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Published in:
Emotion

DOI:
10.1037/emo0000970

Emotion dynamics in children and adolescents: A meta-analytic and descriptive review

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Public significance statement: This review synthesizes 102 studies and 689 estimates of emotion dynamic patterns in 19.928 children and adolescents. Adolescents reported more variable positive emotions and more intense negative emotions. Youth with mental health problems reported more variable and less intense positive emotions and more intense anxiety.

Emotion dynamics in children and adolescents: A systematic and meta-analytic and descriptive review

Abstract

Theories on children and adolescents emotion dynamics were reviewed using data from 102 ecological momentary assessment studies with 19.928 participants and 689 estimates. We examined age-graded differences in emotional intensity, variability, instability, inertia, differentiation, and augmentation/blunting. Outcomes included positive versus negative affect scales, discrete emotions (anger, sadness, anxiety, and happiness), and we compared samples of youth with or without mental or physiological problems. Multi-level models showed more variable positive affect and sadness in adolescents compared to children, and more intense negative affect. Our additional descriptive review suggests a decrease in instability of positive and negative emotions from early to late adolescence. Mental health problems were associated with more variable and less intense positive affect, and more intense anxiety and heightened sadness variability. These results suggest systematic changes in emotion dynamics throughout childhood and adolescence, but the supporting literature proved to be limited, fragmented, and based on heterogeneous concepts and methodology.

Keywords: Emotional intensity, emotional variability, emotional instability, emotional inertia, emotion differentiation.

Emotions are key concepts to understand the human condition and most psychological phenomena. Functionally, emotions are dynamic and contextualized processes that enable humans to appraise and act on changes in their (internal or external) environment that are relevant to their well-being (Cole, 2015; Frijda, 2007; Larsen, 2000; Scherer, 2009). Emotions serve as windows into the psychological impact of events in our lives, our needs, and as markers of mental health (Rosenblum & Lewis, 2003; Saarni, 1999). The development of competent emotion functioning, including the expression, understanding, and regulation of emotions, is one of the most critical tasks of childhood and adolescence (Barrett, Lewis, & Haviland-Jones, 2016; Cole, 2015; Saarni, 1999).

Individuals who show similar average emotions levels can differ considerably in how their emotions fluctuate during the day (Fisher, Medaglia, & Jeronimus, 2018; Larson & Lampman-Petraitis, 1989). The emotion literature has become increasingly focused on such patterns of emotional change in the hope that this pursuit of *emotion dynamics* improves our understanding of well-being and psychopathology (Houben et al., 2015; Kuppens et al., 2012; Silk et al., 2011). One important avenue is an improved understanding of how emotion dynamics unfold over childhood and consolidate in adolescence to create a basis for our social and psychological well-being and psychopathology throughout the lifespan (e.g., Barrett et al., 2016), as these trajectories remain unclear. Emotional experiences in adolescence were recently reviewed by Bailen et al. (2019), although this review took a descriptive approach and did not focus on short-term emotional changes in daily life. Using a meta-analytic approach, Houben et al. (2015) showed that adult emotion dynamic patterns associate with variance in psychological well-being and mental health. Findings from both reviews are discussed in detail below.

This paper provides a meta-analytic review of emotion dynamic patterns in children and adolescents and estimates age differences in (a) the most studied emotion dynamic measures (as outlined in Table 1), and specifically between (b) emotions with a positive versus negative affective valence and (c) the discrete emotions anger, anxiety, sadness, and happiness. Additionally, (d) we compare emotion dynamics between different population groups such as typically developing youth versus those with mental or physiological problems. These results may improve our understanding of the development of emotion dynamic patterns and how they connect to health and well-being. Finally, we summarize methodological concerns and suggest new angles for future research.

Emotion Dynamics

Emotion researchers have proposed several patterns or parameters to describe emotional changes over time (see Houben et al., 2015; Krone et al., 2018; Kuppens & Verduyn, 2017; Trull, Lane, et al., 2015). Emotion dynamics have been defined as "trajectories, patterns, and regularities with which emotions, or one or more of their subcomponents (such as experiential, physiological, or behavioral components) fluctuate over time, their underlying processes, and downstream consequences" (Kuppens, 2015, p. 298). Emotion dynamics pertain the relationships between various constituent components of the emotions that we experience and whether our mental state remains stable or changes under influence of forces inside or outside our body (e.g., Barrett, 2018; Bunge, 2003, p. 35; Von Bertalanffy, 1968). Emotion dynamic patterns are therefore a unique source of information on interactions between the building blocks of psychological functioning and the flexibility, vulnerability, and regulative capacity of our emotion systems (Kunnen et al., 2019).

Momentary emotional change is best captured in intensive longitudinal data using ambulatory methods including ecological momentary assessment (EMA, Shiffman et al., 2008) and experience sampling (Csikszentmihalyi & Larson, 1987). Ambulatory methods limit the retrospective bias inherent to emotion assessments via standard (cross-sectional) questionnaires or interviews, as memories of past experiences are colored by individual differences and current emotional states (Shiffman et al., 2008; Solhan et al., 2009). Additionally, repeated assessments of participants during their daily lives boosts ecological validity (Shiffman et al., 2008) and enables researchers to track dynamic patterns in emotions and other psychophysiological states *within* individuals (Fisher et al., 2018). This review therefore covers studies with repeated emotion assessments of children and adolescents during daily life.

EMA studies predominantly measured emotions using self-reported item scores that are aggregated into broad scales of positive and negative affect (PA/NA), each composed of emotion items that are similar in valence (i.e., positive and negative) but often differ in terms of arousal level and underlying appraisals, such as Watson et al.'s (1988b) Positive and Negative Affect Schedule (PANAS). This complicates the comparison of studies that used scales composed of different items (see Harmon-Jones et al., 2016, for a discussion on this issue). Moreover, aggregated affect scales might show temporal patterns that differ from trajectories of the single emotions they comprise (e.g., Verduyn et al., 2015). The current review therefore focuses both on aggregated scales (PA/NA) and the most commonly studied single or discrete emotions separately (i.e., anger, anxiety, sadness, and happiness).

Emotion Dynamics and Youth's Psychological Health

Emotional functioning, and emotional dynamics in particular, plays a central role in normative psychological development and youth functioning (e.g., Saarni et al., 1999). For example, a toddler who is fearful of a new childcare worker at a child care center may avoid being in this worker's presence to reduce anxiety. Emotional functioning may become maladaptive, however, when it impedes healthy development and long-term well-being. Extreme patterns of emotional change may indicate maladaptive emotional responding and regulation, which may eventually cascade into psychopathology (Borsboom & Cramer, 2013; Kuppens, Allen, & Sheeber, 2010; Rutter et al., 2011; Wichers et al., 2015). Psychopathology is often episodic, and – as is true for emotional responding and regulation – considering the aspect of time and timing is therefore important when trying to understand its nature and development. Several studies in adolescents and adults have shown that particular emotion dynamic patterns and intra-individual changes therein precede changes in well-being and psychopathology (e.g., Jeronimus et al., 2019; Kuppens et al., 2007, 2012; van de Leemput et al., 2014; Wichers, Groot et al., 2016). These interconnections are subject of a rudimentary but burgeoning literature which falls outside the scope of this review.

Emotion Dynamic Patterns

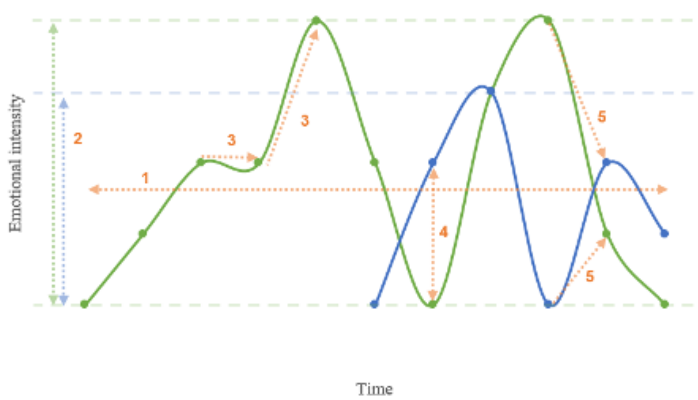
Emotion dynamic patterns are often studied as stationary processes which assumes stability over time (Houben, Ceulemans, & Kuppens, 2020). The simplest pattern is that of a single emotion across time but the interconnected behavior of multiple emotions can also be studied. In this paper we focus on the most prominent and studied emotion dynamic patterns: emotional intensity, variability, instability, inertia, differentiation, and augmentation/ blunting (see Table 1). Below we first introduce their methodological conceptualization, rationale, and potential developmental trajectories.

Table 1
Definitions of emotion dynamic concepts, their components, and their occurrence in the literature on children and adolescents

Emotion or component	Emotion dynamic feature	Definition	Calculation (within-person)	Ref
Single variable	Intensity	Average intensity across time	Mean (*M*) of emotion or component scores across time	a, c
	Variability	Overall amplitude/ range of fluctuations	Standard deviation (*SD*) or variance	a-c
	Inertia	Temporal dependency, or tendency to carry over from moment-to-moment	Autocorrelation; autoregressive coefficient	a-c
	Instability	Magnitude of moment-to-moment fluctuations	Mean squared successive difference (*MSSD*) scores; Probability of acute changes (*PAC*)	a-c
Multiple variables	Augmentation and blunting	Degree to which current emotion increases (augments) or decreases (blunts) another	Cross-lagged correlation or regression estimate between emotions across time	a-c
	Differentiation or granularity	Degree of covariation of emotions across time	Average cross-correlations across time; Intraclass correlation coefficient (*ICC*) across time; *ICC* for each measurement occasion across variables	a-c

Note. A detailed description of each emotion dynamic is provided in the introduction. References: a= Krone et al., 2018; b= Kuppens et al., 2015; c= Houben et al., 2020. In total we report on 689 estimates of emotion dynamic parameters, see Table 2 and Table S3 for details.

Figure 1.
Graphical representation of five emotion dynamic characteristics



Note. Graphical representation of five emotion dynamic characteristics that describe the trajectories of emotion X in green and emotion Y in blue over time: (1) Emotional intensity or time average, (2) Emotional variability, (3) Emotional inertia, (4) Emotional covariation, and (5) Emotional cross-lags. Detailed descriptions of each emotion dynamic characteristic is provided in the introduction of the review.

Emotional Intensity

Emotional intensity captures the strength of an emotion over a protracted period of time and reflects how strong someone experiences an emotion on average. Individuals can experience certain emotions at a higher intensity level than other emotions (a *within*-person difference) or more intensely than other people do (a *between*-person difference). Intensity is the least dynamic characteristic of emotional experience and is typically communicated as the vertical position of a time series (see Figure 1, characteristic 1).

