Emotion

Shifting Qualities of Negative Affective Experience Through Adolescence: Age-Related Change and Associations With Functional Outcomes

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Funded by:

- National Institutes of Health
- National Science Foundation

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Abstract word count: 255
Body word count: 6,701
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Acknowledgments: The authors thank Graham Baum, Brenden Tervo-Clemmens, and Shirley Wang for guidance on data analysis and data presentation. The authors also thank Deanna Barch, Melanie Grad-Freilich, Cynthia Hodge, Kat Kabotyanski, and Petra Lenzini for assistance with data acquisition protocols and data access. Finally, the authors would like to acknowledge the efforts of the Human Connectome Project in Development Consortium (PIs: Deanna Barch, Susan Bookheimer, Randy Buckner, Mirella Dapretto, Stephen Smith, Leah Somerville, Kathleen Thomas, David Van Essen, and Essa Yacoub).

Funding:
Research reported in this publication was supported by NIH grants U01MH109589 and U01MH109589-S1 and by the 14 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience Research, by the McDonnell Center for Systems Neuroscience at Washington University, and by the Office of the Provost at Washington University. This work was also supported by a National Science Foundation Graduate Research Fellowship (DGE1745303) to KAG.

Conflict of Interest Statement: The authors declare no conflicts of interest.

The processed data and analysis code can be found at https://osf.io/dsxnu/.

Abstract

Research shows negative affect increases in healthy adolescents, and this normative change is paralleled by increasing risk for the onset of psychopathology. However, research is limited in characterizing qualitative differences in the type of negative affect experienced beyond the positive-negative valence dimension. In the current study, we establish the relationship between different forms of negative affect and functioning outcomes (i.e., different facets of social functioning and life satisfaction), and examine whether these forms of negative affect are differentially prevalent across late childhood and adolescence. 770 participants aged 8-17 years completed self-report measures that assessed a wide range of negative affective experiences. A factor analysis on the negative affect items revealed a 4-factor solution that characterized the dimensions of affective experience, with factors reflecting *general anxiety, anger, evaluative anxiety, and sadness*. Generalized additive model approaches revealed *general anxiety* increased non-linearly with age and was associated with decreased reports of emotional support, a facet of social functioning. *Anger* was associated with increased perceived hostility, perceived rejection, and decreased life satisfaction, and remained stable across the age range. *Evaluative anxiety* was associated with greater loneliness and increased linearly with increasing age. *Sadness* was associated with all outcome measures and showed non-linear changes with age, with notable increases in mid-adolescence. These results show that subsuming these subtypes of negative affect under a singular concept may obscure meaningful relationships between affect, age, and functioning. Exploring diverse forms of negative affect may help refine theories of emotional development and ultimately inform windows of risk for psychopathology.

Keywords: Emotion, affect, development, childhood, adolescence

Introduction

Adolescence is a developmental transition beginning around the onset of puberty and ending when a person reaches adult-like levels of independence, and this transition is marked by substantial change at the experiential and psychological levels (Somerville, 2016). Research shows that among healthy adolescents, there is a downward shift in emotional experience in the direction of more frequent negative and less frequent positive states (Larson et al., 2002). While this increase in negative emotional experience, or *negative affect*, is thought to be developmentally normative, current theories suggest that experiences and regulation of negative emotion can contribute to the onset and maintenance of adolescent psychopathology. For example, increases in the intensity, frequency, and lability of negative affect and difficulties in emotion regulation have been linked to depression symptoms in adolescence (Silk et al., 2003; Larson et al., 1990). More broadly, adolescence is characterized by increased risk for the onset of many forms of psychopathology, such as major depression, eating disorders, and substance use disorders (Kessler et al., 2005). While many cases of psychopathology remit before adulthood, research shows that about half of boys and two-thirds of girls with psychopathology during adolescence will go on to experience at least one further episode in young adulthood (Patton et al., 2014). Thus, adolescence is a key phase of life in which emotional experiences transform and may confer tangible, long-term health risks.

Much of the previous research on affective experience during adolescence has measured affect based on a positive-negative valence dimension (e.g., Larson et al., 2002; Larson & Richards, 2000) or using single-item measures of affect (e.g., the semantic differential Sad-Happy scale with "sad" and "happy" on polar ends; Moneta et al., 2001). However, within the broad category of negative valence, individuals frequently experience affect as a more precise

feeling state (e.g., anger, fear, sadness) (Russell, 1980). Previous research examining negative affect as a singular concept has been limited in its capacity to characterize the range of negative affective experiences and their expression over development.

Research suggests there is value in examining affect, and specifically affect-psychopathology relationships, at this more granular level. Watson and colleagues (2011) found that in adults, general negative affect showed broad and nonspecific associations with internalizing psychopathology, but when different forms of negative affect were examined at a more detailed level, specific relationships emerged. For example, the extent to which participants reported feeling fear mimicked general negative affect as a broad predictor of psychopathology, whereas feelings of sadness and guilt were related to major depression but had weaker links to anxiety disorders, and anger and hostility displayed relatively weak associations with the disorders examined. This research suggests that different forms of negative affect have distinct correlates, highlighting the limitations of previous studies that have relied on global positive and negative affect scores.

Because little work has been done to comprehensively characterize different forms of negative affect in adolescence, we know little about the relationship between qualitatively different forms of negative affect and daily functioning, such as social functioning, in youth. A critical domain of change in an adolescent's life is in the social realm, as they begin to spend more time with peers and are increasingly confronted with social evaluation (Rudolph & Hammen, 1999; Rudolph et al., 2000). While research shows close links exist between social and affective experiences during this adolescent period (e.g., Rodman et al., 2017, Somerville, 2013), few studies have examined the relationship between different forms of negative affect and social functioning.

More globally, negative affect is also associated with lower life satisfaction, or a cognitive evaluation of one's life as a whole. Negative affect consistently predicts lower satisfaction with life across numerous studies (e.g., Pilcher 1998; Thompson et al. 2007) and is inversely associated with life satisfaction across the adult lifespan (Siedlecki et al. 2008). Satisfaction with life is an important part of psychological health and well-being (Diener, 1984; Pavot & Diener, 2008) and predicts many physical health outcomes, such as increased mortality (e.g., Chida & Steptoe, 2008). The current study explores this association between negative affect and life satisfaction at a more detailed level by identifying the relationships between different forms of negative affect and life satisfaction in a large youth sample.

