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Exploring the perception of stress in childhood and early adolescence

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ABSTRACT

Stressful life experiences may jeopardize the healthy development of children. To improve interventions, more knowledge is needed on the perception of stress by children. In adults, stress is regarded as a state of low valence and high arousal. It is unclear whether children perceive stress similarly. In the current study, 35 children of the general population completed three tasks aiming to provide insight into their knowledge of the concept stress. In the first task, participants were asked about their verbal knowledge of the concept stress. In the second task, they rated the valence and arousal of eight emotion-evoking vignettes. In the final task, participants completed an experience sampling survey for at least 1 day, consisting of a stress thermometer and pictorial scales of valence and arousal. Participants' perception of stress was found to be mainly valence focused. Age and sex were found to play a role in the degree of arousal focus. Older participants differentiated more in arousal levels than younger participants, as did girls in comparison with boys. Because the perception of stress depends on developmental and other individual factors, using stress as a single measurement dimension in a survey is not recommended.

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Introduction

Throughout our daily life, we encounter several stressful situations. Although it has been suggested that the neurological effects of stress vary in a lifespan (Lupien et al., 2009), there is only little research on how the perception of stress develops from childhood to adulthood.

The most frequently used methods to study stress in children and adolescents include semistructured interviews and questionnaires, which can be event-based measures of stress or perceived measures of stress. The Youth Life Stress Interview (Rudolph & Flynn, 2007), for example, is an event-based measure of stress that assesses chronic and acute stressors in several domains such as health and close friendships. The interviewer scores the stressfulness in each of the domains; the respondents' subjective perceptions of stress are not used as input to the rating. This is in contrast to the Perceived Stress Scale (PSS), a questionnaire that is also available for children and adolescents (Cohen, Kamarck, & Mermelstein, 1983). The PSS assesses chronic stress as perceived by the respondents in the past month. The focus is on the appraisal of stress rather than the domains or events with which it is associated. The Daily Hassles is another example of a questionnaire assessing stress. Like the PSS, it focuses on the appraisal of the respondents, although for specific daily events such as "not being liked by someone in your class" (Kanner et al., 1981; Parfenoff, 1989; Wright et al., 2010). These methods, however, do not give insight into the ability of children and adolescents to recognize stress within themselves. Nevertheless, the perception of emotions, more specifically the ability to make fine-grained distinctions between emotions that is also referred to as emotional granularity or emotion differentiation (Barrett, 2004), has been suggested to be an important factor in the ability to cope with negative emotions (Barrett et al., 2001). Individuals who have the skill to verbally characterize their negative experiences with greater detail are less likely to be overwhelmed by stress (Kashdan et al., 2015). This has been established not only in adults (Starr et al., 2017) but also in adolescents (Nook et al., 2021; Starr et al., 2020a). Given this importance of emotion differentiation, it might be helpful in the design of interventions to have a clearer view on how children perceive emotions, including stress.

Initially, Mehrabian and Russell (1974; see also Russell & Mehrabian, 1977) described the domain of emotions as consisting of three basic dimensions: valence, arousal, and dominance. Valence refers to pleasantness, ranging from unpleasant to pleasant, whereas arousal refers to excitement, ranging from sleepy to highly aroused. Finally, dominance refers to submissiveness, ranging from feeling controlled or submissive to being in control. In subsequent studies, Russell found no empirical evidence for the dominance dimension (Russell, 1978), which led to the definition of a new emotional model in which the affective space was presented as a circumplex structure organized around two bipolar axes: valence and arousal (Russell, 1980). According to this model, adults consider stress as a specific state of low valence and high arousal at 135 degrees in the affective space (Russell, 1980). Regarding children and adolescents, however, there is still uncertainty whether they also perceive emotions as organized around the same two axes. To understand the developmental trajectory of the concept stress, it is crucial to understand the developmental trajectory of emotions in the affective space.