Intensity has often been studied in cross-sectional or panel studies. EMA studies using bipolar response scales that range from positive to negative (e.g., from 'happy' to 'sad') suggest that average emotional states become less positive as children navigate towards early adolescence (Larson et al., 1989, 2002; Moneta et al., 2001), and that this trend levels out in late adolescence (Larson et al., 2002; Moneta et al., 2002). Nowadays PA and NA are increasingly operationalized as relatively independent emotion dimensions (Russell & Carroll, 1999; Watson et al., 1988a; but also see Dejonckheere et al., 2018), and studies using this unipolar approach suggest that PA intensities decrease across adolescence whereas NA intensities remain stable (Weinstein et al., 2007). A descriptive review of mainly cross-sectional and panel studies of adolescents concluded that positive emotional intensity declines across adolescence, whereas negative emotional intensity remains stable (Bailen et al., 2019).

Studies of the developmental trajectories of discrete emotions evidence a linear increase in depressed mood and sadness from late childhood to late adolescence, whereas anxiety seems to increase somewhat over middle and late adolescence only (e.g., Maciejewski et al., 2017, using EMA; van Oort et al., 2009, using cross-sectional data). Happiness, in contrast, seems to decrease linearly from late childhood to late adolescence (Maciejewski et al., 2017). Combined, these studies suggest an independent development of emotions with a positive versus negative valence, and decreases in happiness over adolescence.

This picture is in keeping with the rapid rise in the incidence of emotional disturbances and the first episodes of anxiety and depression disorders that typically develop over adolescence (Kessler et al., 2005; Rutter et al., 2011). Throughout childhood and adolescence, more intense PA has generally been linked to favorable outcomes, although very low and very high levels of PA can also be indicative of maladjustment and psychopathology (reviewed by Davis & Suveg, 2014; Gilbert, 2012). Very low NA intensity has been associated with insensitivity to context and risk-taking (Bentall, 1992; Herpertz & Sass, 2000), whereas high NA intensity predicts virtually all adverse outcomes (Jeronimus et al., 2016, 2019). Apparently there is an Aristotelian "Goldilocks zone" of adaptive emotion intensity. Understanding emotion dynamic patterns, however, requires measures of individual fluctuations around such average intensities.

Emotional Variability and Instability

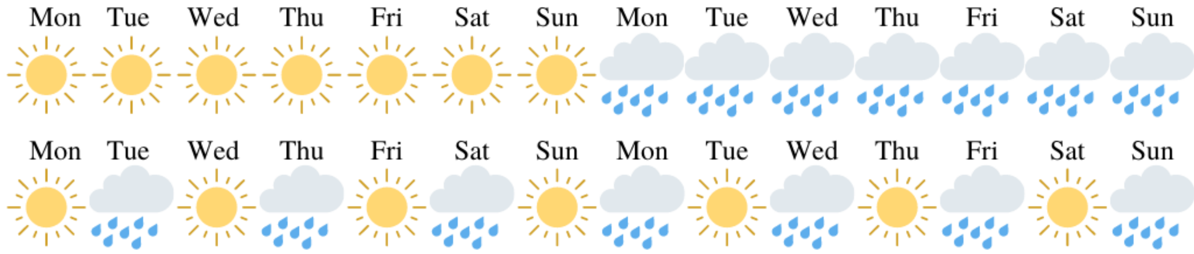
The transition from childhood to adolescence is characterized by a number of important physical, cognitive, and social changes, which are often thought to increase emotional variability (e.g., Arnett, 1999; Buchanan et al., 1992; Steinberg, 2005). Emotional variability is commonly defined as the range of fluctuations around an individual's average emotional intensity, operationalized as the intra-individual standard deviation (*ISD*) or variance (see Figure 1; e.g., Jongerling et al., 2015).

The limited EMA research on developmental changes in emotional within-person variability suggests more variability over early adolescence followed by more stability over mid-adolescence (Larson et al., 2002) and more pronounced changes in girls (Larson & Lampman-Petraitis, 1989; Weinstein & Mermelstein, 2013). Higher PA and NA variability associate with lower psychological well-being and more mental health symptoms in both youth (Silk et al., 2003; Van Roekel et al., 2017) and adults (Houben et al., 2015) and predict the development of anxiety and depression over adolescence (Neumann & van Lier et al., 2011).

Emotional variability captures the general dispersion of emotional intensity but an estimate of *instability* also requires information on the temporal dependency of such fluctuations (Ebner-Priemer et al., 2009; Jahng, Wood, & Trull, 2008; Trull et al., 2015). Although some studies treat emotional variability and instability as interchangeable constructs (e.g., Bailen et al., 2019), emotional instability refers to high variability *combined* with a low level of temporal dependency (see Figure 2; Jahng et al., 2008). Moment-to-moment changes in emotional intensity scores can be expressed with Mean Squared Successive Difference scores (MSSDs; von Neumann et al., 1941; see Table 1) or Mean Absolute Successive Difference scores (MASDs or Gini (1912) mean differences), which are unaffected by trends in the data (Philips et al., 2014). Alternative and less often used operationalizations include the probability of acute change (PAC; Jangh et al., 2008), spectral density functions (Larsen, 1987), or dynamic system topologies (Butner et al., 2014; Kunnen et al., 2019).

Emotional instability plays a role in the development of most kinds of psychopathology in the Diagnostic and Statistical Manual of Mental Disorders (5^{th} ed. [DSM-5], American Psychiatric Association [APA], 2013) and is a hallmark of many disorder definitions, such as borderline personality disorder, which typically emerges over adolescence (De Clercq et al., 2014). Higher emotional instability was found to be indicative of lower psychological well-being in adults (Houben et al., 2015) and in children and adolescents with more internalizing and externalizing mental problems (Cole & Hall, 2008). However, repeated momentary assessments in youth populations remain scarce (e.g., Morgan et al., 2017; Silk et al., 2011). A synthesis of empirical studies on youth's emotional variability and instability in different age and population groups may provide insights into normative and deviant developmental trajectories.

Figure 2.
Schematic representation of two weather patterns illustrating the difference between variability and instability



Note. Both weather patterns show similar levels of variability but a low (upper panel) versus high (lower panel) level of instability. This figure was inspired by Ebner-Priemer et al. (2009), p. 196.

Emotional Inertia

Dependency scores of emotion components over time capture the extent to which one's current emotional state predicts future states (Jongerling et al., 2015; Koval et al., 2015; Kuppens et al., 2010, 2012). High predictability or temporal persistence is known as emotional inertia, which indicates that emotions are resistant to change (Suls et al., 1998; see Figure 1). Inertia is often expressed as the autocorrelation or autoregressive coefficient (see Table 1) which capture temporal dependencies (but not the amplitude of fluctuations; Ebner-Priemer & Sawitzki, 2007).

High emotional inertia may indicate cognitive inflexibility and psychological maladjustment (Hollenstein, 2015; Kuppens et al., 2010) and features in the definition of mood disorders, schizotypy, and autism (DSM-5). The normative development of emotional inertia across childhood and adolescence has not been studied. In adults, PA and NA inertia have typically been associated with lower well-being and maladjustment (Houben et al., 2015), but in some context, PA inertia can also predict recovery (Heller et al., 2009; Höhn et al., 2013). High emotional inertia in children or adolescents might reflect an early form of emotional dysregulation and a vulnerability for the development of psychological problems (Kuppens et al., 2012).

Emotion Differentiation

Emotion differentiation quantifies the ability to describe emotional experiences with a high degree of specificity (Kashdan et al., 2015). Emotion differentiation or "granularity" is often operationalized as emotional covariance or dependencies and co-occurrences between multiple emotions. High emotional covariance can indicate that someone does not differentiate between various emotions beyond their general affective (un)pleasantness (Barrett et al., 2001; Kashdan et al., 2015). Emotion differentiation is typically captured using the intraclass correlation coefficient of a set of emotions, either between variables at one assessment (e.g., Tomko et al., 2015), or across assessments over time (e.g., Demiralp et al., 2012; Van der Gucht et al., 2018). Alternatively, the average within-person correlation between two emotions is used (e.g., Barrett et al., 2001).

Emotion differentiation can facilitate adaptive responding to environmental challenges, for example, via distinct emotion regulatory responses (Barrett et al., 2001; Kashdan et al., 2015; Tooby et al., 2010). Being able to label feelings as sad or afraid can already decrease the subjective intensity of these experiences (Lieberman et al., 2011). Higher emotion differentiation has been associated with higher well-being in adolescents and adults (Erbas et al., 2014; Kashdan et al., 2010; Lennarz et al., 2018), but emotion differentiation may also fluctuate within individuals over time (Erbas et al., 2021).

Little is known about the development of emotion differentiation in childhood. Previous experimental research on negative emotion differentiation showed a nonlinear (quadratic) trajectory with age (Nook et al., 2018), as differentiation decreases from childhood to early adolescence, but subsequently increases towards adulthood. High emotion differentiation in childhood may reflect difficulties to understand that one can experience multiple emotions simultaneously, as children tend to report experiencing emotions in a mutually exclusive fashion (Harter & Buddin, 1987; Wintre & Vallance, 1994). When older children understand that different emotions can co-occur, they show decreased emotion differentiation. Children also learn to distinguish a broader range of emotion concepts to give meaning to different situations, which explains the typical increase in differentiation with age and experience (Widen, 2016). Across adolescence and into adulthood emotion concepts become more refined and emotion differentiation typically increases again (Nook et al., 2017, 2018).

Emotion Augmentation and Blunting

Most people experience a sequence of different emotions throughout the day, and the intensity of each emotion can influence the intensity of subsequent emotions, either by increasing (augmenting) or decreasing (blunting) their future intensities (Pe & Kuppens, 2012; Winterich et al., 2010). This continuous interaction between emotions creates continuity in people's emotional lives and "could account for a host of everyday psychological phenomena in which our emotional experiences are aggravated or attenuated by how we respond to previous events" (Pe & Kuppens, 2012, p. 1320)". It has been hypothesized that substantial augmentation and blunting could indicate emotional maladjustment, via lower emotional responsiveness to external stimuli (Kuppens & Verduyn, 2015), which may prevent people to steer away of perilous places. Augmentation and blunting is operationalized as the prospective (cross-) lagged relationships or cross-regressive effects between emotions (Houben et al., 2020; Kuppens & Verduyn, 2017). Although patterns of augmentation and blunting have been studied in adults (e.g., Ernst et al., 2020), these development across childhood and adolescence and their underlying mechanisms remain largely uncharted territory.

Study Aims

To recapitulate, this systematic and multi-level meta-analytic review of emotion dynamic patterns in children and adolescents examines (a) age differences in emotional intensity, variability, instability, inertia, differentiation, and augmentation/ blunting for (b) emotions with a positive versus negative affective valence, and (c) the discrete emotions anger, anxiety, sadness, and happiness. Additionally, we compare differences (d) between different population groups such as typically developing youth versus those with mental or physiological problems. Finally, we examine (e) the number of assessments per participant per day as a predictor in our analyses. Assessment frequency can be a potentially relevant influence when analyzing multiple EMA studies because of the unknown time course of many emotional-cognitive processes underlying emotion dynamics (Ebner-Priemer et al., 2007). Multi-level models parceled variance over participant, outcome, and study levels. Data on age and population differences in specific emotion dynamics that did not suffice for statistical pooling were reviewed descriptively.