In addition to a focus on the valence dimension, previous work has been limited by small participant samples (e.g., Larson et al., 2002), with some exceptions (e.g., Moneta et al., 2001). To address limitations outlined above in the prior work, in the current study we identify and characterize negative affective experiences in a subset of children and adolescents using self-report data from the Human Connectome Project in Development (Somerville et al., 2018), a large-scale study of brain connectivity and psychological development in youth. Moreover, efforts to recruit a representative sample with respect to race, ethnicity, sex, and socioeconomic status ensures a high degree of generalizability to youth in the United States. In the current study, we *1)* apply a data-driven approach to identify the latent variables represented within negative affect items, *2)* identify the degree to which different forms of negative affect are associated with social functioning, *3)* identify the degree to which forms of negative affect are associated with global life satisfaction, and *4)* identify and describe age-related changes in the forms of negative affect across the sample, aged 8-17 years. While our primary focus is on adolescence, we examined children as young as 8 to inform the childhood to adolescent transition; thus, our

sample is well suited to characterize experiences from late childhood to adolescence. While prior research informs the expected negative relationship between negative affect as a whole and the functioning measures, the relationship between different forms of negative affect and social functioning and life satisfaction were considered exploratory. Similarly, we predicted global negative affect to increase with increasing age, but tests for distinct age-related patterns for different forms of negative affect were considered exploratory.

Methods

Participants

The current study examined data from a subset of participants from the Human Connectome Project in Development (HCP-D; Somerville et al., 2018). We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. Data from seven hundred and eighty-three participants ages eight to seventeen years were made available at the time of analysis from the HCP-D investigators in advance of public data release. Participants ages 5-7 years were not included because the only affect measures available were parent-report (not self-report), and participants 18 years and older were not included in the current analysis due to a lack of overlap in measures.

Data from thirteen participants were excluded due to incomplete data (i.e., greater than 20% of affect data missing; see **Supplementary Section 1** for flow chart of sample selection). Remaining missing data was median replaced. For the life satisfaction analysis, 544 participants (ages 8.00–17.97 years, mean age=11.53 years) with overlapping data were analyzed, as the remaining participants completed a different subset of life satisfaction items.

Thus, final analysis included data from 770 participants (see **Supplementary Section 2** for age distribution; age range = 8.01 – 17.97 years, M_{age} = 12.60, SD_{age} = 2.84, 49.6% female, 15.7% Hispanic or Latino, 70.4% White, 15.5% Black/African American, 1.4% Native American, 0.4% Native Hawaiian or other Pacific Islander, 8.8% Asian, 18.8% more than one race, 1.6% don't know). Gender was defined based on parent-reported gender identity reported during the phone screening, and no participants were excluded from analyses of gender differences. Sampling aimed to match the diversity across ethnicity, race, and socioeconomic status in the United States (Somerville et al., 2018). All participants were fluent in English and did not have cognitive impairments limiting their ability to provide assent or complete tasks. To preserve heterogeneity in the sample, participants were included if they had elevated symptoms of psychiatric illness as long as they had not been diagnosed and treated for 12 months or longer (see **Supplementary Section 3** for overview of inclusion and exclusion criteria).

Participants were recruited from four sites across the USA: Harvard University, University of California – Los Angeles (UCLA), University of Minnesota (UMinn), and Washington University in St. Louis (WUSTL) (see **Supplementary Section 4** for participant demographics by site). Guardians of minor participants provided informed consent prior to participation, and minors assented to participation. All procedures were approved by a central Institutional Review Board administered at Washington University in St. Louis.

Measures

The current study focuses on a subset of measures from the broader HCP-D project that were selected *a priori* to match the research questions described above. We selected measures with items assessing negative affective experience (i.e., subjective experiences of one's

emotional state), social functioning, and life satisfaction for analysis, as described below. We then applied a data-driven approach to identify the latent variables represented within these items.

All measures analyzed were self-reported by the participant. To ensure comprehension and accuracy in reporting for younger participants (ages 8 to 11 years), the experimenter read the survey items out loud and watched as the child made their selection. Many items used in analysis were drawn from the NIH Toolbox (Gershon et al., 2013), a set of age-specific measurements that were developed and validated to be psychometrically sound in each of the age groups surveyed. All NIH Emotion Toolbox measures are described below using descriptions from the NIH Toolbox Scoring and Interpretation Guide (https://nihtoolbox.my.salesforce.com/sfc/p/#2E000001H4ee/a/2E0000004yR3/Ckb_AKw1oFUC56tgf6tdxcGDYaYbu8rsmBSFOX2Ec4g) and the NIH Toolbox Brochure (http://www.healthmeasures.net/images/nihtoolbox/NIH_Toolbox_brochure_June_2017.pdf)

Negative Affect Experience

The NIH Emotion Toolbox negative affect measures assess the emotional domains of sadness, fear, and anger by asking participants to rate how often they have felt specific emotional experiences within the past seven days on a 5-point Likert scale from "Never" to "Almost Always". The Sadness Survey measures unpleasant feelings or emotions of sadness; the Fear Survey assesses fear, anxious misery, and hyperarousal; and the Anger Survey assesses angry mood and aggression (verbal and physical). We also used a child-adapted version of the behavioral inhibition scale from the Behavioral Inhibition/Behavioral Activation Scale

(BIS/BAS; Pagliaccio et al., 2016; Carver & White, 1994), which measures concern about possible negative or punishing events and sensitivity to the occurrence of such events. Participants rated statements about their thoughts and feelings on a 4-point Likert scale from "Not True" to "Very True". All items were administered on digital platforms, as described in Somerville et al. (2018).