A multitude of hypotheses regarding the development of emotion perception has been formulated based on a variety of lab-related tasks, including labeling of pictures, facial expressions, semantic expressions, and narratives. McManis et al. (2001) and Sharp et al. (2006), for example, used a labeling task with pictures of varying affective content selected from the International Affective Picture System (IAPS; Lang et al., 1997). Participants of different age groups labeled the pictures using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994), which consists of pictorial scales for valence, arousal, and dominance. In these studies, children aged 7 to 11 years were found to perceive the valence and arousal within the pictures in a comparable way as adults. Based on the aggregated data of more than 1000 children aged 2 to 9 years (originally reported in 11 studies), Widen (2013) found contrasting results using picture labeling tasks in which children were free to select the emotional labels. Children around 3.5 years of age divided facial expressions into mainly-two groups: positive and negative. Only at an older age did children gradually label more specific emotions (Widen, 2013). These findings support the hypothesis that during childhood and adolescence emotion perception (and potentially emotion experience) shifts from a focus on valence to a multidimensional representation, including arousal. Verbal knowledge was identified as a potential mechanism underlying this age effect (Nook

et al., 2017). Interestingly, although following this mechanism adolescents have more refined emotion representations than young children, they have been found to demonstrate lower emotion differentiation (Nook et al., 2020; Starr et al., 2020b). Nook and Somerville (2019) suggested that this difference originates from, on the one hand, the increased complexity of life in adolescence, leading to more frequent co-occurrence of emotions, and on the other hand, an oversimplification of emotional experiences in young children, although the latter could not be confirmed by Starr et al. (2020b).

In contrast to the valence and arousal focused theory of Russell, Watson et al. (1988) defined positive affect and negative affect as the most important dimensions of emotion. A 20-item scale with 10 positive affect items and 10 negative affect items was developed, referred to as the Positive and Negative Affect Schedule (PANAS) scale. Perceived stress has been studied through correlation with positive and negative affect (Myin-Germeys et al., 2003; van Eck et al., 1998; Watson, 1988) rather than valence and arousal, in particular in daily life (Myin-Germeys et al., 2009).

When studying emotions in daily life, the experience sampling methodology (ESM) is used (Hektner et al., 2007). In ESM research, participants receive a diary (e.g., an electronic diary such as a smartphone), on which they fill in a questionnaire whenever a notification is given, typically multiple times per day. The ESM allows for capturing the dynamic interaction between the environment and psychopathological experiences (Myin-Germeys et al., 2009). Because the time between an event and the reporting on the event is shortened, the ESM reduces recall bias in participants (Bolger et al., 2003). It has been adopted to explore mood and affective states of children in a limited number of studies (for a review, see Heron et al., 2017). All these studies used response scales expressed in words or numbers, whereas Heron et al. (2017) recommended using pictorial response options or thermometers instead of traditional Likert scales for children.

Little is known about the perception of stress in children, and the developmental trajectories of the two-dimensional valence–arousal affective space is still unclear, although evidence points toward an early valence-based differentiation (Nook et al., 2017; Widen, 2013). Emotion differentiation and perceived stress are strongly associated with mental health (Kashdan et al., 2015). In addition, self-reports get increasingly important in the context of ambulatory methods such as experience sampling methodology (Heron et al., 2017). We wanted to increase the insight into the perception of stress by children and in how they position stress in the valence–arousal affective space. Therefore, we administered a set of three tasks among 6- to 14-year-old children, evaluating their verbal characterization of stress (Task 1) and their ability to differentiate valence and arousal using emotional vignettes and a pictorial scale (Task 2). In Task 3, we compared their perception of daily life experienced stress and the valence and arousal of their experienced emotions in an exploratory ESM study. Based on the findings of Widen (2013) and Nook et al. (2017), we hypothesized that stress would have a mostly valence-focused representation in children and young adolescents.

Method

Participants

A total of 35 children (16 boys and 19 girls) participated in this study. These participants were recruited during summer camps addressing typically developing children aged 6 to 14 years in regular education. Because most participants had attended primary school for at least 1 year, basic reading and writing levels could be expected. In addition, camp leaders verbally guided participants throughout the experiment. The age range of our participants was 6.01 to 13.60 years (M = 9.49 years, $SD_{.}$ = 1.88).

Measures

Note that all tasks and instructions were administered in Dutch. For the purpose of this publication, all materials were translated to English by the authors. All analyses were carried out in R (R Core Team, 2018).

