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Teachers' situational physiological stress and affect

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ABSTRACT

Since teaching is a demanding and stressful profession, the study of teachers' physiological stress in the classroom setting is an emerging field. In cross-sectional studies self-reported stress and affect are related, but less is known about the intraindividual relations between situational physiological stress and corresponding positive and negative affect. The aim of our study was to investigate the associations between situational physiological stress (six salivary cortisol samples per day) and self-reported situational affect (Positive and Negative Affect Schedule four times a day) among 61 Finnish primary school teachers over two workdays. We present a novel multilevel structural equation model (MSEM) that includes cortisol, with time since awakening as a flexibly coded time-varying covariate and affect with time since cortisol measurement as a time-varying covariate. Higher levels of teachers' situational physiological stress were related to lower situational positive affect (e.g., enthusiasm) and higher negative affect (e.g., nervousness), demonstrating the acute/situational effects of stress on affect. In our discussion, we emphasize the importance of the sequence of sampling and observations for further theoretical modeling of relations between stress and affect. We also propose practical implications for improving teachers' awareness of their well-being.

1. Introduction

The teaching profession is considered more stressful than other occupations, impacting both teachers' physical and psychological well-being (Johnson et al., 2005), which has consequences for both themselves and their students. Lower levels of teachers' well-being have been associated with poorer student outcomes and less positive student–teacher relationships (Aldrup et al., 2018; Arens and Morin, 2016). Teachers' positive emotions (e.g., enjoyment) have been associated with student engagement while negative ones (e.g., anxiety) with student disengagement (Frenzel et al., 2020; Li et al., 2022). Thus far, most studies investigating teachers' well-being have utilized self-reported stress (e.g., Keller et al., 2014) and have focused on individual differences between teachers (e.g., Hamama et al., 2013). We go beyond previous studies of teachers' stress and affect by investigating the time-dependent within-level relationship between teachers' physiological stress and affect.

We apply multilevel structural equation models (MSEMs) to investigate the within-person associations between teachers' situational cortisol levels and situational positive and negative affect over two workdays. Both physiological and affective reactions are considered as responses to stress (Schlotz, 2019). Thus far, research on situational cortisol and affect has mostly utilized multilevel models (MLMs) that allow for only one (time) dependent variable (Doane and Adam, 2010; Hoppmann and Klumb, 2006). Structural equation modeling (SEM) has been used in combining different cortisol samples from different timepoints and/or days with latent traits (Doane et al., 2015; Miller et al., 2016). We specified MSEMs that partitioned variances into within- (timepoints) and between-level variances (teachers), but allowed for covariate effects on both the dependent (affect) and independent (cortisol) variables, providing more flexibility in the model-specification than MLMs overall (Asparouhov and Muthén, 2020).

1.1. Physiological stress and affect

Physiological stress has major negative consequences on one's physical and mental health, and well-being in general (Schneiderman et al., 2005). However, studies thus far have indicated that physiological stress as measured by excretion of the cortisol hormone might be weakly or not at all related to self-reported stress or exhaustion (e.g., Bellingrath

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et al., 2008), which makes it especially important to address physiological stress separately.

Affect is a feeling or state of mind of which one is conscious (Fredrickson, 2001). Positive affect as a trait is all-inclusively related to better health and well-being in general, and as a state, it mitigates situational physical or psychological distress (Lyubomirsky et al., 2005). In contrast, negative health outcomes are related to negative affect (Diener et al., 2017). In laboratory studies, the physiological and affective (i.e., self-reported) stress responses measured in situation tend to be weakly and rather inconsistently related (Campbell and Ehlert, 2012). Furthermore, the suppression of physiological stress response does not involve the decrease in emotional response (Ali et al., 2017). Inconsistent associations are partly explained by methodological issues (see Campbell and Ehlert, 2012 for a review) and might be partly due to the heterogeneity of the sample of participants as shown in Simon et al. (2022).

Ambulatory studies to date have mostly focused on associations between physiological stress and affect at the between-person level (e.g., Miller et al., 2016). In most cases, it has been concluded that higher positive affect is related to lower daily cortisol levels (see Steptoe, 2019 for a review; Polk et al., 2005 for the exception), while between-person relations between negative affect and cortisol have shown either positive (e.g., Polk et al., 2005) or no relations (e.g., Miller et al., 2016). A recent meta-analysis by Joseph et al. (2021) emphasized the need to clearly distinguish situational within-person relations between physiological stress and affect from between-person ones. They also showed that within-person relations between cortisol and affect are quite homogeneous and in the same direction as between-person relations (Joseph et al., 2021).

1.2. Teachers' studies

Teaching is deemed as a very stressful job (Broughton, 2010) and teachers' self-reported stress is therefore widely studied. In general, the self-reported stress is negatively related to positive affect and positively related to negative affect (Hamama et al., 2013; Montgomery and Rupp, 2005). However, studying teachers' physiological stress in the classroom environment is still in its early stages. To date, it has been found that teachers' physiological stress is higher at the end of the school year, compared to the beginning of the school year (Katz et al., 2018). Teachers' cortisol levels are also higher on workdays than on weekends (Wettstein et al., 2020). Teachers' physiological stress does not appear to correlate with their self-reported stress or burnout (Katz et al., 2016; Nislin et al., 2016).

