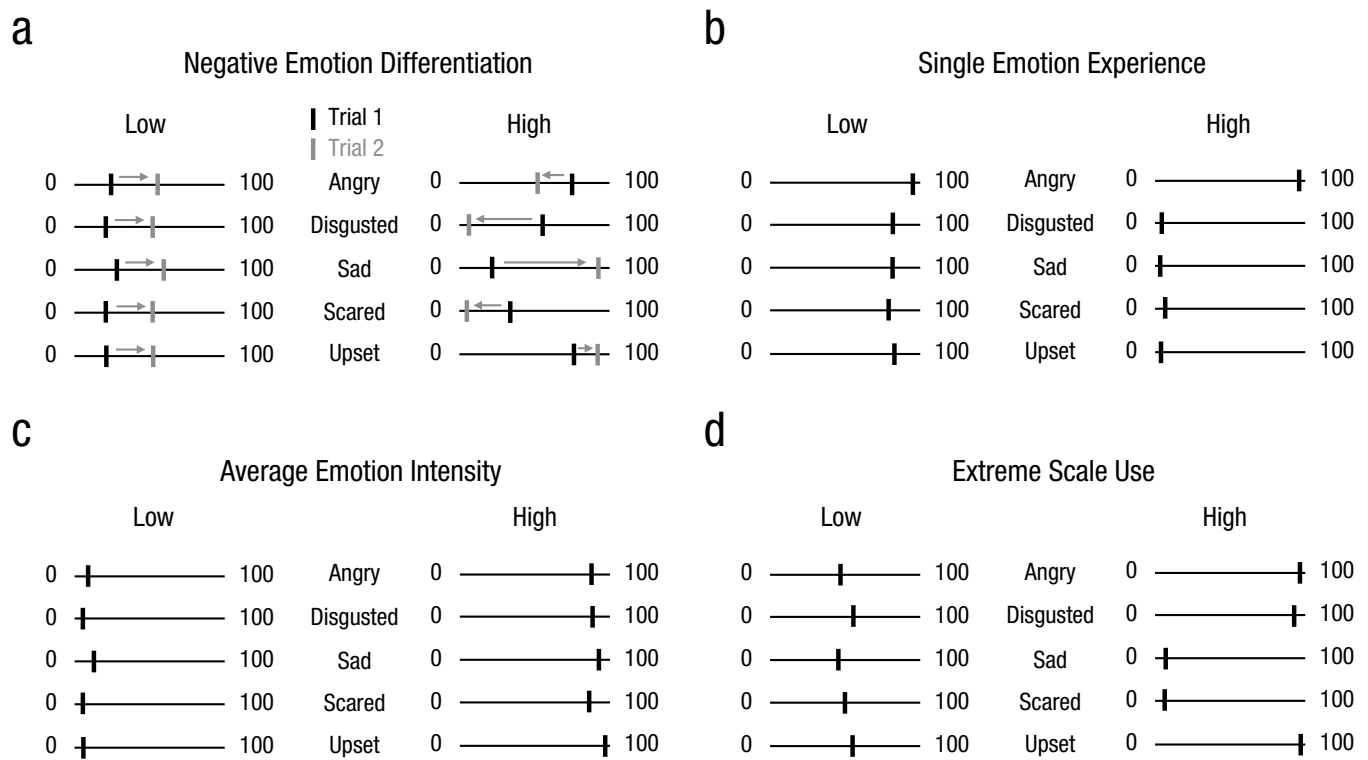
a
Negative Emotion Differentiation

b
Single Emotion Experience

c
Average Emotion Intensity

d
Extreme Scale Use

Fig. 2. Visual representations of trials that would produce low and high scores for the study's four dependent variables. Negative emotion differentiation (a) was computed by reverse-scoring the intraclass correlation of emotion ratings across trials. Two trials are displayed to clarify that this measure depended on intercorrelations between emotion ratings across trials. Single emotion experience (b) was defined as the average distance between the highest-rated emotion and all other emotions, averaged across trials. Average emotion intensity (c) was defined as the average rating for all emotion ratings across all trials. Extreme scale use (d) was defined as the average distance from the midpoint of the scale for all emotion ratings across all trials.