Task 1: Knowledge of stress

A short self-developed survey was included to examine the children's knowledge of the concept stress, consisting of two questions. The first question was, "Do you know the word 'stress'?" The answers "yes" and "no" were presented as tick boxes. The second question was presented as an open question: "If you answered 'yes,' what do you think 'stress' means?"

The answers to the first question were used to calculate a point-biserial correlation with age. The answers to the second question, containing each participant's description of stress, were summarized into a maximum of three keywords or key expressions. Similar keywords were grouped together and ranked according to their count and by the age of the participants using them.

Task 2: Affective rating

The understanding of valence and arousal was studied using emotional vignettes. A total of eight stories were designed by the researchers so that two stories covered each of the four quadrants of the valence–arousal two-dimensional space: low valence/low arousal, high valence/low arousal, low valence/high arousal, and high valence/high arousal. Note that the valence/arousal value of the vignettes was unanimously attributed by the research team, but this was not validated by other individuals. The English translations of the original stories are included in the online supplementary material (Table S1). All stories were followed by adapted SAM scales to indicate valence and arousal (Bradley & Lang, 1994). The original nine-point SAM scales were reduced to three-point scales to improve correspondence with the three-point stress scale in the third task.

This three-point stress scale, presented as a thermometer, was adopted from current practices in education (Burg, 2005; Macklem, 2007). Studies including children most often depicted the SAM in five-point scales (Musser et al., 2011; Quesada et al., 2012; Vasa et al., 2006), but there have been studies using the SAM depicted in three-point scales as well (Syssau & Monnier, 2009; Whissell, 2009). In addition, the figures of the SAM were redesigned to have a more modern and child-friendly look by rounding the shapes of the manikins and removing their hairpieces (Supplementary Fig. S1).

The valence and arousal ratings were summarized per story using graphic analyses, means, and standard deviations. The stories were tested for significant differences in valence and arousal ratings by a Kruskal–Wallis test. Post hoc comparisons were performed using a Dunn test with Benjamini–Hochberg corrections of the p values. A linear mixed-effects model was used to examine the relationship between ratings and story input. Age and sex were added as confounders, and a random intercept was included per participant. Sex was recoded into a binary variable with male as 0 and female as 1. The variable age was kept continuous but was rescaled to have 0 as a minimum and 1 as a maximum. Such transformations are common in multilevel modeling when variables are on a different scale because it improves the interpretability of the coefficients and increases likelihood of model convergence (Gelman & Hill, 2006; Harrison et al., 2018). A linear mixed-effects model was selected for its ability to model repeated-measures data and handle missing data. The full model was reduced to an optimal model by stepwise selection in both directions (p value based). Lastly, the relationship between arousal ratings and valence ratings was further investigated also by means of a linear mixed-effects model.

Task 3: Experience sampling method

To compare the perception of daily life stress with the valence and arousal of experienced emotions, participants took part in an ESM study. A new stress scale was designed for the ESM in children. To be easily answerable for young children in daily life, the scale was limited to three options: "no stress," "somewhat stressed," and "stressed." The layout was based on a thermometer going from blue to red. The scales of valence and arousal, as presented previously, were added to the ESM survey, resulting in a one-page survey. Participants were asked to complete the ESM survey-three times a day for 5 days. The survey was printed 15-fold in a booklet: three surveys for a maximum of 5 days. The camp leader was free to choose the registration moments. A total of 35 participants completed the ESM task, but only participants who reported to know the concept stress (Task 1) were included in the analysis (N = 30). This resulted in 273 responses in total, or an average of 9.1 responses per person (range = 1–15 responses, SD = 3.81).

The three levels of stress were tested for significant differences in valence and arousal ratings by means of a Kruskal–Wallis test. A linear mixed model was used to examine the relationship between stress ratings and valence and arousal ratings. The full model, including all possible two-way interactions among arousal rating, valence rating, age, and sex, was reduced to an optimal model via *p*-value-based stepwise selection.

Procedures

The social and societal ethics committee (SMEC) at KU Leuven approved all research procedures. At the start of each camp, the experimenter informed participants and requested written consent from the parents or legal guardians of the participants. Participants received a personal paper booklet consisting of the three tasks described above. Participants first completed Tasks 1 and 2. All instructions were read aloud for the entire group of children when they all had the written text in front of them. Participants completed the tasks individually. In the subsequent days, participants completed the ESM survey-three times a day. At the end of the camp, all participants received a piece of candy as a reward.

