Affective Science
https://doi.org/10.1007/s42761-024-00248-y

RESEARCH ARTICLE

The Emergence of Organized Emotion Dynamics in Childhood

Mira L. Nencheva[1] · Erik C. Nook[1] · Mark A. Thornton[2] · Casey Lew-Williams[1] · Diana I. Tamir[1]

Received: 10 July 2023 / Accepted: 19 June 2024

Abstract
Emotions change from one moment to the next. They have a *duration* from seconds to hours and then *transition* to other emotions. Here, we describe the early ontology of these key aspects of emotion dynamics. In five cross-sectional studies ($N = 904$) combining parent surveys and ecological momentary assessment, we characterize how caregivers' perceptions of children's emotion duration and transitions change over the first 5 years of life and how they relate to children's language development. Across these ages, the duration of children's emotions increased, and emotion transitions became increasingly organized by valence, such that children were more likely to transition between similarly valenced emotions. Children with more mature emotion profiles also had larger vocabularies and could produce more emotion labels. These findings advance our understanding of emotion and communication by highlighting their intertwined nature in development and by charting how dynamic features of emotion experiences change over the first years of life.

Keywords Emotion development · Language learning · Emotion labels · Emotion dynamics

Emotions are dynamic experiences. For example, when we feel excited, this experience often lasts for a finite amount of time before transitioning to a different emotion, such as happiness. Babies can be excited by a rattle at one moment and then cry from hunger the next. Prior developmental work on emotion dynamics has focused on individual differences in the ways emotions unfold over time (e.g., emotion inertia, network density, and differentiation) and has found important implications for mental health outcomes from infancy through adolescence and beyond (Reitsema et al., 2022; Somers et al., 2020; Somers & Luecken, 2022; Dejonckheere et al., 2019; Nelson et al., 2020; Shin et al., 2022). Yet we know little about the development of the typical patterns of how long emotions last and the way they transition from one to the other. The current investigation focuses on two aspects of how the emotion experiences of young children unfold over time: the duration of an emotion (i.e., how long someone feels excited) and the structure of their transitions (i.e., what emotion someone is likely to feel next). Longer emotion duration (Scherer & Wallbott, 1994; Verduyn & Lavrijsen, 2015; Verduyn, Delvaux, et al., 2009; Verduyn, Van Mechelen, et al., 2009) and predictable emotion transitions (Thornton & Tamir, 2017) are hallmarks of adults' emotion experiences. In the current investigation, we examined how these two features evolved over early development. Based on emerging arguments that language shapes emotion, we also tested whether linguistic development might explain age-related changes in these emotion processes (e.g., Cole et al., 2010; Eisenberg et al., 2005; Fabes et al., 2001; Hoemann et al., 2019; Nook et al., 2017; Plate et al., 2019; Woodard et al., 2021).

How long one experiences the same emotion (i.e., emotion duration) is an important part of emotion dynamics (Frijda et al., 1991; Verduyn, 2021; Verduyn, Delvaux, et al., 2009, 2015). Adults' emotion experiences typically last from several minutes to hours (Scherer & Wallbott, 1994; Thornton & Tamir, 2017; Verduyn & Lavrijsen, 2015; Verduyn, Delvaux, et al., 2009; Verduyn, Van Mechelen, et al., 2009). For example, in an experience sampling study, participants were likely to continue experiencing the same emotion over multiple consecutive data points, collected 3 h apart (Thornton & Tamir, 2017). Different emotions have reliably different relative durations; for example,

Handling editor: Eric A Walle

✉ Mira L. Nencheva
nencheva@princeton.edu

[1] Department of Psychology, Princeton University, Princeton, USA

[2] Department of Psychological and Brain Sciences, Dartmouth College, Hanover, USA

sadness and joy typically last longer than fear and anger (Scherer & Wallbott, 1994; Verduyn & Lavrijsen, 2015; Verduyn, Delvaux, et al., 2009; Verduyn, Van Mechelen, et al., 2009). Children's emotion experiences, in contrast, are short: tantrums typically last only a few minutes (Potegal et al., 2003), far shorter than the typical duration of anger or sadness in adults of several hours (Verduyn & Lavrijsen, 2015). However, beyond this finding, it is unknown whether the duration for all emotions or relative differences in duration between specific emotions varies systematically across ages.

A second important component of emotion dynamics is the pattern of transitions between emotions. Adults tend to transition between emotions in predictable ways (Prasetio et al., 2020; Thornton & Tamir, 2017). Specifically, they are likely to transition to an emotion similar to the one they are currently experiencing. According to the 3d Mind Model (Thornton et al., 2022; Thornton & Tamir, 2020), similarity along several social, cognitive, and affective dimensions shapes adults' emotion transition patterns. The most prominent of these dimensions is valence (i.e., the relative positivity or negativity of an emotion; Thornton & Tamir, 2017). For example, adults, on average, are more likely to go from feeling happy to feeling calm (a positive emotion) than to feeling angry (a negative emotion; Thornton & Tamir, 2017). We refer to the extent to which one's emotion transitions follow this pattern as organization by valence. Do young children show such organization by valence from infancy, or is this a pattern they gradually converge on during development?

Language is a key factor that may relate to the development of adult-like emotion dynamics. According to the theory of constructed emotion (Barrett, 2017), how people label emotion experiences influences how they categorize, understand, and communicate feelings. Further, emotion development may support language by allowing children to break into the structure of the social interactions in which they experience language. These links between emotion and language have been found in adult emotion dynamics (Barrett, 2006; Thornton & Tamir, 2017; Thornton et al., 2020). In development, verbal abilities relate to the emergence of emotion understanding (Nook et al., 2017), and children start matching labels and facial expressions correctly at around the same age that they produce emotion labels (i.e., 2 years of age; Frank et al., 2017; Wu et al., 2022). However, it is unknown whether language shapes the development of *dynamic* features of emotions or vice versa or whether they co-emerge as the result of other developmental processes. Likely, language and emotion bidirectionally permeate each other on a microscale over the course of development. If this is the case, we would predict that as children learn more emotion-related words, their emotion dynamics will more closely match those of adults, and vice versa. Previous scholars (e.g., Nook, 2021) have identified a critical need for investigating how the early development of emotion dynamics from infancy through early childhood interacts with language during this formative period when children's vocabularies are rapidly expanding (Goldfield & Reznick, 1990).

Although most adults follow a shared pattern of emotion durations and transitions (Scherer & Wallbott, 1994; Thornton & Tamir, 2017; Verduyn & Lavrijsen, 2015; Verduyn, Delvaux, et al., 2009; Verduyn, Van Mechelen, et al., 2009), we know little about how this organization develops. While emerging work shows that language relates to other aspects of emotion development, researchers have not determined how language relates to the development of dynamic emotion experiences. Here, we addressed these gaps to advance a theoretical understanding of emotion and its development that is grounded in the dynamic nature of emotions and their interactions with other cognitive processes. We first described the development of children's emotion dynamics (duration and transitions) through the lens of their caregivers' perceptions. We then related this emotion development to children's language development. We hypothesized that, between the ages of 0 and 5, children's emotion duration and transitions would become more similar to those of adults. Further, we predicted that a child's emotion vocabulary would relate to the structure of their emotion experiences. We measured children's emotion transitions using a combination of methods. In studies 1–3, parents estimated their child's emotion duration and transitions. In study 4, we recorded parent and child emotions multiple times per day for 10 days using ecological momentary assessments (EMAs). Studies 1–4 all described the shift to an adult-like pattern of emotion dynamics between the ages of 0 and 5 years. Studies 3 and 4 additionally examined whether emotion duration and emotion transition organization follow a similar developmental trajectory. Finally, studies 3 and 4 probed whether emotion language predicts the maturity of a child's emotion dynamics. This multi-part investigation allowed us to carry out preregistered replications across studies and methods.