other emotion types (Fig. 2a). For example, an individual can have a specific understanding of how anger and sadness differ from each other, even if these emotions sometimes co-occur. However, if these emotions always co-occur, then the individual appears to not differentiate these emotions. This is captured statistically using the ICC, which quantifies not how much emotion ratings co-occur but instead how they covary.
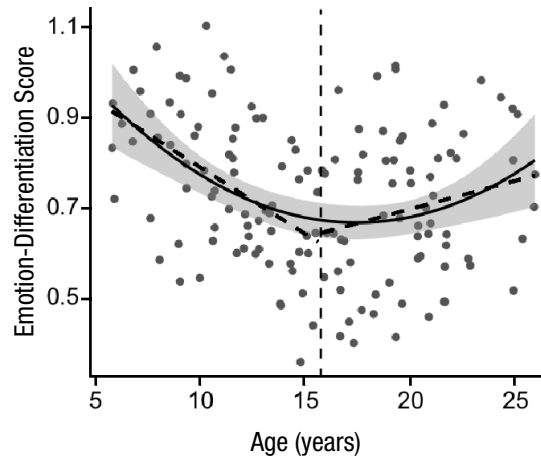
Consider one individual who consistently provides a rating of 100 for one emotion and ratings of 0 for all other emotions across all trials, but the specific emotion that is given a high rating changes across trials (i.e., some images make this person scared and others make him or her sad; Fig. 2b). Contrast this with an individual who provides a rating of 0 for one emotion and ratings of 100 for all other emotions, and again the specific emotion that receives a low rating changes across trials (i.e., some images make this person feel everything except fear, and others make this person feel everything except sadness). Both of these individuals have identically high emotion-differentiation scores. At the conceptual level, this is warranted as they both have specific conceptualizations of each emotion type and

can differentiate when they are feeling (or not feeling) each emotion. However, these individuals differ markedly in their tendency to experience emotions one at a time, with the first individual having a very high single emotion experience. We describe these extreme examples here to illustrate two routes to emotion differentiation.

Analyses

Data visualization suggested a U-shaped relationship between emotion differentiation and age (see Fig. 3a). We tested this relationship by (a) conducting a robust linear regression between emotion differentiation and age, (b) conducting a robust quadratic regression on emotion differentiation that included both linear and quadratic age regressors, and (c) comparing these models using the Bayesian information criterion (BIC). To construct the quadratic age regressor, we subtracted the sample's mean age from each age value and squared the resulting values. In this sample, there was not a significant correlation between the linear and quadratic age regressors, $r(141) = .02$, 95% confidence interval (CI) =
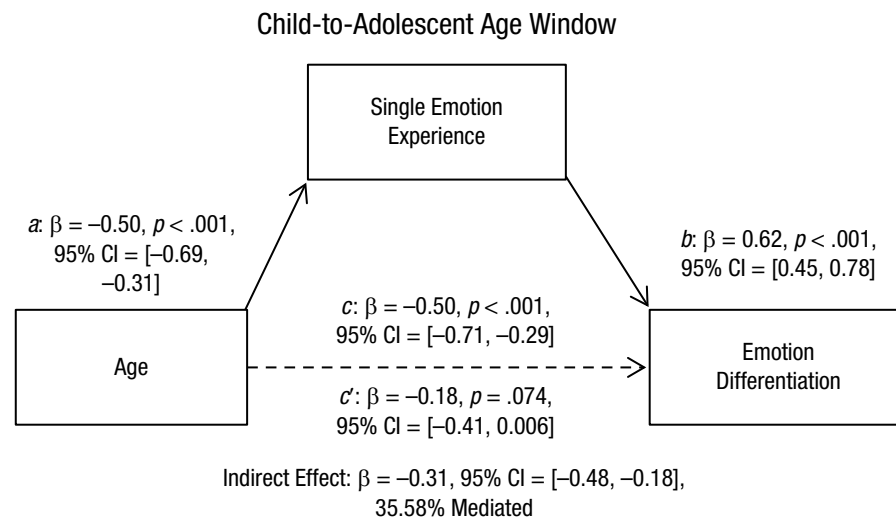
a

b

Child-to-Adolescent Age Window

Indirect Effect: β = −0.31, 95% CI = [−0.48, −0.18],
35.58% Mediated

Fig. 3. Negative emotion-differentiation score across age and results of the mediation analysis. Negative emotion differentiation (a) exhibited a significant quadratic (curved solid line) relationship with age. The two-lines analysis (diagonal dashed lines) revealed a significant reduction in emotion differentiation from childhood to adolescence (break point = age 15.77, vertical dashed line) and an increase from adolescence to adulthood that was trending according to a null-hypothesis test and significant according to a nonparametric bootstrapping test. The gray band represents the 95% confidence interval of the robust quadratic relationship. The mediation analysis (b) within the child-to-adolescent age window revealed that single emotion experience significantly mediated the relationship between age and negative emotion differentiation. The results on the *c* path show the total effect, and the results on the *c′* path show the direct effect after controlling for the mediator. The dashed line indicates that the relationship between age and emotion differentiation was mediated by the indirect effect via single emotion experience. CI = confidence interval.

