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Article

# Psychological Stress = Physiological Stress?

## An Experimental Study With Prospective Teachers

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**Abstract:** The present study analyzed experimentally the association between the experience of psychological stress and the physiological stress response of prospective teachers. The experienced stress was assessed by self-reported data. Cortisol concentrations via saliva samples reflected the physiological response. The results show no difference between the stress and the control group in the experience of psychological stress. However, the stress group had significantly increased cortisol concentrations compared to the control group. The study could not show any correlation between the two stress parameters. The results suggest that a stress response should be validated based not only on the experience of psychological stress but also on the physiological stress response. This is particularly crucial in light of the fact that the majority of studies concerning stress in teachers are limited to experiences of psychological stress so far. Due to this, the results may provide a first important contribution to a more comprehensive stress assessment for teachers.

**Keywords:** psychological stress, PANAS, physiological stress, salivary cortisol, prospective teacher

The teaching profession is one of those professions with the highest levels of work-related stress (Kyriacu, 2015). The complex classroom environment and the high density of interactions as well as discipline problems, unmotivated students, and classroom disruptions are cited as potential acute stressors (Van Dieck et al., 1999; Schönwälder et al., 2003). As a result of work-related stress, many teachers retire early (Ingersoll & Strong, 2011; Friedman, 2006). Compared to other professional groups, stress symptoms – such as exhaustion, fatigue, headaches, tension, and psychological and psychosomatic illnesses – are overrepresented in teachers (Aloe et al., 2014; Scheuch et al., 2015). Further, work-related stress results in some of the highest rates of burnout in teachers. For example, the study by Schmitz (2004) estimates the proportion of teachers being affected by burnout at 80%. It could be shown repeatedly that stress affects the mental and physical health of teachers and has a negative impact on the quality of their teaching and consequently on the performance and motivation of their students (Klusmann et al., 2016). This impact might be related to the influence of the physiological stress response on cognitive functions (Becker, 2022; Becker et al., 2020).

Studies on teacher stress can be characterized by a variety of different concepts and definitions. Due to different conceptualizations of stress, either the physiological stress response or the experience of psychological stress is focused on. These different conceptualizations lead to different assessments of the stress response, either by physiological measures or by self-reported data. The majority of studies concerning teacher stress in education or the health sector are limited to experiences of stress recorded retrospectively by participants (Krause et al., 2013). In contrast, stress research in the field of psychology or psychobiology is largely based on the physiological stress response, usually assessed by measuring the activity of the hypothalamic-pituitary-adrenal (HPA) axis or a combination of psychological and physiological measures. This is particularly important for studying the effects of stress on cognitive processes. However, up to now, there is little empirical evidence regarding the association between the experience of psychological stress and the physiological stress response in teachers (Krause et al., 2013; Wettstein et al., 2020). Therefore, the present study examines the influence of an acute stress induction on the experience of psychological stress as well as on the physiological stress response and the association between the two measures.

## Physiological Stress Response

The physiological stress response can be elicited by an acute stressor, such as noise, and serve to mobilize physiological resources providing the body with the energy

needed for the stress response. The activation of stress response triggers changes in the autonomous nervous system, the sympathetic and parasympathetic balances, a hormonal response as well as a decrease in cognitive skills (Ashburner & Friston, 2005). One of the physiological processes which respond is the activation of the HPA axis, which is stimulated by the brain. Among other things, the HPA axis regulates the release of the stress hormone cortisol, which influences many bodily and immunological functions (Nelson, 2005; Sapolsyk et al., 1986). Cortisol is a lipophilic molecule that can pass through cell membranes (Nelson, 2005) and binds to two intracellular receptors, the high-affinity type I or mineralocorticoid receptor (MR) and the lower-affinity, but more ubiquitous, type II or glucocorticoid receptor (GR). As a result of a stress response, there is an extensive saturation of the occupancy of the MR, and, as a consequence, the GR becomes increasingly occupied. These receptors are found throughout the body, including in the brain, e.g., in the prefrontal cortex (Lupien et al., 2007; Nelson, 2005; Seiferth & Thienel, 2013). Through receptors in specific brain areas, cortisol affects cognitive capacities and can thus influence memory functions as well as memory processes (Becker, 2022; Becker et al., 2020; Seiferth & Thienel, 2013). Because of this, cortisol is especially crucial for studies examining the impact of stress on cognitive functions (e.g., Blackhart et al., 2007; Düsing et al., 2016).