From these measures, we selected items for analysis using two criteria. First, as we are interested in characterizing affect, we selected items that specifically assessed affective experiences (i.e., the subjective experience of valence and arousal), rather than emotion-related thoughts or beliefs (e.g., "I felt upset" describes an affective state and was included, whereas "I felt everything in my life went wrong" describes a belief and was excluded). Second, we included items that were administered to, and completed by participants, in the entire age range. For the NIH Emotion Toolbox modules, participants of different ages received a different number of items, and some modules were Computer Adaptive Tests (i.e., the test varied based on the participants' answers). Therefore, if an item was only administered to a subset of participants in the 8-17 year age range, the item was excluded from analysis. See **Supplementary Section 5** for the final selected items.

Social Functioning

The NIH Emotion Toolbox modules measuring the structure, extent, and quality of social relationships were used to measure social functioning. These modules include the Emotional Support Survey (measuring the perception that people in one's social network are available to listen to one's problems with empathy, caring, and understanding), the Friendship Survey (measuring the perceptions of the availability of friends or companions with whom to interact or

affiliate), the Perceived Hostility Survey (self-reported perceptions of hostility, e.g., measuring the perceptions of how often people argue with me, yell at me, or criticize me), the Perceived Rejection Survey (measuring perceived insensitivity, e.g., how often people don't listen when I ask for help, or don't pay attention to me), and the Loneliness Survey (measuring the perception that one is alone, lonely, or socially isolated from others). For the Emotional Support and Friendship surveys, higher scores indicate better social functioning (i.e., increased emotional support and friendship); for the Perceived Hostility, Perceived Rejection, and Loneliness surveys, higher scores indicate poorer social functioning (i.e., increased perceived hostility, perceived rejection, and loneliness).

Items that query the juncture of social and affective experiences (e.g., experiences of loneliness) required a decision to categorize the item as "affective" or "social" for analyses. In these cases, we followed the original categorization made during the construction of the NIH Toolbox categories. Thus, experiences of loneliness were characterized as reflecting the social domain.

Life Satisfaction

To measure life satisfaction, the NIH Emotion Toolbox General Life Satisfaction Survey was used. This survey measures global feelings and attitudes about one's life (e.g., my life is going well).

Aims and Analyses

Exploratory Factor Analysis

The first aim of the study was to uncover the latent structure of the negative affect variables to obtain meaningful summary scores for different forms of negative affect in our sample. We implemented a data-driven approach to identify forms of negative affect rather than relying on scale summary scores, as this approach 1) allowed us to only include items measuring negative affective experience, rather than emotion-related thoughts or beliefs, and 2) allowed items capturing similar affective experiences to group together without being tied to a priori assumptions.

To achieve aim, we conducted an exploratory factor analysis (EFA) using the *fa* function from the *psych* package (version 1.8.12, Revelle, 2018) in R (R Core Team, 2020). Twenty-two items measuring a range of negative affective experiences were selected from the self-report measures. Two items were eliminated due to consistently low loadings across bootstrapped samples in a supplementary analysis (see **Supplementary Section 6**) and the remaining twenty items were input to the EFA. Because the items all measure negative affect and are assumed to be related, we used an oblimin rotation to achieve a non-orthogonal (oblique) solution that would allow the factors to be correlated. Additionally, the negative affect variables were all 4 or 5-point Likert scale items, and thus polychoric correlations were used in the EFA to accurately estimate the correlations between the ordinal variables. When choosing the number of factors to retain, we considered a scree plot using the elbow method, eigenvalues > 1 criteria, parallel analysis (in which a factor is considered as "significant" if its eigenvalue is larger than the 95% quantile of those obtained from a random data matrix of the same size as the original), and interpretability. Because parallel analysis is cautioned to be partially sensitive to sample size (i.e., for large

samples, the eigenvalues of random factors will tend to be very small resulting a larger number of factors than using other criteria; Revelle (2015)), the parallel analysis was weighted less strongly. The resulting factor solution was compared to three additional theoretically identified and data-driven factor solutions to ensure it was the best fitting model (see **Supplementary Section 7**).

While our primary analyses focus on forms of negative affect, to compare our results with prior work that has studied negative affect as a singular concept, we conducted a supplementary analysis of overall negative affect, in which all negative affect measures were combined into a single score using factor analysis (see **Supplementary Section 8**).

Confirmatory Factor Analysis

To evaluate the fit of the factor structure extracted in the EFA, we conducted a confirmatory factor analysis (CFA) using the *cfa* function in R's *lavaan* package (version 0.6-9, Rosseel, 2012). We calculated and report the standard measures and fit rules (Hu & Bentler, 1999) to assess how well the proposed model produced by the EFA captures the covariance between the measured items. The fit indices used include the comparative fit index (CFI, should be >= 0.95), root mean square error of approximation (RMSEA should be <= 0.05, upper CI bound <= 0.10), standardized root mean square residual (SRMR, should be <= 0.08), Tucker-Lewis index (TLI, > .90 indicates good fit), McDonald fit index (MFI, higher values indicate better fit), and the chi-squared test (a non-significant p-value suggests the model fits) was also used. While we report the chi-square for completeness, this statistic becomes more significant with larger samples and has low power at smaller samples (Gatignon, 2010); due to the large sample size in the current study, we did not rely on this statistic for determining fit. To improve

model fit, we identified and removed items with non-significant loadings. These fit indices represent an upper bound on the fit that would be expected in an independent sample because the model was developed and tested using the same data.

Relationship between Negative Affect and Social Functioning

The second aim of the study was to identify the degree to which different facets of negative affect were significantly associated with social functioning. Twenty-nine social functioning items were taken from five different modules in the NIH Emotion Toolbox measuring emotional support, friendship, perceived hostility, loneliness, and perceived rejection. We calculated summary scores by summing the Likert response scores for each social functioning domain ("Never" = 1, "Rarely" = 2, "Sometimes" = 3, "Usually" = 4, "Always" = 5). We chose to undertake the factor analysis approach for modeling the latent structure of negative affect items, as it allowed us to select only questions about affect, did not require *a priori* assumptions about how items would group together. By contrast, the social functioning outcome items were all taken directly from existing sub-scales from the NIH Emotion Toolbox modules as they more straightforwardly represented the constructs of interest.

