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ORIGINAL PAPER

Reading Skills, Social Competence, and Physiological Stress in the First Grade

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Abstract

An awareness of school-related antecedents of children's physiological stress at the beginning of school helps educators to prevent and mitigate children's stress, the one of the major obstacles to their well-being and academic progress. We aimed to study the effect of reading skills and social competence on first-grade students' salivary cortisol levels in natural settings. Based on previous results of the effects of everyday situations on children's stress according to gender, we expected that both academic and social skills would affect girls' physiological stress more, compared to boys. Our sample consisted of 277 students (7–8 years old, 50.2% girls). We used the highest salivary cortisol level of three morning samples and a cortisol level from the middle of the school day as physiological stress indicators. Reading skills were assessed by group-administered tests and social competence by teacher ratings. We found that lower reading comprehension skills and lower disruptiveness were related to higher cortisol levels for girls but not for boys. Higher empathy and lower disruptiveness moderated the effect of better reading comprehension on higher psychological stress in the middle of the school day only for girls. By recognizing the antecedents of children's stress and supporting their academic and social skills, children's, especially girls', physiological self-regulation and coping skills in the primary grades will benefit.

Keywords Physiological stress · Reading skills · Social competence · Children · Gender differences

Introduction

Children's ability to meet the complex social and academic demands in the classroom has an effect on their further academic learning (Duncan et al., 2007; Vitiello & Williford, 2016) and on their general well-being at school (Jones et al., 2015). Upon entering school, children face increased expectations to learn basic academic skills and formulate social relationships with their classmates and teacher simultaneously (Wong, 2015). Worrying about their academic progress or social competence might indicate a general lack of well-being and self-efficacy (Hascher, 2008; Lauermann et al., 2017). Stress, one of the major threats to well-being, has several negative consequences academically, socially, and physiologically in the long term (Blair & Raver, 2015; Hjern et al., 2008). The antecedents of daily stress, such as adverse life events, have been widely studied (e.g., Blair & Raver, 2015; Escobar et al, 2013). Still, an understanding is lacking of how school-related factors are associated with physiological stress, especially in young children.

We aimed to study how first-grade students' physiological stress levels are related to their reading skills and social competence, and the interactions between those two. Thus far, students' stress levels in school have mostly been studied using self-reported questionnaires (e.g., Escobar et al., 2013; Hjern et al., 2008). Studies with adult samples have shown that one's self-perceived stress level might not always be related to physiological stress (Weckesser et al., 2019; Yim et al., 2010). Therefore, we used salivary cortisol as an indicator of children's physiological stress levels, and we investigated how academic skills and social competence might pose

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a risk for high physiological stress in a nonclinical sample of children at the end of their first school year.

Students' Stress at School

Students' stress can be addressed as a part of their physiological self-regulation (Blair & Raver, 2015). To best support children's development, it is important for educators to understand the aspects in learning and teaching that are related to students' stress levels, to monitor their stress response, and to support its regulation (Blair & Raver, 2015). It is especially important because school-related stress affects both academic success and health in the broader sense and in the long term (Shankar & Park, 2016). For example, adolescents who feel higher levels of academic stress have more health complaints, both psychological, such as sadness, irritability, or fatigue, and physiological, such as headaches or abdominal pain (Hjern et al., 2008; Torsheim & Wold, 2001).

To prevent and mitigate students' stress, it is important to acknowledge students who are at elevated risk for stress. Previous studies have indicated that differences in socio-economic background and childhood adversity can be related to higher physiological stress in early childhood and, therefore, accompany physiological and psychological risks in the future (Blair & Raver, 2015; Obradović, 2012). We expand this idea into the authentic classroom by investigating two interrelated skills that are important for children to acquire at the beginning of their school careers—reading skills and social competence—both of which are crucial for students' further success in school (Cooper et al., 2014; Rabiner, Godwin, & Dodge, 2016) and are potentially interactive correlates of salivary cortisol as an indicator of physiological stress.

Cortisol as a Physiological Stress Indicator

Salivary cortisol is widely used as an indicator of childhood physiological stress in epidemiological and health sciences (Tervahartiala et al., 2019; Vanaelst, DeVriendt, Huybrechts, Rinaldi, & De Henauw, 2012a). Studies investigating young children's cortisol levels have shown that they have a clear diurnal pattern similar to adults' cortisol curve already at preschool age (Bäumler, Kirschbaum, Kliegel, Alexander, & Stadler, 2013; Messerli-Bürgy et al., 2018). Cortisol as a stress indicator has been validated using heart-rate variability as a marker of parasympathetic activity and self-reported stressful life events. Higher cortisol levels are related to lower parasympathetic activity and, therefore, higher stress (Michels et al., 2013). Furthermore, a child's greater diurnal salivary cortisol output is accompanied by a higher number of negative events in the past 3 months of the child's life (Vanaelst et al., 2012b).

Using salivary cortisol as a stress indicator is an evolving practice in educational and developmental research. Similarly to health research, in the classroom context, higher cortisol levels are predominantly interpreted as a negative physiological implication (Dimolareva et al., 2018; Schonert-Reichl et al., 2015). Developmental studies have shown that higher cortisol levels are related to less effortful control (Blair et al., 2011) and more difficulties in behavioral self-regulation already at preschool age (Lisonbee et al., 2010).

The advantage of using any physiological measure in addition to or instead of self- or observer-reports is that the latter ones can only grasp subjective self-perceptions or the stress that is manifested in behavior (Quas, 2011). From the perspective of stress and its interactions with the environment and resources, subjective measures mainly address one's evaluations of his/her own coping abilities, while physiological measures capture one's reactions to the situation in the environment (Weckesser et al., 2019). Applying cortisol in addition to psychometric data to study students' stress responses unravels the psychophysiological development and allows for intervening in the evolvement of severe stress-related disorders (Michels et al., 2012a).

In general, there are some gender differences in cortisol release. Specifically, girls typically have larger cortisol variations, and they have a steeper cortisol awakening response. Nevertheless, these differences have mostly been found in adolescents and rarely in studies that have included younger children (for a review, see Hollanders et al., 2017). The few studies with younger children have found almost no gender differences in cortisol release (e.g., Michels et al., 2012b; Yang et al., 2017; see Rosmalen et al., 2005 for the exception) and have demonstrated similar physiological stress reactivity for pre-pubertal boys and girls in both experimental and natural settings (Wålinder, Gunnarson, Runeson, & Smedje, 2007; Yim et al., 2010). However, a relationship between higher perceived stress and higher cortisol levels during the day has been found among girls (Osika, Friberg, & Wahrborg, 2007). Therefore, even if there is a reason to assume that no gender differences exist in young children's physiological stress per se, the differences between boys and girls in the relationships between reading skills and social and physiological stress have not been previously studied.