Results

Task 1: Knowledge on stress

Of the 35 participants, 5 indicated that they had never heard of the word stress before, including the 3 youngest participants (6.01, 6.34, and 7.03 years of age). A point-biserial correlation analysis revealed a positive correlation between age and knowledge of the concept stress (= .46, p = .005). Of the 30 participants who indicated that they had heard of the word stress before, 24 answered the second question (age range = 7.48–13.60 years, M = 10.25, SD = 1.70; 11 boys). The most recurring theme was "feeling nervous" (n = 9). Many children described an example situation, often in combination with the statement of feeling nervous: being late (n = 1), going into an amusement park attraction (n = 1), taking a test (n = 4), performing in a show or play (n = 2). The latter example, which is more achievement related, was combined with an expression for fear of failure, also a recurring theme (n = 5). Very few bodily indications were included in the answers; only 2 participants reported indications of physical arousal: "feeling shivers" and "walking around nervously." Table 1 shows, for all recurring themes, the number of participants, grouped by age, who used this theme to describe stress.

Task 2: Affective rating

Because two stories were selected to cover each of the four quadrants of the valence–arousal emotional space, all ratings were expected to form pairs in the corners of the two-dimensional affective space. Fig. 1 illustrates the location of each story by the mean valence and arousal ratings of the 35 participants. For the valence scale, all markers are located at the outer ends (see Fig. 1), suggesting that

Table 1
Frequencies of categorized themes in participants' descriptions of stress grouped by age.

Key theme	Example	<9 years (n = 4)	9–10 years (n = 7)[a]	10–11 years (n = 6)	>11 years (n = 5)
Valence	Not fun	1			
Arousal	Shivers		2		
Equivalent emotion	Nervous	3	4	6	5
Nonevaluative context	Being late		2		1
Evaluative context	Exam		4	2	4

Note. Some responses included multiple themes. Therefore, frequencies are allowed to total to a higher number than the number of included participants.

[a] There were 9 responses of participants aged 9 and 10 years, although 2 responses could not be categorized (e.g., "not knowing how things will end").

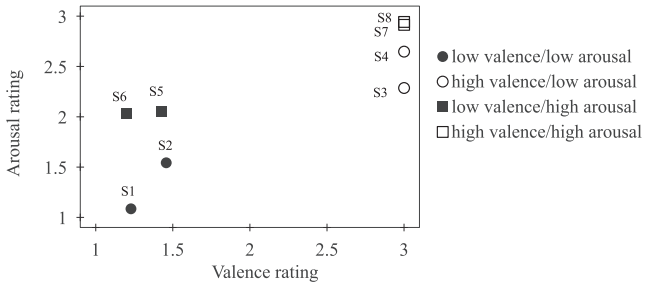

Fig. 1. Participants' mean arousal and valence ratings per story (N = 35). The shape of the markers corresponds to the valence and arousal categories as expected by the researchers.

participants mostly used ratings 1 and 3 to rate valence. A post hoc multiple comparisons test (Dunn test), following a significant Kruskal–Wallis test (χ^2 = 237.03, p < .001), indicated significant differences (p < .001) only in valence ratings between the low valence and high valence stories. However, for the arousal scale, half the ratings had a rather unexpected location. The ratings of the stories designed to represent low valence and high arousal (marker ■) seemed lower in arousal than the stories designed to represent high valence and low arousal (marker ○). A post hoc multiple comparisons test (Dunn test), following a significant Kruskal–Wallis test (χ^2 = 150.74, p < .001), indicated no significant differences in arousal ratings between Story 3 and Stories 5 and 6. The arousal ratings for Story 4 were significantly higher than the ratings for Story 5 (adjusted p = .004) and Story 6 (adjusted p = .004). Table 2 summarizes the valence and arousal means and standard deviations for all stories.