[−.24, .27], *p* = .794, which justified including them in the same regression model. We also conducted the more stringent, recently developed "two-lines" analysis (Simonsohn, 2017) to assess whether there was both a significant decrease in emotion differentiation from childhood to adolescence and a significant increase in emotion differentiation from adolescence to adulthood. Not only is this piecewise two-lines analysis useful in validating a true U-shaped relationship, it also identifies a data-driven change point for the U-shaped relationship.

We utilized bootstrapping simulations to conduct nonparametric tests of significance for all analyses in

addition to traditional null-hypothesis tests of significance. Bootstrapped analyses involved simulating 10,000 samples with replacement from our final sample, computing statistics of interest for all analyses within all samples, and computing the 95% CIs of each statistic. All CIs noted in the manuscript were obtained using bootstrapping methods, and bootstrapped CIs that did not include 0 were deemed significant at 95% confidence. Some researchers consider nonparametric tests superior to traditional null-hypothesis tests because they require fewer assumptions about the distributions underlying a test's variables.

We then conducted mediation analyses to explore potential explanations for the U-shaped relationship between emotion differentiation and age. We tested whether the three potential mediators defined above (i.e., single emotion experience, average emotion intensity, and extreme scale use; Figs. 2b–2d) mediated age-related changes in emotion differentiation from childhood to adolescence or from adolescence to adulthood. Analyses described above revealed that negative emotion differentiation decreased from childhood to adolescence and increased from adolescence to adulthood (see the Results). These mediation analyses evaluated each of these linear changes separately to identify whether common or distinct mediators explained these downward and upward trajectories.

We split the data set according to the data-driven change point identified by the two-lines analysis and conducted robust mediation analyses within each age window. We then assessed the suitability of conducting mediation analyses. Within each age window, we used robust regressions to test (a) whether each mediator changed significantly across age and (b) whether each mediator was significantly related to emotion differentiation. If a mediator met both criterion a and criterion b, we then conducted robust mediation analyses to test whether that mediator explained age-related changes in emotion differentiation within each age window. A parallel mediation analysis that combined these potential mediators into a single analysis (Nook et al., 2017) was not appropriate because of the strength of correlations between potential mediators (Table 1).

All regressions (including those used in the two-lines analysis and the mediation analyses) were robust using the *rlm* function in R's Modern Applied Statistics With S (MASS) package (Venables & Ripley, 2002) to reduce undue influence from single points. Mediations were implemented with 10,000 bootstrapped resamples using the *boot* package (Davison & Hinkley, 1997). Significant mediation at an α of .05 was defined as 95% bias-corrected and accelerated (BC_a) CIs of indirect effects that did not include 0.

Table 1. Relations Between Age and Dependent Variables

Sample and variable	1	2	3	4
Full sample				
1. Age (5.78–25.91 years)	—			
2. Negative emotion differentiation	[a]	—		
3. Single emotion experience	**–0.19* [–0.38, –0.01]**	**0.63*** [0.46, 0.79]**	—	
4. Average emotion intensity	–0.14 [–0.28, 0.01]	0.07 [–0.12, 0.25]	–0.04 [–0.23, 0.19]	—
5. Extreme scale use	**–0.35*** [–0.50, –0.17]**	0.14 [–0.05, 0.33]	**–0.27** [–0.42, –0.12]**	**0.58*** [0.40, 0.74]**
Child-to-adolescent window				
1. Age (5.78–15.56 years)	—			
2. Negative emotion differentiation	[a]	—		
3. Single emotion experience	**–0.50*** [–0.64, –0.25]**	**0.71*** [0.55, 0.81]**	—	
4. Average emotion intensity	–0.15 [–0.34, 0.13]	–0.10 [–0.39, 0.16]	–0.12 [–0.49, 0.15]	—
5. Extreme scale use	**–0.47*** [–0.62, –0.24]**	**0.37** [0.11, 0.55]**	–0.20 [–0.40, 0.03]	**0.67*** [0.41, 0.80]**
Adolescent-to-adult window				
1. Age (15.77–25.91 years)	—			
2. Negative emotion differentiation	[a]	—		
3. Single emotion experience	0.15 [–0.01, 0.40]	**0.55*** [0.35, 0.75]**	—	
4. Average emotion intensity	–0.07 [–0.28, 0.26]	0.22[†] [–0.04, 0.43]	0.08 [–0.17, 0.40]	—
5. Extreme scale use	–0.14 [–0.45, 0.19]	–0.23[†] [–0.50, 0.09]	**–0.42*** [–0.62, –0.24]**	**0.37** [0.09, 0.64]**