Reading Skills and Stress

According to the Simple View of Reading (Gough & Tunmer, 1986), reading comprehension is the product of efficient decoding to read words quickly and accurately, and linguistic comprehension. Therefore, a skilled reader can read fluently and comprehend the written language (Kirby & Savage, 2008). However, some children fail to acquire these basic reading skills and struggle with their reading and, therefore, feel anxious about reading because of past

difficulties associated with reading situations (Katzir et al., 2018). Additionally, general anxiety in young children has been found to be negatively associated with reading skills (Grills-Taquechel et al., 2012). In contrast, a physiological stress level is not longitudinally related to the development of students' reading skills at the beginning of school career (Blair, Ursache, Greenberg, Vernon-Feagans, & FLP Investigators, 2015). Still, the relationship between reading skills and a child's concurrent physiological stress level is not understood among the beginning readers in Grade 1. Considering older students and their self-reported stress, higher perceived stress is related to lower reading efficiency and comprehension during preadolescence (O'Neal, 2018). Adolescent students with reading disabilities experience more stress at school and a higher number of depressive symptoms (Undheim & Sund, 2008).

Gender might also play a role in the relationship between reading skills and well-being. Overall, during the first years of schooling, girls have better language skills, compared to boys (Katzir, et al., 2018; Voyer & Voyer, 2014). Additionally, adolescent girls have shown a stronger effect of learning outcomes on subjective health complaints compared to boys (Låftman & Modin, 2012). Furthermore, a comparison between boys and girls in Finland and Sweden found that the strongest relationship between school grades and health complaints occurred in Finnish girls (Modin et al., 2015). Moreover, gender moderates the relationship between adolescents' learning difficulties and well-being, as well-being is affected by learning difficulties for girls but not for boys (Kiuru et al., 2011). Therefore, it is reasonable to assume that the relationship between young children' reading skills and stress might be gender dependent to some extent.

Social Competence and Stress

The ability to develop positive relationships with peers and teachers is a crucial factor in determining school adjustment (Kiuru et al., 2015). Social competence indicates students' context-appropriate attitudes and skills that they apply to their behavior and in social situations or processes (Junttila et al., 2006). The development of social competence in childhood is an interaction of individual factors, such as cognition and affect, and external factors, such as family and classroom environments (Beauchamp & Anderson, 2010).

Social competence is related to students' reading skills already in primary school (Algozzinne, Wang, & Violette, 2011). In addition to previous reading skills, children's and early adolescents' reading skills are predicted by social competence and peer relationships. Students with higher social skills and better relationships with peers have better reading skills later on (Kiuru et al., 2015; Oberle et al., 2014). Adolescents with reading difficulties appraise themselves as being less socially competent, compared to their peers without reading difficulties (Undheim & Sund, 2008).

Regarding social skills and stress, in general, students with higher social competence report fewer experiences with daily stressors in everyday life and cope better with stressors (Brophy-Herb, Lee, Nievar, & Stollak, 2007; Escobar et al., 2013). A meta-analysis has shown that stress resulting from social relations and situations tended to elevate the cortisol levels in an adult sample (Miller et al., 2007). Evidence about the relationships between young children' physiological stress and social skills, including problem behavior, is somewhat controversial. Some studies have demonstrated no relationships between behavioral problems with peers or prosocial behavior and cortisol levels (Messerli-Bürgy et al., 2018; Simons et al., 2017). It has also been shown that peer-rejected children have higher cortisol levels, while teacher-rated externalizing behavior and poor effortful control are related to lower physiological stress (Catherine et al., 2012; Gunnar et al., 2003). However, poorer social skills and impulsivity have also been found to be related to higher cortisol levels in young children (Turner-Cobb et al., 2008).

Studies with adolescent samples have indicated that negative social experiences are more strongly related to higher stress in girls. Girls tend to feel more stress in peer-related situations, compared to boys (Seiffge-Krenke, Aunola, & Nurmi, 2009), while boys report feeling more school-related stress (Hirvonen et al., 2019). The physiological stress response tends to remain the same for young adults—women have a higher cortisol response to social stressors and men to academic stressors (Stroud, Salovey, & Epel, 2002). However, knowledge of gender differences in relation to social competence in the classroom context and physiological stress in young children is clearly lacking.

Aims and Hypotheses

To prevent or mitigate young children's stress and its health-related and academic consequences, educators need to recognize children at risk for high stress levels. Very few studies have shed light on the physiological stress of young children in nonclinical settings (for a review, see Parent et al., 2019). Furthermore, research about the school-related antecedents of children's physiological stress has thus far been scarce. The present study aims to investigate how first-grade students' physiological stress levels are related to their reading skills and social competence, and the interaction between those two, and the role of gender in these relationships. Our specific research questions and hypotheses are as follows:

(1) How are reading skills, such as fluency and comprehension, and social competence related to children's physiological stress in the first grade? We expected that lower reading skills would be related to higher

physiological stress. Thus far, studies with much older students have demonstrated a negative relationship between reading skills and perceived school stress (Grills-Taquechel et al., 2012; O'Neal, 2018; Undheim & Sund, 2008). We also expected that poorer social competence would be related to higher physiological stress in first-grade students. Poor social competence has been shown to promote negative social and emotional consequences, while better social competence and good social relations are related to lower physiological stress levels in childhood (Beauchamp & Anderson, 2010; Blair & Raver, 2015).

(2) Do reading skills and social competence interact in affecting physiological stress? We expected that poorer social competence would increase the negative relationship between reading skills and physiological stress; or, alternatively, that better social skills would decrease the relationship between poorer reading skills and higher physiological stress. Previous research has shown that in young children, poor reading skills only do not lead to lower academic success in the future, but poor reading skills together with lower social competence do (Cooper et al., 2014).

(3) Do these relationships depend on gender? We expected that both the effect of reading skills and social competence on physiological stress would be stronger for girls. It has been shown that the relationships between reading difficulties and anxiety, and learning outcomes are stronger for girls than for boys (Devine, Fawcett, Szücs, & Dowker, 2012; Katzir et al., 2018). Additionally, in samples of adolescents and adults, it has been shown that females are more stressed from stressors arising from the social environment (Seiffge-Krenke et al., 2009; Stroud et al., 2002). Furthermore, we expected that the interaction effect between reading skills and social competence on physiological stress would be stronger for girls.

Method

Participants

The study was a part of larger project focusing on the effects of teachers' and students' stress levels and interaction quality in the classroom on well-being and learning outcomes. In total, 880 students aged 7–8 years participated in the larger project from 53 classrooms in 36 schools. In the current study, the sample consisted of 277 first-grade students (50.2% girls) who were randomly selected from each class (3–6 students per classroom) to give saliva samples.