Thus far, very few studies on teacher stress have differentiated between inter- and intrapersonal levels of analyses, although it is strongly recommended in the analytical literature (Hamaker, 2012). Using heart rate as a stress indicator has shown that lower student engagement coupled with teacher-centered instructional practice is related to teachers' higher situation-specific physiological stress (Junker et al., 2021). Higher physiological arousal, also measured by heart rate, in association with classroom agency is related to higher enjoyment in the classroom (Donker et al., 2020). To the best of our knowledge, no previous studies have explored the intraindividual relations between teachers' situational physiological stress measured by cortisol and affect during the workday.

1.3. The current study

Taken together, the association between physiological stress and affect has been quite widely studied, but thus far, mostly as associations in cross-sectional studies. When MLMs have been specified, models have only included one dependent variable at a time, limiting the ways in which more complex relationships between variables can be specified. In the current study, we follow an intraindividual approach to modeling, in which time-points are nested in persons. Specifying multilevel structural equation models (MSEM) allows us to separately model associations and directional relationships (here, cortisol predicting experienced affect) at the within and between levels. This is consistent with the ergodicity-assumption (Molenaar, 2004), that it is not possible to draw conclusions about intraindividual processes, changes, and variability based on individual differences (i.e., mean-level differences between persons). Between-person relations do not allow making claims about the covariations between two indicators within one person (Molenaar, 2004). Indicators that are positively related in between-person analysis, might be negatively related in within-person level and vice versa (Curran and Bauer, 2011; Hamaker, 2012).

Also, the MLMs impede using two or more dependent variables and, consequently, manage the discrepancies in cortisol measurements and affect observations. Studies using affect to predict cortisol levels have mostly measured affect and cortisol at exactly the same time, without considering the time difference between cortisol sampling and affect observations (Doane and Adam, 2010; Hoppmann and Klumb, 2006). We assumed that on workdays and in ambulatory settings, it would be difficult to ensure the exact same time stamps for both cortisol and affect, a risk also acknowledged by Joseph et al. (2021). This warrants taking the time lag into account when modeling cortisol and affect.

Specifically, we aimed to investigate within-person relations between teachers' physiological stress and affect during the workday. Consistent with previous studies (Hoppmann and Klumb, 2006; Joseph et al., 2021), we expected that teachers' higher physiological stress is related to lower positive and higher negative affect at the within-person level (Hypothesis 1). Our theoretical two-level model with two time-varying indicators is presented in Fig. 1 (see also Sections 2.2.3 and 2.3).

2. Method

2.1. Sample and procedure

Our study was part of a larger longitudinal research project (Lerkkanen and Pakarinen, 2016-2022) investigating primary school teachers' and students' stress interactions in the classroom. Our study sample consisted of 61 primary school teachers (5 male) from Central Finland. Forty-nine of them taught 8–9-year-old students in Grade 2, and 12 of them taught 9–10-year-olds in Grade 3. The mean age of the participating teachers was 45.3 years (SD = 9.4), and their mean work experience was 17.8 years (SD = 10.1).

Data were collected over two workdays during the spring semester of the year 2019 (49 teachers) or 2020 (12 teachers). Overall, data

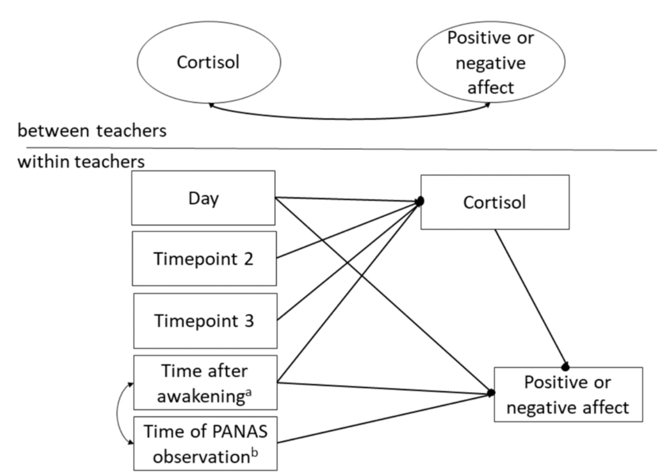

Fig. 1. Theoretical model of two-level associations between cortisol and positive or negative affect. Note. [a] Time after awakening of cortisol sampling in hours. [b] Time lag between the affect self-report and the cortisol sampling in hours.

collection lasted from late February to the beginning of May in 2019 and from late February to the middle of March in 2020. For 47 teachers, the two working days were consecutive; in 9 cases, they were three days apart, including over a weekend; in 5 cases, there were 3–6 days between two measurements, and 2 teachers did not provide data on Day 2. Prior to data collection, the participants received written instructions for collecting cortisol samples and responding to affect questionnaires, and they were personally instructed by trained research assistants. The research assistants were present in class during the first day of data collection to offer support. The teachers could also get in touch with a research assistant via phone at any time.

The data collection and analysis procedures followed the principles of The Declaration of Helsinki. The university ethics committee approved the study before the data collection started. All teachers provided their written consent to participate in the study.