Note: Values outside brackets are standardized coefficients from robust regression analyses assessing linear relationships between variables; values inside brackets are 95% confidence intervals (CIs) from bootstrapped simulations. Significant results are boldfaced.
[a]See the text for linear, quadratic, and two-lines analyses.
[†]*p* < .10. *p < .05. **p < .01. ***p < .001.

Split-sample replication

A split-sample replication tests whether results hold when the overall sample size (*N*) is treated as two separate samples of size *N*/2. Conducting a split-sample replication allows one to test whether results are (a) stable enough to replicate across separate samples and (b) strong enough to be detected within much smaller sample sizes. We carried out this test by randomly assigning participants to two subsamples (n_1 = 72 and n_2 = 71) and conducting primary analyses within both subsamples. Primary analyses we sought to replicate included (a) the regression of quadratic-transformed age on emotion differentiation, (b) the Simonsohn two-lines analyses, and (c) the mediation analysis testing whether decreased single emotion experience explains decreased emotion differentiation from adolescence to adulthood. Results of these analyses are shown in Table S2 in the Supplemental Material.

Results

Development of negative emotion differentiation

Data visualization suggested a U-shaped relationship between age and negative emotion differentiation (Fig. 3a). Although a robust linear regression revealed a significant linear decrease in negative emotion differentiation across age, β = −0.22, 95% CI = [−0.38, −0.05], *p* = .016, BIC = 413.01, a robust quadratic regression provided a better fit to the data and revealed both significant linear, β = −0.22, 95% CI = [−0.38, −0.06], *p* = .008, and quadratic, β = 0.32, 95% CI = [0.18, 0.47], *p* < .001, BIC = 402.66, effects of age. This indicates that the quadratic effect is to be interpreted (Rodman, Powers, & Somerville, 2017; Somerville et al., 2013). Additionally, the recently developed two-lines analysis (Simonsohn, 2017) suggested a significant decrease in negative emotion differentiation from childhood to adolescence, *t*(139) = −4.23, 95% CI = [−5.83, −2.18], *p* < .001, change point = 15.72 years, 95% CI = [13.78, 17.38], and an increase in differentiation from adolescence to adulthood that was significant according to bootstrapping methods but trended toward significance according to traditional null-hypothesis tests, *t*(139) = 1.79, 95% CI = [0.31, 4.27], *p* = .075. Split-sample techniques replicated (a) the quadratic effect of age on emotion differentiation, (b) evidence that the quadratic age model provides a better fit to the data than the linear age model, and (c) the linear decrease in emotion differentiation from childhood to adolescence using Simonsohn's (2017) two-lines analysis (Table S2).

Child-to-adolescent mediation analyses

Results of robust regressions assessing whether each mediator was significantly related to (a) age and (b) negative emotion differentiation within the child-to-adolescent age window (i.e., within the 72 participants between the ages of 5.78 and 15.56) are presented in Table 1. Single emotion experience decreased significantly from childhood to adolescence, and it exhibited a significant positive association with emotion differentiation (Table 1). Thus from childhood to adolescence, individuals decreased their tendency to report feeling one emotion at a time, and a greater tendency to report feeling one emotion at a time was significantly related to higher emotion-differentiation scores. Furthermore, a robust mediation analysis with 10,000 resamples revealed that single emotion experience significantly mediated decreased emotion differentiation from childhood to adolescence (Fig. 3b). Hence, children evinced higher emotion differentiation than adolescents, in part because of a greater tendency to report feeling one emotion at a time. The result of this mediation was significant in both subsamples of the split-sample replication (Table S2).

By contrast, average emotion intensity did not change significantly within this age window, and it was not significantly associated with negative emotion differentiation. Because these relations did not emerge, average emotion intensity was not further investigated as a potential mediator.