The study was carried out following the ethical guidelines of The Finnish National Board on Research Integrity (Finnish Advisory Board on Research Integrity, 2012). The ethics committee of the university approved the study before commencement of the data collection. The schools were recruited on a voluntary basis. All schools were Finnish-speaking public schools. The students' ethnic background was homogeneous. All teachers and parents of the participating students gave written consent for their participation in the study. Students' consent was sought orally by explaining them the study and data collection plans, and explaining them their rights. Participating students could refuse to perform the tasks or giving saliva samples any time even if their parents had given consent for their participation. During the data collection, three students first randomly selected to give saliva samples refused to give samples and were not included to the sample of current study.

Measures

Physiological Stress

The salivary cortisol level was used as an indicator of students' physiological stress on particular school day. In total, six saliva samples from each child were collected, using Salivette® cortisol swabs as follows: upon awakening, 30 and 45 min after awakening, at 10 am, after school (between 12 and 1 pm), and in the evening before bedtime. Saliva samples were collected on the same day the students completed their reading tests. The first three samples and the last one were administered by the students' parents, and the samples collected during the school day were administered by trained research assistants. The cortisol levels from the morning samples and from the 10 am sample were used in current study (four samples in total), representing the beginning and middle of the school day.

Cortisol samples were assayed in Dresden LabService GmbH, Germany, with Cortisol Luminescence Immunoassay RE62011 (CLIA, produced by IBL International GmbH, Hamburg, Germany). Of the randomly chosen samples, 20% were double assayed, giving an inter-assay coefficient of variation less than 7%.

Several measures are estimated from diurnal cortisol samples that can be used as indicators of physiological stress (for reviews, see Adam & Kumari, 2009; Khoury et al., 2015). We used the maximum value of the first three morning samples (the peak) and the cortisol level in the middle of the school day at 10 am. The peak measure was used as an indicator of morning cortisol because the cortisol awakening response (CAR) of 23% of our participants was negative. A decrease in the cortisol levels between the first two samples of the day indicates that the samples had probably been taken with some time lag from the protocol (Michels et al., 2012b), as children at the age in our study usually maintain a positive CAR (Bäumler, et al., 2013). A higher cortisol

peak value was interpreted as a higher physiological stress level after awakening on a particular school day. A higher cortisol level at 10 am was interpreted as higher stress in the middle of the particular school day (see Berry et al., 2014; Michels et al., 2013).

Parents filled in a form to report their child's cortisol sampling timings as well as the last time the child had eaten and had drunk before each sampling. According to the parents' reports, data from samples collected on the wrong day (four students) were removed from further analyses. Comparing the parents' reports about the time of sampling and the time the child had eaten before sampling, 11 single samples were excluded because of violating the requirement not to eat less than 30 min before the sampling.

Raw cortisol concentrations over 73 nmol/l were excluded from the study as physiologically implausible. Determined by CLIA, 73 nmol/l refers to the standard excluding cut-off concentration of 60 nmol/l (Miller et al., 2013). In total, 20 single samples were deleted from four sampling points. Descriptives of raw cortisol levels in single sampling points are presented in Table 1. For regression analyses, both cortisol measures were transformed using the formula $X' = (X^{.15} - 1)/0.15$, as suggested for single samples in Miller and Plessow (2013).

Reading Skills

Reading fluency and reading comprehension were assessed using a group-administered subtest of a nationally normed reading test battery (ALLU; Lindeman, 1998). Reading is general competency in the Finnish National Core Curriculum for Basic Schools that is practiced and developed in every subject lesson in Grade 1 (Finnish National Agency For Education, 2014).

Students conducted the tests during the regular school day under the supervision of trained research assistants. Research assistants were instructed to make the situation to the students as comfortable as possible. Students were explained about the general goals of the research project and emphasized that the tasks they are going to comply are similar to their regular reading tasks in school. Students were told that their performance is not going to be assessed. In the reading fluency task, each of the 80 items consisted of a picture with four phonologically similar words. The students read four words silently and then drew a line to connect the picture with the word, matching it semantically. The reading fluency task had a 2-min time limit. In the reading comprehension task, students read a fiction story (144 words) silently and then answered 11 multiple-choice questions and 1 question in which they had to arrange five statements in the correct sequence, based on the information gathered from the text. Students fulfilled the task at their own pace, although maximum time limit due to the group testing situation was 30 min. The text was on students' desk during the task, and they were allowed to read it as many times they needed when answering questions.

Both reading fluency and comprehension tasks have been widely used in previous research and have shown good construct validity (e.g., Soodla et al., 2015; Torppa et al., 2007). Kuder–Richardson reliability coefficients were 0.95 for reading fluency and 0.83 for reading comprehension. Z-scores of the sums of correct answers were used as reading fluency and comprehension scores in further analyses.

Table 1 Descriptives of raw cortisol levels used in the study

Cortisol sample/measure	N	Mean	SD	Min	Max
Upon awakening	260	23.82	10.74	1.27	67.16
30 min after awakening	265	31.90	10.94	8.31	71.61
45 min after awakening	265	27.34	10.67	6.42	63.85
at 10 am	270	9.48	6.34	2.17	41.94
Maximum level of cortisol of morning samples	270	34.92	10.88	10.00	71.61

Social Competence

Students' general social competence was rated by their classroom teachers using the Multisource Assessment of Social Competence Scale (MASCS; Junttila et al., 2006). In MASCS, social competence is measured by four subscales: cooperating skills (five items, e.g., "Invites other students to participate in activities," Cronbach's alpha = 0.86); empathy (three items, e.g., "Is sensitive to the feelings of others," alpha = 0.82); impulsivity (three items, e.g., "Is easily irritated," alpha = 0.90); and disruptiveness (four items, e.g., "Bothers and annoys other students," alpha = 0.90). Teachers rated students' general social competence as the frequencies of each student's behaviors on a 4-point scale (1 = never, 4 = very often). Confirmatory factor analysis using the WLSMV estimator and type = complex to take into account the nested structure of the teachers' ratings verified our data fitting factor structure uniformly to the original scale (Junttila et al., 2006). Model fit indices for the four-factor scale ($\chi^2 = 208.57$, df = 84, CFI = 0.98, TLI = 0.97, RMSEA = 0.07) referred to a good data-model fit. A Z-score of the mean of the items was used as a child's score for each subscale.