Because the physiological stress response in its complexity is not directly observable from the outside, increases in cortisol concentrations are considered a reliable description of the endocrine stress response in the individual (Kirschbaum & Hellhammer, 1999). Cortisol can be determined in saliva and blood serum – levels in both correlate with each other to a high degree (Kirschbaum, 1991). Like some other hormones, cortisol is mainly present in bound form in the blood serum. In contrast, the cortisol in the saliva is the unbound, free, biologically active form of the hormone. Accordingly, analysis of saliva yields direct and accurate results on cortisol concentration, making this analysis preferable to that of blood serum (Shirtcliff, 2001).

## Experience of Psychological Stress

Stress is not only manifested in physiological reactions but can also be experienced psychologically. Psychological stress arises when a situation is interpreted to be threatening and, at the same time, resources are judged to be insufficient to cope with the situation (Lazarus & Folkman, 1984). As such, a thinking and feeling person – when dealing with a challenging situation – can experience negative affects, such as nervousness or anxiety. Kyriacu (2015) defines teacher stress as the experience of unpleasant emotions such as tension, frustration, anxiety, anger, and depression resulting from ones' job as a teacher.

The experience of psychological stress can be conceptualized in terms of negative affects, which are predominantly assessed in research through self-reported data. Standardized questionnaires are primarily used for the subjective evaluation of ones' own experience of psychological stress. In these questionnaires, the current psychological state is assessed by means of a list of adjectives that describe negative affects, for example, "nervous" or "angry". An example of such a questionnaire is the *Positive And Negative Affect Schedule* by Watson et al. (1988). The goal of self-reports and self-assessments is to make psychological phenomena, such as stress visible. However, it should be noted that self-reports and self-assessments are retrospective and depend on the respondent as well as the subjective experience of a situation. Additionally, self-reported stress is dependent on the interpretation of a question or the translation of an experience into the communicated response (Hussy et al., 2013). Further, the person must be willing and able to comment on a questionnaire (Epel et al., 2018). If he or she is not, corresponding biases must be expected, such as the social desirability of the response. However, even a person who is willing and able to answer a questionnaire may experience various biases, which may include personality traits but also the current state of situational factors. Because of this, self-reported data must be considered less objective than physiological parameters.

## Associations Between Experience of Psychological Stress and Physiological Stress Response

Associations between the different stress outcome systems have been assumed for several decades (for a review, see Mauss & Robinson, 2009). The prefrontal cortex, a brain structure involved in the cognitive evaluation of the significance of a stimulus and the availability of coping strategies, has been proposed as the location for these associations. The prefrontal cortex is believed to evoke psychological experiences via limbic connections, ultimately activating physiological systems as the HPA axis (Feldman & Weidenfeld, 1997; Herman et al., 2016). Thus, a corresponding association between the experience of psychological stress and physiological arousal should be anticipated. However, Pennebaker (2011) pointed out that many physiological processes are not consciously experienced. Therefore, self-reported data represent the experience of psychological stress or subjectively perceived stressors but do not always validly represent physiological stress responses (Campbell & Ehlert, 2012; Pennebaker, 2011; Wilhelm & Grossman, 2010).

Empirical studies explicitly addressing the association between the experience of psychological stress and the physiological stress response are rare. These few studies report inconsistent results. The review of Campbell and Ehlert (2012) examined the association between cortisol responses and perceived emotional stress variables following experimental stress induction by the Trier Social Stress Test (Kirschbaum & Hellhammer, 1993). Divergent results were presented in the review, ranging from zero correlations to high correlations (Campbell & Ehlert, 2012). Of the 30 studies reporting associations between cortisol responses and the experience of psychological stress, significant associations were found in approximately 25% only.

For teachers and the school context, physiological stress has hardly been studied so far. Therefore, there are only a few studies available on the association between the experience of psychological stress and the physiological stress response. One example is a pilot study from the University of Teacher Education Bern, Switzerland, which investigated psychological and physiological stress in the everyday working life of teachers in 2020. During two working days and one day off, stress was measured in eight healthy teachers throughout the entire day. The experience of psychological stress and cortisol concentrations were higher on workdays than on days off (Wettstein et al., 2020). Furthermore, correlations between the experience of psychological stress and the physiological stress response could be shown. However, the small sample size of $N = 8$ participants does not provide a reliable basis for generalization. Wolfram et al. (2013) assessed, in a larger sample of $N = 53$ teachers, the association between chronic work stress and the HPA axis regulation. The results of the study show a significant association between higher plasma cortisol profiles and emotional exhaustion, measured with the Maslach Burnout Inventory. In a further study, Wolfram et al. (2012) assessed cortisol responses to a demonstration lesson in $N = 21$ teachers and compared the cortisol responses as well as the individual chronic work stress between a working day and a day off. However, both studies by Wolfram et al. focused on individual chronic work stress and compared it to a physiological stress response.