Method

Transparency and Openness

Compliance with Ethical Standards

This research was approved by the Institutional Review Board at Princeton University, and parents provided informed consent prior to participating in all online studies. On behalf of all authors, the corresponding author states that there is no conflict of interest.

Availability of Data and Code

Data and analysis code for all studies can be found here: https://osf.io/hku68/?view_only=f330c97d6ce944caa814b15a5f534fac.

Preregistration and Exploratory Analyses

Preregistration for studies 1b and 3 can be found here: https://aspredicted.org/blind.php?x=64a3xr, and the preregistration for study 4 can be found here: https://aspredicted.org/DTG_GJH.

Originally, study 1b and study 3 were preregistered to be part of the same sample that would replicate findings from study 1a and test novel hypotheses. However, when including all questionnaires in the same study, the study duration became too long to obtain reliable responses from participants (likely due to fatigue). Therefore, we conducted the study by collecting two separate samples: Study 1b was a direct replication of study 1a, and study 3 tested novel hypotheses. We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

Recruitment and Exclusion Criteria

Studies 1–3 recruited parents on Amazon Mechanical Turk (MTurk). We used MTurk's built-in recruitment filters, considering participants' responses to demographic questions about the age of their children. Because these questions did not precisely ask for a date of birth, some caregivers provided responses for children older than five. Even though this extended the age range beyond what was originally preregistered, we chose to include those responses. In order to ensure that the participants were truthfully reporting their parenting status, participants filled out a short survey prior to the main part of the study, where they were asked (among other questions) if they were the primary caregiver for a child under 5. Depending on their response, they were given the option to complete the survey for their child for a bonus payment. Importantly, if they answered "no" to this question, they still received the base payment, meaning that payment was not contingent on parenting status. Study 4 recruited parents from the Princeton Baby Lab database, based out of a relatively high socio-economic status area in central New Jersey.

Participants were excluded if they reported a lack of English proficiency. Additionally, in the preregistered studies 1b and 3, participants were instructed to skip one of the pre-survey questions as an attention check and were excluded if they failed to do so. Attention checks were not included for studies 1a and 2, as data collection for these studies served as pilot data. As preregistered, study 4 participants were excluded if they did not complete the pre-study survey or if they filled out fewer than five surveys over the course of the study. We did not collect demographic information for the children in studies 1–3; however, general information about the demographics of MTurk workers can be found in Shaw and Hargittai's (2021) study. More female (vs. male) caregivers completed the surveys (S1a: 60% F, 40% M; S1b: 54% F, 46% M; S2: 65% F, 35% M; S3: 66% F, 34% M). In study 4, 52% of children were female, and 48% were male. Race was not reported for 47% of study 4 participants 8% were Asian, 2% Black, 4% Hispanic, 3% Mixed race, and 35% White. Maternal education was unknown for 49% of study 4 participants, 3% reported high school as their highest education level, 12% bachelor's, 31% master's, and 4% doctorate.

Sample Size

Information about sample size and exclusion is included in Table 1, and histograms of the age distribution for each study can be found in Supplementary Fig. 1.

In exploratory studies 1a and 2, the sample size was modeled after prior studies on the development of emotion concepts in older children (e.g., Nook et al., 2017, 2018). The sample sizes in studies 1b, 3, and 4 were preregistered to achieve a power of 80% in the analyses of interest based on an independent pilot sample using the simr package in R for power analyses in mixed effect models. In studies 1b and 3, we computed power based on the effect of age on the valence organization of transitions in an independent pilot sample of 150 participants. In study 4, we computed power based on the effects of (1) age, (2) vocabulary size, and (3) knowledge of the label based on an independent pilot sample of 20 participants. To ensure an equal number of participants in each of the five age groups (0–5 years) and address the uneven sampling of different age ranges resulting from broader recruitment, we expanded the sampling beyond the initially planned sample size. The decision to continue data collection was made prior to any data analysis and was purely based on achieving approximately even sampling across the age range.

Measures

Emotion Intensity Profile Questionnaire

In studies 2–4, parents reported how the intensity of each emotion (e.g., "surprise") changes from its onset (0 s) to 2 h after its onset (i.e., the emotion's intensity profile; Sonnemans & Frijda, 1994; Verduyn et al., 2009) for their child (and in study 2 for themselves as well). At each trial, they

Table 1 Participant information

Study	Final sample	Preregistered	Age range	Excluded participants
Study 1a	148 children; 129 parents (110 reported on 1 child; 19 reported on 2 children)	N/A	0 to 5;0 years*	41 total excluded (41 English proficiency)
Study 1b	255 children and parents	170	0;2 to 7;1 years*	121 total excluded (113 attention check; 8 English proficiency)
Study 2	161 children; 134 parents (108 reported on 1 child; 25 reported on 2 children; 1 reported on 3 children)	N/A	0;0 to 5;0 years*	0
Study 3	239 children	170	0;2 to 7;0 years*	66 total excluded (51 attention check; 15 English proficiency)
Study 4	99 children (80 reported on 1 child; 8 reported on 2 children; 1 reported on 3 children)	70	0;1 to 4;11 years*	5 total excluded (4 missing pre-study surveys; 1 fewer than 5 surveys)

*The reported ages follow the format *years; months*

saw a graph where the *y*-axis represented the intensity of the emotion (with 100% being the peak intensity and 0% the lowest), and the *x*-axis had time intervals from 0 s, marking the onset of the emotion, to 2 months after the onset of the emotion (see Fig. 1a). Participants indicated the emotion intensity at each time by dragging the points on the graph up and down with their cursor.

Emotion Transition Likelihood Questionnaire

In studies 1a, 1b, and 3, parents reported how likely they (1a and 1b) and their child (1a, 1b, and 3) were to transition between 70 pairs of emotions. For example, participants might estimate the likelihood of HAPPY → SAD, which means if they were feeling happy (the first emotion in the pair), how likely would they be to feel sad (the second emotion) next? They reported this likelihood using a slider with continuous values from 0 (extremely unlikely) to 100 (extremely likely). We selected a subset of emotion states (*happy*, *irritated*, *calm*, *interested*, *sad*, *stressed*, *serious*, *confused*, *surprised*, and *disgusted*) from Thornton and Tamir (2017) that spanned the 3-dimensional affective space (including rationality and social impact in addition to valence) described by Thornton and Tamir (2017) and Tamir et al. (2016). Based on adult norms from 1,205 participants in Tamir et al.'s (2016) study, half of the states we selected were positive, half were negative, and each valence category had equal numbers of high vs. low rationality and social impact states (Supplementary Table 2).

Vocabulary and Emotion Label Production

In studies 3 and 4, parents completed a vocabulary questionnaire for their child. They reported whether their child "understands" or "understands and says" (i.e., produces) a set of 64 words. This included 19 emotion labels (including the 10 used in previous tasks) and 45 other words from the English words and sentences MacArthur-Bates Communicative Development Inventory (Fenson et al., 2007). The latter were evenly split across neutral, negative, and positive valence and were matched on child production at the midpoint in the age range of the study (2;6 years), based on data from WordBank (Frank et al., 2017; see Supplementary Fig. 2). In studies 3 and 4, vocabulary size refers to the count of words the child can produce.

Additionally, we marked each child's production of the 10 emotion labels whose transition likelihood and duration we measured. This measure allowed us to relate emotion label production to emotion dynamics across tasks. Additional preregistered analyses about the contents of children's vocabularies can be found in the Supplement.