2.2. Measures

2.2.1. Physiological stress

Salivary cortisol was used as an indicator of the teachers' physiological stress. It is recommended as an ecologically valid measure for ambulatory assessments (Kudielka et al., 2012). Cortisol is released in the body during the stress response and it affects a wide range of tissues. The main aim of cortisol is to support organisms to cope with stress and maintain homeostasis (de Kloet et al., 1998). Cortisol release in the body has a certain diurnal rhythm—cortisol levels increase rapidly in the morning, after awakening (i.e. cortisol awakening response—CAR), then followed by a sharp decline and then decrease smoothly during the day (Kudielka et al., 2012).

The teachers were asked to provide six saliva samples (at the time of awakening, 30 and 45 min after awakening, at 10 am., at the end of the school day approximately at 12–13 pm, and before bedtime) per day over two workdays for a total of 12 samples per teacher. Teachers reported their time of awakening and the time of each cortisol sampling. Synthetic Salivette® Cortisol swabs (by Sarstedt) were used for saliva sampling. The teachers were instructed not to eat or drink anything other than water, brush their teeth, or smoke 30 min before sampling. The participants were asked to gently chew the swabs for one minute immediately upon awakening, 30 and 45 min after awakening, at 10 am, at the end of the workday (around 12–1 pm), and at bedtime.

Saliva samples were stored in the deep freezer after the sampling. Research assistants collected samples from schools after the Day 2 sampling, labeled and stored them in a deep freezer at the university. Samples were transported to the lab by courier service in 1–2 days. Saliva samples were assayed at the Dresden LabService GmpH facilities, using Cortisol Luminesence Immunoassay (CLIA RE62011 by IBL International) to determine cortisol concentrations. Of the samples, 20% were randomly selected to be assayed twice, giving an inter-assay coefficient of variations below 7%.

Upon screening the quality of the data, the following cortisol samples were excluded from analyses (see Fig. 2): 3 cortisol samples were collected on an erroneous sampling day; 15 samples violated eating restrictions, as determined by self-reported meal or snack times; and 12 samples had cortisol concentrations larger than 73 nmol/l (equal to 60 nmol/l assayed by tandem mass-spectrometry [LC-MS/MS] as a reference method (Miller et al., 2013)) and were excluded as physiologically implausible. The first three morning samples from two teachers from one day were excluded because the gap between awakening and the first

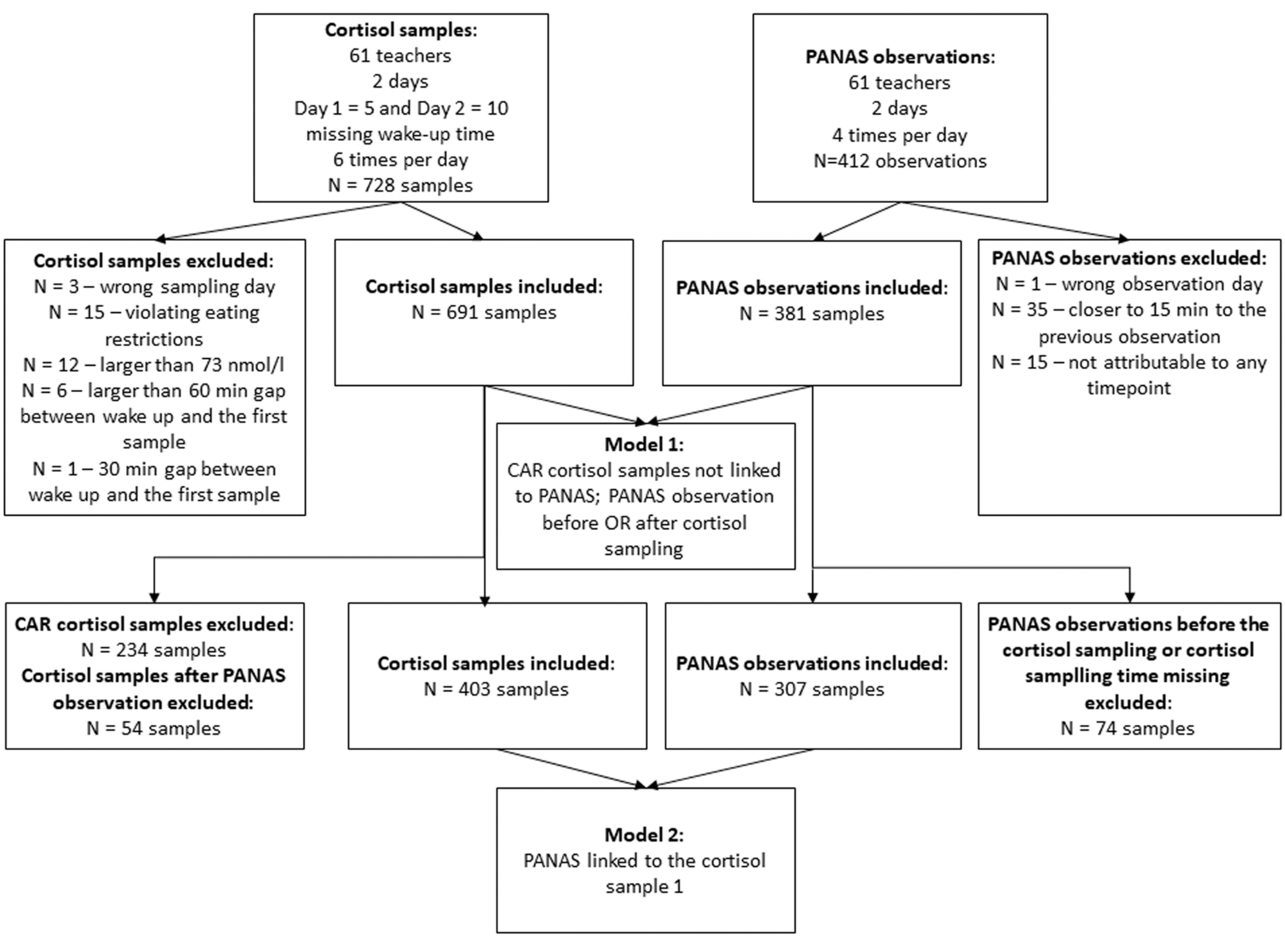

Fig. 2. Data exclusion criteria.