Extreme scale use decreased significantly from childhood to adolescence, and it was significantly associated with negative emotion differentiation (Table 1). Hence, from childhood to adolescence, individuals decreased their tendency to use the ends of the scales, and greater use of the ends of the scales was significantly related to higher emotion-differentiation scores. However, a robust mediation analysis revealed that extreme scale use did not significantly mediate decreased emotion differentiation within this age window, indirect effect β = −0.10, 95% CI = [−0.24, 0.006], 16.45% mediated. Hence, decreased emotion differentiation from childhood to adulthood was not explained by children's tendency to use extreme ends of the scales.

Adolescent-to-adult mediation analyses

Slightly different results emerged within the 71 participants between the ages of 15.77 and 25.91 in the adolescent-to-adult age window. Single emotion experience was not significantly related to age in this window, whereas it increased in the childhood-to-adolescence age window. However, single emotion experience continued to show a significant and strongly positive

relationship with negative emotion differentiation (Table 1). Thus, adolescents and adults who showed a greater tendency to experience only one emotion at a time had higher emotion-differentiation scores. Because single emotion experience was not significantly related to age within this age window, it was not further investigated as a mediator of the relationship between age and emotion differentiation.

Average emotion intensity was not significantly associated with age in this age window. Null-hypothesis testing suggested that average emotion intensity exhibited a trend-level relationship with negative emotion differentiation (Table 1): Individuals with higher emotion differentiation also reported more intense emotional reactions to the images, $p = .062$. However, bootstrapping simulations suggested that this relationship was not significant. Average emotion intensity was not further investigated as a mediator because neither of these relationships reached conventional levels of significance.

Extreme scale use did not vary across age within this window. Null-hypothesis testing suggested that it exhibited a trending relationship with negative emotion differentiation that was in the opposite direction as the child-to-adolescent window (Table 1): More extreme scale use was associated with lower emotion differentiation in this age window, $p = .070$, whereas the reverse was true for the child-to-adolescent window. However, bootstrapping simulations again suggested that this relationship was not significant. Extreme scale use was not further investigated as a mediator within this age window because neither of these relationships reached conventional levels of significance.

Discussion

This study investigated the developmental trajectory of negative emotion differentiation from childhood to adulthood. Emotion differentiation exhibited a quadratic relationship with age: It decreased from childhood to adolescence and increased from adolescence to adulthood. Reduced reports of feeling one emotion at a time explained decreased emotion differentiation from childhood to adolescence. However, this mediator did not explain increased emotion differentiation from adolescence to adulthood. Neither extreme scale use nor average emotion intensity mediated age-related changes in emotion differentiation.

Contrary to the hypothesis that emotion differentiation increases across development, emotion differentiation is high in early childhood. Even though children tend to place excess emphasis on whether emotions are merely positive or negative (e.g., Nook et al., 2017;

Pons, Harris, & de Rosnay, 2004; Widen, 2013), their tendency to report experiencing emotions in isolation (i.e., in a mutually exclusive fashion; Wintre & Vallance, 1994) ultimately yields differentiated emotional experiences. However, experiencing emotions one at a time represents a different route to high emotion differentiation than the ability to differentiate several emotions that occur simultaneously. Hence, our results not only demonstrate that emotion differentiation has a nonlinear developmental trajectory, but they also reveal that the predominant route to emotion differentiation varies depending on one's developmental period (i.e., children have high emotion differentiation because they experience emotions one at a time, whereas adults have high emotion differentiation potentially because of increased ability to specifically identify coexperienced emotions).

One important question is why children tend to report experiencing one emotion at a time. Drawing on the constructionist theory of emotion (Barrett, 2006)— which posits that emotions arise via the application of emotion concepts to parse core affective experiences into specific types—this may occur either because children's core affective experiences are naturally parceled into discrete types or because children apply only a single emotion label to categorize core affect. The first explanation seems unlikely because robust evidence suggests that core affect—one's internal somatic and physiological sensations—does not share a one-to-one mapping with specific emotion types (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000; Lindquist & Barrett, 2008). Instead, children may believe emotions can occur only in a singular fashion (leading them to apply only a single emotion concept at a time) or they lack the ability to represent their core affect as fitting multiple emotion concepts simultaneously (Hoemann, Gendron, & Barrett, 2017). Interestingly, prior work suggests that the medial prefrontal cortex may play a role in the application of emotion concepts to parse affect (Satpute et al., 2016), and this region also undergoes significant developmental changes from childhood to adolescence (Somerville et al., 2013). Hence, one possibility is that children are still developing the psychological and neural foundations for representing multiple co-occurring emotions. Future work should investigate this hypothesis.