To test the extent to which the negative affect factors relate to the identified social domains across the age range as a whole, we fit regression models in R using the *mgcv* package (version 1.8-28, Wood, 2003). For each social domain, a separate regression model was run to identify which negative affect factors (all included as linear predictors within the same model) are significantly associated with that social functioning domain score. Thus, the parameter estimates were conditioned on the other negative affect variables in the model. Development leads to linear and non-linear changes in both affect and social functioning, so the spline of age

was included as a control. Standardized regression coefficients (β) are reported, which can be interpreted as effect sizes (such that one standard deviation of the predictor results in β standard deviations change in the outcome). Multiple comparisons were accounted for using the Holm method, which controls the family-wise error rate (Holm, 1979).

We additionally evaluated whether the negative affect factors had differential effects on the outcome variable (compared to a null hypothesis where all factors have an equal impact). We fit two regression models: one in which the coefficients were allowed to differ for each of the negative affect factors, and one in which the coefficients were constrained to be equal across all affect factors. The two models were then compared using Akaike Information Criterion (AIC) values, and we selected the one with the smallest value. The difference in AIC values between the two models (Δ AIC) is reported.

Relationship between Negative Affect and Life Satisfaction

The third aim was to identify the degree to which different forms of negative affect relate to overall life satisfaction. We calculated a summary score for life satisfaction by summing the Likert response scores from the items in the General Life Satisfaction survey from the NIH Toolbox. To test the extent to which the negative affect factors are associated with life satisfaction, we conducted linear regression models as described above. Life satisfaction was the dependent variable and all negative affect factors (in addition to the spline of age) were included in the same model as independent variables.

Age-Related Changes in Negative Affect

The final aim of the study was to identify and describe age-related changes in the negative affect factors across our sample, aged 8-17 years. Because age trends are not limited to linear patterns, we compared models with age modeled both linearly and non-linearly.

To explore non-linear age-related changes, we used generalized additive models (GAM) with thin-plate regression splines (see Wood, 2017). This method produces regression equations that fit the data using cross-validation procedures but are also penalized for the number of parameters to prevent overfitting (Wood, 2003). The result of these models is a stable, smooth curve that describes the data's age-related change but is not constrained to stereotyped linear, quadratic, or cubic shapes.

For each negative affect factor, we tested a linear and spline model, with the negative affect factor as the dependent variable and age as the independent variable, as well as a null model with no age predictors. Linear analyses were tested using the *lm* function in R's *stats* package (R Core Team, 2020), and GAM models were tested using the *gam* function in the *mgcv* package. The two models were then compared using AIC values. The model with the lowest AIC was considered the best fit and interpreted. In cases where the spline model yielded a linear fit, the AIC values for the linear and spline model are identical and a linear model should be interpreted. Multiple comparisons were accounted for using the Holm method.

To fully describe the age-related changes in the negative affect factors, we aimed to identify the specific windows of age during which experiences of that form of negative affect significantly increased or decreased. Unlike linear models, which are restricted to identifying a constant rate of change, spline models may identify age-related increases or decreases in some parts of the curve and not others. Thus, for negative affect factors for which the spline model was

the best fitting model, post-hoc analyses identified the windows of accelerated change across the age range. We calculated the first derivative of the smooth function of age using finite differences (a method used to approximate derivatives where the derivative is calculated at a set number of points), and a simultaneous 95% confidence interval for 100 points along the derivative (Ruppert et al., 2003). The set of simultaneous confidence intervals is defined so that, given other modeling assumptions, the true population value (e.g., a negative affect factor at a certain age) falls outside the set at the nominal rate (5%, in this case). This ensures that inferences based on our set of 100 confidence intervals are adjusted for multiple comparisons. Intervals of change can be identified as areas where the simultaneous confidence interval of the derivative does not include zero. The *derivatives* function in R's *gratia* package (version 0.4.1, Simpson, 2020) was used to calculate the derivatives and simultaneous confidence intervals (Simpson, 2020). The processed data[1] and analysis code can be found at https://osf.io/dsxnu/. This study was not preregistered.

Although outside of the scope of the primary line of questioning, we conducted additional analyses *1)* testing the robustness of the factor solution across age and gender, *2)*, testing gender as a moderator in affect – functioning relationships, *3)* evaluating the relations between pubertal stage and negative affect, *4)* characterizing the relationship between age and social functioning and life satisfaction measures, and *5)* evaluating the relationship between the primary measures and a dimensional self-report measure of psychopathology. See the **Supplementary Materials** for the methods and results of these additional inquiries.

[1] Due to HCP-D sharing restrictions we are not able to post the full data, but permission to access the raw data may be requested at https://www.humanconnectome.org/study/hcp-lifespan-development/data-releases

Results

Exploratory Factor Analysis

The scree plot (see **Supplementary Section 9**) indicated that 2 or 5 factors may be optimal, the eigenvalues > 1 criteria indicated 3 factors, and the parallel analysis indicated 5 factors. Two, 3, 4, 5-factor solutions were extracted to compare interpretability. A 2-factor solution (52.3% of variance explained) consisted of a factor with items relating to evaluative anxiety (i.e., items centered around anxiety about making mistakes or being negatively evaluated) and a factor with anger, general anxiety (i.e., general feelings of worry, fear, or nervousness), and sadness items. A 3-factor solution (59.6% of variance explained) consisted of a general anxiety factor, an anger factor, and an evaluative anxiety factor, with sadness items loading weakly on the anxiety and anger factors. A 4-factor solution (64.5% of variance explained) resulted in a general anxiety factor, an anger factor, an evaluative anxiety factor, and a sadness factor. A 5-factor solution (68.5% of variance explained) was consistent with the 4-factor solution with an added factor of one item, "I usually get very tense when I think something unpleasant is going to happen". Due to common conceptualization of anger, anxiety, and sadness as distinctly experienced negative emotions (Russell, 1980) we eliminated the 2-factor solution. Due to the weak loadings of the sadness items, we eliminated the 3-factor solution. Finally, due to the difficulty of interpreting the 5th factor distinctly from the general anxiety and evaluative anxiety factors of the 4-factor solution and the limited utility in a 1-item factor, we chose the 4-factor solution as the optimal solution (**Figure 1**).