sample was longer than 60 min, as indicated by the self-reports. One teacher's first sampling time was 30 min after awakening; therefore, the first and second samples were redefined as the second and third samples, respectively, and the actual third sample was removed from the data. In total, 691 salivary cortisol samples were included in the analyses. The distributions of the teachers' cortisol levels over two days are presented in Fig. 3. Raw cortisol values (nmol/l) were natural logarithm transformed for the analyses because of the positive skewness (Adam and Kumari, 2009).

2.2.2. Positive and negative affect

A Finnish version of the Positive and Negative Affect Schedule (PANAS) was administered (Crawford and Henry, 2004; Hietalahti et al., 2016), which included five items capturing the teachers' situational positive affect (e.g., "attentive," "enthusiastic") and five items representing negative affect (e.g., "nervous," "scared"). The teachers responded using smartphones or in one case personal computers four times a day (upon awakening, at 10 am, at the end of the workday, and before bedtime), regarding to what extent each emotion best described them at that particular moment (1 = "does not describe me at all," 5 = "describes me very well"). Teachers were asked to complete the PANAS questionnaire approximately at the same time as they gave a cortisol sample. The response time was recorded in the device.

The mean of five items was used as a positive affect indicator (Cronbach's α ranged from.74 to.94 for 8 timepoints). The items measuring negative affect were highly skewed, with four out of five items having the answer "does not describe me at all" 83–94% of the time. Two reasons might be plausible for the skewness. First, the PANAS scales ask about very intense emotions (Diener et al., 2017), which tend to occur less frequently (see Hoyt et al., 2016 for a comparison). Second, linguistic and cultural differences might be present, as emotions are less easily expressed in Finnish than in English (Chen et al., 2012). In conclusion, we used negative affect as a binary indicator, coding it as 0 if the teacher had not felt any negative emotions at all at particular time point, and coding it as 1 if the teacher indicated that at least one negative affect item described them at a particular time point. Internal consistency of the negative affect scale (ordinal α) ranged from.50 to.96 for 8 time points.

In total, we received 412 affect reports, up to four reports for each of two days from each participant, in total up to eight reports per participant. The following observations were excluded before the analyses (see Fig. 2 to the right): observations closer than 15 min to the previous observation, which were considered repeat measurements (n = 35 reports); one observation on the wrong day (n = 1), and timing was not attributable to any timepoint (n = 15). For example, if a teacher had filled in the questionnaire upon awakening and also an hour later, and again at 10 am, one of the first two reports was omitted. In total, 361 affect reports were included in the analyses. The distribution of the means of positive affect over the day are presented in Fig. 3 and raw data in Table 1.

2.2.3. Linking cortisol and affect observations

We linked cortisol observations with self-reports so that the first cortisol sample coincided with the first PANAS observation, and the second and third cortisol samples were unrelated with the affect reports. The three remaining cortisol samples coincided with three PANAS observations. The resulting dataset included up to 12 samples of each teacher's cortisol (six samples per day), and up to eight responses for positive and negative affect (four reports per day). This linkage gave a data structure with two affect reports missing per day by design.

The flexibly coded time indicator for cortisol was the time of sampling from the time of awakening in hours. For self-reported affect, the time of observation from awakening was very highly correlated to the cortisol time indicator. In order to avoid multicollinearity in our models, we used the flexibly coded time indicator, giving the time lag from the cortisol measurement. For example, if the fourth cortisol sample was taken at 12 pm, 5.5 h since awakening, and the self-reported affect at 12:10, the two time-varying covariates would be 5.5 for cortisol and 0.167 h since the cortisol sample. Five teachers were missing wake-up time data on day 1 and 10 teachers on day 2; therefore, their wake-up