Interestingly, single emotion experience explained changes in emotion differentiation for only one developmental window. Although parsimony would encourage scientists to search for a single mechanism that can explain age-related changes in psychological phenomena across long developmental periods, our data indicate that different mechanisms may operate within different developmental windows. The current study did not reveal a mediating mechanism for increased

emotion differentiation from adolescence to adulthood, but prior work suggests that emotion concept development (and potentially familiarity with applying these concepts to co-occurring emotions; Nook et al., 2017) might explain this increase.

Our results suggest that adolescence is a period in which emotions co-occur with greater frequency, but these emotions are poorly differentiated. This finding contributes to basic understanding of the social and emotional changes that arise during adolescence (Somerville & McLaughlin, 2018). The novel experience of simultaneous emotions could produce meta-emotions such as confusion or potentially interfere with effective emotion regulation as adolescents struggle to select optimal strategies for regulating simultaneously experienced emotions (Kashdan et al., 2015). Although speculative, our results suggest that low emotion differentiation—which has previously been associated with psychopathology (Kashdan et al., 2015)—may be one factor that contributes to the increased onset of mental illness in adolescence (Kessler et al., 2005; Somerville & McLaughlin, 2018). Difficulty applying emotion concepts to parse ambiguous affect (Nook, Lindquist, & Zaki, 2015) may contribute to the spike in psychopathology that occurs in adolescence. Indeed, prior work demonstrates that a high incidence of co-occurring emotions is associated with nonsuicidal self-injury in adolescents (Andrewes, Hulbert, Cotton, Betts, & Chanen, 2017), whereas high emotion differentiation protects people with borderline personality disorder from self-injuring (Zaki, Coifman, Rafaeli, Berenson, & Downey, 2013). However, future research is needed to empirically evaluate whether low emotion differentiation in adolescence does indeed contribute to increased mental illness in this developmental period. Additionally, if emotion differentiation in childhood reflects a different psychological process (i.e., singular emotion experiences) than in adulthood, it is possible that high emotion differentiation may not be adaptive in this period of development. Hence, research should establish whether or not emotion differentiation is related to mental health outcomes in childhood before assuming that increased differentiation is beneficial to children.

Future research should address two limitations of the current study. First, although we demonstrated that single emotion experience has some specificity in explaining reduced emotion differentiation from childhood to adolescence (i.e., neither emotional intensity nor scale use explained this change), these methods are inherently correlational and merit further validation. Longitudinal designs would allow for more causal conclusions. Second, because methods of assessing emotion differentiation require participants to provide ratings of emotional experiences, these studies can include only individuals who understand emotion terms used in these tasks. However, very young children may not know all of these terms, producing a lower age boundary for which emotion differentiation can be assessed. Hence, new methods of assessing emotion differentiation should be developed to study this construct in young children.

In sum, this study reveals a nonlinear developmental trajectory for emotion differentiation. Shifts away from experiencing emotions as single, mutually exclusive states from childhood to adolescence produce a nadir in emotion differentiation in adolescence. These results extend affective and developmental theories and prompt new directions for future research.

Action Editor

Erika E. Forbes served as action editor for this article.

Author Contributions

All authors collaboratively developed the study design. E. C. Nook programmed the computer tasks. E. C. Nook, S. F. Sasse, and H. K. Lambert collected the data. E. C. Nook analyzed the data. E. C. Nook and L. H. Somerville interpreted the results. E. C. Nook and L. H. Somerville drafted the manuscript, and all other authors provided critical revisions. All the authors approved the final manuscript for submission.

ORCID iD

Erik C. Nook (iD) https://orcid.org/0000-0001-7967-0792

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797618773357

Open Practices

All data and materials have been made publicly available via the Open Science Framework and can be accessed at https://

osf.io/8yufm/. The design and analysis plans for the experiment were not preregistered. The complete Open Practices Disclosure for this article can be found at http://journals.sage pub.com/doi/suppl/10.1177/0956797618773357. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

References

Andrewes, H. E., Hulbert, C. A., Cotton, S. M., Betts, J., & Chanen, A. M. (2017). An ecological momentary assessment investigation of complex and conflicting emotions in youth with borderline personality disorder. *Psychiatry Research*, *252*, 102–110. doi:10.1016/j.psychres.2017.01.100

Baron-Cohen, S., Golan, O., Wheelwright, S., Granader, Y., & Hill, J. (2010). Emotion word comprehension from 4 to 16 years old: A developmental survey. *Frontiers in Evolutionary Neuroscience*, *2*, Article 109. doi:10.3389/fnevo.2010.00109

