Supplemental Materials

To accompany

The non-linear development of emotion differentiation:

Granular emotional experience is low in adolescence

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Contents

1. Power simulations

Because no prior work has examined the development of emotion differentiation, an *a priori* power analysis was not possible for this study. Instead, we conducted a series of *post hoc* power simulations. Classical tests of power utilize statistical equations to compute power from a given sample size, an effect size, and alpha level. However, more modern approaches utilize simulation techniques to estimate the power that many different sample sizes have to detect effects of given sizes (Green & Macleod, 2016). This approach can allow researchers to observe the window of effect sizes for which a given sample size will be adequately powered.

Power simulations involve (i) creating many samples of several different sizes that are randomly drawn from populations in which effects of a given size exist, (ii) testing whether an effect is detectable within each sample at conventional levels of significance (i.e., $p < .05$), (iii) computing the percentage of samples of each size in which an effect can be detected, and (iv) plotting these estimates of power to observe the relationship between sample size and power for each effect size. We simulated the power of sample sizes ranging from $N = 5$ to $N = 250$ to detect effects of 4 different sizes: a large-sized effect ($\beta = .5$), our observed effect-size for our primary analysis (i.e., the relation between emotion differentiation and quadratic-transformed age, $\beta = .32$), a medium-sized effect ($\beta = .3$), and the smallest effect for which classical power equations suggest our sample of $N = 143$ should be 80% powered ($\beta = .23$).

Using the steps outlined above, we estimated the power of samples ranging in size from 5 to 250 participants in increments of 5 for each of these effect sizes. We simulated 1,000 samples for each sample size. We also specifically simulated power at our final sample size (i.e., $N = 143$) to produce the power estimates reported in the main text. To mimic our actual analyses, we tested whether the effect could be detected in each sample at $p < .05$ through robust regressions

using the *rlm* function. We then computed and plotted the proportion of the 1,000 simulated samples within each sample size and effect size for which a significant effect was found.[1]