Methods

Search Strategy

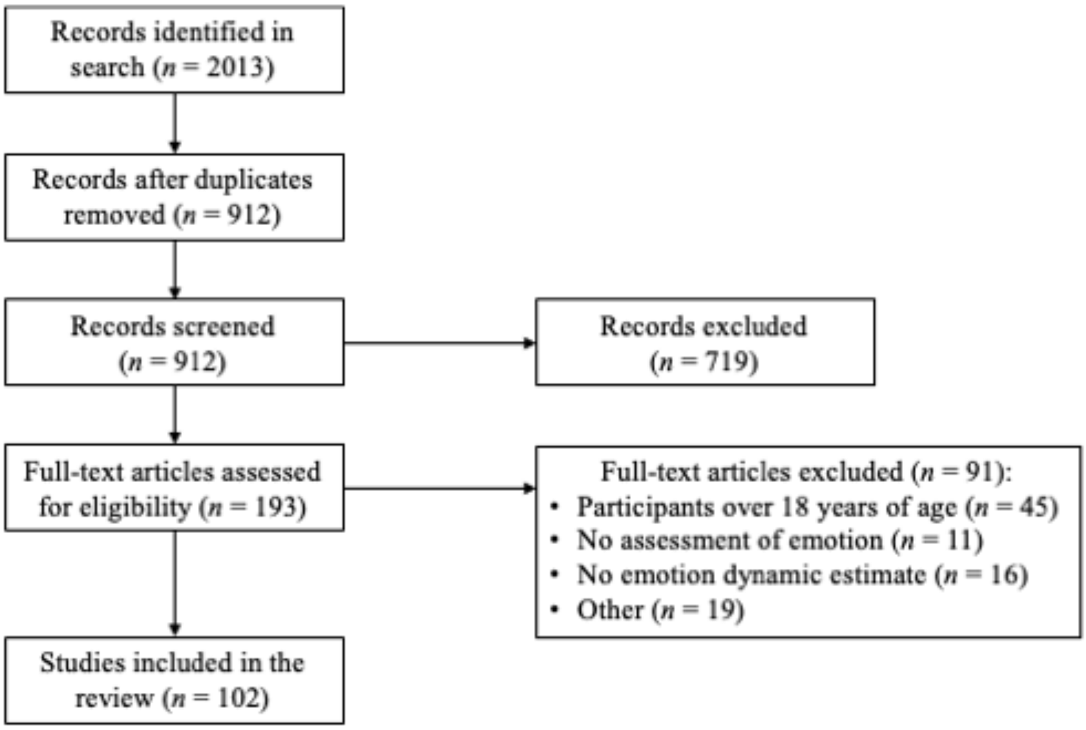
This systematic review followed the PRISMA (Moher et al., 2009) and MARS guidelines (APA, 2008). Peer reviewed studies with time-series data of emotions or related constructs in children and adolescents that reported on emotion dynamics were identified in a systematic literature search of the databases PsycInfo, Web of Science, and PubMed in September 2018. Our search string is provided in supplementary (S) Table S1 and included (a) mood, emotion, affect, or feelings, (b) emotion dynamic components (e.g., change, variability, covariation), (c) descriptor terms of EMA methodology, (d) indicators of youth (e.g., child, adolescent, teen), and (e) a string that excluded several words (e.g., genetic, genes, climate). This search yielded 912 papers and 1101 duplicates were removed. All papers and their references were screened using our inclusion criteria (see Figure 3 for the flowchart).

Included papers presented data from (a) empirical studies of (b) participant samples with a mean age below 18[1] and (c) self- or other-reported emotion constructs including affect, mood, arousal, stress, and psychological symptoms that (d) were reported over at least three consecutive time points with (e) a maximum measurement interval of one week. Furthermore, (f) estimates of at least one emotion dynamic had to be reported (see Table 1) and (g) the papers had to be written in English, Dutch, or German language. If two studies used an identical dataset, both were included only if they examined different emotion dynamics, and/or examined similar dynamics but with additional waves of data. Otherwise, only the most recent publication was included.

The requirement of three measurement waves (criterion d) excluded cross-sectional and test-retest studies and retrospective assessments of emotions. The one-week measurement interval requirement (criterion e) excluded studies of long-term changes, including follow-up assessments after an intervention[2]. This strategy mirrored the work by Houben and colleagues (2015) and captured studies that cover Kuppen's (2015) definition of emotion dynamics. All inclusion criteria were specified jointly by three reviewers. Subsequent selection was conducted by one reviewer (AM), and a third of these choices were checked by a second rater (BJ, *n*= 300, Cohen's kappa= .81). Disagreements were resolved by discussion among the three reviewers. This selection process resulted in 102 studies being included in the review.

[1] The inclusion of participant samples based on mean age below 18 means that some samples include participants aged 18 year or older.
[2] The requirement of three measurement waves and one-week measurement interval led us to exclude 178 papers in the initial abstract screen and full-text review.

Figure 3.
Flowchart adopted in this systematic review based on the PRISMA protocol



Data Collection Process

From the 102 included papers we extracted sample characteristics, data collection methods, and emotion dynamic measures. Extracted characteristics included the first author and publication year, sample size and type, mean age (*SD*) and range, and percentage (%) of women. Samples with a mean age of 9 years or younger were categorized as childhood, and those of 10 years and older as adolescent (World Health Organization [WHO], 2017). We categorized samples over five population types: (a) typically developing youth, (b) youth with internalizing mental health problems, including symptoms or a diagnosis of anxiety disorder, major depressive disorder, obsessive compulsive disorder, and bipolar disorder, or youth with (c) externalizing or other mental health problems, (d) physical health problems including diabetes or juvenile arthritis, and (e) other samples such as youth from high risk neighborhoods.

From each study we coded the emotion measure and number of items and answer categories (e.g., length of Likert scales), the assessment device, number of measurements per day, the recall period at each measurement (e.g., current, peak, past day or week), the prompt schedule, the length of the data collection in days, and the emotion dynamic construct (Table 1). An additional ‘other’ category was included for infrequently used measures, such as variance ratios and measures from recurrence quantification analysis (RQA, such as entropy, laminarity, and recurrence rate, see Kunnen et al., 2019).

Emotional intensity was retrieved via mean emotion scores across participants *(M)* and their associated between-person *SD*s. In several cases, we converted measures using formulas provided in Table S2, such as the standard error *(SE)* to a *SD*. The mean emotion scores and *SD*s were transformed onto a common scale that runs from 1-10. Emotional variability was retrieved as average intra-individual standard deviations *(ISD)* and the associated sample variance. The average *ISD*s had to be converted from the within-person variance in several cases, before being transformed to a 1-10 scale.

For emotional inertia, we retrieved the first-order autoregressive coefficient (*AR*). For emotion differentiation, the average within-person bivariate correlation or intraclass correlation coefficient (*ICC*) between emotions with similar valences were retrieved. A strong positive correlation between emotions with a similar valence indicates that such concepts are used in a non-specific way, whereas a weak (or zero) correlation or a strong negative correlation may indicate stronger differentiation (Barrett et al., 2016). The within-person *ICC* reflects an individual’s ratio of variability across assessments versus variability within assessments of ratings of similarly valenced emotions.

A conservative approach was used, insofar that only parameter estimates which were clearly intra-individual were included. Consequently, *SD*s for which it remained unclear whether these concerned estimates of between- or (average) within-individual variation were excluded. Several papers that reported on an emotion dynamic parameter did not provide an estimate, or only estimated the dynamic together with other predictors in one statistical model (e.g., an autoregressive coefficient in a multilevel regression model with more predictors). Fourteen authors were contacted to requests such missing 'raw' emotion dynamic estimates, and six authors (43%) provided this information (see Table S3).

Statistical Analyses

For each emotion dynamic parameter we aimed to examine differences across (a) mean sample age and (b) between different populations in terms of (i) positive affect and (ii) negative affect dimensions, and for emotional episodes of (iii) anger, (iv) anxiety, (v) sadness, and (vi) happiness specifically. To minimize error introduced by statistical dependencies between estimates from single samples (Maciejewski et al., 2017; Rusby et al., 2012), estimates across different measurements bursts were pooled, such as daily and weekly fluctuations, or weekly fluctuations at three different measurement bursts. When the low number of estimates for an emotion dynamic or highly heterogeneous methodology did not allow for a statistical analysis, the differences between age groups and populations were reviewed descriptively.

Because dependencies between subgroup estimates from single samples can decrease error estimates - such as typically developing versus clinical youth, we fit multilevel models to estimate variance components (a) between all estimates at level one – which reflect differences in *SD*s around the estimates due to sample size and random sampling variance, (b) between estimates from single studies at level two (i.e., dependencies within studies), and (c) variance due to methodological differences between studies (e.g., in terms of measurement scales) at level three (cf. Houben et al., 2015; Hox, 2002; Van den Noortgate et al., 2013). This model allows effect sizes to vary between participants (level 1), outcomes (level 2), and studies (level 3). Each of the variance components was divided by the total amount of variance to derive a proportional estimate (Assink & Wibbelink, 2016). The importance of these variance components was tested using a likelihood ratio test of difference in deviance score between a model including all variance components and a restricted model, using the chi-square distribution.

Separate three-level mixed effects models were fitted to examine the linear relationship between emotion dynamics and age, differences in estimates between population types, and variation due to assessment frequency (i.e. number of assessments per participant per day). To examine non-linear associations, second-order and third-order polynomial regression models were fit[3]. Due to family-wise inflation, we only interpreted estimates that were significant at $p<.01$ (two-sided). As outlined, data on age and population differences in specific emotion dynamics that did not suffice for statistical pooling were reviewed descriptively. Datasets and scripts are available at https://osf.io/ebs6k/?view_only=4c93f751babe46a393d380d56b0921df

Missing data. Emotional intensity estimates for which the *SD* was missing were omitted from the analyses.[4] Because average *ISD* associated sample variances were missing in 17 studies we calculated sample variance from the reported standard error (*SE*) or imputed the average variance using all estimates of a similar construct assessed at a similar sampling frequency.

Publication bias. Publication bias was examined using funnel plots of estimates against their standard errors based on empty random-effects models (i.e., not including moderators). Plot symmetry was examined visually, via Duval & Tweedie's trim-and-fill

[3] These models were all statistically insignificant (all *p*'s <.05) and results are available from the first author upon request.
[4] Imputation of these missing values, by taking the average *SD* of other estimates of the same construct (e.g., negative affect) assessed at a similar sampling frequency (e.g., current affect), led to an extreme decrease in between-study level variance, which would invalidate statistical inferences.

method (2000) to estimate the number of missing studies, and using a regression test for funnel plot asymmetry (Egger et al., 1997).

Results

In total, 102 papers with 689 estimates (henceforth *k*) based on 19.928 participants were included (see Table 2 and Table S3), covering a total period of 29 years of EMA studies. Below we review the commonalities and differences in study methodology, and the role of age and population type in our meta-analytic estimates of emotional intensity, variability, and instability. Data scarcity impeded reliable aggregated estimates of emotional inertia, differentiation, and augmentation/ blunting, and these dynamics are therefore reviewed descriptively.