Barrett, L. F. (2006). Solving the emotion paradox: Categorization and the experience of emotion. *Personality and Social Psychology Review*, *10*, 20–46. doi:10.1207/s15327957pspr1001_2

Barrett, L. F., Gross, J. J., Christensen, T. C., & Benvenuto, M. (2001). Knowing what you're feeling and knowing what to do about it: Mapping the relation between emotion differentiation and emotion regulation. *Cognition and Emotion*, *15*, 713–724. doi:10.1080/02699930143000239

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (2000). The psychophysiology of emotion. In R. Lewis & J. M. Haviland-Jones (Eds.), *Handbook of emotions* (2nd ed., pp. 173–191). New York, NY: Guilford.

Chambers, C. T., & Johnston, C. (2002). Developmental differences in children's use of rating scales. *Journal of Pediatric Psychology*, *27*, 27–36.

Davison, A. C., & Hinkley, D. V. (1997). *Bootstrap methods and their applications*. Cambridge, England: Cambridge University Press.

Demiralp, E., Thompson, R. J., Mata, J., Jaeggi, S. M., Buschkuehl, M., Barrett, L. F., . . . Jonides, J. (2012). Feeling blue or turquoise? Emotional differentiation in major depressive disorder. *Psychological Science*, *23*, 1410–1416. doi:10.1177/0956797612444903

Erbas, Y., Ceulemans, E., Boonen, J., Noens, I., & Kuppens, P. (2013). Emotion differentiation in autism spectrum disorder. *Research in Autism Spectrum Disorders*, *7*, 1221–1227. doi:10.1016/j.rasd.2013.07.007

Erbas, Y., Ceulemans, E., Lee Pe, M., Koval, P., & Kuppens, P. (2014). Negative emotion differentiation: Its personality and well-being correlates and a comparison of different assessment methods. *Cognition and Emotion*, *28*, 1196–1213. doi:10.1080/02699931.2013.875890

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*, 493–498. doi:10.1111/2041-210X.12504

Harter, S., & Buddin, B. J. (1987). Children's understanding of the simultaneity of two emotions: A five-stage developmental acquisition sequence. *Developmental Psychology*, *23*, 388–399. doi:10.1037//0012-1649.23.3.388

Hoemann, K., Gendron, M., & Barrett, L. F. (2017). Mixed emotions in the predictive brain. *Current Opinion in Behavioral Sciences*, *15*, 51–57. doi:10.1016/j.cobeha.2017.05.013

Kashdan, T. B., Barrett, L. F., & McKnight, P. E. (2015). Unpacking emotion differentiation: Transforming unpleasant experience by perceiving distinctions in negativity. *Current Directions in Psychological Science*, *24*, 10–16. doi:10.1177/0963721414550708

Kashdan, T. B., & Farmer, A. S. (2014). Differentiating emotions across contexts: Comparing adults with and without social anxiety disorder using random, social interaction, and daily experience sampling. *Emotion*, *14*, 629–638. doi:10.1037/a0035796

Kashdan, T. B., Ferssizidis, P., Collins, R. L., & Muraven, M. (2010). Emotion differentiation as resilience against excessive alcohol use: An ecological momentary assessment in underage social drinkers. *Psychological Science*, *21*, 1341–1347. doi:10.1177/0956797610379863

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry*, *62*, 593–602. doi:10.1001/archpsyc.62.6.593

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual* (Technical Report No. A-8). Gainesville: University of Florida.

Larsen, J. T., To, Y. M., & Fireman, G. (2007). Children's understanding and experience of mixed emotions. *Psychological Science*, *18*, 186–191. doi:10.1111/j.1467-9280.2007.01870.x

Larson, R. W., Moneta, G., Richards, M. H., & Wilson, S. (2002). Continuity, stability, and change in daily emotional experience across adolescence. *Child Development*, *73*, 1151–1165.

Lennarz, H. K., Lichtwarck-Aschoff, A., Timmerman, M. E., & Granic, I. (2018). Emotion differentiation and its relation with emotional well-being in adolescents. *Cognition and Emotion*, *32*, 651–657. doi:10.1080/02699931.2017.1338177

Lindquist, K. A., & Barrett, L. F. (2008). Constructing emotion: The experience of fear as a conceptual act. *Psychological Science*, *19*, 898–903. doi:10.1111/j.1467-9280.2008.02174.x

Nook, E. C., Lindquist, K. A., & Zaki, J. (2015). A new look at emotion perception: Concepts speed and shape facial emotion recognition. *Emotion*, *15*, 569–578. doi:10.1037/a0039166

Nook, E. C., Sasse, S. F., Lambert, H. K., McLaughlin, K. A., & Somerville, L. H. (2017). Verbal knowledge mediates development of multidimensional emotion concept representations. *Nature Human Behaviour*, *1*, 881–889.