To further investigate the relationship between valence or arousal ratings, age, sex, and the represented categories, linear mixed-effects models were carried out for the dataset including 35 participants. The four categories of stories were represented by the variables ValenceS (valence story) and ArousalS (arousal story), with two levels per variable: 0 (low) and 1 (high). The variable age was scaled to values between 0 and 1. A full model, including all interaction effects was examined and reduced with stepwise regression. The best fit for the valence ratings (conditional R^2 = .83) included only the valence category as a significant predictor (b = 1.67, t = 36.09, p < .001). The best fit for the arousal ratings (conditional R^2 = .53) contained multiple predictors, all presented in Table 3. This table shows that a story's arousal rating was significantly predicted by its valence category (b = 1.02, t = 14.92, p < .001). Two interaction effects emerged for the arousal ratings, both involving the arousal category of the story, one with age and the other with sex.

Fig. 2A illustrates the interaction effect between age and arousal category (ArousalS) on arousal rating. As participants became older, they differentiated more between stories with low versus high arousal levels (low vs high ArousalS). Fig. 2B illustrates the interaction effect between sex and arousal category (ArousalS) on arousal rating. Girls tended to differentiate more in arousal levels than boys.

Lastly, in a follow-up analysis, the linear relationship between the arousal ratings and the valence ratings, as suggested by Fig. 1, was further examined. A linear mixed-effects model was used to

Table 2
Participants' mean valence and arousal ratings (and standard deviations) per story.

Affective space	Low valence/Low arousal		High valence/Low arousal		Low valence/High arousal		High valence/High arousal	
Story title	Story 1: "Going to school tired"	Story 2: "Watching a sad movie"	Story 3: "Sitting at the campfire"	Story 4: "Having your favorite food"	Story 5: "Speaking in public"	Story 6: "Taking a test"	Story 7: "Visiting an amusement park"	Story 8: "Cheering for a soccer game"
Valence	1.23 ± 0.49	1.46 ± 0.66	3.00 ± 0.00	3.00 ± 0.00	1.43 ± 0.56	1.20 ± 0.47	3.00 ± 0.00	3.00 ± 0.00
Arousal	1.09 ± 0.28	1.54 ± 0.66	2.29 ± 0.57	2.65 ± 0.54	2.06 ± 0.73	2.03 ± 0.86	2.91 ± 0.28	2.94 ± 0.24

Table 3
Best fits for arousal ratings.

	Estimate	*SE*	*t*	*p*
Intercept	1.72	0.13	13.33	<.001
ValenceS	1.02	0.07	14.92	<.001
ArousalS	−0.01	0.18	−0.05	.959
Age	−0.53	0.20	−2.67	.008
Sex (female)	−0.17	0.10	−1.71	.089
ArousalS * Age	0.97	0.28	3.44	<.001
ArousalS * Sex (female)	0.30	0.14	2.15	.033

Note. ValenceS, valence story; ArousalS, arousal story.

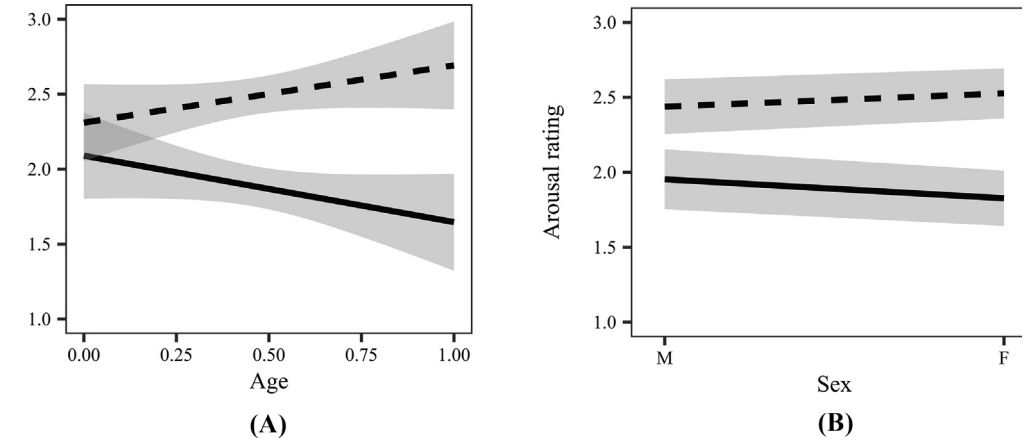

Fig. 2. Interaction effect of arousal category (depicted by line style: high ArousalS - - - [dashed line]; low ArousalS [solid line]) with age (A) and sex (B) on participants' arousal ratings. M, male; F, female. ArousalS, arousal story.