Analysis Strategy

Bivariate correlations were performed in the R statistical platform as single (student) level analyses (R Core Team, 2019). Path models for estimating interaction effects were conducted using statistical package Mplus version 7.4 (Muthén, & Muthén, 1998–2015). Eight separate two-level

path analyses were performed to test the interaction effects of each combination of reading skills variables and social competence subscales predicting both cortisol morning peak and cortisol at 10 am (see Fig. 1 for the theoretical model). Eight separate models were chosen because of the risk of multicollinearity due to the several very high correlations between independent variables (see Table 2). Two-level analyses were chosen because students' reading skills as well as social competence variables had considerable amount of variance explained in teacher or classroom level (ICCs = 0.11 … 0.21). Preliminarily, we tested for the outliers for each reading skills and social competence combination using Mahalanobis distances ($p < 0.001$; Kline, 2011). One outlier was excluded from further analyses from four interaction models (between reading fluency and cooperating skills, reading fluency and empathy, reading fluency and disruptiveness, and reading comprehension and empathy).

In each path model, reading fluency or comprehension and social competence subscale variances were divided into students' (within) level and classroom (between) level in two-level analysis. Students' gender and cortisol levels as well as interaction terms had statistically non-significant variance in classroom level and therefore these variables were specified only in student level. Each model was first tested with all four possible interaction effects—two-way interactions of reading fluency or comprehension x social competence subscale, reading fluency or comprehension X gender, social competence subscale X gender, and a three-way interaction of reading fluency or comprehension X social competence subscale X gender. Wald-test statistics of all regression parameters constrained to zero were used

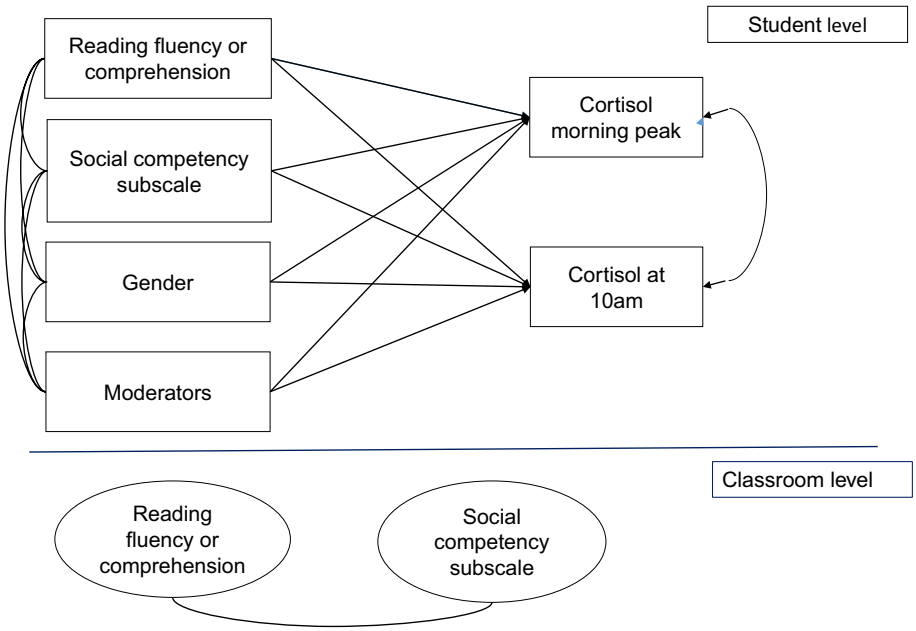

Fig. 1 Theoretical model

Table 2 Student-level descriptives and bivariate correlations between measures used in the study

Measure	N	Mean	SD	Min	Max	1	2	3	4	5	6	7
1. Reading fluency	277	17.16	9.08	2	50	–						
2. Reading comprehension	271	5.08	3.35	0	12	.47***	–					
3. Cooperating skills	273	2.89	0.64	1	4	.18**	.33***	–				
4. Empathy	273	3.14	0.57	1	4	−.02	.21***	.58***	–			
5. Impulsivity	273	1.67	0.79	1	4	−.02	−.11	−.17**	−.42***	–		
6. Disruptiveness	273	1.66	0.71	1	4	.01	−.15*	−.14*	−.50***	.75***	–	
7. Maximum level of cortisol of morning samples[a]	270	4.62	0.52	2.75	5.99	−.08	−.20**	−.03	−.01	−.16*	−.17**	–
8. Cortisol at 10am[a]	270	2.48	0.76	0.82	5.01	−.01	−.12	−.04	−.03	−.17**	−.09	.41***

[a]Raw cortisol concentration values are transformed using the formula $X' = (X^{0.15}-1)/0.15$

*$p < .05$, **$p < .01$, ***$p < .001$,

to decide on the presence of the effect(s) in the model. To reduce the chance of multiple comparison, the significance level of $p < 0.006$ (Bonferroni corrected p value corresponding to $p < 0.05$) was used for the Wald statistics. Six models out of eight met this requirement and were further analyzed. Namely, the interactions models of (a) reading fluency and impulsivity, (b) reading fluency and disruptiveness, (c) reading comprehension and cooperating skills, (d) reading comprehension and empathy, (e) reading comprehension and impulsivity, and (f) reading comprehension and disruptiveness. From the final models presented in the results section, non-significant interaction terms were excluded.

The maximum-likelihood procedure with non-normality robust standard errors (MLR) was used to assess the model parameters for correcting the standard errors in case of non-normally distributed variables. All path models were saturated with zero degrees of freedom and perfect model fit. In the results section, standardized parameter estimates are provided.

Descriptives and bivariate correlations of all measures used in the study are presented in Table 2. Descriptive statistics for boys and girls separately and the results of t tests are presented in Table 3. Girls performed better than boys in the reading comprehension test, but they did not differ in the reading fluency test. The teachers rated girls as having better cooperating skills and higher empathy, while they rated boys as being slightly more impulsive and more disruptive, compared to girls. There were no gender differences in the means of cortisol indicators.

Results

Relationships of Reading Skills and Social Competence to Physiological Stress

First, we aimed to investigate how reading skills and social competence are related to physiological stress on a particular school day. Regarding reading skills, we found that only better reading comprehension skills were related to a lower morning cortisol peak ($r = -0.20$, $p = 0.001$). We also found that reading comprehension skills were marginally related to students' cortisol levels in the middle of the school day ($r = -0.12$, $p = 0.056$). Reading fluency showed no effect on cortisol levels neither in the morning nor in the middle of the school day (see Table 2).

Concerning the relationships between social competence and physiological stress, first we found no direct relationship between cooperating skills and empathy, and physiological stress. Impulsivity and disruptiveness were related to cortisol levels. The more impulsive students were, the lower was their cortisol level both in the morning and at 10 am ($r = -0.16$, $p = 0.010$, and $r = -0.17$, $p = 0.006$, respectively). In addition, more disruptive students had lower cortisol morning peaks ($r = -0.17$, $p = 0.005$). In other words, less impulsive and less disruptive students tended to have higher physiological stress.