Due to the data-driven nature of our approach, we selected the following names to describe the affective state expressed in each group of items without direct reference to the original scales or to clinical terminology: *general anxiety*, *anger*, *evaluative anxiety*, and

sadness. *General anxiety* contained items originally from the NIH Toolbox Fear Survey, *anger* contained items from the NIH Toolbox Anger Survey, *sadness* contained items from the NIH Toolbox Sadness and Anger Surveys, and *evaluative anxiety* contained items originally from the BIS scale.

The correlations between factors were as follows: *general anxiety* and *anger* ($r(768) = .61$, $p < .001$), *general anxiety* and *evaluative anxiety* ($r(768) = .31$, $p < .001$), *general anxiety* and *sadness* ($r(768) = .64$, $p < .001$), *anger* and *evaluative anxiety* ($r(768) = .30$, $p < .001$), *anger* and *sadness* ($r(768) = .45$, $p < .001$), and *evaluative anxiety* and *sadness* ($r(768) = .18$, $p < .001$).

Confirmatory Factor Analysis

The CFA indicated that all items had significant loadings (range of standardized loadings: .623 - .877), so all items were retained for the analysis (see **Supplementary Section 10** for all parameter estimates). The fit statistics of the final four-factor solution were as follows: chi-squared test statistic = 523.26 (df = 164, $p < 0.001$), CFI = .992, RMSEA = .053 (CI = .048, .059), SRMR = .051, TLI = .991, MFI = .792. The CFI, SRMR, and TLI are all within the recommended range to suggest a well-fitting model (CFI >= .95, SRMR <= .08, TLI > .90). The RMSEA is slightly higher than the recommended value (<= .05), however, the upper CI bound is within the recommended range (<= .10). Therefore, taken together, the CFA fit indices suggest the four-factor solution is a well-fitting model.

Relationship between Negative Affect and Social Functioning

Table 1 presents the results of the linear models conducted to identify which negative affect factors were significantly associated with different domains of social functioning. For all

significant relationships, increased negative affect was associated with decreased social functioning. *General anxiety* was significantly associated with lower reports of emotional support (β = -.16, p = .024). *Anger* was significantly associated with greater perceived hostility (β = .34, p < .001) and perceived rejection (β = .23, p < .001). *Evaluative anxiety* was significantly associated with greater loneliness (β = .14, p < .001). *Sadness* was significantly associated with lower reports of emotional support (β = -.16, p = .007) and friendship (β = -.21, p < .001), and greater perceived hostility (β = .15, p = .003), loneliness (β = .47, p < .001), and perceived rejection (β = .28, p < .001). The unconstrained models (where the coefficients were allowed to differ for each of the negative affect factors) had a lower AIC value than the constrained models (where the coefficients were equal for all negative affect factors) for all regressions: emotional support (Δ AIC = 17.07), friendship (Δ AIC = 4.64), perceived hostility (Δ AIC = 17.28), loneliness (Δ AIC = 61.17), and perceived rejection (Δ AIC = 11.71).

The spline of age in the above models was significant in the emotional support (F = 5.55, p < .001) and perceived hostility (F = 16.24, p < .001), and was not significant in friendship (F = 1.78, p = .124), loneliness (F = 1.45, p = .230), or perceived rejection (F = 1.20, p = .322). For the significant age terms, increasing age is related to higher levels of emotional support and lower levels of perceived hostility.

Relationship between Negative Affect and Life Satisfaction

The results of the linear model to identify which negative affect factors were significantly associated with life satisfaction are summarized in **Table 1**. *Sadness* (β = -.28, p < .001) and *anger* (β = -.22, p < .001) were significantly associated with decreased life satisfaction. The unconstrained model had a lower AIC value than the constrained model (Δ AIC = 19.76).

Age-Related Changes in Negative Affect

Results are summarized in **Table 2** and **Figure 2** (see **Supplementary Section 11** for Figure 2 with raw data points overlaid). For the *general anxiety* and *sadness* factors, the spline models produced a better fitting model than the linear model; thus, the spline models were selected for inference. *General anxiety* (p = .021) and *sadness* (p < .001) showed significant age-related changes that could be described as "u" shaped, with slight decrease during childhood and sharper increases in adolescence. To explore these non-linear changes further, we conducted a "two-lines test" (Simonsohn, 2018; Nook et al., 2018) to determine whether the apparent u-shape was statistically reliable (see **Supplementary Section 12** and accompanying text for details). We found evidence for a significant "u-shape" for both factors: when broken into two separate regressions, the curves showed a significant negative slope between ages 8 and 13 followed by a significant positive slope between the ages of 13 and 17. Calculations of the derivatives to identify significant age windows of change indicated that *sadness* increases significantly between the ages of 14.7 and 15.6 years. For the *evaluative anxiety* factor, the linear model produced a better fitting model than a spline model and was selected for inference. *Evaluative anxiety* was shown to increase linearly with increasing age (β = .26, p < .001). *Anger* was not significantly associated with age (β = .004, p = .913); thus, we interpret *anger* as remaining stable across our age range.

In our supplemental analyses, we found that *1)* our factor structure is invariant across males and females and across age as indicated by two multi-group CFAs, (see **Supplementary Section 13**), *2)* gender did not significantly moderate any of the observed affect – functioning relationships after correcting for multiple comparisons (see **Supplementary Section 14)**, *3)* *evaluative anxiety* and *sadness* show significant puberty-related changes in addition to age-

related changes (see **Supplementary Section 15**), *4)* emotional support and loneliness show significant, non-linear increases with age and perceived hostility shows significant, non-linear decreases with age (see **Supplementary Section 16**), and *5) general anxiety, evaluative anxiety,* and *anger* show significant, specific relationships with DSM-derived domains from a dimensional self-report measure of psychopathology (see **Supplementary Section 17**).