estimate the predictive value of valence rating with respect to arousal rating, independent from the affective categories as expected by the researchers. Age and sex were added to the model, as were their interactions with valence rating. Valence rating was a significant predictor of arousal rating (b = 0.66, t = 6.18, p < .001). Age and sex had negative interactions with valence rating, indicating a decreasing influence of valence rating on arousal rating over age and for female participants, although the effects were not significant (Valence Rating × Age: b = −0.20, t = −1.15, p = .250; Valence Rating × Sex: b = −0.01, t = −0.15, p = .881).

Task 3: Experience sampling method

Fig. 3 shows an apparent undersampling of stressful moments. Most of the time, the children reported to be "not stressed" and provided high ratings for both valence and arousal.

The overall mean valence and arousal ratings per stress rating are presented in Fig. 4. A multiple comparison test (Kruskal–Wallis) showed a significant difference between valence ratings for the different stress categories [$\chi^2(2)$ = 15.11, p < .001]. A following post hoc test (Dunn test) confirmed that with increasing stress, the valence ratings significantly decreased ("not stressed"–"somewhat stressed," d = 0.92 [0.18, 1.66], adjusted p = .029; "not stressed"–"very stressed," d = 2.47 [1.22, 3.71], adjusted p < .001; "somewhat stressed"–"very stressed," d = 1.18 [0.05, 2.30], adjusted p = .051). There was no significant difference between the arousal ratings of the different stress labels (Kruskal–Wallis χ^2 = 4.7288, df = 2, p = .094).

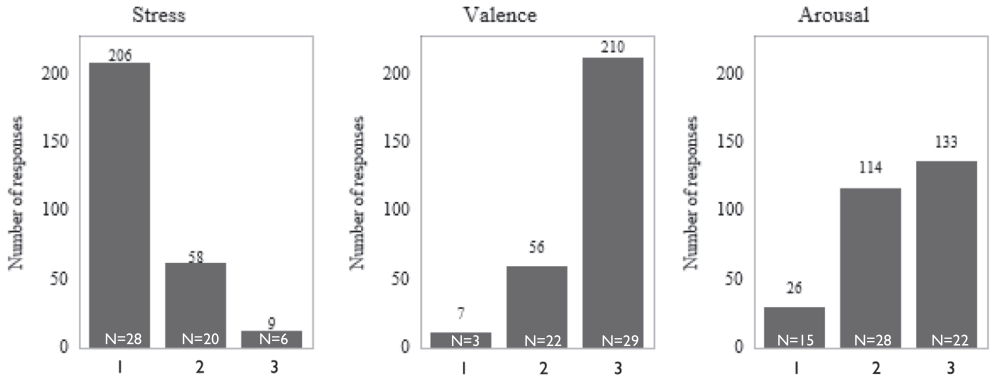

Fig. 3. Distribution of participants' stress, valence, and arousal ratings in the experience sampling methodology (ESM) task. Per rating label (1, 2, or 3), the number at the top of each bar indicates the number of responses within this label. The number at the bottom (depicted by *N*) indicates the number of distinct participants who used the specified rating label at least once.

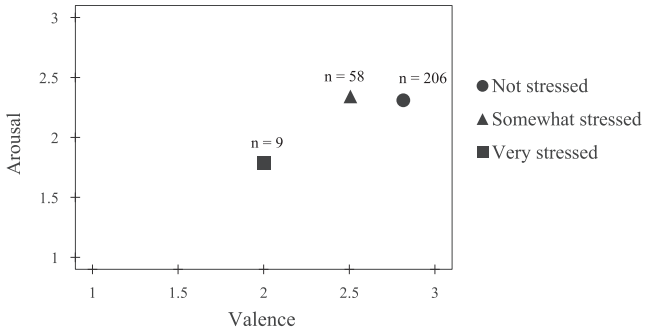

Fig. 4. Participants' mean valence and arousal ratings grouped per stress label (*n* = number of responses within each stress label). The shape of the markers corresponds to a specific stress label (see legend at right).