Most studies reported on emotional intensity and variability (see Table 2 and Table S3). Estimates of emotional inertia and instability were scarce. One study specifically examined emotion differentiation using average within-person *ICC*'s, although average within-person correlations (i.e., between two emotions) were reported more frequently in the context of other analyses (*k*= 38). While emotional augmentation/ blunting features in the adult emotion dynamic literature, these processes have apparently not been studied in children and adolescents, beyond cross-lag relationships between an emotion construct and a non-affective construct such as sleep (e.g., Cousins et al., 2011). Furthermore, some studies reported estimates that did not fit our categories, such as ratios between positive and negative affect (PA/NA) over time (e.g., Forbes et al., 2012; Silk et al., 2011), or estimates derived through recurrence quantification analysis (e.g., Rosen, Epstein, & Van Orden, 2013).

Most studies (64%) assessed dimensions of PA and NA. Fewer studies examined discrete emotions, and when they did, these emotions varied as we encountered 60 distinct emotional constructs. Most emotion constructs were operationalized using a scale by summing multiple items, typically unipolar scales (e.g., “not at all sad” to “very sad”, about 84%). Sometimes bipolar scales were used that ran from negative to positive such as “extremely bad/ negative mood” to “extremely good/ positive mood” (see Rabbits et al., 2014). Studies also differed markedly in their sampling protocol and format (e.g., paper and pencil versus electronic devices), assessment contingencies (e.g., fixed versus random sampling scheme), and sampling frequency (ranging from not even daily up to 30 times per day). Sampling differences can influence study results via the extent to which participants have to rely on memory (e.g., past day versus current experience), the study burden as high assessment frequency may lead to missing data, and construct differences as current affect requires highly frequent sampling schemes versus more stable daily or general mood (Jeronimus, 2019). The present review aimed to account for most methodological differences via the selection of the results we chose to pool and the strategies we outlined in the method section.

Table 2
Number of studies and estimates for each emotion dynamic

Measure		Total	%[a]	PA	NA	Anger	Anxiety	Sadness	Happiness
Intensity	N	74		25	31	15	18	14	11
	K	313	45%	36	48	19	23	19	14
Variability	N	27		8	7	7	5	7	2
	K	179	26%	10	9	9	5	9	3
Instability	N	13		2	2	5	5	5	5
	K	93	14%	3	4	12	15	15	12
Inertia	N	10		4	2	1	3	2	1
	K	35	5%	5	4	6	9	7	1
Differentiation	N	4		1	1				
	K	69	10%	1	1				
Augmentation and blunting	N	0							
	K	0							

Note. Multiple estimates could be derived from most studies, [a] Percentage of total number of included estimates, covering both unipolar and bipolar response scales (*K*= 689), *K*= number of estimates of each dynamic; *N*= number of studies; *NA*= negative affect; *PA*= positive affect. See Table 1 for definitions of all emotion dynamic parameters.

Meta-Analytic Data Pooling: Differences by Age and Population

Emotional intensity. Emotional intensity was measured using unipolar rating scales in 68 studies with 294 estimates. The distribution and significance of the within- and between-study variances in emotional intensity estimates are shown in Table S4A and B. Because early childhood was covered with only ten estimates, and previous studies suggested nonlinear developments in emotional intensity across childhood and adolescence (Larson et al., 2002; Moneta et al., 2002), we also report differences over adolescence specifically (i.e., 10 years and older).

Age. PA intensity seems to decrease with age (see Figure 4A) whereas NA intensity appears to increase (see Figure 4B) although this was only significant for NA (Table 3; for adolescents only Table S5). The intensity of anger, anxiety, as well as happiness was similar across age groups (Table 3; for adolescents only Table S5). A trend towards increasing sadness intensity across adolescence can be seen in Figure 4E but was not statistically significant across the entire age range (Table 3). A small increase in sadness intensity over adolescence was observed in the secondary analyses (0.26 point per year, on a 10-point rating scale, 95% Confidence Interval or *CI*= [0.01 to 0.51], $t_{(16)}$= 2.23, *p*= .04, see Table S5).

Population. Comparing population groups showed higher PA intensity in typically developing youth (*M*= 6.32, [5.95 to 6.69]) than in youth with internalizing mental disorders (*M*= 5.39 [4.93 to 5.85]) or physical problems (*M*= 4.88 [3.79 to 5.97]; see Figure 4A and Table 3). NA intensity was equivalent across population groups, except for a trend towards increased NA intensity in typically developing youth (see Figure 4B and Table 3), and equal across different assessment frequency schedules (see Table 3). Youth with internalizing mental disorders reported significantly higher anxiety intensity (*M*= 4.18 [3.02 to 5.34]) than typically developing youth (*M*= 2.49 [2.13 to 2.84], see Table 3 and Figure 4D). The intensity of anger, sadness, and happiness did not differ between population groups.

Table 3.

Results of the three-level mixed-effects models for intensity of positive affect, negative affect, anger, anxiety, sadness, and happiness

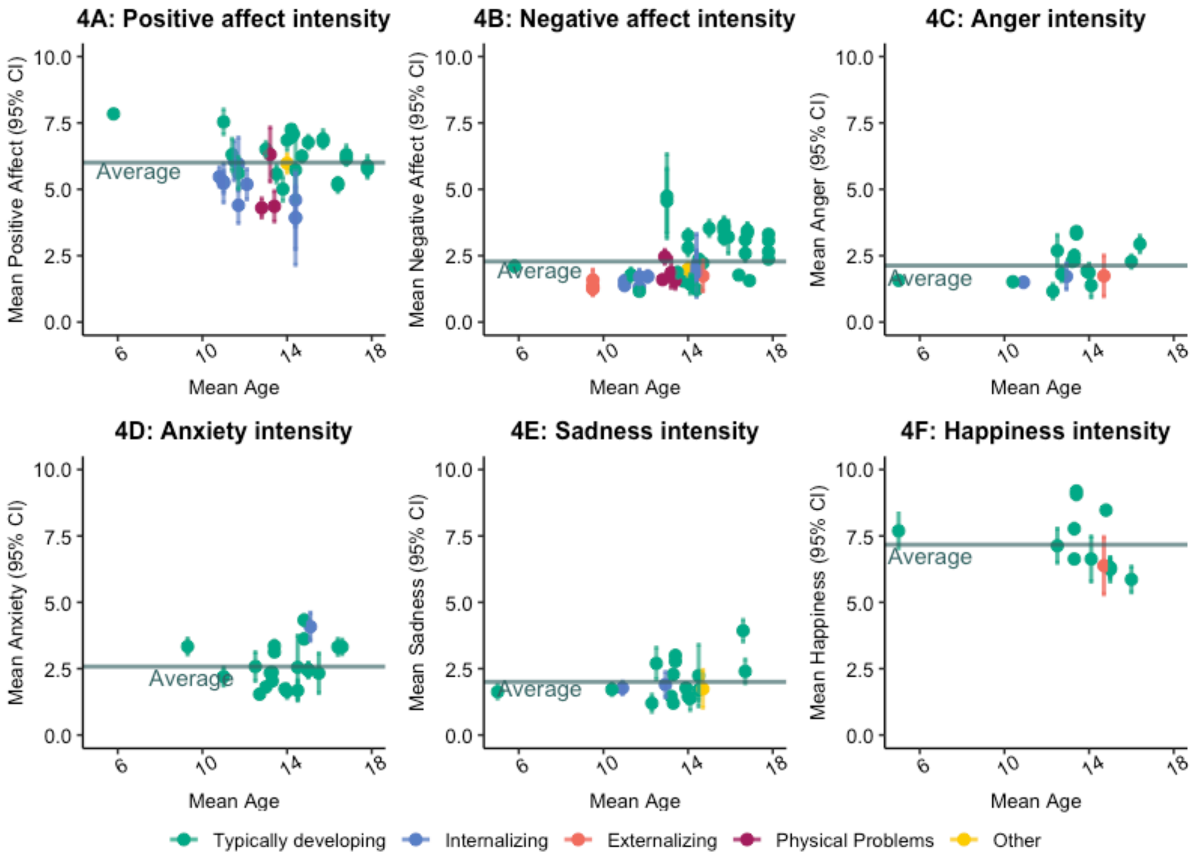
Model		Moderator	N	K	β_0	β_1	95% CI	Test statistic	*p*
1	**PA**	*Empty model*	25	36	**6.00*****		**5.60 to 6.40**	**$t_{(35)}$= 30.55**	**<.001**
2		Age	25	36	**6.84*****		**4.56 to 9.11**	**$t_{(34)}$= 6.11**	**<.001**
						-0.06	-0.22 to 0.10	$t_{(34)}$= -0.75	.46
3		Population	25	36				**$F_{(3, 32)}$= 7.59*****	**<.001**
		Typically developing (RC)	19	22	**6.32*****		**5.98 to 6.69**	**$t_{(32)}$= 34.55**	**<.001**
		Internalizing Dx	5	10		**-0.93*****	**-1.39 to -0.47**	**$t_{(32)}$= -4.13**	**<.001**
		Physical problems	3	3		**-1.44***	**-2.53 to -0.36**	**$t_{(32)}$= -2.70***	**.01**
		Other	1	1		-0.34	-2.05 to 1.37	$t_{(32)}$= -0.41	.69
4		Assessments per day	25	36	**5.35**		**4.67 to 6.03**	**$t_{(34)}$= 16.04**	**<.001**
						0.17*	**0.02 to 0.31**	**$t_{(34)}$= 2.34***	**.03**
1	**NA**	*Empty model*	31	48	**2.31*****		**2.01 to 2.60**	**$t_{(47)}$= 15.68**	**<.001**
2		Age	31	48	0.29		-1.21 to 1.79	$t_{(46)}$= 0.39	.70
						0.14**	**0.04 to 0.25**	**$t_{(46)}$= 2.74**	**<.01**
3		Population	31	48				$F_{(4, 30)}$= 0.48	.76
		Typically developing (RC)	23	30	**2.38*****		**2.03 to 2.72**	**$t_{(43)}$= 13.94**	**<.001**
		Internalizing Dx	4	8		0.14	-0.38 to 0.66	$t_{(43)}$= 0.54	.59
		Externalizing & other Dx	2	5		-0.20	-1.10 to 0.71	$t_{(43)}$= -0.44	.66
		Physical problems	4	4		-0.51	-1.44 to 0.43	$t_{(43)}$= -1.09	.28
		Other	1	1		-0.39	-2.14 to 1.37	$t_{(43)}$= -0.45	.66
4		Assessments per day	31	48	**2.30*****		**1.92 to 2.67**	**$t_{(46)}$= 12.25**	**<.001**
						0.00	-0.05 to 0.06	$t_{(46)}$= 0.09	.93
1	**Anger**	*Empty model*	15	19	**2.17*****		**1.84 to 2.50**	**$t_{(18)}$= 13.85**	**<.001**
2		Age	15	19	0.80		-0.78 to 2.37	$t_{(17)}$= 1.08	.30
						0.10	-0.02 to 0.22	$t_{(17)}$= 1.83	.09
3		Population						$F_{(2.16)}$= 0.30	.75
		Typically developing (RC)	15	16	**2.16*****		1.82 to 2.50	**$t_{(16)}$= 13.54**	**<.001**
		Internalizing Dx	2	2		0.08	-0.22 to 0.38	$t_{(16)}$= 0.55	.59