Ecological Momentary Assessment

In study 4, parents were prompted to report how their child felt 6 times per day for 10 days at random intervals (normally distributed around 2 h between surveys, with a standard deviation of 15 min). This time interval matches the typical intervals used for ecological momentary assessment studies in adults (Thornton & Tamir, 2017). A transition was marked as any consecutive surveys on a given day. Prior work has shown that the structure of emotion transitions is relatively stable across varying time intervals: transitions which are more likely over short intervals also tend to be more likely over longer ones (Thornton & Tamir, 2017). Some participants missed a few surveys, and some chose to complete the survey a few additional times. On average, participants completed 55.78 surveys (sd = 4.92; min = 41, max = 64).

Each survey began by asking the parent if, in the past 15 min, they were present with their child and their child was awake. If not, the survey ended. Otherwise, the parent

selected all emotions (out of 10) their child was currently experiencing, with the option to select multiple (or no) emotions if applicable. Parents were asked to give their best estimate of their child's feelings.

Other Measures

In studies 1b and 3, we collected responses on the caregiver's emotion expressivity and child duration of orienting for exploratory purposes. Analyses and details of these measures are included in the Supplementary Materials.

Study Plan, Procedure, and Order

The measures included in each study and the order of presentation re outlined in Table 2. In studies 1a, 2, and 4, some caregivers reported on multiple children (the exact breakdown is available in Table 2).

Analysis

Quantifying Transition Likelihood

The likelihood of a transition between two emotions was quantified in three ways. In studies 1–3, it was measured as the likelihood rating provided by caregivers in the emotion transition likelihood questionnaire.

In study 4, transitions were registered as a sliding window across two consecutive timepoints in the study (i.e., two consecutive surveys completed by the parent). We marked that a transition occurred if the caregiver checked off the first emotion of the transition in the first survey and the second emotion in the next survey. For example, if a caregiver reported that the child was happy on a survey completed at 9:36 am and sad on the next survey they completed at 11:24 am, we marked that a transition between happiness and sadness occurred. Based on this definition, we computed two measures of transition likelihood. First, we measured the frequency of the transition as the total number of transitions between two emotions observed over the 6 days of the study. Because this measure did not control for the base frequency of each of the emotions in the transition, we computed a second measure of transition likelihood—a log odds ratio, which controlled for the base frequency of transitions that involved each of the emotions in the pair. This measure was computed using the odds ratio function in the "epitools" package in R (Aragon, 2020), based on the frequency of the transition between the two emotions of the pair (e.g., happiness and sadness), the frequency of transitions between each of the emotions in the pair and other emotions (e.g., between happiness and any other emotion, not including sadness), and the frequency in transitions between emotions that are not in the pair (e.g., any two emotions that are not happiness or sadness).

Quantifying Valence Organization

Valence organization of emotion transition measures the extent to which a child (or an adult) is more likely to transition to a more (vs. less) similar emotion. For each pair of emotions, we computed the absolute difference in valence score for each state. These scores reflect the average ratings made by 1,205 adults on a continuous 100-point scale (Tamir et al., 2016). In all studies, it was measured as the standardized regression coefficient of the similarity in valence ($-\Delta V$; valence difference multiplied by -1) predicting the transition likelihood (likelihood $\sim \beta(-\Delta V)$). This quantity (β) is referred to as the Valence Organization Index (VOI) in the text.

Table 2 Study design

	Study 1a	Study 1b	Study 2	Study 3	Study 4
Emotion transition likelihood questionnaire	Parental report on self and child	Parental report on self and child	–	Parental report on child	–
Emotion intensity trajectory questionnaire	–	–	Parental report on self and child	Parental report on child	Parental report on child
Vocabulary and emotion label production	–	–	–	Parental report on child	Parental report on child
Ecological momentary assessment	–	–	–	–	Parental report on child
Presentation order	Parent, then child	Order counterbalanced	Parental report on self first, then child	Order randomized	The intensity trajectory and vocabulary questionnaires were completed in a pre-study survey

Inferential Statistics

In this investigation, we characterized how age, vocabulary, and emotion duration correlated with changes in valence organization. We expect in all cases that valence similarity will predict a higher transition likelihood. We further predicted that this relation should be strongest if a variable of interest, like age and vocabulary size, were high. In studies 1a, 1b, and 3, we did so by constructing a regression model in which the predicted variable was the VOI, and the predictors were the corresponding variables of interest (as preregistered in studies 1b and 3). In study 4, we preregistered a slightly more sensitive regression model, in which we omitted the intermediate step of computing a summary VOI by the participant. Instead, we quantified how the predictor of interest (e.g., age, vocabulary) modulated the effect of valence similarity on transition likelihood (captured by VOI in previous studies). The models used for study 4 predicted the likelihood of the transition (i.e., the transition frequency or the log odds ratio) and included valence similarity, the variable of interest, and their interaction. In this model, we focused our analyses on the interaction term (valence similarity × predictor of interest). For the main analyses, we computed the shared effect across all studies. In those cases, just for the shared regression, we followed the model structure of studies 1a, 1b, and 3. For all analyses, we used an alpha level of 0.05.

For all mixed effect regressions in the manuscript, we used the lmerTest package, with a Satterthwaite approximation for the degrees of freedom and an alpha level of 0.05. We followed a shared rule for selecting the structure of the model. We always started with the most random model—including both random slopes and intercepts by the relevant factor(s) (e.g., by participant or emotion). If this most random model returned a convergence error, or a singular fit warning, we instead used a smaller model that only included random intercepts (and omitted random slopes). See also Supplementary Table 3 for alternative analyses.

Results

Developmental Changes in Emotion Dynamics in Early Childhood

We characterized two aspects of children's emotion dynamics during the first 5 years of life: the duration and transition organization of children's emotion experiences as perceived by caregivers.

Emotion Duration in Early Childhood

Studies 2–4 examined the development of the duration of emotion experiences (i.e., the amount of time children spend in the same emotional state). We estimated a half-life for each emotion as the time between the onset of the emotion and the time when the intensity of the emotion returned to half of its peak intensity (as indicated by the caregiver).

Over the first 5 years, emotion half-life increased with age (S2: $\beta_{age} = 0.08$, 95% CI [0.02, 0.13], $t(1215) = 2.85$, $p = 0.004$; S3: $\beta_{age} = 0.1$, 95% CI [0.07, 0.16], $t(2039) = 5.31$, $p = 1.2 \times 10^{-7}$; S4: $\beta_{age} = 0.1$, 95% CI [0.04, 0.16], $t(863) = 3.1$, $p = 0.002$; Fig. 1e). Combining the results from the three studies into a single regression model with a random intercept for study revealed an overall association between age and emotion half-life ($\beta_{age} = 0.1$, 95% CI [0.07, 0.13], $t(4130) = 6.8$, $p = 1.3 \times 10^{-11}$). Further, in study 2, which measured both adult and child emotion duration, children had significantly shorter emotion half-life than adults ($t(287) = 5.83$, $p = 1.5 \times 10^{-8}$).

Even though the average emotion half-life increased with age, the relative order of half-lives across emotions between caregivers and children did not change. For example, both for adults and children, happiness lasted longer than surprise or irritation. We tested this by computing the rank-order Spearman correlation between each child's and their caregiver's emotion durations in study 2. There was no significant association between the child's age and the magnitude of the correlation ($\beta_{age} = 0.03$, 95% CI [−0.14, 0.19], $t(143) = 0.35$, $p = 0.73$). Together, these results suggest that caregivers perceived children's emotion experiences to be reliably shorter than those of adults and to increase in duration during the first 5 years of life. However, which emotions last longer or shorter remains similar to that of their caregivers across ages.