Discussion

This study assessed distinct forms of negative affect and their relationship to social functioning, life satisfaction, and age in a large developmental sample. Four negative affect factors – *general anxiety*, *anger*, *evaluative anxiety*, and *sadness*– were extracted from an exploratory factor analysis, and fit indices from a confirmatory factor analysis suggested the model was plausible. *General anxiety* was associated with lower levels of emotional support and showed non-linear changes with age. Increased *anger* was associated with two types of maladaptive social functioning (perceived hostility and perceived rejection) and decreased life satisfaction and did not change significantly across the age range. *Evaluative anxiety* was associated with increased loneliness and increased linearly with increasing age. *Sadness* was significantly associated with all types of social functioning (emotional support, friendship, perceived hostility, loneliness, perceived rejection) and with decreased life satisfaction *Sadness* showed non-linear increases with age, with accelerated change between the ages of 14.7 and 15.6 years.

Taken together, our findings show an overall negative relationship between negative affect and daily functioning and an increase in negative affect from childhood into adolescence (see **Supplementary Materials** for an analysis of *overall negative affect* in our sample). These

findings are largely consistent with previous work studying negative affect as one concept (e.g., Larson et al., 2002; Siedlecki et al. 2008). However, these relationships varied in strength across the four different forms of negative affect, as described below. By examining qualitatively different forms of negative affect within the broad positive-negative valence dimension, specific affect-functioning and affect-age relationships emerged.

General anxiety was significantly related to lower reported emotional support. This finding aligns with previous research in clinical populations that have demonstrated a link between anxiety and poorer social functioning in adolescence (de Lijster, 2018; La Greca, 1998; Biggs, 2012) and with work in adults showing negative correlations between trait anxiety and perceived social support (e.g., Hyde et al., 2011). Our findings also reveal that *general anxiety* declines slightly until around the transition to adolescence (~age 13) and then increases robustly during adolescence. Because the items in this factor describe a general anxiety without a specified cause (i.e., "I felt worried" rather than "I felt worried about…"), we speculate that the "u" shape we observe could be due to age-related differences in the source of the affective experience. For example, work done on normative samples of youth shows that separation anxiety and anxiety surrounding death and danger are predominant in children, whereas social anxiety and fear of failure and criticism are predominant in adolescence (Weems & Costa, 2005). Individuals around age 13 may be at a developmental period where they are no longer experiencing anxieties of a child but for whom the social anxieties of an adolescent are just emerging. The increase in anxiety observed in adolescence also aligns with emotional development theories that suggest negative experiences such as anxiety and worry may increase as individuals transition into adolescence, as their world of concerns widens (e.g., anxiety associated with politics) (Larson & Asmussen, 1991).

Anger was significantly related to an increase in the perception of others' hostility and rejection. These two particular social domains are categorized as "social distress" by the NIH Toolbox (in contrast to other social domains of "perceived social support" or "companionship"), which is the extent to which an individual perceives his or her daily social interactions as negative or distressing. This link between anger and perceived rejection is consistent with previous research on "rejection sensitivity", or the tendency to anxiously or angrily expect or perceive rejection (Downey & Feldman, 1996; Feldman & Downey, 1994). *Anger* was also associated with reductions in life satisfaction, with aligns with previous research showing a link between these domains (e.g., Arrindell, 1991; Pilcher, 1998). Anger did not show significant age-related changes, indicating this affective experience remains relatively stable across the 8-17-year-old range examined in the current study.

Evaluative anxiety is a notable affective factor in that it consists of various affective states (i.e., worry, tension, and feelings of being hurt and upset) specifically in response to making mistakes, performing poorly, or being scolded. These items, originally from the BIS/BAS scale, are theorized to arise from a behavioral inhibition system in which the motivation is to avoid aversive outcomes (Carver & White, 1994). In the clinical realm, this experience resembles social anxiety, which includes symptoms such as fear of social or performance situations in which one is exposed to scrutiny by others (American Psychiatric Association, 2013). *Evaluative anxiety* was significantly and positively related to the social domain of loneliness, which aligns with research showing close links between these two experiences (e.g., Johnson et al., 2001, Lim et al., 2016) *Evaluative anxiety* increased linearly with increasing age, which aligns with previous research showing increases across childhood and

adolescence (Pagliaccio et al., 2016) and supports the possibility that with an emerging social understanding in adolescence comes an increase in evaluative concerns (Weems & Costa, 2005).

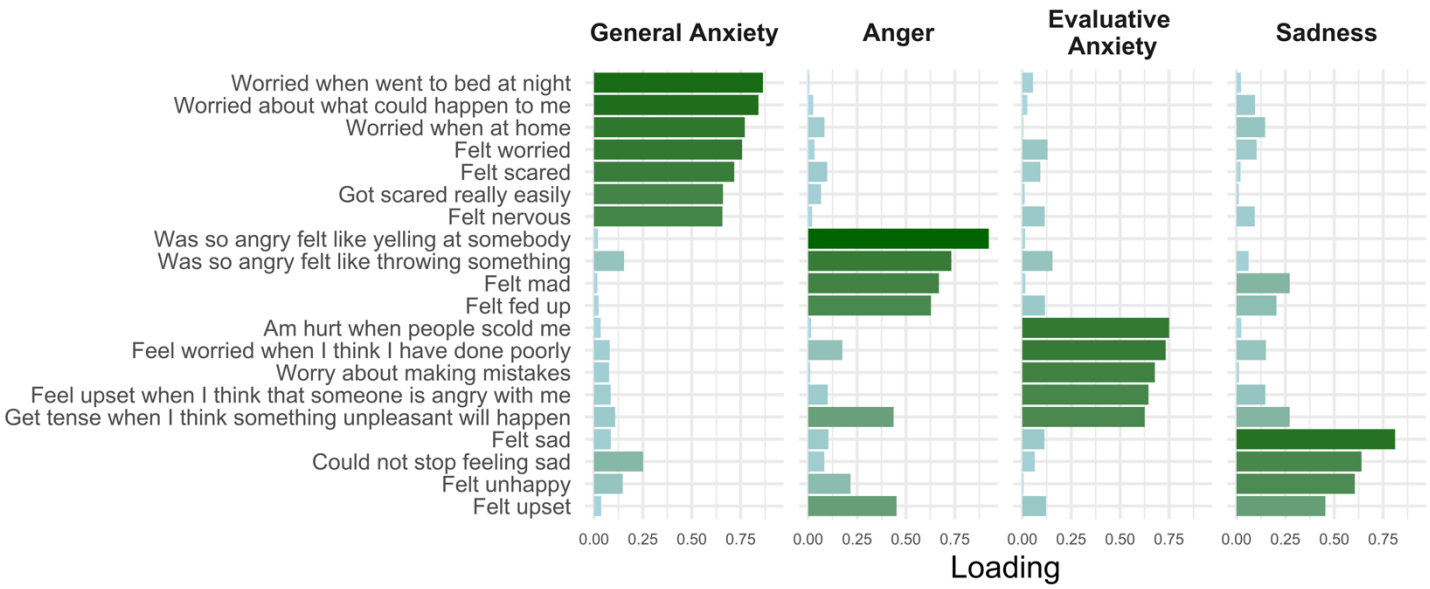
While *general anxiety*, *anger*, and *evaluative anxiety* each showed specificity in their relationships to the outcome domains, *sadness* was globally related to all social functioning domains and to life satisfaction. While previous work does not comprehensively cover the sadness-functioning relationships investigated in this study, the relationships observed are overall consistent with previous work showing close links between sadness and functioning outcomes. For example, in a study examining adolescents' perceptions of loneliness, loneliness was positively associated with feelings of sadness (Buchholz & Catton, 1999). In addition, the severity of depression symptoms, which is linked to experiences of sadness in adolescence (Chaplin, 2006), is strongly negatively correlated with life satisfaction (Headey et al., 1993). As with *general anxiety*, *sadness* declines slightly until around the transition to adolescence and then increases robustly during adolescence. Similar to *general anxiety*, this may be due to normative developmental differences in the cause and type of sadness experienced, especially in the context of changing social contexts (i.e., sadness from parents vs. sadness from peers or romantic relationships). However, our data cannot inform the cause for the observed age-related differences, and future research is needed to identify potential underlying mechanisms. We additionally find that *sadness* begins a period of particularly accelerated change at 14.7 years of age, which coincides with the median age of onset for any Diagnostic and Statistical Manual (DSM-IV) disorder (Kessler et al., 2005). These findings encourage translational research that investigates whether causal links exist between increasing sadness during mid adolescence and the onset of mental illness.