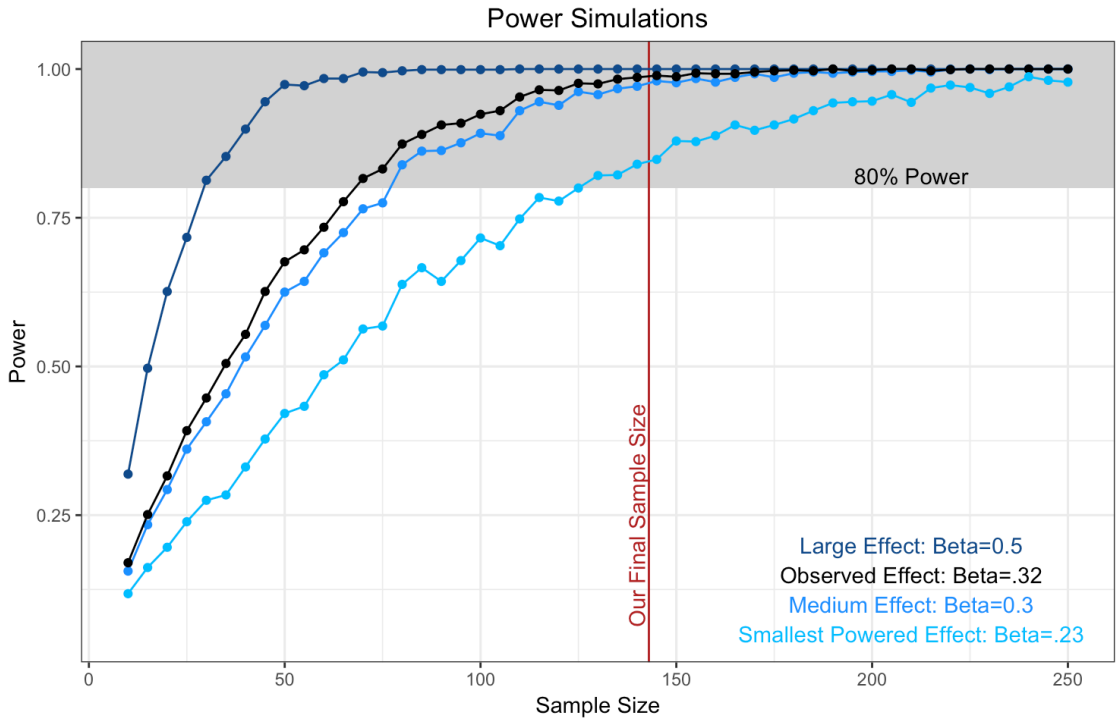

Fig S1. Results of power simulations. Each line represents the percentage of simulated samples of each sample size in which the effect was successfully detected at $p < .05$. The grey region represents sample sizes that exceed the conventional standard for power (i.e., > 80%), and the vertical red line represents the final sample size for which we report results ($N = 143$).

As can be seen from **Figure S1**, simulations suggest that our sample size is sufficiently powered for all 4 effect sizes tested, including the effect size observed in the key finding of the current study ($\beta = .32$, black line). Notably, even though classical equations suggest that $\beta = .23$ would be the smallest effect in which our study is adequately powered, simulations suggest that 80% power for this effect size occurs at a sample size of 130, and our sample of $N = 143$ actually has more than 80% power for detecting an effect of this size. This may arise because our use of robust regressions boosts the stability of regression estimates by reducing the influence of extreme points.

[1] Code for power simulations adapted from Byrnes, J. (2016, October 18). Linear model power analysis with dplyr. Retrieved from http://www.imachordata.com/linear-model-power-analysis-with-dplyr/.

2. Analyses including participants who showed only marginal recognition of emotion terms

Of the 30 participants who were excluded from primary analyses because they did not show full understanding of the 5 emotion terms in the negative emotion differentiation task, 22 demonstrated marginal understanding of these terms (i.e., they received at least a score of 1 on all 5 terms in the emotion vocabulary assessment). Here we present analyses that include 164 participants who meet these relaxed inclusion criteria (age range = 5.54-25.91, M_{age} = 15.42, SD_{age} = 5.23, 52.44% female, 61.59% Caucasian, 3 did not disclose race) and are not excluded for other reasons (see main text). Note that 1 additional participant was a statistical outlier in this expanded dataset (i.e., 9 participants were excluded due to outliers). As in the main text, 95% CIs for statistics listed below are generated from 10,000 bootstrapped resamples.

Development of negative emotion differentiation. As in the restricted sample, a robust linear regression revealed a significant linear decrease in negative emotion differentiation across age, β = -.18, 95% CI = [-.34, -.02], p = .039, BIC = 475.01. However, a robust quadratic regression provided a better fit to the data and revealed both significant linear, β = -.19, 95% CI = [-.34, -.04], p = .018, and quadratic effects of age, β = .26, 95% CI = [.12, .41], p = .001, BIC = 469.09. In this expanded dataset, the two lines analysis (Simonsohn, 2016) suggested a significant decrease in negative emotion differentiation from childhood to adolescence, $t(160)$ = -3.62, 95% CI = [-5.19, -1.52], $p < .001$, change-point = 15.48 years, 95% CI = [13.35, 18.69], and an increase in differentiation from adolescence to adulthood that was again significant according to bootstrapped simulations but not according to null hypothesis tests, $t(160)$ = 1.41, 95% CI = [.12, 3.94], p = .158. Hence, the significance level of these results was consistent between this sample and the restricted sample reported in the main manuscript.

Child-to-adolescent mediation analyses. See **Table S1** below for results of robust regressions assessing whether each potential mediator was significantly related to age and negative emotion differentiation within the child-to-adolescent age window (i.e., within the 83 participants aged 5.54-15.47). Results are identical in significance to those presented in the main manuscript. Single emotion experience decreased significantly from childhood to adolescence, and it exhibited a significant positive association with emotion differentiation (**Table S1**). Again, single emotion experience significantly mediated decreased emotion differentiation from childhood to adolescence, indirect effect β = -.25, 95% CI = [-.41, -.14], 38.17% mediated. Hence, even in the expanded dataset, children's tendency to report feeling only one emotion at a time explained increased emotion differentiation in childhood compared to adolescence.