Emotion Transition Organization in Early Childhood

In four studies, we characterized the organization of young children's emotion transitions, as perceived by caregivers. First, we tested whether valence organized emotion transitions at each age. A one-sample *t*-test in each of the four studies showed that the Valence Organization Index was significantly greater than zero at all ages, from zero to 7 years (see Fig. 2 and Supplementary Table 1). This suggests that, even in infancy, emotion transitions are already organized, at least partially, by valence.

Second, we evaluated whether the level of organization by valence changes over development. In all four studies, we found that caregivers perceived the organization of children's emotion transitions by valence as increasing with age (Fig. 2; Fig. 3b). Children become increasingly likely to

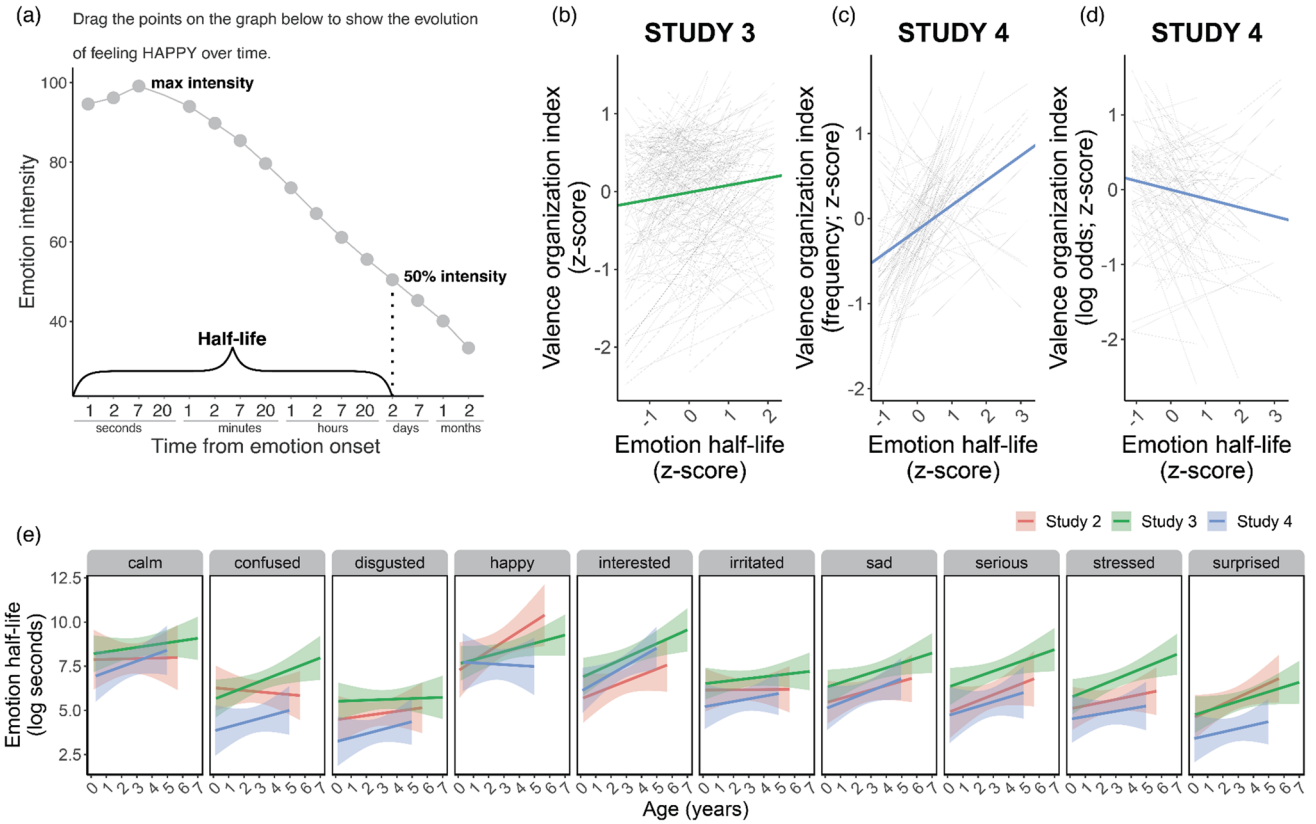

Fig. 1 **a** Measuring emotion duration. In this example trial, a parent would drag the points on a graph using their mouse cursor to show how the intensity of the target emotion (e.g., happiness) changes over time from the onset of the emotion till 2 months after the emotion onset. Half-life is the time between the emotion onset and the time when the emotion reaches half of its maximum intensity. The correlation between emotion half-life and valence organization in study 3 (**b**) and the two measures in study 4 (**c**, **d**). The thin black lines show the regression line for each participant. The thick colored line (green for study 3 and blue for study 4) shows the fixed effect regression line from the mixed effects model with random intercepts by participant. **e** Changes in each emotion's half-life by age in studies 2 (red), 3 (green), and 4 (blue)

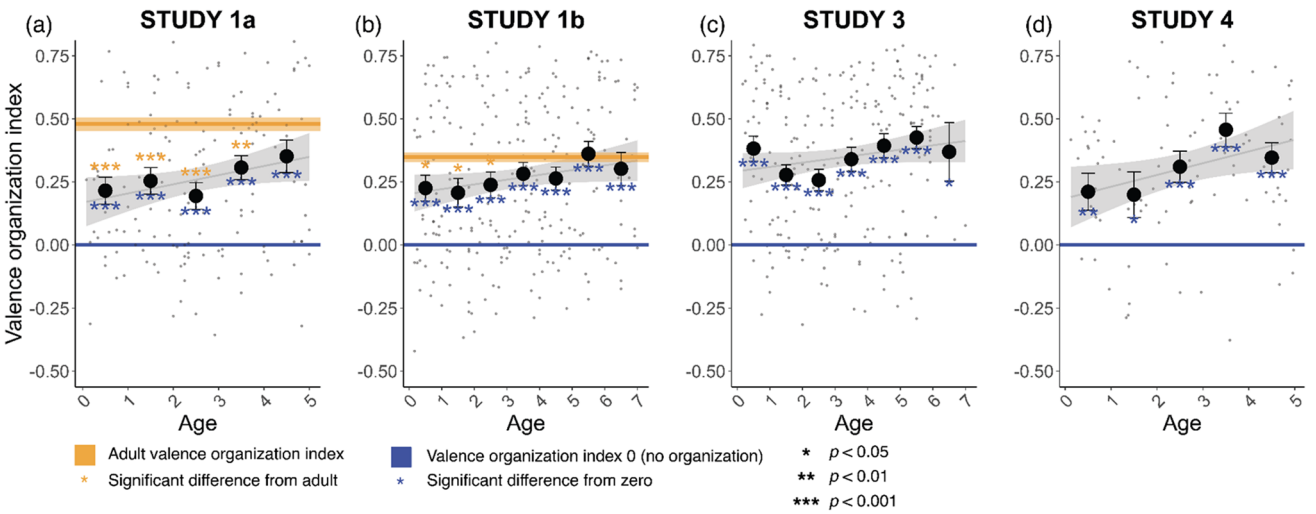

Fig. 2 Organization of emotion transitions by valence for children between 0 and 7 years (**a**–**d**) for studies 1a, 1b, 3, and 4, respectively