Interaction of Reading Skills, Social Competence, and Gender in Predicting Physiological Stress

Next, we investigated the interaction effects of reading skills, social competence, and gender in predicting cortisol morning peak and cortisol level at 10 am (see Fig. 1 for a theoretical model). Among all eight interaction models (reading fluency or comprehension x one out of four social competence subscales predicting both cortisol morning peak or cortisol level at 10 am), there were six models meeting the requirement of significant Wald statistic at level $p < 0.006$. Three of these six, the interaction model between reading fluency, impulsivity, and gender, the interaction model between reading fluency, disruptiveness, and gender, and the interaction model between reading comprehension, impulsivity, and gender showed no significant interaction effects.

In response to our second research question, we found that the effect of reading comprehension on physiological

Table 3 Student-level descriptives of measures used in the study and t-statistics for boys and girls separately

Measure	Boys			Girls			t-statistic
	N	Mean	SD	N	Mean	SD	
Reading fluency	138	17.38	9.31	139	16.95	8.88	0.39
Reading comprehension	134	4.61	3.21	137	5.53	3.42	2.28
Cooperating skills	136	2.77	0.63	137	3.02	0.63	3.23
Empathy	136	3.06	0.60	137	3.21	0.53	2.16
Impulsivity	136	1.76	0.85	137	1.58	0.73	1.89
Disruptiveness	136	1.85	0.79	137	1.46	0.56	4.63
Maximum level of cortisol of morning samples[a]	134	4.57	0.52	136	4.68	0.52	1.61
Cortisol at 10 am[a]	135	2.54	0.76	135	2.43	0.76	1.21

[a]Raw cortisol concentration values are transformed using the formula $X' = (X^{0.15} - 1)/0.15$

stress in the middle of the school day was moderated by empathy and disruptiveness. Poorer readers having higher empathy had higher cortisol level at 10am ($\beta = -0.24$, $p = 0.002$, see Fig. 2). The effect of poor reading comprehension skills on physiological stress was also larger for students with lower teacher-rated disruptiveness ($\beta = 0.16$, $p = 0.037$, see Fig. 3).

Our third research question concerned the gender effect on the relationships between reading skills or social competence and children's physiological stress, as well as on

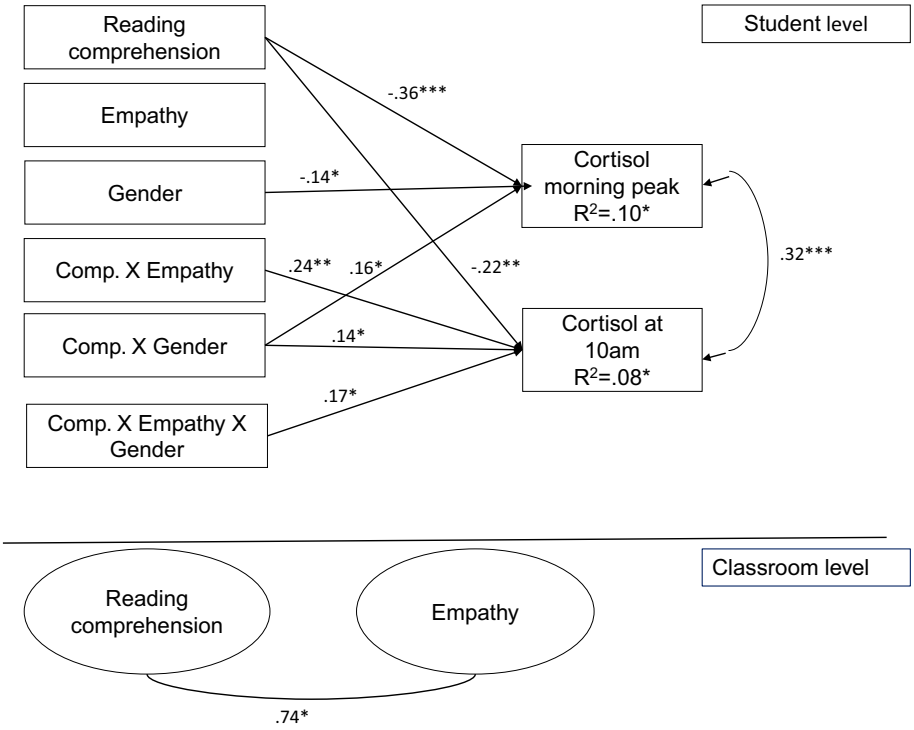

Fig. 2 Interaction of reading comprehension, empathy, and gender. Standardized coefficients are presented. For readability, only the significant paths are presented, and all the covariances between independent variables are omitted from the figure. Comp. = reading comprehension. Gender: 0 = girls, 1 = boys. *$p < .05$. **$p < .01$. ***$p < .001$

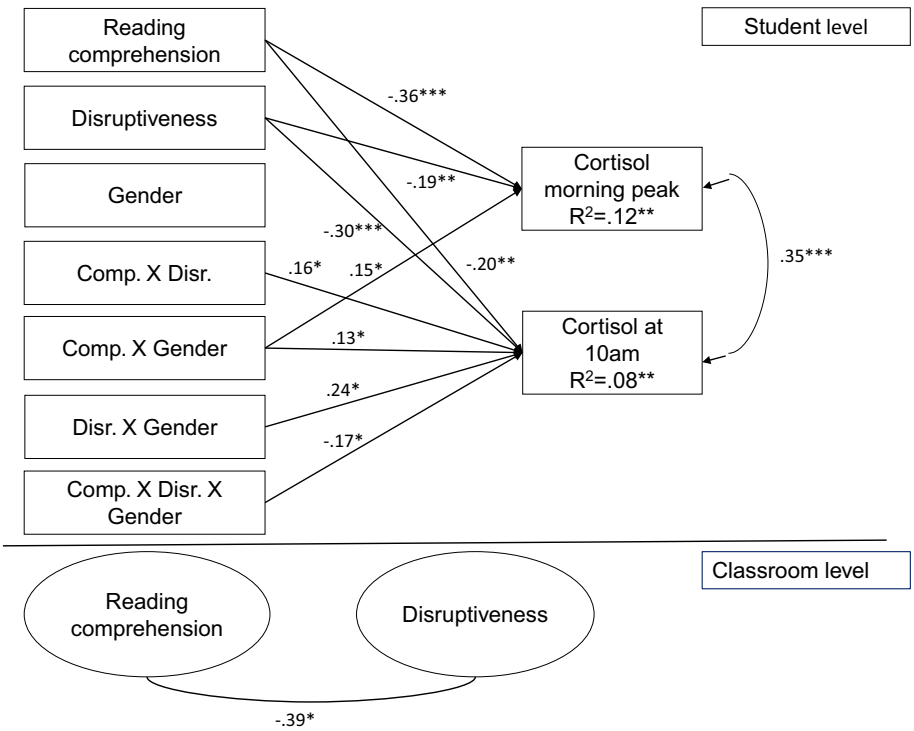

Fig. 3 Interaction of reading comprehension, disruptiveness, and gender. Standardized coefficients are presented. For readability, only the significant paths are presented, and all the covariances between independent variables are omitted from the figure. Comp. = reading comprehension. Disr. = disruptiveness. Gender: 0 = girls, 1 = boys. *$p < .05$. **$p < .01$. ***$p < .001$

the interaction between reading fluency or comprehension and the subscales of social competence affecting children's cortisol levels.