Again, average emotion intensity did not change significantly within this age window, and it was not significantly associated with negative emotion differentiation. Hence, it was not further investigated as a potential mediator in the expanded dataset.

Extreme scale use decreased significantly from childhood to adolescence, and it was significantly associated with negative emotion differentiation (**Table S1**). However, extreme scale use did not significantly mediate decreased emotion differentiation within this age window, indirect effect β = -.08, 95% CI = [-.22, .04], 16.07% mediated. Hence, decreased emotion differentiation from childhood to adulthood was not explained by children's tendency to use extreme ends of the scales.

Hence, results within the childhood-to-adolescence window replicate primary analyses even when including participants who showed only marginal understanding of emotion terms. Replicating these results in the expanded dataset further supports the study's claims and suggests that the inclusion criteria for primary analyses did not have inordinate influence on the results.

Adolescent-to-adult mediation analyses. Results are also largely similar when adding participants who showed marginal understanding of emotion terms to the adolescent-to-adulthood age window (i.e., the 81 participants aged 15.56-25.91). Single emotion experience was not significantly related to age in this window, and it continued to show a significant and strongly positive relationship with negative emotion differentiation (**Table S1**). Average emotion intensity was also not significantly associated with age. However, in the expanded dataset, it exhibited a positive relationship with negative emotion differentiation that was not significant according to bootstrapping techniques, but it was significant according to null hypothesis tests (**Table S1**). This provides tentative evidence that adolescents and adults who reported more intense emotional reactions to the images also exhibited higher emotion differentiation, potentially because they experienced more emotion that could be more specifically parsed into discrete types. Extreme scale use was not significantly associated with age within this window, but it again exhibited a relationship with negative emotion differentiation that was not significant according to bootstrapping techniques but was trending towards significance according to null hypothesis tests (**Table S1**).

Because age was not significantly associated with any of the potential mediators in this age window—even in the expanded dataset—they again were not further explored as mediators. The replication of results in this expanded dataset supports claims made in the manuscript.

3. Supplemental Table 1

Table S1. Relations between age and dependent variables when including participants who showed marginal understanding of emotion terms.

	1.	2.	3.	4.
Full sample				
1. Age (5.54-25.91)	-			
2. Negative emotion differentiation	†	-		
3. Single emotion experience	**-.13$^{\#}$ [-.30, .03]**	**.61*** [.45, .77]**	-	
4. Average emotion intensity	-.08 [-.22, .08]	.07 [-.09, .24]	-.05 [-.24, .16]	-
5. Extreme scale use	**-.35*** [-.49, -.18]**	.08 [-.10, .27]	**-.24** [-.38, -.08]**	**.51*** [.33, .69]**
Child-to-adolescent window				
1. Age (5.54-15.47)	-			
2. Negative emotion differentiation	†	-		
3. Single emotion experience	**-.41*** [-.55, -.14]**	**.68*** [.51, .79]**	-	
4. Average emotion intensity	-.11 [-.28, .16]	-.07 [-.32, .18]	-.08 [-.44, .21]	-
5. Extreme scale use	**-.50*** [-.63, -.29]**	**.29* [.01, .48]**	-.17 [-.36, .04]	**.58*** [.28, .74]**
Adolescent-to-adult window				
1. Age (15.56-25.91)	-			
2. Negative emotion differentiation	†	-		
3. Single emotion experience	.13 [-.02, .38]	**.53*** [.36, .73]**	-	
4. Average emotion intensity	-.04 [-.23, .30]	**.23*** [-.02, .43]	-.01 [-.24, .29]	-
5. Extreme scale use	-.03 [-.33, .26]	**-.22$^{\#}$** [-.45, .08]	**-.38*** [-.58, -.16]**	**.37** [.10, .63]**