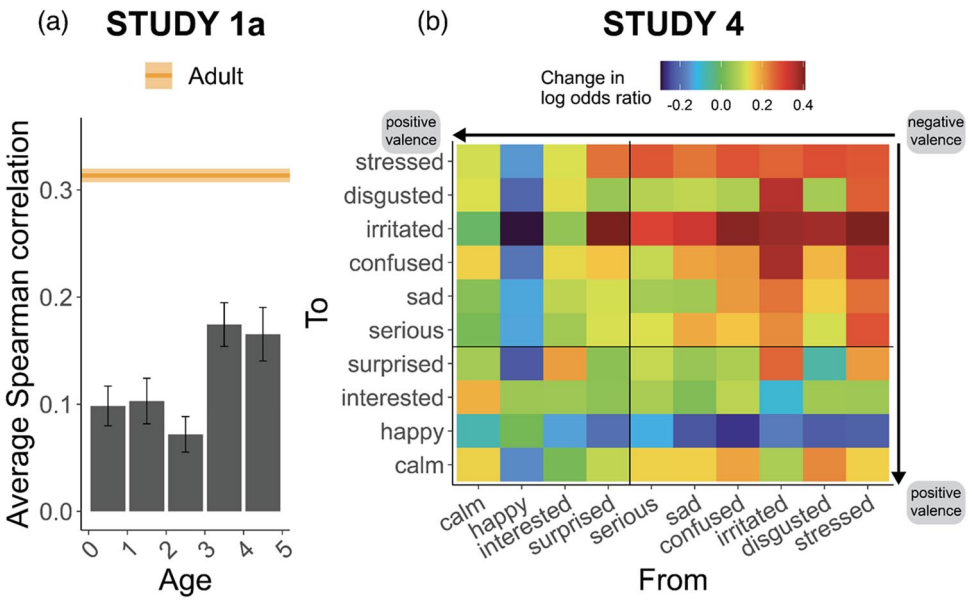

Fig. 3 **a** The consistency in children's emotion transitions across individuals at a given age (computed as the average Spearman correlation) is plotted on the *y*-axis. The error bars represent a 95% confidence interval. The shared orange line shows the Spearman correlation observed in adult caregivers. **b** The color of each cell represents the extent to which the likelihood of the transition (log odds ratio) from a given emotion (on the *x*-axis) to another emotion (on the *y*-axis) correlates with age. Red hues signal that the transition became more likely with age, whereas blue hues show a decrease in the likelihood of the transition. Green hues represent little or no change with age. The emotions listed on each axis are ordered by valence, with the black lines representing neutral valence (a value of 0). An increase in valence organization is marked by an increase in transition odds between similarly valenced states (between negative states in the top right quadrant and positive states in the bottom left quadrant) and a decrease in transition odds between other states

transition between similarly valenced emotions (e.g., from sad to frustrated) and less likely to transition between differently valenced emotions (e.g., from sad to happy). Age predicted VOI in study 1a [study 1a: $\beta_{age} = 0.17$, 95% CI [0.01, 0.33], $t(146) = 2.11$, $p = 0.037$]. In studies 1 and 3, the effect was positive but did not reach significance [study 1b: $\beta_{age} = 0.12$, 95% CI [−0.004, 0.24], $t(248) = 1.9$, $p = 0.059$; study 3: $\beta_{age} = 0.11$, 95% CI [−0.02, 0.24], $t(237) = 1.68$, $p = 0.09$]. Finally, in study 4's experience sampling data, children's emotion transitions also became more organized by valence with age. A preregistered analysis predicting the likelihood of a transition between two emotions revealed a significant interaction between how similar the valence of two emotions was and the child's age, such that valence similarity was a stronger predictor of valence transitions at older ages. This was true for both measures of transition likelihood [$\text{frequency}_{\text{age} \times \text{valence similarity}} = 0.04$, 95% CI [0.02, 0.06], $t(5{,}761) = 4.71$, $p = 2.52 \times 10^{-6}$; log odds ratio: $\beta_{\text{age} \times \text{valence similarity}} = 0.09$, 95% CI [0.06, 0.11], $t(5{,}682) = 7.42$, $p = 1.3 \times 10^{-13}$]. Finally, we found a shared effect of age on valence organization across studies using a mixed effect model with random slopes and intercepts for study [$\beta_{age} = 0.14$, 95% CI [0.06, 0.25], $t(4.76) = 3.56$, $p = 0.017$]. Together, these retrospective and in vivo measures provide converging evidence that over the first 5 years of life, children's emotion transitions become increasingly organized by valence. Through early childhood, children become more likely to transition between emotions that are similar in valence and less likely to transition between emotions that are different in valence.

In an exploratory analysis, we arbitrated between two patterns that are consistent with an increase in valence organization of emotion transitions: (1) children's emotion transitions are initially idiosyncratic (i.e., each child may transition in unique ways) or (2) young children follow a consistent pattern that is simply less organized by valence (i.e., all children may transition in similar ways). In study 1a, the consistency in emotion transition likelihoods quantified as the average rank-order correlation between the transition likelihoods for all emotion pairs of same-aged children in the sample, increased with age (see Fig. 3a; $\beta_{age} = 0.13$, 95% CI [0.09, 0.16], $t(2{,}219) = 6.13$, $p = 1.02 \times 10^{-9}$). Infants' emotions were highly idiosyncratic, and over time, these idiosyncratic patterns converged into a shared mature pattern of emotion transitions—one organized by valence.

Relation Between Emotion Duration and Emotion Transition Organization

In studies 3 and 4, we probed whether the duration of a given emotion relates to the organization of its transitions. In study 3, the half-life of an emotion positively related to its

Valence Organization Index in a mixed regression with random intercepts per participant ($\beta_{\text{half-life}} = 0.09$, 95% CI [0.04, 0.14], $t(1{,}930.56) = 3.8$, $p = 0.0001$). This effect held after controlling for the child's age ($\beta_{\text{half-life}} = 0.09$, 95% CI [0.04, 0.14], $t(1{,}938.52) = 3.74$, $p = 0.0002$). In study 4, half-life was related to the effect of valence similarity on transition likelihood, measured as frequency (captured by VOI in previous studies; $\beta = 0.04$, 95% CI [0.02, 0.06], $t(4{,}916) = 3.18$, $p = 0.001$), even when controlling for age ($\beta = 0.04$, 95% CI [0.02, 0.06], $t(4{,}916) = 3.18$, $p = 0.002$). This effect was not significant with the log odds ratio measure of transition likelihood ($\beta = -0.01$, 95% CI [−0.03, 0.02], $t(5{,}000) = 0.77$, $p = 0.44$).

Despite the divergent results between the two measures in study 4, the results in studies 3 and 4 suggest that the organization of children's emotion transitions is positively associated with the duration of their emotion experiences. That is, longer emotions tend to transition to more similarly valenced emotions.

Relation Between Emotion Vocabulary and Emotion Dynamics

Next, we examined whether the dynamics of emotion relate to young children's growing vocabularies in studies 3 and 4. We examined two preregistered predictions: (i) overall vocabulary size will relate to valence organization, measured across all emotions, and (ii) children's production of the label for a specific emotion will relate to the organization of that same emotion's transitions.

First, we tested the preregistered prediction that children with larger vocabularies will have emotion transitions more organized by valence. This was the case in study 3 ($\beta = 0.18$, 95% CI [0.06, 0.30], $t(237) = 2.87$, $p = 0.004$; Fig. 4a), and this effect remained significant after controlling for age ($\beta = 0.25$, 95% CI [0.05, 0.45], $t(236) = 2.46$, $p = 0.01$). Similarly, in study 4, overall greater vocabulary size was related to greater valence organization [frequency: $\beta = 0.04$, 95% CI [0.02, 0.05], $t(5{,}761) = 4.16$, $p = 3.16 \times 10^{-5}$; log odds ratio: $\beta = 0.07$, 95% CI [0.04, 0.09], $t(5{,}761) = 5.56$, $p = 2.83 \times 10^{-8}$, Fig. 4b], but the effect did not hold after controlling for age [frequency: $\beta = -0.02$, 95% CI [−0.05, 0.02], $t(5{,}759) = -0.95$, $p = 0.34$; log odds ratio: $\beta = 0.02$, 95% CI [−0.02, 0.07], $t(5{,}759) = 1.00$, $p = 0.32$]. It is important to note that age was highly correlated with vocabulary size [$r = 0.85$, $t(97) = 16.02$, $p = 5.43 \times 10^{-29}$]. Together, these results suggest that children's growing vocabulary skills may be related to the organization of their emotion transitions. However, other developmental factors that increase with age likely also contribute to this relation.