Four limitations of the current study should be acknowledged. First, the data used in the current study are cross-sectional, which limits the inferences on the processes underlying the observed age-related changes in different forms of negative affect. A longitudinal design is needed to examine within-person changes in affect across adolescence, which could help identify emotion-related risk factors for the development of psychopathology. Second, the forms of negative affect observed were naturally limited by the range of items input to the EFA. While the items available in the current sample covered core affective categories such as anger, sadness, and fear, they did not include negative emotions such as guilt, embarrassment, or shame. Future studies should include a wider range of negative affect items to identify any additional existing forms of negative affect and their specific relationships to daily functioning. In addition, while we focused on affective experience, emotions are complex mental constructions that include additional levels that should be explored and characterized in adolescent samples (e.g., physiological responses, facial expressions, appraisals). Third, the data assessing associations between affect, social functioning, and life satisfaction are inherently correlational. Indeed, the emotional and social world of an adolescent is complex and the relationships between affective experiences, social functioning, and life satisfaction are likely bidirectional. Future work using experimental designs or longitudinal data with lead-lag analyses could permit more precise interpretations on the directionality of influence. Fourth, because participants age 18+ were administered different items from children and adolescents, these older ages were not examined in the current study. Given the observed changes in negative affect toward the end of the adolescent age range studied and recent work suggesting mood disorders peak in early adulthood (Solmi et al., 2021), future research is needed to explore the age-related changes in forms of negative affect across this adolescent to adulthood transition.

One additional promising area for future research is to investigate how qualitatively distinct forms of negative affect relate to brain connectivity in youth samples. Extensive research has shown that resting state and task-based functional connectivity is related to emotional processes in adolescent samples (Stevens, 2016 for review). However, little work has studied how qualitatively different negative affect states relate to connectivity profiles. Previous studies in adult samples suggest that distinct affective states have dissociable neural signatures (Petrican et al., 2015; Weathersby et al., 2019), but this should be investigated in developmental samples.

Conclusion

In this study we identified qualitatively different forms of negative affect in a developmental sample, and explored their relationship with social functioning, life satisfaction, and age. Results suggested that different forms of negative affect have distinct age-related changes and distinct associations with functioning outcomes, cautioning against studying negative affect as a singular concept and highlighting the importance of studying negative affect in this fine-grained way in youth samples. These findings motivate translational research to elucidate relationships between discrete negative affect forms and risk for psychopathology.



Figures

Figure 1. EFA loading plot. The absolute values of the loadings are plotted, sorted by loading strength. Higher loading strengths are depicted by larger values on the x-axis and a darker green color. Items submitted to affect factor analysis are paraphrased on the left; the full items are available in the Supplementary Materials.