Due to the studies presented, there is a lack of studies, especially quantitative experimentally studies, investigating the association between the experience of psychological stress and an acute physiological stress response within teachers.

## Factors Influencing the Experience of Psychological Stress and the Physiological Stress Response

Measures of cortisol concentration must take into account that the secretion of the hormone cortisol has a 24-hour circadian profile under basal conditions. The diurnal fluctuations are regulated, among other things, by the sleep-wake rhythm and the light-dark alternation. The release of the hormone occurs with a morning peak and a decrease throughout the day (Kirschbaum, 1991). In the afternoon hours, between 2 and 5 p.m., the concentration of the hormone can be considered relatively stable (Het et al., 2005).

It could be repeatedly shown that there are additional factors influencing the reactivity of the HPA axis to a stressor. One of the best studied factors is smoking, leading to a reduced response to an acute stressor (Kirschbaum, Wüst, & Strasburger, 1992; Kudielka et al., 2009; Rohleder & Kirschbaum, 2006). Furthermore, caffeine consumption can affect the acute stress response, leading to higher cortisol reactivity (Klein et al., 2010; Lane et al., 1990; Lane & Williams, 1985). Also, chewing gum and eating food just before an acute stress induction can also affect cortisol levels (Kudielka et al., 2009; Schultheiss & Steven, 2009; Stalder et al., 2016). Therefore, those factors need to be captured in studies or excluded when possible. Furthermore, sex differences are often cited as one explanation for inconsistent results. For example, stronger HPA axis responses to standard psychosocial stress have been found in men than in women (Kirschbaum & Hellhammer, 1994; Kirschbaum, Wüst, & Hellhammer, 1992; Kudielka & Kirschbaum, 2005; Stephens et al., 2016). Both gender socialization and biological sex are often listed as reasons for this difference (Chetkowski et al., 1986; Strahler et al., 2017). Regarding the experience of psychological stress in laboratory situations, studies have shown that women reported higher subjective stress levels than men (Kelly et al., 2006, 2008) and more negative feelings (Kroenke & Spitze, 1998; Thomsen et al., 2005). Consequently, sex is typically considered as an influencing factor in psychobiological studies investigating stress responses.

Because factors that influence the experience of psychological stress, as well as physiological stress responses, can only be insufficiently excluded in a case study, there is a need for experimental studies in a laboratory setting that makes it possible to exclude or control these factors. In order to introduce stress experimentally and then examine the experience of psychological stress as well as the physiological stress response, stress tests such as the Socially Evaluated Cold-Pressor Test (SECPT; Schwabe et al., 2008) can be used.

## Aims and Research Questions

Empirical studies on the effects of stress in the field of teacher stress and teacher health are largely based on the experience of psychological stress. In contrast, empirical studies in the field of psychophysiological stress research

are based on physiological and thus largely objective measures of the stress response or are based on a combination of the two stress measures. However, there is little empirical evidence on the association between the two measures in teachers. Particularly in teachers, for whom chronic social evaluations and potential conflicts with students can act as repeated stressors, it would be relevant to know whether the experiences of stress and the physiological stress responses correspond. Furthermore, there is a scarcity of experimental studies which would allow the examination of the association between the two measures while controlling the influencing factors.