Next, we tested the hypothesis that language and emotion dynamics will be related to the level of individual emotions. In study 3, an exploratory mixed effect regression (which included random slopes and intercepts by emotion) showed that when parents reported that their child produced the label for a given emotion, the way that their child transitioned from that emotion was more organized by valence ($\beta_{\text{label production}} = 0.13$, 95% CI [0.04, 0.23], $t(6.63) = 2.78$, $p = 0.03$; Fig. 4c). This effect did not remain significant when controlling for child age ($\beta_{\text{label production}} = 0.08$, 95% CI [−0.01, 0.21], $t(11.94) = 1.86$, $p = 0.09$). A preregistered analysis in study 4 replicated this effect [frequency: $\beta_{\text{valence similarity} \times \text{label production}} = 0.08$, 95% CI [0.07, 0.14], $t(5{,}652.71) = 5.9$, $p = 3.3 \times 10^{-9}$; log odds ratio: $\beta_{\text{valence similarity} \times \text{label production}} = 0.11$, 95% CI [0.10, 0.2], $t(5{,}689.32) = 6.16$, $p = 7.68 \times 10^{-10}$; Fig. 4c], which remained significant when controlling for the effect of age on valence organization [frequency: $\beta_{\text{valence similarity} \times \text{label production}} = 0.07$,

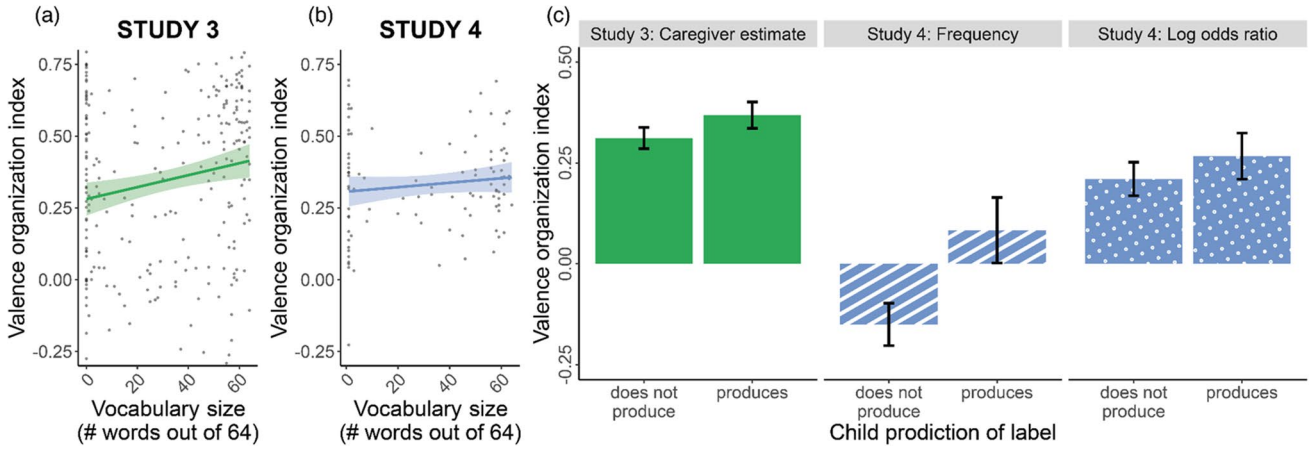

Fig. 4 Vocabulary size related to valence organization in **a** study 3 and **b** study 4. **c** Valence more strongly organized the transitions of emotions that a given child can label (vs. ones the child cannot yet name) in study 3 (green) and study 4 (blue), using both log odds ratio (striped) and frequency (dotted). Error bars show a 95% confidence interval

95% CI [0.04, 0.14], $t(5{,}761) = 3.36$, $p = 7.9 \times 10^{-4}$; log odds ratio: $\beta_{\text{valence similarity} \times \text{label production}} = 0.06$, 95% CI [0.005, 0.13], $t(5770) = 2.13$, $p = 0.03$]. Together, these results show that when a child experiences an emotion that they can name (as opposed to an emotion they cannot name), they are more likely to transition to similarly valenced emotions. However, given that this effect did not hold after controlling for age in study 3, other developmental factors linked to age may also be at play.

Discussion

The current investigation characterized the change in children's emotion dynamics over the first 5 years of life, as perceived by caregivers, and its relation to language development. Across four studies, we observed an increase in emotion duration and transition organization. These changes paralleled children's growing emotion vocabulary. Together, these results add to a rich literature showing that childhood is a formative period in emotion development, likely with a bidirectional influence between emotion dynamics and early language development.

Caregivers reported that the duration and transition organization of children's emotions increased over development. Infants start with highly idiosyncratic emotion transitions and, over time, converge onto a canonical adult-like pattern. There are several ways in which children come to develop canonical emotion dynamics. During the first few years of life, children accumulate knowledge about emotion durations and emotion transitions by observing the statistics of others' emotion experiences. Extensive research in the field of statistical learning suggests that children readily learn statistical patterns such as the durations (Addyman et al., 2014) and transitions of complex events and actions (Lew-Williams et al., 2011; Monroy et al., 2017, 2019; Saffran & Kirkham, 2018). Studies have shown that children also extract statistics from emotion experiences. For example, older children (6–10 years) track the frequency of emotion facial configurations (Plate et al., 2019; Woodard et al., 2021), and young infants track the "emotional history" of individuals (Repacholi et al., 2016a, 2016b). Collectively, these findings suggest that children may gradually develop adult-like patterns of emotion durations and transitions by observing socially relevant statistics in their environment.

In addition to children's growing experience with emotion dynamics in the first years of life, children's advancing language skills may help them learn how emotions unfold over time. Children with larger vocabularies had more canonical emotion transitions, controlling for age. Further, when children could label a specific emotion, their transitions for that emotion were more organized by valence. These findings align with prior work linking both general and emotion-specific language to emotion development (Fabes et al., 2001; Nook et al., 2017; Roben et al., 2013; Streubel et al., 2020). When emotion labels co-occur with observed or experienced emotions, they may help children connect different instances of the same emotion, in line with the theory of constructed emotion (Barrett, 2017; Hoemann et al., 2019). This could, in turn, enable them to extract fine-tuned statistics about each specific emotion, such as its average duration and its likelihood of transitioning to other emotions (Cole et al., 2010; Hoemann et al., 2019; Lindquist et al., 2015; Nook & Somerville, 2019; Ruba & Repacholi, 2020; Ruba et al., 2022; Shablack et al., 2020). Further, the broader ability to reason about and participate in real-world social situations through language can support both conceptual (Bowerman & Levinson, 2001) and emotion development (Nook & Somerville, 2019). Alternatively, children's emotion development may scaffold their emotion language (Vigliocco et al., 2009). Most likely, there are bidirectional links between emotion and language development, such that shifts toward the mature state in each domain reinforce each other across time.