		Externalizing & other Dx	1	1		0.25	-0.72 to 1.22	$t_{(16)}$= 0.55	.59
		Assessments per day	15	19	**2.29*****		1.74 to 2.84	**$t_{(17)}$= 8.73**	**<.001**
						-0.04	-0.19 to 0.11	$t_{(17)}$= -0.58	.57
1	**Anxiety**	*Empty model*	18	23	**2.56*****		**2.20 to 2.93**	**$t_{(22)}$= 14.51**	**<.001**
2		Age	18	23	1.30		-1.73 to 4.33	$t_{(21)}$= 0.89	.38
						0.09	-0.13 to 0.31	$t_{(21)}$= 0.88	.39
3		Population	18	23				**$F_{(1, 21)}$= 9.23***	**<.01**
		Typically developing (RC)	18	22	**2.49*****		**2.13 to 2.84**	**$t_{(21)}$= 14.61**	**<.001**
		Internalizing Dx	1	1		**1.70****	**0.54 to 2.86**	**$t_{(21)}$= 3.04**	**<.01**
4		Assessments per day	18	23	**2.95*****		**2.48 to 3.42**	**$t_{(21)}$= 13.05**	**<.001**
						-0.16*	**-0.30 to -0.02**	**$t_{(21)}$= -2.30***	**.03**
1	**Sadness**	*Empty model*	14	19	**2.00*****		**1.59 to 2.42**	**$t_{(18)}$= 10.17**	**<.001**
2		Age	14	19	0.45		-1.52 to 2.42	$t_{(17)}$= 0.48	.64
						0.12	-0.03 to 0.27	$t_{(17)}$= 1.69	.11
3		Population	14	19				$F_{(2, 16)}$= 0.72	.50
		Typically developing (RC)	14	16	**1.98*****		**1.55 to 2.41**	**$t_{(16)}$= 9.78**	**<.001**
		Internalizing Dx	2	2		0.25	-0.25 to 0.75	$t_{(16)}$= 1.06	.30
		Externalizing & other Dx	1	1		0.28	-0.76 to 1.31	$t_{(16)}$= 0.56	.58
4		Assessments per day	14	19	**2.22*****		**1.42 to 3.01**	**$t_{(17)}$= 5.88**	**<.001**
						-0.07	-0.31 to 0.16	$t_{(17)}$= -0.68	.51
1	**Happiness**	*Empty model*	11	14	**7.13*****		**6.45 to 7.81**	**$t_{(13)}$= 22.61**	**<.001**
2		Age	11	14	**8.70**		5.09 to 12.31	**$t_{(12)}$= 5.30**	**<.001**
						-0.11	-0.38 to 0.15	$t_{(12)}$= -0.94	.37
3		Population	11	14				$F_{(1, 12)}$= 0.23	.64
		Typically developing (RC)	11	13	**7.14*****		**6.45 to 7.83**	**$t_{(12)}$= 22.66**	**<.001**
		Externalizing & other Dx	1	1		-0.33	-1.81 to 1.15	$t_{(12)}$= -0.48	.64
4		Assessments per day	11	14	**7.34*****		**6.30 to 8.38**	**$t_{(12)}$= 15.33**	**<.001**
						-0.09	-0.40 to 0.23	$t_{(12)}$= -0.60	0.56

Note. Significance: $^{*}p$<.05, $^{**}p$<.01, *** p<.001 (in bold). *Dx*= diagnoses; *K*= number of estimates; *N*= number of independent samples; *NA*= Negative Affect; *PA*= Positive Affect; *RC* = reference category. Categories for which no information was available (e.g., physical problems) could not be calculated, and have been left out, see method section for details. The empty model includes no predictors.

Figure 4

Intensity of positive affect, negative affect, anger, anxiety, sadness, and happiness across age and different population groups



Note. *CF*= confidence interval.

Emotional variability. Emotional variability or intensity amplitude was measured using unipolar response scales in 20 studies (*k*= 106). In all six multilevel models, most variance was explained by differences between studies (i.e., level 3, see Table S6A and S6B). Within-study variability was small but significant in most models, except for anxiety variability (*p*= 1.00) and sadness variability (*p*= .13, see Table S6A).

Age. Age differences were observed only in the models for sadness variability. Specifically, variability of sadness appeared to increase with age (0.92 point per year [0.52 to 1.32] on a 10-point rating scale, $t_{(7)}$= 5.44, *p*< .01, see Table 4 and Figure 5E). Secondary analyses examining estimates from adolescence only showed a similar pattern, with an increase in sadness variability over early adolescence (1.04 point per year [0.60 to 1.48], $t_{(6)}$= 5.74, p< .01, see Table S7).

Population. Differences between population groups were found for PA variability as well as sadness variability (Table 4 and Figure 5A and 5E). PA variability was significantly higher in youth with internalizing mental disorders (*M*= 2.93 [1.60 to 4.26]) compared to typically developing youth (*M*= 1.37 [0.71 to 2.03], see Table 4). Sadness variability was significantly higher in youth with either internalizing mental disorders (*M*= 2.01 [1.66 to 2.37]) or externalizing or other mental disorders (*M*= 1.84 [1.37 to 2.32]), compared to typically developing youth (*M*= 1.27 [0.56 to 1.98], see Table 4). Age and population group differences were not observed for NA variability, anger, anxiety, nor happiness. Number of assessments per day in each study was unrelated to any of the emotional variability estimates.

Table 4

Results of the three-level mixed-effects models for variability of positive affect, negative affect, anger, anxiety, sadness, and happiness

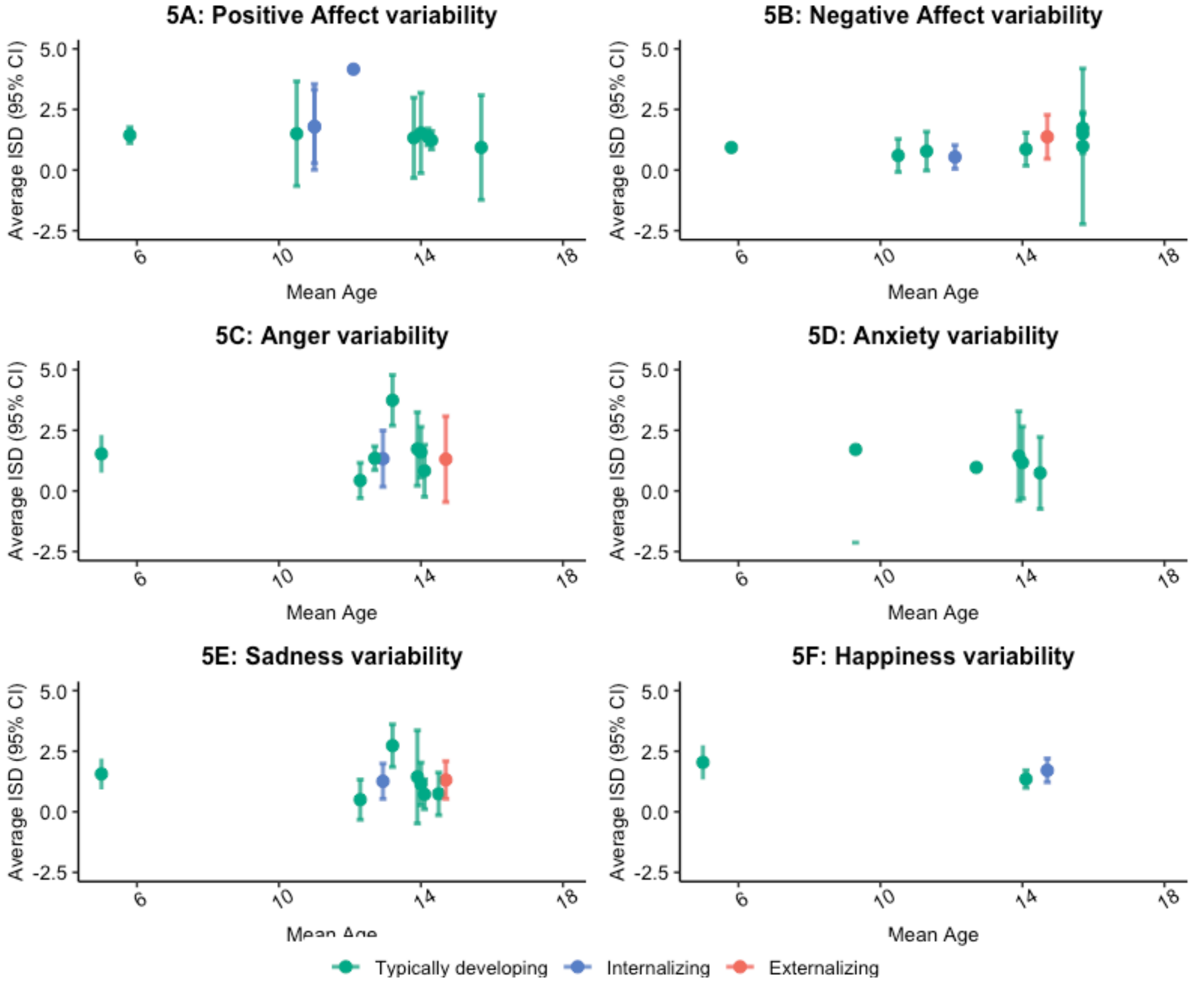
Model		Moderator	N	K	β_0	β_1	95% CI	Test statistic	*p*
1	**PA**	*Empty model*	8	10	**1.76*****		**0.98 to 2.54**	$\mathbf{t_{(9)} = 5.11}$	**<.001**
2		Age	8	10	2.48		-1.13 to 6.09	$t_{(8)} = 1.59$	.15
						-0.06	-0.35 to 0.23	$t_{(8)} = -0.47$	.65
3		Population	8	10				$\mathbf{F_{(1, 8)} = 7.32}$	**.03**
		Typically developing (RC)	6	7	**1.37****		**0.71 to 2.03**	$\mathbf{t_{(8)} = 4.79}$	**<.01**
		Internalizing Dx	2	3		**1.56***	**0.23 to 2.89**	$\mathbf{t_{(8)} = 2.71}$	**<.05**
4		Assessments per day	8	10	**2.18***		**0.51 to 3.86**	$\mathbf{t_{(8)} = 3.00}$	**<.05**
						-0.11	-0.48 to 0.27	$t_{(8)} = -0.66$	.53
1	**NA**	*Empty model*	7	9	**0.91****		**0.45 to 1.37**	$\mathbf{t_{(8)} = 4.54}$	**<.01**
		Age	7	9	0.17		-1.24 to 1.57	$t_{(8)} = 0.28$	.79
						0.06	-0.05 to 0.17	$t_{(8)} = 1.32$	.23
2		Population						$F_{(2, 6)} = 2.43$	.17
		Typically developing (RC)	6	7	**0.93****		**0.49 to 1.37**	$\mathbf{t_{(6)} = 5.17}$	**<.01**
		Internalizing Dx	1	1		-0.50	-1.51 to 0.51	$t_{(6)} = -1.20$	.27
		Externalizing & other Dx	1	1		0.50	-0.18 to 1.17	$t_{(6)} = 1.79$	.12
3		Assessments per day	7	9	0.44		-0.35 to 1.23	$t_{(7)} = 1.32$	.23
						0.15	-0.06 to 0.35	$t_{(7)} = 1.68$	.14
1	**Anger**	*Empty model*	7	9	**1.68****		**0.56 to 2.81**	$\mathbf{t_{(8)} = 3.45}$	**<.01**
2		Age	7	9	2.28		-0.34 to 0.24	$t_{(7)} = -0.40$	.70
						-0.05	-0.31 to 0.28	$t_{(7)} = -0.11$	.92
3		Population	7	9				$F_{(2,6)} = 1.13$	.38
		Typically developing (RC)	7	7	**1.66***		**0.48 to 2.83**	$\mathbf{t_{(6)} = 3.45}$	**<.05**
		Internalizing Dx	1	1		0.51	-0.95 to 1.97	$t_{(6)} = 0.86$	.42
		Externalizing & other Dx	1	1		0.09	-1.46 to 1.64	$t_{(6)} = 0.14$	.90
4		Assessments per day	7	9	**2.11***		**0.29 to 3.94**	$\mathbf{t_{(7)} = 2.11}$	**<.05**
						-0.13	-0.56 to 0.30	$t_{(7)} = -0.72$	.49
1	**Anxiety**	*Empty model*	5	5	**1.23****		**0.78 to 1.68**	$\mathbf{t_{(4)} = 7.57}$	**<.01**
2		Age	5	5	**3.67***		**0.28 to 7.06**	$\mathbf{t_{(3)} = 3.45}$	**.04**
						-0.19	-0.45 to 0.07	$t_{(3)} = -2.34$	.10