Pond, R. S., Kashdan, T. B., DeWall, C. N., Savostyanova, A., Lambert, N. M., & Fincham, F. D. (2012). Emotion differentiation moderates aggressive tendencies in angry people: A daily diary analysis. *Emotion*, *12*, 326–337. doi:10.1037/a0025762

Pons, F., Harris, P. L., & de Rosnay, M. (2004). Emotion comprehension between 3 and 11 years: Developmental periods and hierarchical organization. *European Journal of Developmental Psychology*, *1*, 127–152.

Riediger, M., Schmiedek, F., Wagner, G. G., & Lindenberger, U. (2009). Seeking pleasure and seeking pain: Differences in

prohedonic and contra-hedonic motivation from adolescence to old age. *Psychological Science*, *20*, 1529–1535. doi:10.1111/j.1467-9280.2009.02473.x

Rodman, A. M., Powers, K. E., & Somerville, L. H. (2017). Development of self-protective biases in response to social evaluative feedback. *Proceedings of the National Academy of Sciences, USA*, *114*, 13158–13163. doi:10.1073/pnas.1712398114

Satpute, A. B., Nook, E. C., Narayanan, S., Weber, J., Shu, J., & Ochsner, K. N. (2016). Emotions in "black or white" or shades of gray? How we think about emotion shapes our perception and neural representation of emotion. *Psychological Science*, *27*, 1428–1442.

Simonsohn, U. (2017). *Two-lines: A valid alternative to the invalid testing of U-shaped relationships with quadratic regressions*. Retrieved from https://ssrn.com/abstract=3021690

Somerville, L. H., Jones, R. M., Ruberry, E. J., Dyke, J. P., Glover, G., & Casey, B. J. (2013). The medial prefrontal cortex and the emergence of self-conscious emotion in adolescence. *Psychological Science*, *24*, 1554–1562. doi:10.1177/0956797613475633

Somerville, L. H., & McLaughlin, K. A. (2018). Normative trajectories and sources of psychopathology risk in adolescence. In A. S. Fox, R. C. Lapate, A. J. Shackman, & R. J. Davidson (Eds.), *The nature of emotion: Fundamental questions* (2nd ed., pp. 386–389). Oxford, England: Oxford University Press.

Starr, L. R., Hershenberg, R., Li, Y. I., & Shaw, Z. A. (2017). When feelings lack precision: Low positive and negative emotion differentiation and depressive symptoms in daily life. *Clinical Psychological Science*, *5*, 613–631. doi:10.1177/2167702617694657

Suvak, M. K., Litz, B. T., Sloan, D. M., Zanarini, M. C., Barrett, L. F., & Hofmann, S. G. (2011). Emotional granularity and borderline personality disorder. *Journal of Abnormal Psychology*, *120*, 414–426. doi:10.1037/a0021808

Tugade, M. M., Fredrickson, B. L., & Barrett, L. F. (2004). Psychological resilience and positive emotional granularity: Examining the benefits of positive emotions on coping and health. *Journal of Personality*, *72*, 1161–1190. doi:10.1111/j.1467-6494.2004.00294.x

Venables, W. N., & Ripley, B. D. (2002). *Modern applied statistics with S* (4th ed.). New York, NY: Springer.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence (WASI)*. San Antonio, TX: Psychological Corp.

Widen, S. C. (2013). Children's interpretation of facial expressions: The long path from valence-based to specific discrete categories. *Emotion Review*, *5*, 72–77. doi:10.1177/1754073912451492

Wintre, M. G., & Vallance, D. D. (1994). A developmental sequence in the comprehension of emotions: Intensity, multiple emotions, and valence. *Developmental Psychology*, *30*, 509–514. doi:10.1037/0012-1649.30.4.509

Zaki, L. F., Coifman, K. G., Rafaeli, E., Berenson, K. R., & Downey, G. (2013). Emotion differentiation as a protective factor against nonsuicidal self-injury in borderline personality disorder. *Behavior Therapy*, *44*, 529–540. doi:10.1016/j.beth.2013.04.008