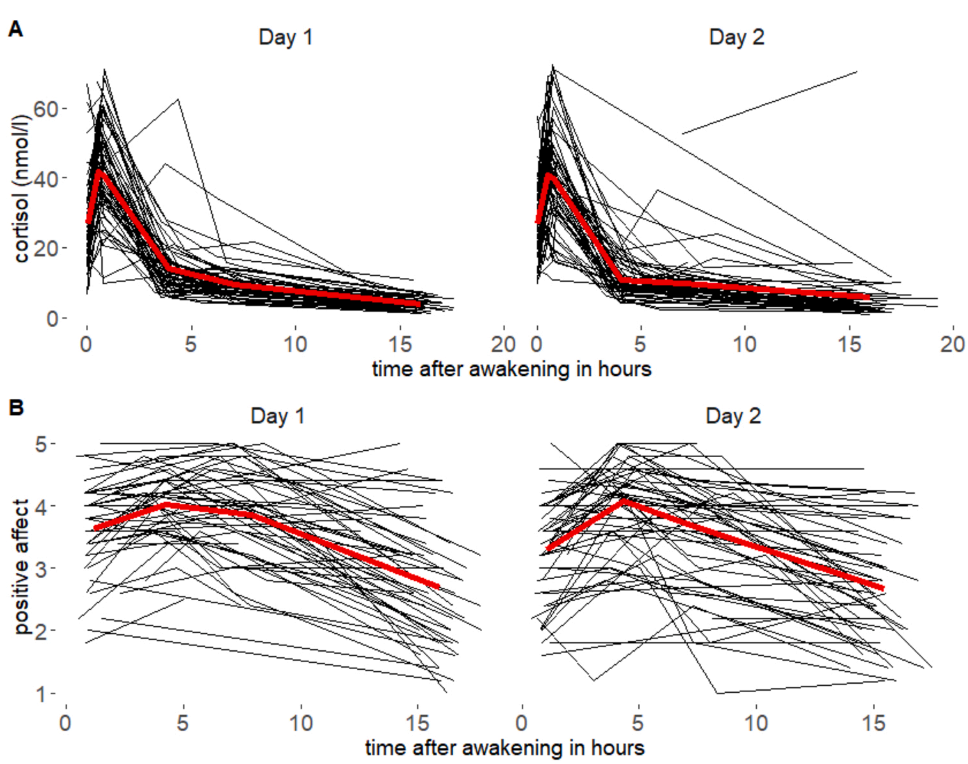

Fig. 3.. Variability of salivary cortisol (A) and positive affect (B) during two measurement days. Note. The thick red-filled line represents the mean cortisol levels (A) and positive affect (B) over the day.

Table 1
Descriptives of indicators for each timepoint.

Indicator	Day 1				Day 2			
	N	M or %	SD	range	N	M or %	SD	range
Cortisol (nmol/l) TP1	59	27.07	12.67	6–67	56	26.91	10.79	9–58
Cortisol (nmol/l) TP2	58	41.85	11.78	13–67	58	40.60	14.05	12–69
Cortisol (nmol/l) TP3	59	40.50	12.91	10–71	59	39.89	14.34	11–72
Cortisol (nmol/l) TP4	60	13.75	9.15	5–62	56	10.77	5.32	4–31
Cortisol (nmol/l) TP5	61	9.28	4.88	4–34	57	9.87	7.83	2–53
Cortisol (nmol/l) TP6	56	3.79	1.91	1–11	52	5.78	9.72	1–70
Positive affect TP1	48	3.62	0.75	1.8–5.0	53	3.31	0.84	1.6–5.0
Positive affect TP4	36	4.03	0.55	2.5–4.8	41	4.07	0.78	1.2–5.0
Positive affect TP5	54	3.85	0.71	2.2–5.0	49	3.65	0.88	1–5.0
Positive affect TP6	51	2.70	0.97	1.0–5.0	49	2.66	0.94	1.2–4.6
Negative affect[a] TP1	48	83			53	59		
Negative affect[a] TP4	36	72			41	51		
Negative affect[a] TP5	54	43			49	59		
Negative affect[a] TP6	51	43			49	31		
Cortisol time[b] TP1	59	0.02	0.04	0.0–0.3	56	0.01	0.02	0–0.1
Cortisol time[b] TP2	58	0.50	0.06	0.3–0.8	58	0.51	0.07	0.3–0.8
Cortisol time[b] TP3	59	0.79	0.08	0.8–1.3	59	0.78	0.06	0.7–1.0
Cortisol time[b] TP4	60	3.90	0.48	3.1–5.7	56	4.03	0.84	3.0–7.8
Cortisol time[b] TP5	61	7.05	0.67	5.9–9.0	57	7.07	0.97	4.1–10.3
Cortisol time[b] TP6	56	16.01	0.82	13.9–17.6	52	15.98	1.14	13.4–19.5
PANAS time[c] TP1	46	1.15	0.58	0.3–2.8	49	1.04	0.42	0.4–2.5
PANAS time[c] TP4	36	0.33	0.52	-0.6–2.1	40	0.40	0.74	-0.8–2.6
PANAS time[c] TP5	54	0.86	1.26	-0.9–5.6	46	0.39	0.82	-0.9–4.4
PANAS time[c] TP6	48	-0.17	0.65	-2.4–1.0	42	-0.21	0.68	-1.9–1.0

Note. [a] Due to skewness of the scale-score (i.e., the mean of the five items recorded on 1–5 scales) negative affect was recoded into 0 = all responses at “1”, 1 = one or more responses at “2” or above). [b] Time after awakening of cortisol sampling in hours. [c] Time lag between the affect self-report and the cortisol sampling in hours. TP = timepoint.

time was replaced with time of the first cortisol sampling.

Our data-structure had up to 12 timepoints for cortisol (6 per day) and up to eight timepoints for affect (up to four per day). In previous research, cortisol data from different measurement days have been aggregated to latent cortisol indicators to estimate between-person differences (Doane et al., 2015; Miller et al., 2016). Our approach enables us to answer research questions concerning intraindividual differences. Preliminary inspection of the data (we regressed cortisol on day) suggested no within-person difference in cortisol response between the two days, supporting this decision. Affect responses differed on the two days, necessitating the need to include day as a covariate in the models. In conclusion, for modeling, we thus used three indicators of the time structure: continuous time of cortisol sampling elapsed since awakening in hours, the time lag between the cortisol response and self-reported affect, and day (0 = Day 1, 1 = Day 2).