Note: Values outside brackets represent standardized betas from robust regression analyses, and values inside brackets represent 95% CIs from bootstrapped simulations. †see supplemental note 2 for linear, quadratic, and two-lines analyses, $^{\#}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

4. Supplemental Table 2

Table S2: Split-sample replication of primary results

	Subsample 1 (N = 72)		Subsample 2 (N = 71)	
Analysis of emotion differentiation	Statistic	Significance	Statistic	Significance
Quadratic effect of age with linear effect added	β = .32	p = .005**	β = .32	p = .009**
Two-lines analysis: Decreasing emotion differentiation childhood-adolescence	$t(68)$ = -2.37	p = .020*	$t(67)$ = -2.94	p = .004**
Two-lines analysis: Increasing emotion differentiation adolescence-adulthood	$t(68)$ = 1.54	p = .128	$t(67)$ = 0.98	p = .322
Mediation analysis: Decreased single emotion experience mediating decreased emotion differentiation from childhood to adolescence	Indirect effect β = -.27	95% CI = [-.61, -.01]*	Indirect effect β = -.27	95% CI = [-.48, -.08]*

Notes: ** $p < .01$, * $p < .05$

5. Emotion vocabulary assessment scoring details

In this assessment, trained experimenters showed participants a series of emotion words, read each aloud, and scored participants' responses. A total of 27 words were assessed (amazed, angry, annoyed, bored, calm, disappointed, disgusted, embarrassed, excited, grumpy, happy, hate, jealous, lonely, love, nervous, pleased, proud, relaxed, sad, safe, scared, sorry, surprised, thankful, upset, and worried). Five of these were relevant to the current manuscript (i.e., angry, disgusted, sad, scared, and upset).

A score of 2 was awarded if the participant's response included (i) a plausible abstract definition of the emotion, (ii) a synonym of the emotion, or (iii) a situation that would conceivably evoke the given emotion and not other emotions. We assembled a list of definitions and synonyms for each emotion from commonsense, dictionary, and thesaurus sources which experimenters could refer to during the session (see below). If the participant did not provide a response that merited a score of 2, the experimenter prompted them to give more information using follow-up questions to ensure that impoverished responses were not due to test anxiety or shyness. If, even after prompting, participants only gave definitions/situations that were of the correct valence but too vague to meet criteria for a 2-point response, that definition received a score of 1. If participants responded saying "I don't know" or gave definitions, synonyms, or situations for emotions of a different valence, that definition received a score of 0. Hence, a score of 0 indicated no understanding of the emotion term, 1 indicated some understanding, and 2 indicated full understanding.

Scoring guide. Definitions below are based on: Merriam-Webster dictionary for adults; Merriam-Webster dictionary for children; Oxford American Dictionary; Google Dictionary. Synonyms are taken from a variety of sources. These definitions are only to serve as a rough

guide in your scoring.

Angry. Definition: strong feeling of being upset, annoyed, displeased, or hostile. Synonyms: irate, mad, annoyed, cross, vexed, irritated, indignant, irked, furious, enraged, infuriated, in a temper, displeasure, fury, aggravated, livid; ticked off, pissed off; losing one's temper.

Disgusted. Definition: a strong feeling of dislike for something that has a very unpleasant appearance, taste, smell, etc.; annoyance and anger that you feel toward some behavior that is not good, fair, appropriate; revulsion or profound disapproval. Synonyms: revolt, repel, repulse, sicken, nauseate, turn someone's stomach.

Sad. Definition: grief or unhappiness; sorrow. Synonyms: unhappy, sorrowful, dejected, depressed, downcast, miserable, down, blue, down in the dumps, blah.

Scared. Definition: afraid of something; nervous, frightened, fearful. Synonyms: afraid, startled, nervous, fearful, panicky, alarmed, intimidated, terrified, petrified, terrorized, spooked.

Upset. Definition: unhappy, worried; disappointed. Synonyms: distress, trouble, unsettled, worried, bothered, agitated, hurt, sadden, grieve, perturbed, disquieted.