3		Assessments per day	5	5	**1.24***		**0.20 to 2.28**	**$t_{(3)}$= 3.79**	**.03**
						0.00	-0.23 to 0.22	$t_{(3)}$= -0.07	.95
1	**Sadness**	*Empty model*	7	9	**1.44****		**0.77 to 2.11**	**$t_{(8)}$= 4.98**	**<.01**
2		Age	7	9	**-10.13****		**-15.96 to -4.31**	**$t_{(7)}$= -4.11**	**<.01**
						0.92**	**0.52 to 1.32**	**$t_{(7)}$= 5.44**	**<.01**
3		Population	7	9				**$F_{(2, 6)}$= 17.65**	**<.01**
		Typically developing (RC)	7	7	**1.27****		**0.56 to 1.98**	**$t_{(6)}$= 4.39**	**<.01**
		Internalizing Dx	1	1		**0.74****	**0.39 to 1.10**	**$t_{(6)}$= 5.14**	**<.01**
		Externalizing & other Dx	1	1		**0.57***	**0.10 to 1.05**	**$t_{(6)}$= 2.99**	**.02**
4		Assessments per day	7	9	**2.03***		**0.65 to 3.40**	**$t_{(7)}$= 3.48**	**.01**
			7	9		-0.15	-0.45 to 0.16	$t_{(7)}$= -1.15	.29
1	**Happiness**	*Empty model*	2	3	**1.67***		**0.59 to 2.76**	**$t_{(2)}$= 6.62**	**<.05**
		Age	2	3	2.06		-2.21 to 6.32	$t_{(2)}$= 6.12	.10
						-0.04	-0.33 to 0.25	$t_{(2)}$= -1.61	.35
2		Population	2	3				$F_{(1, 1)}$= 0.00	.96
		Typically developing (RC)	2	2	1.68		-2.70 to 6.07	$t_{(1)}$= 4.89	.13
		Externalizing & other Dx	1	1		0.03	-4.59 to 4.64	$t_{(1)}$= .07	.96
3		Assessments per day	2	3	2.99		-7.43 to 13.42	$t_{(1)}$= 3.65	.17
						-0.37	-3.07 to 2.34	$t_{(1)}$= -1.72	.34

Note. Dx= diagnoses; *K*= number of estimates; *N*= number of independent samples; *NA*= Negative Affect; *PA*= Positive Affect; *RC* = reference category. Categories for which no information was available (e.g., physical problems) could not be calculated, and have been left out, see method section for details. *Significance:* $^{*}p$<.05, $^{**}p$<.01, $^{***}p$<.001 (in bold). The empty model includes no predictors.

Figure 5

Variability of positive affect, negative affect, anger, anxiety, sadness, and happiness across age and different population groups

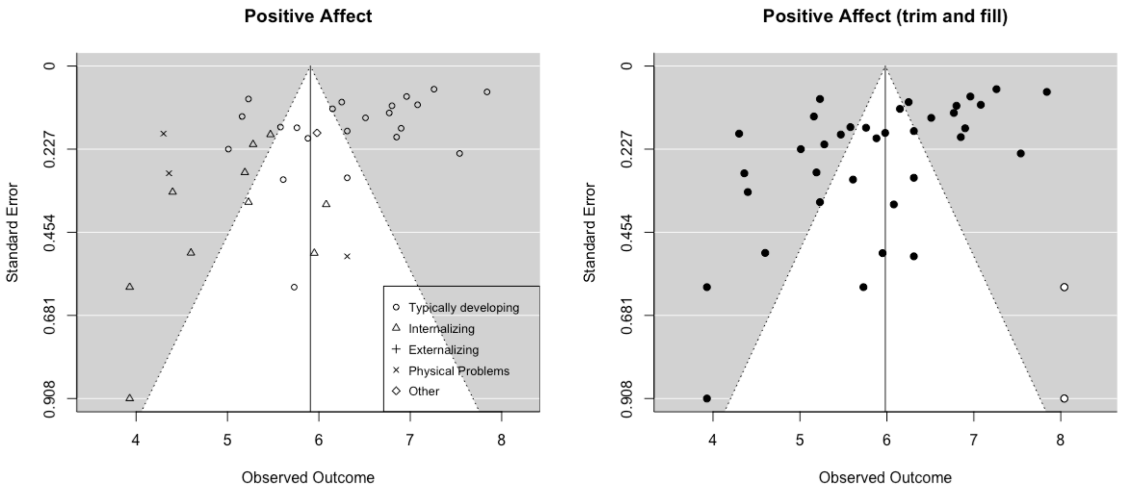


Note. CF= confidence interval, *ISD*= intraindividual standard deviation.

Publication bias. Overall, we observed no systematic bias in the reporting of effect sizes in the included studies. The funnel plots for the empty random-effects models of emotional intensity and emotional variability showed a symmetrical spread of effect sizes (see Figures S1 and S2), which was supported by the trim-and-fill method and Egger's tests. The only exception was the model for PA intensity (see Table S8), an asymmetry that probably reflects subgroup heterogeneity, as estimates from populations with internalizing disorders were generally lower than estimates from other populations (see Figure 6).

Figure 6

Funnel plot for the empty random-effects model of positive affect intensity (left) and after trim-and-fill method



Results of the Descriptive Review

Emotional instability. Emotional instability was analyzed in 13 studies (*k*= 93) that often used the same dataset. Specifically, one group of children (8-12 years of age) with and without an ADHD diagnosis appears to be studied by Leaberry et al. (2017), Rosen et al., (2015), Factor et al. (2014), and Walerius et al. (2014). One longitudinal assessment of the same group of early adolescents (age 13 at baseline) were studied by Van Lissa et al. (2017), Maciejewski et al. (2014, 2015) and Neumann et al. (2011). The other four studies were based on unique samples (O'Donell et al., 2018; Liefferinge et al., 2018; Van Roekel et al., 2016, and Rusby et al., 2012).

Despite differences in their analytic approach, all studies operationalized instability as the average of a participants' successive difference scores between consecutive emotion ratings. Before averaging, most authors squared the successive differences (MSSD, e.g., Rosen & Factor, 2015; Van Roekel et al., 2016), to give more weight to larger changes between measurements. Other authors did not square but used absolute differences (MASD, e.g., Maciejewksi et al., 2015), or computed the square root of the MSSD (rMSSD), which yields an estimate in a unit similar to the emotion ratings (O'Donell et al., 2018; Van Roekel et al., 2015). Due to this variation in computation, emotional instability estimates could not be directly compared and meta-analyzed and are therefore reviewed descriptively.

Age. Age differences were reported by Van Lissa et al. (2017), Maciejewski et al. (2015), and Van Roekel et al. (2016). The first two studies used the same dataset and five annual assessment wave with an EMA period of three weeks. Emotion instability significantly decreased from early to late adolescence, in happiness, sadness, and anger instability, according to Maciejewski et al. (2015). Anxiety instability, on the other hand, showed a cubic curve: an initial increase in early adolescence, followed by a decrease over middle adolescence, and an increase again in later adolescence. Van Roekel et al. (2015) reported higher PA instability in middle adolescence (*M*= 14.2, *SD*= 0.54) than late adolescence (*M*= 20.91, *SD*= 1.81).

Population. In children and early adolescents (ages 8-12 years), four studies examined the association between emotional instability and ADHD with or without comorbidity (Factor et al., 2014; Leaberry et al., 2017; Rosen & Factor, 2015; Walerius et al., 2014). Youth with ADHD and a comorbid disorder showed higher parent-reported total affect instability compared to those without comorbidity, and compared to typically developing children (Factor et al., 2014). NA instability was not significantly higher in youth with ADHD compared to typically developing peers (Factor et al., 2014). However, youth with ADHD and comorbid internalizing or externalizing problems reported higher NA instability than those with ADHD alone (Factor et al., 2014; Leaberry et al., 2017). PA instability did not differ between typically developing youth, those with ADHD, and those with additional comorbidities (Factor et al., 2014).

In adolescence, emotion instability was associated with internalizing symptoms, both concurrently (Van Roekel et al., 2016) and prospectively (Maciejewski et al., 2014).

Specifically, higher PA instability associated with depressive symptoms, but not with anhedonia in middle and late adolescence (Van Roekel et al., 2016). Instability of anger, anxiety, sadness, and happiness predicted anxiety disorder symptoms one year later (Neumann et al., 2011), whereas emotion instability did not predict depressive symptoms. Interestingly, emotion intensity showed a divergent pattern of associations with anxiety and depressive symptoms, that is, a significant prospective association with depressive symptoms, but not with anxiety symptoms. Using the same dataset, but with four additional years of data, Maciejewski et al. (2014) reported that general emotion instability (derived from summing the four emotions) prospectively predicted anxiety as well as depressive symptoms across the ages 14 to 16 years.