2.3. Statistical procedures

First, we inspected the within- and between-level variations in the teachers’ physiological stress and affect. We specified three separate MLMs for change for a) cortisol (Eq. 1), b) positive affect, and c) negative affect (Eq. 2) in the MSEM framework, using MPlus 8.6 (Muthén and Muthén, 1998–2017). With timepoints (t) nested in individuals (i) and a value of cortisol level for individual (i) at time (t) as a dependent variable, Eq. (1) was as follows:

$$\text{Cortisol}_{ti} = \beta0 + \beta1\text{Time}_{ti} + \beta2\text{Timepoint2}_{ti} + \beta3\text{Timepoint3}_{ti} + \beta4\text{Day}_{ti} + \upsilon_{0i} + \varepsilon_{1i} \quad (1)$$

$\beta0$ is the overall cortisol intercept, $\beta1$ is the slope (change in cortisol over time), υ_{0i} is the random part of the intercept, and ε_{1i} is the residual. We also specified the CAR by including two dummy-coded variables, $\beta2$ and $\beta3$ (cortisol samples taken 30 and 45 min after awakening) to reflect CAR (Doane and Adam, 2010; Katz et al., 2018).

For affect, we specified a similar regression model without dummies to reflect CAR. In order to inspect whether the time lag between the saliva sample and self-report had an effect on affect observations, we tested the model with two time indicators, including $\beta2\Delta\text{Time}_{ti}$ (see Eq. 2) to explain positive or negative affect, as follows:

$$\text{Affect}_{ti} = \beta0 + \beta1\text{Time}_{ti} + \beta2\Delta\text{Time}_{ti} + \beta3\text{Day}_{ti} + \upsilon_{0i} + \varepsilon_{1i} \quad (2)$$

In order to answer our main research question—how physiological stress is related to affect in within-level—we specified a joint MSEM model as shown in Fig. 1. At the within-level, we regressed cortisol on time after awakening and day, and we regressed affect on cortisol, time of self-reported affect since the cortisol sample, and day. Cortisol sampling time after awakening and relative time of PANAS observation were allowed to correlate.

We used the maximum likelihood (ML) estimator for the cortisol only model, and cortisol and positive affect models; and we used ML with Monte Carlo integration to facilitate convergence of modeling cortisol and the binary negative affect outcome. Raw estimated parameters and standard errors are reported in the Results section, as we used negative affect as a binary dependent variable. MPlus does not provide standardized parameter estimates for two-level models with within level regressions on binary outcomes.

3. Results

Descriptive statistics of untransformed cortisol concentrations and PANAS observations at each timepoint as well as time lags from awakening for cortisol and the time differences between PANAS and cortisol measurements are presented in Table 1. Raw cortisol concentrations and the levels of teachers’ positive affect over the two measurement days are shown in Fig. 3.

We first present findings for physiological stress and positive and negative affect separately, and then present findings for positive and negative affect regressed on physiological stress.

3.1. Teachers’ physiological stress and affect during the workday

The cortisol-only model (Eq. 1) indicated a decline of cortisol levels ($B = -0.11$, $p < .001$ for time after awakening) and higher cortisol levels for CAR timepoints (B = 0.71, $p < .001$ for both timepoint 2 and timepoint 3). Teachers' cortisol levels did not differ by measurement day (B = −0.02, $p < .50$). The cortisol-only model was saturated with the perfect model fit.

In the positive affect model (Eq. 2), teachers reported a lower positive affect later in the day (B = −0.07, $p < .001$), and this did not depend on the time lag of PANAS observations from the cortisol sampling (B = −0.05, p = .36). Positive affect was lower on the second measurement day (B = −0.51, p = .03). The positive affect-only model was also saturated with the perfect model fit like the cortisol-only model.

In the negative affect model, the negative affect was also lower later in the day (B = −0.13, $p < .001$), and it did not depend on the time lag from cortisol sampling (B = −0.30, p = .08). Similar to positive affect, the teachers tended to report fewer negative feelings on the second measurement day (B = −0.56, p = .03).

3.2. Intrapersonal relations between physiological stress and affect

Next, we combined initial cortisol-only and affect-only models and regressed situational affect on situational cortisol. Cortisol was explained by continuous time of sampling after awakening, two dummy CAR timepoints, and day (see Model 1 in Fig. 2). Positive or negative affect was predicted by time of cortisol sample prior to the self-report after awakening, the difference between the time of PANAS observation and cortisol sampling, and day. The same model was applied twice: once for positive affect as an outcome and another for negative affect. In both models, we found the within-level effect of physiological stress on affect in expected directions. As for models using Monte Carlo integration, the absolute model fit indices are not available; we could not examine the fit for the negative affect model. Nevertheless, the fit indices of the positive affect model did not demonstrate good model fit ($\chi^2 = 213.47$, df = 9, $p < .001$, CFI =0.86, RMSEA =0.18, $SRMR_{within}$ =0.14, $SRMR_{between}$ =0.17) (Hu and Bentler, 1999).