Therefore, the aim of the present study was to investigate the association between the experience of psychological stress and the physiological stress response in prospective teachers following acute stress induction. The first research question was: is an experimental stress induction in prospective teachers reflected in the experience of psychological stress? (Research Question 1 [RQ1]). Since stress induction by the SECPT and measure of psychological stress experienced with the PANAS have been repeatedly demonstrated empirically and can therefore be interpreted as reliable, we assume that the acute stress induction will be reflected in the experience of psychological stress (Hypothesis 1 [H1]). The second question was: is an experimental stress induction reflected in the experience of physiological stress? (Research Question 2 [RQ2]). Based on the physiological stress response repeatedly demonstrated due to the SECPT, it is hypothesized that the stress induction is reflected in increased cortisol concentrations in prospective teachers (Hypothesis 2 [H2]). The third question examined: is the experience of stress associated with the physiological stress response in prospective teachers? (Research Question 3 [RQ3]). The empirical evidence for this association is divergent. In the few studies in which both stress measures were collected, zero correlations to high correlations were shown (Campbell & Ehlert, 2012). Because the findings of teacher stress have been largely based on the experience of psychological stress so far, it should be assumed that there is an association between the two measures (Hypothesis 3 [H3]). Furthermore, we were interested in the question of whether sex (female/male) influenced the experience of psychological stress (Research Question 4 [RQ4]) or the physiological stress response (Research Question 5 [RQ5]). According to previous findings, women show higher psychological stress levels and report increased negative feelings than men due to experimental stress induction. Data concerning sex differences in cortisol response patterns have revealed inconsistent results. Most studies showed that male participants show a higher increase in cortisol concentrations than female participants. Based on the study results presented, it can also be assumed for the investigated group that prospective female teachers will report higher subjective stress levels in the laboratory setting than prospective male teachers (Hypothesis 4 [H4]), and prospective male teachers will show a significantly higher increase in cortisol concentrations than prospective female teachers (Hypothesis 5 [H5]).

# Methods

In the following, the sample, the test instruments used, and the design of the experiment are described.

## Participants

The sample comprised of $N$ = 64 prospective teachers ($M_{age}$ = 22.72, $SD$ = 4.20; $N$ = 47, 73.4% female). The prospective teachers participated voluntarily in this experimental study investigating the influence of stress on diagnostic judgment processes (Becker, 2022; Becker et al., 2020). The participants were randomly assigned to a control group or a stress group – participants in the latter group only were artificially stressed before the diagnostic task. Participants were asked in writing to refrain from brushing their teeth, eating food, consuming caffeine and nicotine, or chewing gum for at least one hour prior to their respective survey. Furthermore, the participants completed a questionnaire in which personal data, such as age and sex, were collected. The female participants were also asked about the use of hormonal contraceptives. Prospective teachers with regular medication were not admitted to the study and were excluded in advance.

## Stress Induction Using SECPT

The stress within the stress group was induced with the help of the SECPT (Schwabe et al., 2008). The SECPT combines a physiological stressor, by asking participants to immerse one hand in ice water, with socially-evaluated components, by observing and videotaping the participants by the camera, and can be therefore regarded as a reliable method of stress induction. At the beginning of the SECPT, the participants were informed that they would – supposedly – be videotaped in the next few minutes and that the video recording would be subsequently evaluated by professionals trained in monitoring nonverbal behavior. In fact, however, the participants were not videotaped, the camera merely served to exert social pressure on the participants (Schwabe et al., 2008). Participants were asked to immerse one of their hands in water, which had a temperature of 0–4 °C in the experimental condition (Schwabe et al.,

2008). In the control condition, the water temperature was 35–37 °C (Schwabe et al., 2008). Participants were instructed to keep their hands in the water for as long as possible. To prevent damage to the skin tissue, the test was canceled after three minutes at the latest (Schwabe et al., 2008) unless the participant had pulled their hand out of the water earlier. At the end of the SECPT, the camera was visibly – supposedly – switched off for the participants. The experience of a social-evaluative threat in terms of being exposed to a potentially negative judgment by others and anticipating an uncontrollable performance outcome have been associated with the largest and most reliable cortisol response compared to other laboratory stressors (Dickerson & Kemeny, 2004). In previous research, cortisol concentrations measured from saliva samples in subjects in the experimental condition were significantly higher than those in the control condition as a result of SECPT and 75% higher than cortisol concentrations after the cold pressor test, which lacks the social evaluating moments (Schwabe et al., 2008). The social evaluative components alone, however, showed no influence on cortisol concentrations in the control condition. According to Schwabe et al. (2008), both a physiological stressor, such as ice water, and social evaluative components, such as video recording, are required for significantly increased cortisol production.

## Self-Report Questionnaire

The experience of psychological stress was measured by the *negative affect scale* of the Positive And Negative Affect Schedule (PANAS; Watson et al., 1988). The PANAS is a self-report questionnaire consisting of two 10-item scales to measure positive and negative affects. Each item is rated on a 5-point scale from 1 = *not at all* to 5 = *very much*. This questionnaire was used before and after the stress induction in order to identify changes.