Emotional inertia. Although several studies (*n*= 10) examined lagged effects of emotions among youth, only three studies focused specifically on emotional inertia (Kuppens et al., 2012; Morgan et al., 2017, van Roekel et al., 2016). Overall, there was a dearth in estimates of emotional inertia.[5] Estimates of PA inertia ranged between 0.27 (first-order autocorrelation at 3-hour intervals; van Roekel et al., 2016) and 0.29 (autoregressive coefficient between morning and evening affect; Lehman et al., 2007), while estimates of NA inertia ranged from 0.19 (autoregressive coefficient between previous evening's and morning's NA; Langguth et al., 2016) to 0.35 (autoregressive coefficient between previous day's and current day's NA; Flook, 2011). The relative strength of these estimates is difficult to compare, because each estimate covers a different time interval, and autocorrelations based

[5] Most other included papers that studied inertia examined whether certain behaviors or cognitions preceded changes in emotional states, thereby controlling for the influence of the lagged effects of the emotional states. Hruska and colleagues (2017), for example, examined whether co-rumination predicted next-day levels of sadness, anxiety, and hostility among adolescents between 14 and 18 years of age, while controlling for previous days' level of affect. In these models, co-rumination did not have a main effect in predicting changes in next-day NA over the autoregressive effects of affective states. Similarly, Kiang and Buchanan (2014) examined both same-day and next-day lagged associations between stress and anxiety, distress, and happiness among Asian-American adolescents. Their models with stress predicting next-day affect controlling for prior-day affect showed positive autocorrelations between all three affect measures, while daily stress had little to no impact on next-day affect.

on longer time-intervals (or multiple time lags) are likely to be lower than autocorrelations based on shorter intervals.

Age. The age range of studies examining emotional inertia was limited to the adolescent period, ranging from fifth- and sixth-grade students (approximately 10-11 years of age, Lehman et al., 2007) to late adolescents (M= 20.91 years, van Roekel et al., 2016). Only van Roekel and colleagues examined age differences in their sample, and showed no differences in PA inertia between middle and late adolescents.

Population. Morgan and colleagues (2017) reported that clinically anxious youth did not return faster to their PA baseline than typically developing peers (i.e., lower inertia), using both momentary and peak PA. Van Roekel et al. (2016) reported a significant positive lagged effect for PA among adolescents, but observed no concurrent relationship with depressive symptoms. Kuppens and colleagues (2012) focused on negative emotions and reported a significant association between emotional inertia and depressive symptoms using emotional behaviors rather than emotional experiences. Inertia in emotional behavior of adolescents during an interaction with their parents, coded by observers as angry, dysphoric, or happy, predicted the development of depression 2.5 years later.

Emotion differentiation. One study examined emotion differentiation explicitly and reported average within-person ICCs of positive affect (PA) and negative affect (NA; Lennarz et al., 2017). Three other studies reported average within-person bivariate correlations between emotions, with 25 estimates pertaining to correlations between negatively valenced emotions (e.g., anger or sadness) and six estimates pertaining to positively valenced emotions (e.g., happiness or satisfaction). Across studies, the correlations between positive emotions were lower than between negative emotions. Emotion differentiation therefore appears stronger between positive emotions than between negative emotions.

Age. There were no studies examining age differences, either in average within-person ICCs or correlations. The majority of participants were between 12 and 14 years of age, which impeded meaningful age-based comparisons between studies.

Population. All studies were conducted with general population samples, except for the study by Rusby et al. (2012), which also included adolescents at risk for rule breaking and substance use. Note that differences in within-person correlations were not estimated between these two population groups. In the sample of typically developing adolescents examined by Lennarz et al. (2017), the differentiation of NA but not PA was related to emotional well-being. Higher NA differentiation was associated with a lower negative emotional propensity and a stronger belief in the malleability of emotions.

Emotion augmentation and blunting. None of the studies included examined prospective (cross-)lagged relationships or cross-regressive effects between different emotions.

Discussion

This multi-level meta-analytic and descriptive review summarizes 102 ecological momentary assessment studies with 689 estimates of emotion dynamic patterns in 19.928 children and adolescents, and aimed to examine age-related differences in emotional intensity, variability, instability, inertia, differentiation, and augmentation/ blunting. These emotion dynamic patterns were also compared between samples of typically developing youth and peers with physiological or psychological problems. Our study yielded seven key observations: 1) The literature on emotion dynamics in youth is surprisingly small and fragmented and few estimates other than emotional intensity and variability were available; 2) The intensity of negative affect (NA) was higher in adolescence compared to childhood, whereas the intensity of positive affect (PA) as well as happiness was independent of age; 3) Youth with internalizing mental health problems reported lower intensity PA than typically developing youth, and more intense anxiety, but not more intense NA, anger, sadness, or happiness; 4) The variability of sadness was higher in adolescence compared to childhood; 5) Compared to typically developing youth, peers with internalizing mental health problems reported higher variability of PA and sadness, while externalizing mental health problems also associated with higher sadness variability; 6) Emotion dynamics seem to stabilize in later adolescence; and 7) Youth reported more differentiated positive emotions than negative emotions. These results are discussed in more detail below.

Emotion Dynamics in Childhood and Adolescence

Emotional changes are key to many theories on normative psychological development and youth functioning (e.g., Saarni, 1999) as well as models of developmental psychopathology (e.g., Cole, 2015). Surprisingly few studies in our review examined emotional changes in childhood and adolescence. Emotion dynamic patterns other than intensity and variability were too scarce (e.g., inertia or differentiation) or inconsistent (emotional stability) to meta-analyze, and had to be reviewed descriptively. Most studies focused on adolescents and studies of children were rare (e.g., only 15.6% of the univariate emotional intensity estimates were from youth <10 years of age [46/294]). Children can reportedly reflect on their thoughts and emotions from age five onwards (e.g., Stone et al., 1990) when they are also able to reason about other people's emotions (Asaba, Ong, & Gweon, 2019), thus perhaps researchers are concerned about children's adherence to EMA study protocols (Vilaysack et al., 2016).

Previous studies that documented lower intensity positive states in middle and late adolescence often used bipolar response scales, which conceal whether this development is driven by a decrease in PA or increase in NA, or both (Larson & Lampman-Petraitis, 1989; Larson et al., 2002; Moneta et al., 2001). Our multi-level model suggested that NA intensity increases from childhood to early and late adolescence, in all population types. PA intensity did not differ by age, and neither did anxiety and anger, but sadness became more intense from mid adolescence onwards. The intensity of happiness did not differ between childhood and adolescence (similar to the results for PA), a finding that is new to an emotion literature in which adolescence is typically understood as rather unhappy (e.g., Maciejewski et al., 2017). This provides further support for the notion that positive and negative mental states are fairly independent and should be considered simultaneously.

Future studies may unravel whether changes in NA intensity over development are driven by trajectories of specific emotions (e.g., sadness) or reflect the aggregation of small changes across multiple emotions. One likely factor to propel the increase in NA over adolescence is a greater emotional *reactivity*, and especially toward social stimuli (Somerville, 2016). The adolescent emotional system has been described as both ‘overheating’ due to greater emotional reactivity and ‘undercooling’ due to comparatively undeveloped emotion regulation capacities (Somerville, 2016, p. 352). Hormonal changes during puberty increase adolescents’ physiological reactivity to stressors (Gunnar et al., 2009). These physiological chances combined with changing social circumstances render adolescents particularly vulnerable for the development of anxiety and mood disorders (Allen & Sheeber, 2008; Somerville, 2016), which in children and adolescents are typically marked by heightened NA intensities (e.g., Chorpita & Daleiden, 2002; Silk et al., 2003, 2011).

Our meta-analysis of children with internalizing mental health problems showed a trend toward more intense NA (albeit non-significant), and more anxiety, compared to typically developing youth. Differences in NA intensity might be concealed by age differences in typically developing youth versus those with internalizing problems. Samples of youth with internalizing problems included only early adolescents whereas samples of typically developing youth included mid- and late-adolescents. Higher NA intensity scores in older adolescents might account for this lack of significant differences between population groups. For anxiety intensity, in contrast, all samples of typically developing youth and those with mental health problems were from youth in mid-late adolescence. PA intensity was lower both in youth with internalizing mental health problems and peers with physical problems, compared to typically developing youth. The absence of other differences in youth with (mental) health problems probably reflected our low statistical power resulting from the scarcity of samples (see Table 4).

Although emotional intensity is the most studied of the reviewed patterns, it is also the least dynamic, as the mean does not capture changes within the time series, and can only differ between multiple measurement bursts. Nonetheless, on a between-subjects level, mean affect intensity seems most informative and predictive for subjective well-being and mood problems when pitted against other dynamic measures (Bos et al., 2018; Dejonckheere, Mestdagh et al., 2019; Koval, 2013). Emotional intensity is one of the most salient individual differences (Larsen & Diener, 1987) and highly influential in how we navigate our lives (Barrett et al., 2016; Kahneman & Egan, 2011). Additionally, the mean of a series of data points (e.g., emotion scores) is the first statistical moment to describe the shape of its distribution and is part of the formula for many other dynamic parameters such as variability (Fisher et al., 2018; Jahng et al., 2008), as expanded upon below.

Greater emotional reactivity in adolescence could translate into higher emotional variability and instability. Adolescence is commonly understood as a period of inner "emotional turmoil" (e.g., Arnett, 1999; Levesque, 2011) and previous studies reported increases in emotional variability through adolescence (Larson et al., 2002), although these age-related changes may be specific to girls (Larson & Lampman-Petraitis, 1989; Weinstein & Mermelstein, 2013). Compared to children, adolescents typically report experiencing more negative events with peers, school, and family (e.g., Laceulle et al., 2015; Larson & Ham, 1993), and we expected these frequent social stressors to result in higher NA variability over adolescence. Our meta-analysis showed no age differences in the variability of valence dimensions (PA, NA) nor in distinct emotions (e.g., anxiety), with the exception of an increase in the variability of sadness over mid-adolescence, after being steady over childhood and early adolescence. Most adolescents are well-adjusted and steady (Levesque, 2011). Youth with internalizing mental health problems, however, did report both more intense and more variable PA and more variable sadness than typically developing youth. The heterogeneity of estimates (k= 103 in total) limited the statistical power in each model, which impeded a test for gender differences.

Due to the wide variety in type of measures used to study emotional instability, inertia, and differentiation, proper meta-analytic pooling was impeded, which forces us to draw tentative conclusions from a descriptive review. Our meta-analysis showed higher sadness variability in adolescence, but was limited to youth in early and mid-adolescence, whereas the descriptive review concerned samples of mid- and late adolescence, which showed that sadness stabilized across adolescence. Variability and instability patterns are conceptually and methodologically related, and these findings combined do not rule out the possibility that sadness variability and instability show an initial increase from childhood to adolescence, followed by a decrease in later adolescence.

Our model showed increased variability of PA and sadness in youth with internalizing mental health problems (such as anxiety and depression) compared to typically developing youth, in line with previous work (see Van Roekel et al., 2016; von Neumann et al., 2011; Maciejewski et al., 2014). PA inertia did not show similar associations with internalizing mental health problems in our descriptive review, which makes theoretical sense, as higher variability and instability are the inverse of resistance to emotional change (i.e., inertia).

We encountered zero studies of emotion augmentation and blunting and emotion differentiation in children and adolescents. Emotions unfold over time, interact with each other, can have additive effects, and are better understood with age, and we expected these dynamics to be an important avenue of study over childhood and adolescence to better understand emotional development. Development in these dynamic characteristics therefore remains an open question. One study focusing on age-based changes in emotion differentiation (Nook et al., 2018), which we excluded from this review because they did not assess emotions in participants' daily lives, suggests that emotion differentiation decreases from childhood to early adolescence, and subsequently increases again towards adulthood. Matching experience sampling evidence is dearly needed.