Gender showed significant effect on the relations between reading comprehension and cortisol morning peak in the interaction models between reading comprehension and cooperating skills ($\beta = 0.15$, $p = 0.034$), reading comprehension and empathy ($\beta = 0.16$, $p = 0.020$, see Fig. 2), and reading comprehension and disruptiveness ($\beta = 0.15$, $p = 0.027$, see Fig. 3). The same appeared for the relation between reading comprehension and cortisol in the middle of the school day, the effect of gender interaction in three aforementioned models was $\beta = 0.13$, $p = 0.071$; $\beta = 0.14$, $p = 0.042$; and $\beta = 0.13$, $p = 0.049$, respectively. Only girls with poorer reading comprehension had higher physiological stress level in the morning and in the middle of the school day. Boys' physiological stress levels appeared not to be related to their reading comprehension skills.

Exploring the interaction effects of gender on the relationships between social competence and physiological stress indicators revealed that the effect of disruptiveness on cortisol at 10 am was moderated by gender in the reading comprehension and disruptiveness interaction model. Girls behaving more disruptively had lower cortisol levels in the middle of the school day, compared to the less disruptive girls or boys regardless of their disruptiveness ($\beta = 0.24$, $p = 0.011$; see Fig. 3).

Concerning the three-way interaction effects between reading skills, social competence, and gender, we found no evidence that the effect of reading skills on morning cortisol peak was moderated by both social competence and gender. We did find an interaction effect while predicting students' cortisol levels at 10 am with reading comprehension, empathy, and gender ($\beta = 0.17$, $p = 0.017$; see Figs. 2 and 4). Girls with lower reading comprehension skills and higher empathy had higher cortisol levels in the middle of the school day. For girls with less teacher-rated empathy, reading comprehension did not affect their cortisol levels. The same applied to boys regardless of their empathy.

The relationship between reading comprehension and physiological stress at 10 am was also moderated by disruptiveness and gender. It appeared that boys' cortisol levels in the middle of the school day depended on neither their reading skills nor their disruptiveness. For girls, poorer readers had higher cortisol levels if they were not rated as disruptive by their teachers ($\beta = -0.17$, $p = 0.045$; see Figs. 3 and 5).

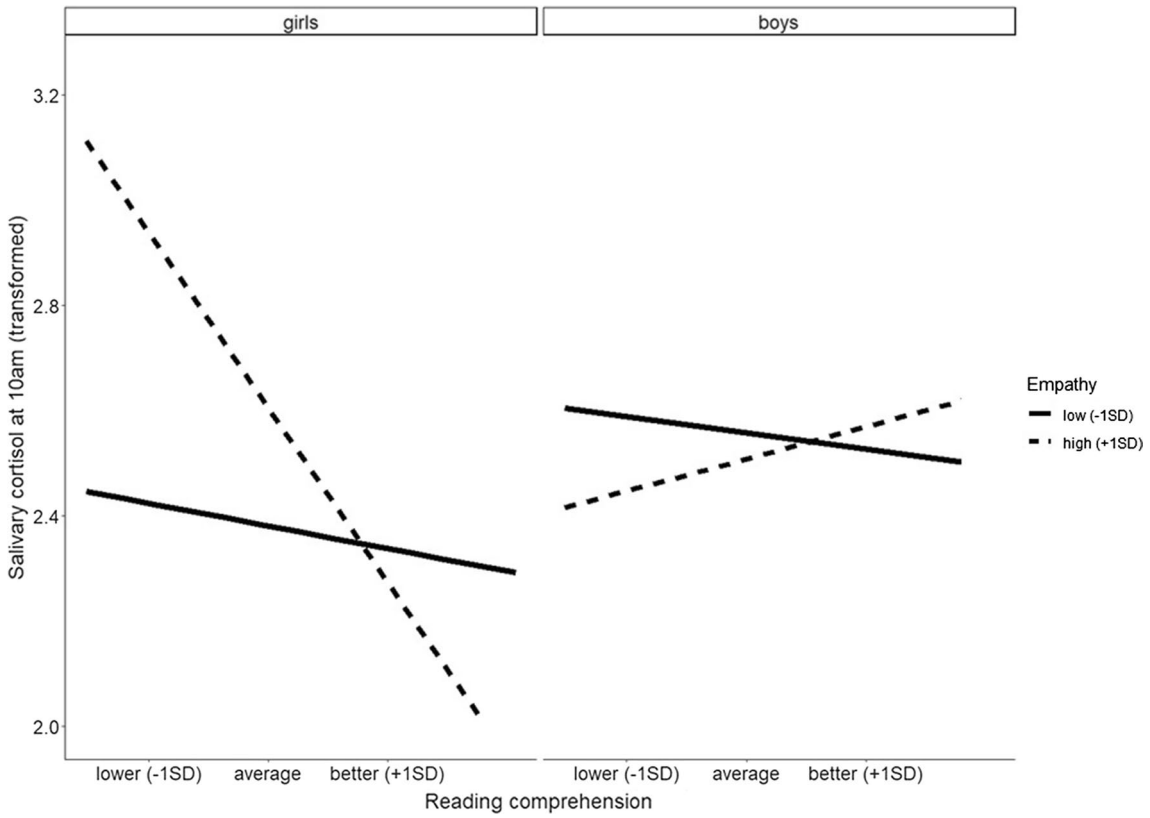

Fig. 4 Interaction of reading comprehension, empathy, and gender in relation to cortisol at 10 am