A linear mixed-effects model was performed to test the effect of arousal ratings, valence ratings, and age on the stress rating (N = 30). Stepwise regression was performed on the full model, including all variables and interactions. Table 4 shows the resulting best fit (conditional R^2 = .28). Stress was found to have a reversed relation to valence; increasing levels of stress were predicted by decreasing levels of valence. Girls were found to report significantly higher stress levels than boys. Age and arousal rating were dropped from the model during the stepwise selection because they appeared to have an insignificant relation with the stress rating.

Table 4
Best fits for stress ratings.

	Estimate	*SE*	*t*	*p*
Intercept	1.96	0.11	17.13	<.001
Valence	−0.89	0.12	−7.62	<.001
Sex (female)	0.19	0.07	2.74	.013

Discussion

The purpose of this study was to increase the insight into children's perception of the concept stress and in how they position stress in the valence–arousal affective space. The study consisted of three tasks.

In the first task, participants described stress mostly as feeling nervous, often followed by either an example situation such as being late, an expression for fear of failure, or a combination of both. This reflects that children link emotion words not just to a facial expression but also to different contextual cues (Widen, 2013). Saarni and Harris (1991) also suggested that young children tend to believe that an emotion originates directly from a situation, whereas older children learn that a mental process occurs as a mediator between the situation and the subsequent emotion. Recently, Nook et al., (2020) used a similar vocabulary test to investigate emotion comprehension in a large sample of participants (N = 196, aged 4–25 years), focusing on 24 emotion words ("stress" not included). They reported an age-dependent shift in the strategies to describe emotions. Young children tented to use concrete strategies such as providing an example situation and describing co-occurring bodily sensations, whereas older participants used more abstract strategies such as providing a general definition or a synonym. Although both methods were present in our sample, we could not establish such an age shift. Older participants also used example situations to explain stress, although most often in an achievement-related context, such as performing well on a test and the co-occurring fear of failure, which could be considered as a reflection of increased school and social demands (Ruble et al., 1980; Strayer, 1986). Remarkably, only 2 participants explicitly referred to bodily sensations. Stressful situations are indeed known to activate the autonomic nervous system (e.g., Gunnar & Quevedo, 2007). However, Hietanen et al. (2016) suggested that these bodily sensations of emotions become more specific with older age.

In the second task, participants rated eight stories on a three-point scale for both arousal and valence. These stories were designed to represent four extremes in the two-dimensional affective space. The linear mixed model on valence ratings showed that all participants were able to differentiate between low and high levels of valence in the absence of any age effects. This finding further supports the hypothesis that valence is a well-known concept by 6 years of age (Nook et al., 2017; Widen, 2013). The model on arousal ratings, however, showed that the ability to differentiate within arousal levels is dependent on both age and sex. Moreover, because there was a significant linear relationship with the story's valence level, the perception of arousal seems mixed with the valence dimension. These findings require us to have a more in-depth discussion on the arousal ratings.

As discussed above, arousal ratings were found to depend on both age and sex. Regarding age effects, older participants were found to differentiate more in arousal ratings based on the arousal of a story than younger participants, and their arousal ratings were also less dependent on the valence of a story. This age effect was also found by Sharp et al. (2006); children's arousal ratings to unpleasant pictures increased with age, but ratings to pleasant or neutral pictures decreased with age. Nook et al. (2017) explicitly stated this shift from a valence-focused perception to a multidimensional perception, including arousal, during development. Regarding sex effects, girls were found to differentiate more in arousal ratings than boys. There was no sex effect on the valence ratings. This is in contrast to previous studies that reported a sex effect for valence ratings and not for arousal ratings (McManis et al., 2001; Sharp et al., 2006; Sylvester et al., 2016). Sex-based differences in emotion knowledge may reflect socialization processes, including different gender roles and expectations for male and female individuals (Brody & Hall, 2008).