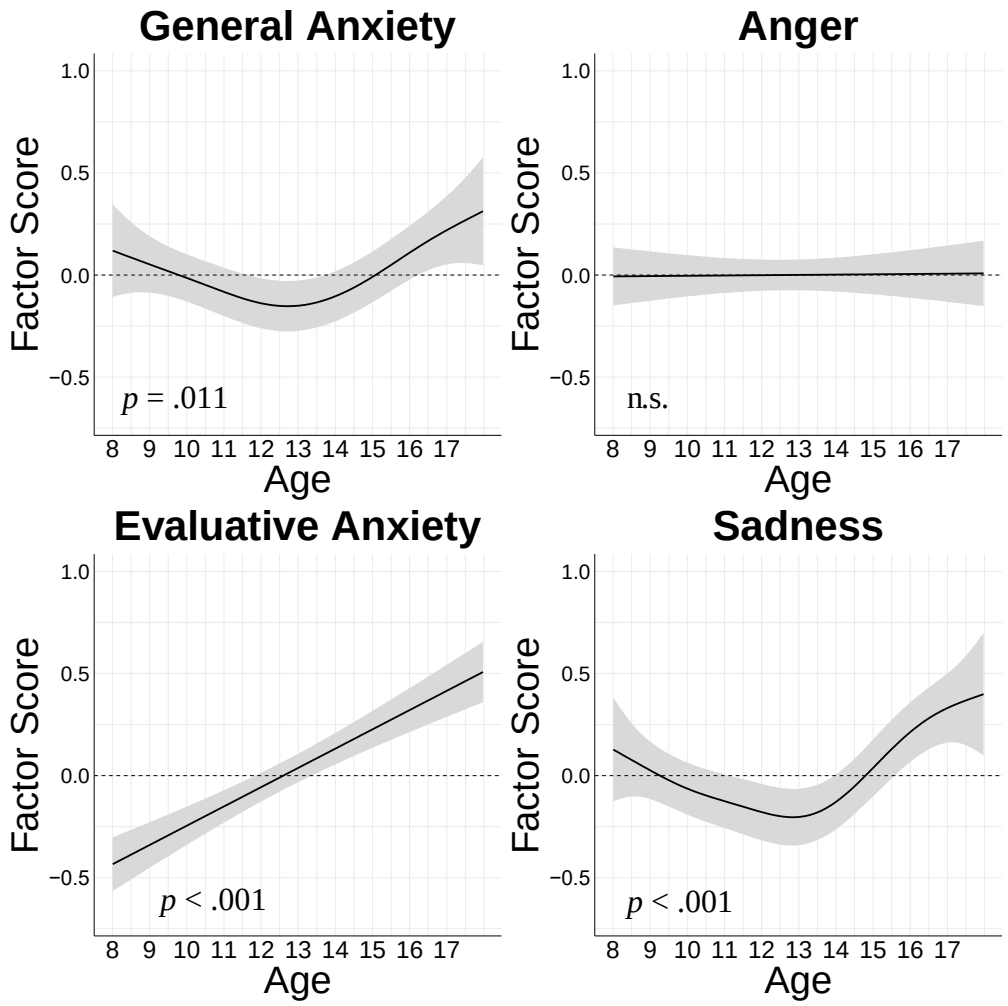


Figure 2. Age-Related Changes in Negative Affect Experience. Solid black line depicts linear or non-linear model fit. Grey shaded region depicts 95% confidence interval. Red shaded region represents the window of accelerated change in the GAM. Y-axis units are factor scores.

Tables

Table 1. Results of linear models for social functioning and life satisfaction dependent variables.

Dependent variable	Independent variables	Coef	95% CI	t-score	df	p-value	Corrected p-value
Emotional Support	**General Anxiety**	**-0.16**	**[-0.26, -0.06]**	**-3.15**	**763.06**	**.002**	**.024**
	Anger	-0.06	[-0.14, 0.03]	-1.30	763.06	.194	.972
	Evaluative Anxiety	0.07	[-0.01, 0.14]	1.77	763.06	.077	.536
	Sadness	**-0.16**	**[-0.24, -0.07]**	**-3.50**	**763.06**	**<.001**	**.007**
Friendship	General Anxiety	-0.04	[-0.14, 0.06]	-0.82	763.04	.412	1.000
	Anger	-0.09	[-0.18, 0.00]	-2.00	763.04	.046	.447
	Evaluative Anxiety	-0.02	[-0.10, 0.05]	-0.55	763.04	.583	1.000
	Sadness	**-0.21**	**[-0.30, -0.12]**	**-4.64**	**763.04**	**<.001**	**<.001**
Perceived Hostility	General Anxiety	0.08	[-0.01, 0.16]	1.65	763.14	.100	.601
	Anger	**0.34**	**[0.26, 0.41]**	**8.63**	**763.14**	**<.001**	**<.001**
	Evaluative Anxiety	0.08	[0.01, 0.14]	2.32	763.14	.021	.247
	Sadness	**0.15**	**[0.07, 0.23]**	**3.78**	**763.14**	**<.001**	**.003**
Loneliness	General Anxiety	0.08	[0.00, 0.17]	2.00	764.00	.046	.447
	Anger	0.07	[0.00, 0.14]	2.01	764.00	.045	.447
	Evaluative Anxiety	**0.14**	**[0.08, 0.20]**	**4.36**	**764.00**	**<.001**	**<.001**
	Sadness	**0.47**	**[0.40, 0.55]**	**12.75**	**764.00**	**<.001**	**<.001**
Perceived Rejection	General Anxiety	0.12	[0.04, 0.21]	2.75	761.80	.006	.080
	Anger	**0.23**	**[0.15, 0.30]**	**5.88**	**761.80**	**<.001**	**<.001**
	Evaluative Anxiety	0.08	[0.01, 0.14]	2.27	761.80	.023	.258
	Sadness	**0.28**	**[0.20, 0.36]**	**6.99**	**761.80**	**<.001**	**<.001**
Life Satisfaction	General Anxiety	0.03	[-0.09, 0.14]	0.46	535.60	.648	1.000
	Anger	**-0.22**	**[-0.32, -0.12]**	**-4.46**	**535.60**	**<.001**	**<.001**
	Evaluative Anxiety	0.02	[-0.06, 0.10]	0.44	535.60	.657	1.000
	Sadness	**-0.28**	**[-0.38, -0.18]**	**-5.39**	**535.60**	**<.001**	**<.001**

Note: Coef: standardized regression coefficient; CI: Confidence Interval. P-values were corrected using the Holm method (6 total regressions each with 4 affect factors = 24 total tests) and were compared to an alpha level of .05 to determine significance. Bold text indicates significant models. Spline age was controlled for in all models.

Table 2. Results of linear and thin plate smoothing spline models for each dependent variable assessing age related change.

Dependent variable	Model	AIC	p-value	Corrected p-value
General Anxiety	Linear	2256.15		
	Spline	**2246.26**	**.012**	**.021**
Anger	Linear	2274.06	.913	.913
	Spline	2274.06		
Sadness	Linear	2208.65		
	Spline	**2193.38**	**<.001**	**<.001**
Evaluative Anxiety	**Linear**	**2154.02**	**<.001**	**<.001**
	Spline	2154.02		

Note: Bold text indicates best fitting model for each dependent variable, as determined by AIC. AIC = Akaike Information Criterion. For spline models, p-value refers to approximate significance of smooth age terms. For linear models, p-value refers to significance of age coefficient. P-values were corrected using the Holm method and were compared to an alpha level of .05 to determine significance.

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