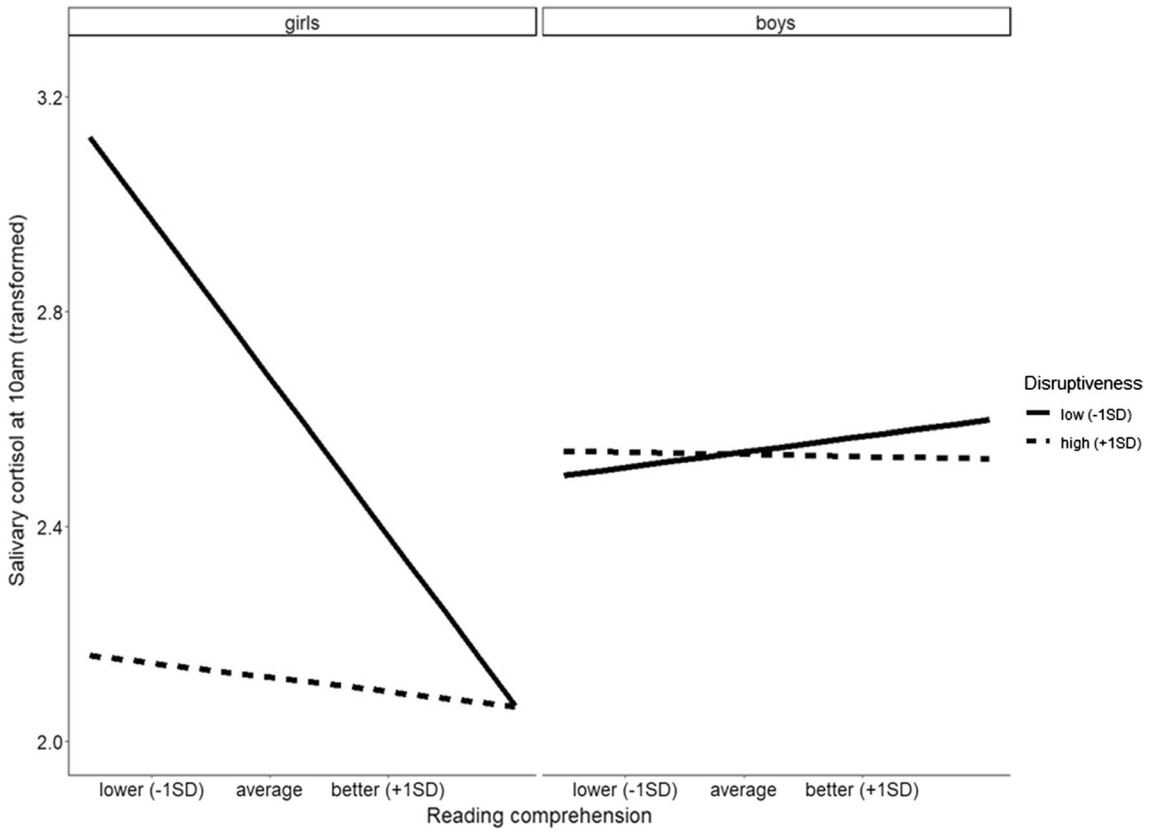

Fig. 5 Interaction of reading comprehension, disruptiveness, and gender in relation to cortisol at 10 am

Discussion

The aims of the study were to investigate how first-grade students' physiological stress levels are related to their reading skills and social competence, the interaction between those two, and the role of gender in these relationships. Previously, it had been concluded that young children's physiological stress may increase at the beginning of their school career due to the transition, and that cortisol levels even out to the baseline level after half a year of schooling (Parent et al., 2019). Therefore, we studied cross-sectional relationships of academic and social competence and physiological stress at the end of the first school year.

Effect of Reading Skills and Social Competence on Physiological Stress

First, we aimed to investigate the relationships between first-grade students' reading skills (fluency and comprehension) and social competence and their physiological stress. We found that children with better reading comprehension had lower physiological stress levels in the morning after awakening. Poorer reading skills were accompanied by higher stress levels in older students (O'Neal, 2018) and general anxiety in younger-aged children (Grills-Taquechel et al., 2012). Notably, we found reading comprehension covarying with students' physiological stress but not reading fluency. The result is understandable when the rapid learning of decoding accurately in a transparent language such as Finnish is recognized (Soodla et al., 2015). Around one-third of the children can decode words when they enter school, and the rest of the children easily reach accurate decoding skills after a few months of schooling (Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004). Therefore, the differences between early readers and other children disappear during the spring semester of the first grade, when practically all children can read words accurately and fluently (Soodla et al., 2015). However, the differences in reading comprehension skills remain during primary school (Soodla, Torppa, Kikas, Lerkkanen, & Nurmi, 2019). From this perspective, it is reasonable that reading comprehension skills were associated with physiological stress in the current study. Reading comprehension skills are more complex and require more higher-level cognitive processes and skills than decoding, and reading comprehension becomes less closely related to decoding skills quite soon after the child can read fluently (Catts et al., 2006). Our results on the relationship between reading comprehension and physiological stress

indicate that poorer readers might be already more stressed in the classroom, and this may worsen when they experience difficulties in trying to comprehend the written text. Therefore, children need sensitive and supportive learning environments and achievable goals in their school work, which will motivate them to focus on tasks and practice their skills (Lerkkanen et al., 2016). There is clear evidence on the relationship between stress and anxiety that children experience when struggling to read (Katzir et al., 2018).

In terms of the relationship between social competence and physiological stress, we expected to find lower cooperating skills and empathy, and higher impulsivity and disruptiveness associated with higher cortisol levels. The findings did not support our hypothesis. Our assumptions were based on the theory of psychobiology behind self-regulated learning (Blair & Raver, 2015) and the relationships between stress and social competence or problem behavior (Brophy-Herb et al., 2007; Escobar et al., 2013). Still, our findings suggest no association between teacher-rated cooperating skills and empathy and physiological stress at the beginning of school. We also found that teacher-rated impulsivity and disruptiveness are related to lower cortisol levels, which concurs with findings from Catherine et al., (2012) and Gunnar et al. (2003). The possible explanation of the relations between behavioral problems in the classroom and biological under arousal definitely needs further investigation.

Interplay of Poorer Reading Skills and Better Social Competence

Our second aim was to study the interaction effect of reading skills and social competence on students' physiological stress. We expected that high social competence would protect poor readers from physiological stress. In this very novel approach, we relied on previous studies on the relationship between social skills and the development of reading skills in primary school (Cooper et al., 2014; Kiuru et al., 2015), and the interaction between emotion regulation and peer victimization, resulting in students' higher physiological stress (Kliewer, 2016). However, the only reading skills and social competence subscale interaction effects we found, were interactions between reading comprehension and empathy, and reading comprehension and disruptiveness predicting physiological stress in the middle of the school day. Both of these relations were contrary to our hypothesis. Students with higher empathy and poor reading comprehension skills were more stressed, and the same applied to students with poor reading comprehension skills but lower disruptiveness. The reasons behind this finding can only be speculated. For example, more empathetic or less disruptive poorer readers might be stressed in the classroom because they are aware of their lower academic progress and, at the same time, put a lot of effort into down-regulating their social behavior.