## Saliva Sampling

The physiological stress response was analyzed based on the reactivity of the HPA axis and examined using repeatedly collected salivary cortisol samples before, during, and after stress induction. Saliva samples were collected using SaliCaps. The participants were asked to fill the SaliCaps halfway with saliva using a tube. The samples were stored on ice after collection. After the testing period, the samples were centrifuged, and the resultant saliva was frozen at −20°C till they were assayed with regard to changes in cortisol concentrations. The analyses were implemented by the Institute of Medical Psychology laboratory, Heidelberg University Hospital.

## Saliva Cortisol Assay

Saliva concentrations of cortisol were measured using a time-delayed solid-phase enzyme immunoassay (ELISA) based on the principle of competitive binding (Engvall & Perlmann, 1971). To validate the ELISA, the intra-assay coefficient of variation (CV) and the inter-assay CV were determined. To determine the intra-assay CV, every fifth sample in the present study was analyzed in duplicate. Intra-assay CV of less than 10% and inter-assay CV of less than 15% demonstrate good reliability (Schultheiss & Steven, 2009).

## Procedure

The experiment was performed in a quiet room at the university between 2 and 5 p.m. During this time, cortisol concentrations can be judged to be largely stable (Het et al., 2005). Each session lasted about 45 min. Participants were informed that they would take part in a stress experiment. After they gave their consent for participation, they were made familiar with the saliva collection procedure. Then the first saliva sample ($t_1$), which reflects the baseline, was collected, and the participants rated the items of the PANAS for the first time. Afterwards, the SECPT was performed, and the participants of the experimental group were artificially stressed. The second saliva sample ($t_2$) was collected immediately after the SECPT, and the participants rated the items of the PANAS for the second time. After 10 minutes, the third ($t_3$) and the fourth samples ($t_4$) were collected 10 min apart; between the third and the fourth samples, participants worked on a diagnostic task on the eye tracker (Becker, 2022; Becker et al., 2020).

## Data Analysis

The physiological stress response of the participants was measured using four repeated saliva samples, which were evaluated with regard to cortisol concentrations. To determine the development of the cortisol concentrations, the *slope* was calculated within both groups. The *slope* represents the increase of the lines between the different cortisol values at the four times of saliva sampling during the experiment. Further, *area under the curve with respect to increase* ($AUC_I$) was calculated using all values from $t_1$ to $t_4$ after subtracting the baseline. Areas under the curve were calculated using the trapezoid rule, which additionally allows a statement about the cortisol concentration itself (Pruessner et al., 2003).

With regard to RQ 1, the negative affect of PANAS was compared within groups using a two-way repeated-measures analysis of variance (ANOVA; see Table 1, Calculation 1). ANOVA was used to compare the negative affect

**Table 1.** Calculations

| Calculation | Independent variable | Dependent variable |
|---|---|---|
| 1. Two-way repeated measures ANOVA | Time | Negative affect of the PANAS |
| 2. Multiple ANOVA | Stress induction through the SECPT | PANAS |
| 3. Multiple ANOVA | Stress induction through the SECPT | Slope $AUC_I$ |

*Notes*. ANOVA = Analysis of Variance; $AUC_I$ = Area Under the Curve with respect to Increase; PANAS = Positive And Negative Affect Schedule; SECPT = Socially Evaluated Cold-Pressor Test.

of PANAS between the stress group and the control group (see Table 1, Calculation 2) and to compare salivary cortisol levels between the two groups (see Table 1, Calculation 3). With regard to RQ 3, Pearson's correlation coefficient was used to test for the association between the negative affect of PANAS before and after the stress induction, the slope, and the $AUC_I$. Based on the theoretical assumptions and the empirical evidence, the hypotheses underlying the third calculation were tested unilaterally. The effect sizes were indicated by the partial eta-squared ($\eta_p^2$). A $\eta_p^2$ (small = .01, medium = .06, large = .14; Cohen, 1988) was calculated for the main effects and interactions to evaluate the practical significance of the intervention.

In addition, female and male participants in the experimental group were examined with regard to sex differences in the experience of psychological stress (H4) using a multivariate analysis of variance (MANOVA). The stress induction represented the independent variable, and the experience of psychological stress represented the dependent variable. Based on the theoretical assumptions and the empirical evidence, H4 and H5 were tested unilaterally. The effect sizes of the sex differences were indicated by the $\eta_p^2$.