Differences in emotion dynamics between typically developing youth and those with health problems were consistently more evident for emotions with a negative versus positive valence, either for emotional instability, inertia, and differentiation. For example, the instability, inertia, and differentiation of negative emotions were shown to be related to comorbid psychopathology in ADHD, depressive behaviors, and emotional well-being, whereas no consistent relationships with dynamic patterns of positive emotions were documented. This stronger predictive power for the dynamic patterns of negative versus positive emotions is in keeping with the stronger effect sizes for negative versus positive emotions in a review of the adult emotion literature by Houben et al. (2015) and the broader life event literature (e.g., Baumeister et al., 2001). In our models the differences in the information value of positive versus negative emotions are already apparent in childhood and adolescence, which is consistent with functional approaches to emotion (e.g., Frijda, 2007; Tooby & Cosmides, 1990); historically one out of two humans did not survive childhood and adolescence (a number that declined 10-fold over the past century, see Volk & Atkinson, 2013), and negative emotions play a key role in survival (Darwin, 1872; Nesse, 2019).

Methodological Considerations

Measurement plays a key role in replicability and calibrates the confidence we can have in our findings. Five methodological concerns warrant mention. First, the broad affect dimensions PA and NA are undoubtedly the most studied experiences, but the PA and NA scales we reviewed comprised quite heterogeneous subsets of items that were typically derived from the Positive and Negative Affect Schedule (PANAS, Watson et al., 1988b, or for children, PANAS-C, Laurent et al., 1999). We do not think that a PA scale composed of 'cheerful', 'joyful', 'happy', 'lively', and 'proud' is equivalent to a PA scale composed of 'agreeable', 'cheerful', 'content', 'happy', and 'pleased'. We question the construct validity of these scales, as well as the absence of theoretical accounts for these differences, or how they relate to theoretical emotion taxonomies (see Weidman et al., 2017 for a review of these problems). When constructing scales for discrete emotions, it is difficult to find equivalent terms, next to the tremendous variability in the emotions that people refer to with the same emotion word (James, 1894, page 517).

Second, another major factor that influences our results is the length of time intervals between assessments, which differed widely across studies, ranging from once per week (O'Donnell, 2018) to once every 25 minutes (Butler, 2009). One's choice of assessment spacing requires a balance between sufficiently frequent assessment to capture meaningful variation on the one hand, and minimizing participant burden and potentially altering the measured constructs by repetitive self-ratings on the other (i.e., response shifts, Schwartz et al., 2006). Most reviewed studies lacked a rationale for their choice of assessment schedule. In our models assessment frequency played a minimal role in explaining differences in emotion dynamic estimates between studies, but the unknown time-course of emotion dynamics and other psychological processes requires us to justify the appropriateness of our sampling schedules in ambulatory studies (Ebner-Priemer et al., 2007).

Third, the various dynamic indices that we reviewed capture distinct aspects of emotion patterns in children and adolescents, but also show considerable overlap (e.g., Dejonckeere et al., 2019; Wendt et al., 2019), and emotional instability, variability, and inertia are also mathematically related (Jahng et al., 2008). For example, emotional variability is typically confounded by emotional intensity (the mean score), especially in the case of bounded measurements or skewed variable distributions (Bos et al., 2018; Mestdagh et al., 2018). In young adults, emotional variability can account for the associations between both emotional instability and emotional inertia of negative affect and depressive symptoms (Bos et al., 2018; Koval et al., 2013). And as outlined, the association between emotional variability and depression (Bos et al., 2018) or subjective well-being (Dejonckheere et al., 2019) in adults is mainly accounted for by the mean. This might also explain our findings that dynamic measures of negative emotions are often more strongly associated with (mental) health problems than dynamic measures of positive emotions. Whereas skewed distributions of negative emotions in ESM research are common in healthy populations, this is not the case for positive emotions.

These findings show that it is crucial to account for the overlap among different emotion dynamic indices and to adjust for the mean emotional intensity (Bos et al., 2018; Dejonckheere, Mestdagh et al., 2019; Koval et al., 2013). Note that temperament and personality are often defined as someone's generalized levels of PA (surgency/extraversion) or NA (negative affectivity/neuroticism) across time and context (McAdams ea., 2019), while PA and NA are also key ingredients of subjective well-being – and it may therefore not be a surprise that these concepts are intimately connected because emotional intensity, moods, and personality may cover different time scales but co-evolve within each of us over development (Jeronimus, 2019).

A fourth methodological point of concern is the computation of emotional instability. The mean squared successive difference (MSSD) is regularly used in research on emotional instability in borderline personality disorder (Trull et al., 2008). In contrast to the mean absolute successive difference (MASD), larger changes receive more weight than smaller changes when they are squared. According to Trull et al. (2008), a magnification of large emotion changes is consistent with conceptualizations of emotional instability in borderline personality disorder. However, the four studies included in our review used the MSSD to study children with attention-deficit/ hyperactivity disorder (ADHD), and it is questionable whether this computational magnification is appropriate, especially when studying phenomena other than borderline personality disorder. These methodological differences impeded our meta-analysis of emotional instability.

Finally, our literature search yielded few studies that measured dynamics other than the main ones discussed above. For example, there were no studies using measures of instability other than the MSSD or MASD, such as spectral analysis (Larsen, 1987), probability of acute change (PAC, see Jahng et al., 2008), and, with the exception of one single study (Rosen et al., 2013), no complex dynamic system topologies (e.g., Butner et al., 2014; Kunnen et al., 2019) or complexity measures such as recurrence quantification plots, despite their promise to enhance our understanding of emotion functioning.

Strengths and Limitations

This is the first review that systematically examined differences in emotion dynamic patterns through childhood and adolescence and between typically developing youth and populations with mental health or physical problems. A strength of this study is the multilevel meta-analytic approach to explicitly account for possible dependencies among effect sizes, thereby avoiding the strong assumption of independence that underlies traditional meta-analytic approaches. Additionally, we enriched the paper via a descriptive review of estimates that could not be pooled and quantified.

Nonetheless, the results from this meta-analysis and qualitative review should be considered in the light of a number of limitations. Most studies used statistical models that account for dependencies between measurements due to repeated assessments of the same individuals, most frequently multilevel regression models. Other studies aggregated data to a single level and conducted ANOVA or single regression analyses, which is problematic in the context of missing data at the lowest level, as this violates the heterogeneity assumption of these models (Schwartz & Stone, 1998), next to the inherent information loss at the individual level (Fisher et al., 2018).

Additionally, most ambulatory studies do not provide methodological information (see Liao et al., 2016; Stone & Shiffman, 2002 for discussions), and several papers did not describe all analytic decisions, such as how predictor variables were centered. As outlined in the method section, we took a conservative approach and excluded estimates for which it was unclear whether they concerned a within- or between-person estimate. This undoubtedly has led to a loss of relevant information, which in turn limited our ability to draw firm conclusions.

Finally, all studies were conducted in European or North American countries, and cultural differences exist in the experience, expression, and regulation of emotions (Mesquita, De Leersneyder, & Boiger, 2016). For example, in more collectivistic cultures the intensity of powerless emotions such as fear, sadness, shame, and guilt is stronger (e.g., Fischer et al., 2004) and negative and mixed emotions are valued more, based on their belief that "negative" emotions facilitate interpersonal harmony and help people to fit in socially (e.g., Curhan et al., 2014; Miyamoto & Ma, 2011; Sims et al., 2015), whereas more individualistic cultures are marked by the desire to maximize positive emotions. Such cultural factors may have influenced our results in ways which we currently do not fully understand.

Future Research

This review yields four key recommendations to push our field forwards. First, future research should include children, which is challenging, but feasible when study protocols are adapted accordingly (see Heron et al., 2017 for recommendations). For example, by using a "measurement burst" design data is collected in waves divided by breaks to lower participant burden, and by including pictorial response options instead of traditional Likert response scales. Furthermore, more samples are needed of youth with specific physical and health problems, from lower socioeconomic strata, with diverse ethnicities, and from non-European and North American countries (see Henrich et al., 2010, for a detailed discussion). Researchers could leverage cultural differences to increase our understanding of the developmental trajectories of emotions and their dynamic patterns and consequences.

Second, the small changes in emotional intensity and variability across childhood and adolescence that we observed probably conceal substantial individual differences in emotion dynamics. An important direction for future research is therefore to zoom in on these individual differences, for example by using approaches that identify subgroups with fairly similar emotion dynamics (e.g., Ernst et al., 2020), although at a certain level of analysis each individual is quantitatively or qualitatively unique (Adolf et al., 2014; Fisher et al., 2018). Furthermore, the antecedents of individual differences need to be entangled, because ambulatory methods may ensure ecological validity but do not easily allow for inferences on factors that underlie differences in emotion dynamic patterns between individuals, which requires experimental manipulations in which occasions are randomly assigned to different experimental conditions outside of the lab (Hamaker & Wichers, 2017). Ambulatory research methods can be enriched by collecting data on individual differences in momentary contexts (e.g., Rauthmann et al., 2014; Sherman et al., 2015). Alternatively, methods can be used that allow for control of the emotional stimuli that individuals are exposed to, such as laboratory experiments, or natural disasters such as the coronavirus pandemic.

Third, future research should focus on dynamic patterns of discrete emotions. Emotion dynamic parameters are most often calculated for averaged scales of multiple items (i.e., PA and NA), but the extent to which these patterns are similar for the single emotions categorized within these dimensions remains unclear. Emotions differ from each other in many characteristics other than valence, such as arousal, contextual understanding, and duration (Mesquita et al., 2016; Jeronimus, 2019; Verduyn & Lavrijsen, 2015). It is therefore likely that different emotions also show distinct dynamic patterns and that this level of detail is required to better understand emotional experiences in context.

Finally, at the most basic level, emotion researchers should create more consensus on the measurement of emotions and the calculation of emotion dynamic parameters. This challenge entails the systematical development of scales to assess affect dimensions and distinct emotions for ambulatory studies (see Weidman et al., 2007; for recommendations), and agreement on the statistical indices used to index dynamic parameters such as emotional instability (Jahng et al., 2008) or differentiation (Erbas et al., 2018; Tomko et al., 2015), but also the inclusion of multiple dynamic measures within a single model (Dejonckheere, Mestdagh et al., 2019). We believe that these combined practices shall expand the boundaries of our knowledge on the development of emotion dynamics in everyday life.

Conclusion

This systematic review covered three decades of research into changes in emotion dynamic patterns through childhood and adolescence using 689 estimates from 102 studies and 19.928

participants. Our meta-analytic model showed increased intensity of negative affect and increased variability of sadness across childhood and adolescence, but no age-based changes in positive affect or happiness. Internalizing mental health problems in youth were characterized by lower positive affect intensity and heightened anxiety intensity, but higher variability of positive affect and sadness. In general, emotion dynamics appear to stabilize across adolescence. Advancement in technology and statistical modeling present developmental psychologists and emotion researchers with unparalleled possibilities to study emotional dynamics in youth's daily lives. With this literature review we join a chorus of voices calling for the unification of methodological approaches towards the study and measurement of emotions and their various dynamics to expand our accumulation of knowledge on emotion dynamics, which may be key to a long and healthy life in which people flourish.

Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

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** Studies included in this systematic review are indicated by an asterisk (see supplementary Table 3).*

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