Therefore, we decided to remove cortisol timepoints indicating CAR (timepoints 2 and 3) from our models and test our hypotheses using the data from four timepoints in a day. We also specified the time sequence of our situation-specific data collection by excluding both cortisol and PANAS data if cortisol samples were collected after the PANAS observation or the cortisol sampling time was missing (N = 74) from our final model (see Model 2 in Fig. 2, n = 403 cortisol samples and n = 307 PANAS observations). The model fit indices for cortisol and the positive affect model were very good ($\chi^2 = 4.09$, df = 3, p = .25, CFI =0.99, RMSEA =0.03, $SRMR_{within}$ =0.03, $SRMR_{between}$ =0.18). Similar to the cortisol only model, teachers' cortisol levels did not differ between the first and second sampling day (see Table 2). Time after awakening negatively predicted the cortisol levels, indicating normal physiological cortisol decline over the day. Situational positive affect was explained by time and day of cortisol sampling after awakening, similar to the positive affect only model. In accordance with Hypothesis 1, the situational cortisol level explained positive affect in within-level (B = −0.31, p = .001). The higher the teachers' physiological stress the less they felt positive affect. Combining physiological stress and negative affect, we found that the probability of feeling negative affect differed on two observation days, as in the negative affect-only model (see Table 2). During the day, time did not explain the probability of feeling negative affect any more in the combined model. The time discrepancy from cortisol sampling was marginally related to negative affect (B = −0.38, p = .051) showing that closer the affect observation was to the cortisol sampling, higher was the probability of feeling negative affect. Our main interest was the intraindividual association between physiological stress and negative affect. We found a positive relation between these two indicators (B = 0.94, p = .004, odds ratio = 2.55, 95% CI-s[1.35, 4.82]). The higher the teachers' physiological stress the higher was the probability of feeling negative affect at the same time.

Table 2
Parameter estimates for two-level SEM models of relationships between cortisol and affect.

Parameter	Positive affect			Negative affect		
	Estimate	SE	p-value	Estimate	SE	p-value
Within-person level						
Cortisol on:						
Cortisol time[a]	-0.12	0.01	< 0.001	-0.12	0.01	< 0.001
Day	0.00	0.05	0.99	0.00	0.05	0.99
Affect on:						
Cortisol time[a]	-0.10	0.01	< 0.001	-0.01	0.05	0.98
Δ PANAS - Cortisol time[b]	-0.02	0.06	0.76	-0.38	0.19	0.05
Day	-0.15	0.08	0.04	-0.66	0.27	0.02
Cortisol	-0.31	0.08	< 0.001	0.94	0.32	0.01
Residual variances						
Cortisol	0.22	0.02	< 0.001	0.22	0.02	< 0.001
Affect	0.40	0.04	< 0.001	NA	NA	NA
Between-person level						
Means/threshold						
Cortisol	3.03	0.05	< 0.001	3.03	0.05	< 0.001
Affect	3.90	0.12	< 0.001	1.26	1.00	0.21
Variances						
Cortisol	0.07	0.02	< 0.001	0.07	0.02	< 0.001
Affect	0.39	0.90	< 0.001	0.90	0.48	0.06
Covariance						
Cortisol with affect	0.02	0.03	0.42	-0.07	0.07	0.30

Note. [a] Time after awakening of cortisol sampling in hours. [b] Time lag between the affect self-report and the cortisol sampling in hours. NA = not available for binary outcome in MPlus.

4. Discussion

We investigated teachers' daily physiological stress and affect and the effect of physiological stress on affect in a situation. Our study offers two novel contributions to the field. First, we applied a multilevel SEM model to investigate two time-varying indicators concurrently. Second, we showed that at the intrapersonal level, measurement time accounted for both stress and affect indicators; teachers' physiological stress has an effect on both positive and negative affect during the workday.

4.1. Modeling time-varying physiological stress and affect

Having intraindividual relations in physiological stress in interest, MLMs have been the most prevalent analysis method (for example see Doane and Adam, 2010). Unfortunately, MLMs do not allow for more than one dependent variable in the model, nor do they provide model fit indices for testing how consistent the model is with the data. Therefore, we proposed a multilevel SEM model to investigate the within-level relations between two time-varying indicators—physiological stress measured by salivary cortisol, and situational affect. It was quite reasonable to expect that the physiological stress and affect measurements would not be exactly time compliant, we needed to use two time indicators in our statistical models. For avoiding multicollinearity of time indicators that had increased the Type II error rates (Grewal et al., 2004) we proposed using two time indicators for PANAS observations—the time of cortisol sampling after awakening and the time of the self-reported affect after the cortisol sampling.

Next, as sample size and resulting low power is often problematic issue in studies collecting physiological data (Adam and Kumari, 2009), we modeled all available data without aggregation, i.e., up to 12 cortisol and 8 affect reports per person. In line with the current research, teachers' cortisol levels do not differ by workday (Bellingrath et al., 2008). Incorporating cortisol samples from different time points from one day and/or from days to the same analysis level has so far been used in latent trait models (Doane et al., 2015; Miller et al., 2016). Our results also showed that teachers' cortisol levels at different time-points did not vary on the two measurement days. Still, both positive and negative affect were lower on the second measurement day.

Taking the modeling part together, our results first showed the expected physiological cortisol curve during the day, and also intrapersonal changes in positive and negative affect over two measurement days. This allowed us to merge two time-varying models in order to investigate the intrapersonal relations between teachers' physiological stress and affect.