# Results

Below, the reliabilities and the results along the research questions are presented.

## Reliability

The reliability of the immunoassay result for analysis of saliva samples with respect to cortisol concentrations is reported as intra-assay CV as well as inter-assay CV. The intra-assay CV was 3.8%, and the inter-assay CV was 8.3%. Thus, the detection of cortisol by ELISA is highly reliable in the present study because an intra-assay CV below 10% and an inter-assay CV below 15% can be considered reliable (see Schultheiss & Steven, 2009).

The internal consistency of the PANAS was acceptable, but not good, before stress induction, with Cronbach's $\alpha$ = .67, and after stress induction, with Cronbach's $\alpha$ = .78.

## Changes in the Experience of Psychological Stress and the Physiological Stress Response

With regard to RQ 1, a repeated-measure ANOVA was calculated to analyze the changes in the experience of psychological stress throughout the experiment.

Table 2 displays, that there was a significant decrease in the negative affects before and after stress induction within the control group. But there was a significant decrease in the negative affects before and after stress induction within the stress group, too. An ANOVA revealed no significant difference between the negative affect of the control group ($M$ = 1.24, $SD$ = 0.22) and the negative affect of the stress group ($M$ = 1.17, $SD$ = 0.15) after stress induction $F(1, 62) = 2.66$, $p = .168$, $\eta_p^2 = .03$. With regard to the positive affect, there was a significant increase from measure point 1 to measure point 2 within the stress group, but no change within the control group (see Table 2).

With regard to RQ 2, the physiological stress response of the participants was measured by four repeated saliva samples, which were evaluated with regard to cortisol concentrations. Figure 1 illustrates the mean cortisol concentrations of the four saliva samples within the stress group and within the control group. To determine the development of the cortisol concentrations, the slope was calculated within both groups.

Throughout the survey, the slopes of the salivary cortisol were significantly higher within the stress group ($M$ = 1.15, $SD$ = 2.30) than within the control group ($M$ = −0.16, $SD$ = 1.81, $F(1, 62) = 6.41$, $p = .007$, $\eta_p^2 = .09$). In addition to the calculation of the slope, $AUC_I$ was also calculated. It could be shown that the cortisol concentrations of the stress group ($M$ = 14.15, $SD$ = 37.54) are significantly higher than the concentration of the control group across the survey period ($M$ = −1.06, $SD$ = 26.10, $F(1, 62) = 3.50$, $p = .033$, $\eta_p^2 = .05$).

## Association Between the Experience of Psychological Stress and the Physiological Stress Response

With regard to RQ 3, the association between the experience of psychological stress and the physiological stress

**Table 2.** Experiences of psychological stress, collected by the negative affect and the positive affect of the PANAS, due to stress induction

| | Before stress induction | | After stress induction | | | | |
|---|---|---|---|---|---|---|---|
| Scale | *M* | *SD* | *M* | *SD* | *F*(1, 29) | *p* | $\eta_p^2$ |
| Control group | | | | | | | |
| Positive affect | 3.05 | 0.65 | 3.06 | 0.69 | 0.07 | .801 | .00 |
| Negative affect | 1.41 | 0.33 | 1.24 | 0.22 | 20.51 | < .001 | .41 |
| Stress group | | | | | | | |
| Positive affect | 2.99 | 0.48 | 3.12 | 0.57 | 5.39 | .027 | .15 |
| Negative affect | 1.27 | 0.18 | 1.17 | 0.15 | 11.64 | .002 | .27 |

*Notes*. On the 5-point scales of the PANAS questionnaire, low values present no agreement (0 = *not at all*), and high values present agreement (5 = *extremely*).

response was investigated in both groups. In the sample, no associations were seen between the experience of psychological stress, measured by the negative affect scale of the PANAS after the stress induction, and the physiological stress response, indicated by the slope of the cortisol concentration, across both groups, $r(62) = .03$, $p = .838$. There were highly significant positive correlations between the negative affects before and after stress induction across both groups, $r(62) = .64$, $p < .001$, and between the two calculations of the physiological stress measures slope and $AUC_I$, $r(62) = .96$, $p < .001$. The two calculations of the physiological stress response refer to the four saliva samples taken repeatedly before and after the stress induction. But there was no statistically significant association between the negative affect after the stress induction and the slope or the $AUC_I$ of the cortisol concentration among the participants of both groups.