The relation between language and emotion dynamics may also reflect the way that caregiver-child communication interacts with parental perceptions. As children communicate and think about their emotions in increasingly granular ways (Nook et al., 2017, 2020; Widen & Russell, 2008), caregivers may recognize more subtle emotion transitions in their child. For example, an infant may not experience a recognizable transition between sadness and anger, instead expressing both states in non-specific ways, whereas an older child may both experience these transitions and communicate their experiences by labeling them explicitly. Further, caregivers can convey more information about emotion to their child as the child's emotion vocabulary increases. Indeed, in older children, caregivers and children mutually influence each other's emotion language (Nook et al., 2023). Over time, this increasingly sophisticated back-and-forth interaction may help children develop adult-like experiences, expressions, and understanding of emotion. It is important to note that the link between language and emotion dynamics did not reliably hold when controlling for age, which leaves open the possibility that other developmental processes may play a role, such as changes in children's memory, attention, and regulation abilities.

Limitations and Future Directions

A major strength of this line of work is that it captures patterns in emotion dynamics across a younger age range than previous studies, expanding our understanding of emotion processes in infancy and early childhood. However, these conclusions must be interpreted with several limitations in mind.

Our measures of children's emotion experiences were indirect, as caregivers reported on their child's emotion experiences. We chose this approach because (1) young infants cannot self-report emotions, (2) physiological and behavioral measures of specific emotions (e.g., differentiating between different high arousal emotions) have not been validated with specificity in infants, and (3) adults have been shown to be quite good at estimating emotion transitions of close others (Zhao et al., 2022). That said, subjective reports of others' emotions likely do not perfectly capture each child's experiences (Lagattuta et al., 2012; López-Pérez & Wilson, 2015). For example, even though caregivers reported their children experiencing each emotion, we do not know the extent to which caregivers believed young children were capable of experiencing these emotional states in an adult-like way (Lozada et al., 2016). Parent reports were also likely biased by their own personal experiences of emotions and emotion transitions. Future research should examine how adults perceive children's minds and emotions more directly. Studies 1–3 asked caregivers to estimate the likelihood of transitions, which may further decrease accuracy. In order to mitigate this concern, we used an EMA approach instead in study 4. As in previous work in adults, we found similar findings across these two methods (Thornton & Tamir, 2017), but future work would need to understand how different sampling intervals shape caregivers' reporting in EMA studies of children's emotions. The EMA approach comes with limitations as well, since it is not possible to sample emotion experiences continuously, and we may miss intermediate transitions between two timepoints in the day. Moreover, future studies could use more ecologically valid measures of emotion experiences, such as facial or vocal expressions in videos of natural interactions, or measure self-reported emotions in older children.

Our work showing that children's language development relates to their emotion experiences is grounded in a North American context. This limits our ability to generalize the findings across cultures and communities. How might language help infants tune into the emotion dynamics of their communities? There is evidence of common valence-based organization of mental-state language across cultures, as well as variability in the meanings of emotion labels (Jackson et al., 2019; Thornton et al., 2022). Thus, there is likely both consistency and variation in the specific structure of the emotions and emotion language that children experience in their home environment. Future work will be able to leverage these individual differences to understand how young children extract emotion-related regularities in diverse environments (Mesquita, 2022).

To understand how children's dynamic and complex emotional worlds change over development, it is important to understand how emotion changes over hours and days. The current investigation applies a dynamic lens to studying emotion development and how it relates to children's developing language skills.

Additional Information

Funding National Institute of Mental Health (R01MH114904); National Institutes of Health (R01HD095912); ACM SIGHPC; Princeton University.

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Availability of data and material Data and analysis code for all studies can be found here: https://osf.io/hku68/?view_only=f330c97d6ce944caa814b15a5f534fac.

Authors' contributions Not applicable

Ethics approval Not applicable

Consent to participate Not applicable

Consent for publication Not applicable

Informed consent Informed consent was obtained from all individual participants included in the study.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42761-024-00248-y.

References

Addyman, C., Rocha, S., & Mareschal, D. (2014). Mapping the origins of time: Scalar errors in infant time estimation. *Developmental Psychology, 50*(8), 2030.

Aragon, T. J. (2020). *epitools: Epidemiology tools* (R package version 0.5–10.1). https://CRAN.R-project.org/package=epitools

Barrett, L. F. (2006). Are emotions natural kinds? *Perspectives on Psychological Science, 1*(1), 28–58.

Barrett, L. F. (2017). The theory of constructed emotion: An active inference account of interoception and categorization. *Social Cognitive and Affective Neuroscience, 12*(1), 1–23.

Bowerman, M., & Levinson, S. C. (Eds.). (2001). *Language acquisition and conceptual development* (Vol. No. 3). Cambridge University Press.

Cole, P. M., Armstrong, L. M., & Pemberton, C. K. (2010). The role of language in the development of emotion regulation. In S. D. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 59–77). American Psychological Association. https://doi.org/10.1037/12059-004

Dejonckheere, E., Mestdagh, M., Houben, M., Rutten, I., Sels, L., Kuppens, P., & Tuerlinckx, F. (2019). Complex affect dynamics add limited information to the prediction of psychological well-being. *Nature Human Behaviour, 3*(5), 478–491.

Eisenberg, N., Sadovsky, A., & Spinrad, T. L. (2005). Associations of emotion-related regulation with language skills, emotion knowledge, and academic outcomes. *New Directions for Child and Adolescent Development, 2005*(109), 109–118.

Fabes, R. A., et al. (2001). Preschoolers' spontaneous emotion vocabulary: Relations to likability. *Early Education and Development, 12*(1), 11–27.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories: User's Guide and Technical Manual* (2nd ed.). Baltimore, MD: Brookes Publishing Co. https://doi.org/10.1037/t11538-000

Frank, M. C., et al. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language, 44*(3), 677–694.

Frijda, N. H., et al. (1991). The duration of affective phenomena or emotions, sentiments and passions. *International Review of Studies on Emotion, 1*, 187–225.

Goldfield, B. A., & Reznick, J. S. (1990). Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of Child Language, 17*(1), 171–183.

Hoemann, K., Xu, F., & Barrett, L. F. (2019). Emotion words, emotion concepts, and emotional development in children: A constructionist hypothesis. *Developmental Psychology, 55*(9), 1830.

Jackson, J. C., et al. (2019). Emotion semantics show both cultural variation and universal structure. *Science, 366*(6472), 1517–1522.

Lagattuta, K. H., Sayfan, L., & Bamford, C. (2012). Do you know how I feel? Parents underestimate worry and overestimate optimism compared to child self-report. *Journal of Experimental Child Psychology, 113*(2), 211–232.

Lew-Williams, C., Pelucchi, B., & Saffran, J. R. (2011). Isolated words enhance statistical language learning in infancy. *Developmental Science, 14*(6), 1323–1329.

Lindquist, K. A., MacCormack, J. K., & Shablack, H. (2015). The role of language in emotion: Predictions from psychological constructionism. *Frontiers in Psychology, 6*, 444.

López-Pérez, B., & Wilson, E. L. (2015). Parent–child discrepancies in the assessment of children's and adolescents' happiness. *Journal of Experimental Child Psychology, 139*, 249–255.

Lozada, F. T., Halberstadt, A. G., Craig, A. B., Dennis, P. A., & Dunsmore, J. C. (2016). Parents' beliefs about children's emotions and parents' emotion-related conversations with their children. *Journal of Child and Family Studies, 25*, 1525–1538.

Mesquita, B. (2022). *Between us: How cultures create emotions*. WW Norton & Company.

Monroy, C. D., Gerson, S. A., & Hunnius, S. (2017). Toddlers' action prediction: statistical learning of continuous action sequences. *Journal of Experimental Child Psychology, 157*, 14–28.