4.2. Relations between teachers' situational physiological stress and affect

Next, our results shed light on the within-level relations between teachers' physiological stress and affect during the workday in authentic classroom settings. Laboratory studies of healthy adults have so far indicated a weak relationship between physiological stress and emotional response (Campbell and Ehlert, 2012). Recently, it has been proposed that associations between physiological and psychological indicators might be heterogenous in the sample (Simon et al., 2022). In most studies conducted in ambulatory settings thus far, adult samples have shown negative relations between situational physiological stress and positive affect, and positive relations between situational physiological stress and negative affect (Joseph et al., 2021).

However, teachers' physiological stress studies are still in their first steps. It has been shown, for example, that teachers' physiological stress is higher on work days compared to the weekend (Wettstein et al., 2020) or that teacher students experience physiological stress response during the laboratory stress test but not emotional response (Becker et al., 2022). Consistent with studies on the relationship between-teachers self-reported stress and affect (e.g. Hamama et al., 2013) and within-person relations between physiological stress and affect (Joseph et al., 2021), our findings confirmed that at the within-person level, if teachers have higher physiological stress, they also typically have lower positive affect. And, vice versa for negative affect—the higher the situational physiological stress, the higher the negative affect.

Therefore, our study adds valuable situational information to previous research about teachers' stress and emotions in the classroom (e.g Frenzel et al., 2020; Keller et al., 2014). Teaching is a very demanding occupation in which stress is considered to be a default feature (Broughton, 2010). Teachers' stress depends on several external (e.g students' behavior, workload, relations in organization) and internal (e.g coping skills, emotions) factors (Montgomery and Rupp, 2005). Physiological stress is related to the classroom environment and teaching practices at the intrapersonal level (Junker et al., 2021). As teachers' affect is highly situation-specific (Keller et al., 2014) it is crucial to grasp the momentary relations of stress and affect. Understanding intrapersonal relations between physiological stress and affect emphasizes the necessity to facilitate educators' awareness of their own stress and affect. It also helps with planning individual interventions to diminish the negative perceptions of stressful events, and support teachers' stress management skills and each teacher's stress regulation during and after the school day. Teachers' well-being can be supported, for example, by peer mentoring groups focused on developing their pedagogical practices in the classroom (Vasalampi et al., 2021). The important role of primary school principals on teachers' well-being is also well recognized (e.g., Aelterman et al., 2007). For example, principals hold the key in giving teachers' opportunities for in-service training and supervision (Bredeson and Johansson, 2000).

Our results open several possible directions for further research. First, as our focus was on intrapersonal relationships between physiological stress and affect, we did not investigate possible between-teacher or -classroom level predictors of stress and affect and the individual differences in change in stress and affect during the day. In further studies, for example, the effect of teachers' work experience, number of students in the classroom, and the proportion of students with behavioral or learning difficulties on teachers' physiological stress and affect should be investigated. Next, as teachers' self-reported stress is related to their classroom practices (Penttinen et al., 2020), it is reasonable to investigate the effect of physiological stress on the quality of classroom interactions and instruction and, further, on student outcomes. Prompted by the results of the interactions between physiological arousal and classroom environment on teachers' enjoyment (Donker et al., 2020), the possible moderators on the associations between physiological stress and affect in the classroom should be studied.

4.3. Limitations

Our study also has some clear limitations we need to raise. We have studied situational stress and affect ideally measured simultaneously. In our study conducted in non-laboratory settings, there are often discrepancies in the timing of cortisol sampling and affect observation. First, we have taken this into account in our model by adding the time difference indicator to explain situational affect. This directed us to exclude cortisol data that were sampled after the self-reported affect (PANAS) and affect reports that were answered before the linked cortisol sampling to enable specifying the direction of the relationship between physiological stress and affect in the MSEM model. Although we have specified the direction of cortisol levels to explain the variance of affect, we do recognize that there is also theoretical support for the opposite regression model and call for further investigations about the direction of the relations between time-varying stress and affect. Furthermore, our solution increases the amount of missingness in our data set.

Secondly, we combined data from the same participants sampled and observed on different days. This was the solution we used to address the lack of power problem, which often occurs in ambulatory studies collecting physiological data. Still, we are very open to discussion about the solution we proposed. As a third limitation, data collected with the negative affect scale was much skewed and we were not able to use negative affect as a continuous variable as in the original PANAS scale. We also have to note the limitation of finding that teachers' affect, both positive and negative, was lower on Day 2. On Day 1 teachers were observed by the research assistants, the data collection Day 2 was a school day as usual. Therefore, we cannot tell the reason for lower affect on Day 2, we can only say that the day was controlled in our models. We also used single cortisol samples for within-person analysis and not any combined cortisol indicator. This makes it impossible to draw any between-person conclusions about the functionality of our sample's HPA-axis.

4.4. Conclusions

Taken together, developments in intraindividual research in education and the increased availability of software pose an interesting future for this field of research. We have shown one option for modeling two or more time-varying indicators in a multilevel SEM framework, and we hope to continue academic discussions about combining different indicators in intraindividual research. We also showed that despite teachers' average levels of physiological stress and affect, their cortisol levels and positive and negative affect are related at a situational level. Our findings emphasize the need to pay attention to each teacher's stress and affect regulation skills.

Declaration of interest

None.

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