Effect of Gender on Relationships between Reading Skills, Social Competence, and Physiological Stress

Finally, we aimed to investigate whether the relationships between reading skills, social competence, and physiological stress depend on the child's gender. Regarding reading skills, boys' cortisol levels in the morning did not differ for poor and better readers, while girls with poor reading comprehension skills had higher cortisol levels. It has been shown that girls are more anxious about their reading skills, compared to boys (Katzir et al., 2018). Our findings expand this idea, indicating that if girls are more worried about their reading or school day, in general, they might also feel more physiological stress. Furthermore, during adolescence, learning outcomes and subjective health are more related in girls than in boys (Låftman & Modin, 2012; Modin et al., 2015). Here, we demonstrate that this might also be valid for younger children and physiological indicators. It has been shown that girls are more sensitive to the classroom atmosphere and their relationship with their teacher (Ewing & Taylor, 2009; Pöysä et al., 2019). The results might imply that girls are more sensitive to feedback on their performance at school. Altogether, our finding suggests that poorer reading comprehension skills are, related to higher physiological stress in the classroom, in general, and at least at the beginning of the school path, girls might be somehow more vulnerable to that than boys are. This is consistent with previous findings of adolescent Finnish girls suffering much more from school-related burnout, compared to the boys (Salmela-Aro, 2017).

Comparing boys and girls in the relationship between social competence and physiological stress, we expected to find a stronger effect of social competence on cortisol levels in girls. The only difference we found appeared in disruptiveness. Girls behaving more turbulently had lower cortisol levels in the middle of the school day, compared to better disciplined girls or boys, despite their disruptiveness.

We also tested the three-way interactions between reading skills, social competence, and gender explaining students' physiological stress. We found an interplay of reading comprehension skills with empathy and disruptiveness in predicting physiological stress only for girls. More precisely, girls with poorer reading comprehension skills and higher empathy had higher cortisol levels in the middle of school day, while there was no effect of reading skills and empathy on boys' cortisol levels nor for girls with low empathy. Additionally, disruptiveness showed an effect on the relationship between reading fluency and physiological stress for girls but not for boys. As these findings fall into a thus far unexplored area, we can only speculate about the reasons behind these gender effects. In the context of higher reading anxiety among girls, the possible role of self-confidence and social expectations have been discussed (Katzir et al., 2018). We can expand this idea and propose that poorer reading

skills affect girls' physiological stress only if their externalizing behaviors are low (e.g., disruptiveness), as their poorer skills coupled with internalizing, increases their physiological stress level.

Finally, we would like to note that all interaction effects, except the gender moderation on the effect of reading comprehension on cortisol, explained the differences between children's physiological stress at 10 am, not the highest cortisol level in the morning. This indicates that during the school day the relations are stronger between reading skills and/or social competence, gender, and physiological stress, compared to the early morning.

Practical Implications

Our results draw attention to children with poor reading comprehension skills and lower impulsivity and disruptiveness. To support children's learning, their stress experiences should be mitigated at school. Educators and school psychologists and nurses need more knowledge about how to recognize students who are at risk for stress and delve into the origins of tensions in students' minds. In light of our results, supporting students' reading skills development and their social competence could be an efficient way to prevent and reduce students' stress. Somewhat surprisingly, students with lower impulsivity and disruptiveness might actually have higher physiological stress in the classroom, which can be difficult for teachers and school psychologists to recognize. Awareness of that has a very practical application in the classroom. It emphasizes that teachers need to monitor systematically students reading skills development and their well-being and be responsive to every student's individual needs, not recognizing only the ones who have explicit behavioral problems. In reality, children with no behavioral problems at the classroom might be actually stressed and at risk of poor well-being. Knowledge on students' perceptions and beliefs related to everyday stress experiences in the classroom environment could be used to support their emotion regulation and stress management skills.

It is widely recognized that controllable social situations or learning tasks are less stressful than uncontrollable social situations or learning tasks (Clarke, 2006; Tsai et al., 2019). Therefore, next to monitoring all students and their individual needs, one very applicable key for educators to prevent and reduce young children's stress at school is to organize the learning environment and tasks on the basis of a self-regulated learning framework, in a way that all students feel that they are in control of their learning. Students have control over their learning if their tasks are achievable, and based on their previous skills and knowledge. They also need learning to learn skills to self-regulate themselves in learning situations and complete the learning tasks. Students could be helped by teachers in realistic goal setting and in use of effective learning strategies, because these support students' beliefs of being in control of their learning (Martin & Marsh, 2006). In addition, creating learning environments that support individual needs (Ruotsalainen et al., 2020) and do not emphasize comparison between students is essential to promote students' motivation and social skills in the classroom (Lerkkanen, 2018; Siekkinen et al., 2013). Furthermore, when education practitioners monitor, evaluate, and assess students' skills it is important to be sensitive to students' beliefs of their capabilities and experiences about learning (e.g., their interpretations of feedback and individual emotional reactions; Peura et al, 2021).

Limitations

This study has some methodological and interpretational limitations that need to be considered when generalizing the results. First, we used salivary cortisol levels as snapshots of students' physiological stress levels during 1 day, and intra-individual differences in cortisol levels are not assembled in the measures we used. Second, although the goal of using two cortisol indicators in the study was to increase the validity of physiological stress measure, we acknowledge that the interpretation of cortisol morning peak indicator is still under discussion. Cortisol morning peak has been argued to be the highest point of morning cortisol release (Dienes et al., 2019; Vammen et al., 2014), but it has not been used with children's samples before. We hope that our study contributes to the discussion about cortisol indicators, including morning peak, in different samples. Finally, we used a cross-sectional design and data from a single measurement point, which allows us to draw conclusions only about the relationships between the studied factors and not about any directional effects.

Conclusions

Our findings add much-needed building blocks to the growing knowledge of the effects of learning and school-related factors on young children's physiological stress levels. Supporting students' physiological stress regulation, as well as their attention and emotions, contributes to the development of general self-regulation skills and, therefore, helps them to acquire academic skills and overcome prospective adverse life events (Blair & Raver, 2015). Therefore, it is crucial to investigate objective measures of physiological stress such as cortisol alongside subjective stress indicators. Paying attention to students' physiological stress enables recognizing their responsiveness in everyday school situations and their academic attainment (Weckesser et al., 2019). We had the opportunity to collect our data in authentic classroom situation, which is the main methodological strength of our study.

There are two major outcomes in our study. First, our study contributes to the field of nonclinical studies of young children's physiological stress by showing that school-related factors, such as reading skills and social competence, are to some extent related to children's physiological stress and self-regulation and, therefore, to well-being in general. Secondly, we found that these relationships emerge especially among girls at the beginning of school. Therefore, placing an emphasis on supporting each student's development in both academic and social domains has the potential to increase their perceived controllability and coping resources, thereby reducing children's stress and contributing to their overall well-being. Identifying children at the beginning of their school careers who are struggling with regulating their stress is crucial, as early achievement and adjustment have long-term consequences for future success and adjustment.

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Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical Approval All teachers and parents of the participating students gave written consent for their participation in the study. The ethics committee of the university approved the study before commencement of the data collection.

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