Monroy, C. D., et al. (2019). The infant motor system predicts actions based on visual statistical learning. *NeuroImage, 185*, 947–954.

Nelson, J., Klumparendt, A., Doebler, P., & Ehring, T. (2020). Everyday emotional dynamics in major depression. *Emotion, 20*(2), 179.

Nook, E. C., et al. (2017). Increasing verbal knowledge mediates development of multidimensional emotion representations. *Nature Human Behaviour, 1*(12), 881–889.

Nook, E. C., et al. (2018). The nonlinear development of emotion differentiation: Granular emotional experience is low in adolescence. *Psychological Science, 29*(8), 1346–1357.

Nook, E. C., et al. (2020). Charting the development of emotion comprehension and abstraction from childhood to adulthood using observer-rated and linguistic measures. *Emotion, 20*(5), 773.

Nook, E. C. (2021). Emotion differentiation and youth mental health: current understanding and open questions. *Frontiers in Psychology, 12*, 700298.

Nook, E. C., & Somerville, L. H. (2019). Emotion concept development from childhood to adulthood. *Emotion in the Mind and Body, 66*, 11–41.

Nook, E. C., Nardini, C., Zacharek, S. J., Hommel, G., Spencer, H., Martino, A., Morra, A., Flores, S., Anderson, T., Marin, C. E., Silverman, W. K., Lebowitz, E. R., & Gee, D. G. (2023). Affective language spreads between anxious children and their mothers during a challenging puzzle task. *Emotion, 23*(6), 1513–1521. https://doi.org/10.1037/emo0001203

Plate, R. C., et al. (2019). Probabilistic learning of emotion categories. *Journal of Experimental Psychology: General, 148*(10), 1814.

Potegal, M., Kosorok, M. R., & Davidson, R. J. (2003). Temper tantrums in young children: 2. Tantrum duration and temporal organization. *Journal of Developmental & Behavioral Pediatrics, 24*(3), 148–154.

Prasetio, B. H., Tamura, H., & Tanno, K. (2020). Deep time-delay Markov network for prediction and modeling the stress and emotions state transition. *Scientific Reports, 10*(1), 18071.

Reitsema, A. M., Jeronimus, B. F., van Dijk, M., & de Jonge, P. (2022). Emotion dynamics in children and adolescents: A meta-analytic and descriptive review. *Emotion, 22*(2), 374.

Repacholi, B. M., Meltzoff, A. N., Hennings, T. M., Ruba, A. L. (2016a). Transfer of social learning across contexts: Exploring infants' attribution of trait-like emotions to adults. *Infancy, 21*(6), 785–806.

Repacholi, B. M., Meltzoff, A. N., Toub, T. S., Ruba, A. L. (2016b). Infants' generalizations about other people's emotions: Foundations for trait-like attributions. *Developmental Psychology, 52*(3), 364.

Roben, C. K., Cole, P. M., & Armstrong, L. M. (2013). Longitudinal relations among language skills, anger expression, and regulatory strategies in early childhood. *Child Development, 84*(3), 891–905.

Ruba, A. L., & Repacholi, B. M. (2020). Do preverbal infants understand discrete facial expressions of emotion? *Emotion Review, 12*(4), 235–250.

Ruba, A. L., Pollak, S. D., & Saffran, J. R. (2022). Acquiring complex communicative systems: Statistical learning of language and emotion. *Topics in Cognitive Science, 14*(3), 432–450.

Saffran, J. R., & Kirkham, N. Z. (2018). Infant statistical learning. *Annual Review of Psychology, 69*, 181–203.

Scherer, K. R., & Wallbott, H. G. (1994). Evidence for universality and cultural variation of differential emotion response patterning. *Journal of Personality and Social Psychology, 66*(2), 310.

Shablack, H., Stein, A. G., & Lindquist, K. A. (2020). Comment: A role of language in infant emotion concept acquisition. *Emotion Review, 12*(4), 251–253.

Shaw, A., & Hargittai, E. (2021). Do the online activities of Amazon mechanical Turk workers mirror those of the general population? A comparison of two survey samples. *International Journal of Communication, 15*, 16.

Shin, K. E., Newman, M. G., & Jacobson, N. C. (2022). Emotion network density is a potential clinical marker for anxiety and depression: Comparison of ecological momentary assessment and daily diary. *British Journal of Clinical Psychology, 61*, 31–50.

Somers, J. A., Kerr, M. L., McNeish, D., Smiley, P. A., Buttitta, K. V., Rasmussen, H. F., & Borelli, J. L. (2020). Quantitatively representing real-time emotion dynamics: Attachment-based differences in mothers' emotion experiences. *Journal of Family Psychology, 34*(4), 480.

Somers, J. A., & Luecken, L. J. (2022). Prenatal programming of behavior problems via second-by-second infant emotion dynamics. *Psychological Science, 33*(12), 2027–2039.

Sonnemans, J., & Frijda, N. H. (1994). The structure of subjective emotional intensity. *Cognition & Emotion, 8*(4), 329–350.

Streubel, B., et al. (2020). Emotion-specific vocabulary and its contribution to emotion understanding in 4-to 9-year-old children. *Journal of Experimental Child Psychology, 193*, 104790.

Tamir, D. I., Thornton, M. A., Contreras, J. M., & Mitchell, J. P. (2016). Neural evidence that three dimensions organize mental state representation: Rationality, social impact, and valence. *Proceedings of the National Academy of Sciences, 113*(1), 194–199.

Thornton, M. A., & Tamir, D. I. (2017). Mental models accurately predict emotion transitions. *Proceedings of the National Academy of Sciences, 114*(23), 5982–5987.

Thornton, M. A., & Tamir, D. I. (2020). People represent mental states in terms of rationality, social impact, and valence: Validating the 3d Mind Model. *Cortex, 125*, 44–59.

Thornton, M. A., et al. (2022). The 3d Mind Model characterizes how people understand mental states across modern and historical cultures. *Affective Science, 3*(1), 93–104.

Thornton, M. A., Rmus, M., & Tamir, D. (2020). *Transition dynamics shape mental state concepts*.

Verduyn, P., et al. (2015). Determinants of emotion duration and underlying psychological and neural mechanisms. *Emotion Review, 7*(4), 330–335.

Verduyn, P. (2021). Emotion duration. *Affect Dynamics*, 3–18.

Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., Van Mechelen, I. (2009). Predicting the duration of emotional experience: Two experience sampling studies. *Emotion, 9*(1), 83.

Verduyn, P., & Lavrijsen, S. (2015). Which emotions last longest and why: The role of event importance and rumination. *Motivation and Emotion, 39*(1), 119–127.

Verduyn, P., Van Mechelen, I., Tuerlinckx, F., Meers, K., & Van Coillie, H. (2009). Intensity profiles of emotional experience over time. *Cognition and Emotion, 23*(7), 1427–1443.

Vigliocco, G., et al. (2009). Toward a theory of semantic representation. *Language and Cognition, 1*(2), 219–247.

Widen, S. C., & Russell, J. A. (2008). Children acquire emotion categories gradually. *Cognitive Development, 23*(2), 291–312.

Woodard, K., et al. (2021). Categorization of vocal emotion cues depends on distributions of input. *Affective Science, 2*, 301–310.

Wu, Y., et al. (2022). Angry, sad, or scared? Within-valence mapping of emotion words to facial and body cues in 2-to 4-year old children. Preprint at https://psyarxiv.com/ka3ed/

Zhao, Z., Thornton, M. A., & Tamir, D. I. (2022). Accurate emotion prediction in dyads and groups and its potential social benefits. *Emotion, 22*(5), 1030.