In addition, a linear relationship between valence and arousal emerged. Although there are several hypotheses on the relationship between valence and arousal, most studies agree on a V-shaped relation of arousal as a function of valence in adults (Kuppens et al., 2013). This V-shaped (or quadratic) relationship has also been reported in children (McManis et al., 2001; Sharp et al., 2006; Sylvester et al., 2016). However, disagreement exists regarding the symmetry of the V shape. Whereas Sharp et al. (2006) found a higher arousal rating for pictures of positive valence, Sylvester et al. (2016) reported higher arousal ratings for affective words of negative valence. The latter is referred to as the negativity bias. In the current study, there were no neutral stories concerning valence and arousal,

which limits the ability to define a V-shaped relationship. However, the data suggest a positivity bias rather than a negativity bias; arousal ratings were found to be higher for positive valence ratings.

It is important to bear in mind the possible limitations of these findings. First, a possible bias might be a negative affect implied in the low arousal "calm" pictorial scale. This hidden affect may have resulted in an underestimation of arousal for low pleasure and an overestimation for high pleasure. It is unlikely that this bias was introduced by the presented adaptations of the SAM because the facial expression of the original low arousal manikin, consisting of closed eyes and a straight line for the mouth, was copied in the adapted version. The SAM has been widely used in previous research with (young) adults. However, the suggested bias has not been described before because most studies report higher values of arousal for low pleasure (Grühn & Scheibe, 2008). Second, the stories used in Task 2 were self-developed by the research team. The stories presenting high pleasure and low arousal contained some indications of activity such as laughing and hugging, which may have biased participants toward rating a higher arousal level. On the contrary, the stories representing low pleasure and high arousal resulted in lower arousal ratings than expected. This is somewhat surprising given that these stories involved taking a test and speaking in public, which are exactly the examples they specified as stressful in the first task. Moreover, both stories contained explicit cues of arousal such as "shivers" and "a fast-pounding heart."

In the third task, a thermometer stress scale was compared with scales of valence and arousal to assess children's daily life experienced stress and emotions using an ESM setup. In line with Task 2, our analyses revealed two trends. First, valence was found to have a strong effect on children's stress ratings. Second, girls were found to report higher stress levels. This result is in line with the literature on perceived stress in adolescents (Charbonneau et al., 2009; Hampel & Petermann, 2006; Östberg et al., 2015; Schraml et al., 2011), although there is only little evidence regarding perceived stress in young children. Both these findings may be somewhat limited by the imbalanced data; only 6 participants reported at least once to be stressed during the study. The context of this study (i.e., a summer camp) may have contributed to this imbalance. Future work may want to examine whether these results are generalizable to other more stressful circumstances. Another limitation of the ESM setup was the person-based prompting. Because the camp leader was free to choose the sampling moments, it is possible that these moments were not random but rather fixed to moments consistently convenient to the camp leader such as break times. These fixed moments were possibly not representative for other nonsampled moments (Myin-Germeys et al., 2018). Lastly, the study was limited in time (5 days). More data are needed to accurately locate the labels of the stress thermometer on the two-dimensional affective space. We recommend that future studies collect more data across a longer period of time.

Albeit in a small sample of participants, the study suggests that children (6–14 years of age) relate stress more strongly to negative valence than to high arousal or activation. The relationship may vary with age and sex. Older participants differentiated more in arousal levels than younger participants, as did girls in comparison with boys. The importance of individual factors was previously reported by Barrett (1998), who showed that one model of discrete emotions does not fit all. Therefore, when studying stress in daily life, it is important to take into account participants' understanding of emotion terms by adapting the study design and including individual differences such as age, gender, and verbal knowledge into the analyses.

Because verbal knowledge plays such an important role, we suggest that future research investigate whether linguistic stimulation across emotion categories prior to participation alters the results regarding emotion understanding and potentially facilitates self-reporting. This would be of particular interest with studies including younger participants. In their review on the role of language in emotion, Lindquist et al. (2015) reported much evidence for the association between parental communication on emotions during early childhood and the development of complex knowledge on emotion categories. In addition, it might be interesting to combine an ESM application with measures of physiology such as skin conductance and heart rate. This combination would allow comparing perception of arousal and stress with measures of physical activation. Daily life measurements, including different types of contexts, will allow for the investigation of contextual influences.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2022.105604.

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