## Sex Differences in the Experience of Psychological Stress and the Physiological Stress Response

Regarding RQ 4 and RQ 5 and sex differences in the experiences of psychological stress as well as in the cortisol concentrations reported in previous studies, ANOVAs were calculated between female and male participants within the stress group after stress induction.

Comparing the female and male participants of the experimental group, there was no significant effect between the negative affect of the PANAS after stress induction. But there was a highly significant effect between the positive affect of the PANAS comparing the female and male participants. According to Cohen (1988), there is medium effect size (see Table 3). With regard to the increase of cortisol concentration within the experimental group, there was a significant effect of sex. Both calculations, the slope and the $AUC_I$, showed that male participants had significantly higher increases as well as significantly higher cortisol concentrations than the female participants. The results indicated high effect size (see Table 3).

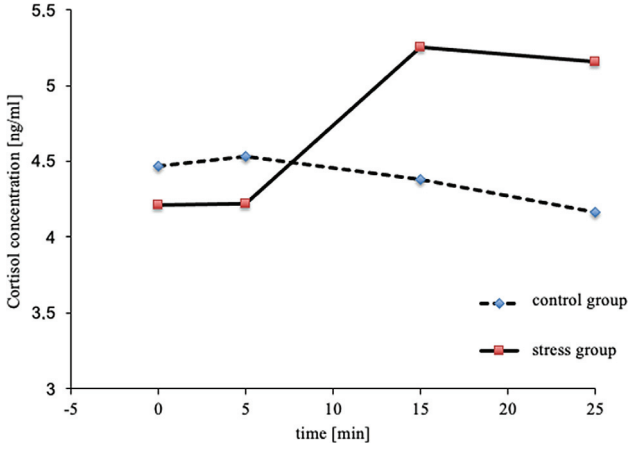


**Figure 1.** Development of the cortisol concentration within the stress group and within the control group during the experiment.

**Table 3.** Sex differences in the experience of psychological stress and the physiological stress response within the experimental group

| | Female participants (*N* = 21) | | Male participants (*N* = 12) | | | | |
|---|---|---|---|---|---|---|---|
| Scale | *M* | *SD* | *M* | *SD* | *F*(1, 31) | *p* | $\eta_p^2$ |
| Negative affect | 1.14 | 0.15 | 1.20 | 0.16 | 1.37 | .126 | .04 |
| Positive affect | 3.00 | 0.54 | 3.30 | 0.59 | 2.13 | .007 | .06 |
| Slope | 0.57 | 1.62 | 2.30 | 2.92 | 5.23 | .015 | .14 |
| $AUC_I$ | 4.81 | 21.57 | 30.50 | 52.89 | 3.89 | .028 | .11 |

*Notes*. On the 5-point scales of the PANAS questionnaire, low values present no agreement (0 = *not at all*) and high values present agreement (5 = *extremely*). $AUC_I$ = Area Under the Curve with respect to Increase.

# Discussion

The current study used an experimental setting to compare the experience of psychological stress and physiological stress responses in prospective teachers following acute stress induction. The experience of psychological stress was based on self-reported data, assessed via a questionnaire. The analysis of saliva samples with regard to cortisol concentrations was used as an indicator of physiological stress. Furthermore, we analyzed sex differences in both measures of stress. The results are discussed in order of the research questions.

Regarding RQ 1, negative affect in the control group decreased significantly, as expected, with a high effect size. However, notably, the stressed group also showed a significant decrease in negative affect. Although the effect size

was smaller, it can still be interpreted as high (Cohen, 1988). One possible explanation would be that the participants in both groups were nervous at the beginning of the study and relieved when the stress induction was over, as shown in reduced negative affects. Based on this, it would be interesting to investigate the psychological stress response more often during stress induction in a further study (see Ditzen et al., 2014). Another possible explanation is that in our sample arousal, as indicated through cortisol increases, improved mood. Based on the results, there should be first a discussion on whether the questionnaire was sufficient to capture the experience of the psychological stress of the participants.

The PANAS questionnaire is a commonly used and reliable test instrument for assessing subjective feelings of stress (Breyer & Bluemke, 2016). According to Lazarus and Folkman (1984), if a situation is evaluated as stressful, the resulting stress response will be associated with negative emotions such as anxiety, anger, or dejection. However, experiences of psychological stress can always refer to different components of the stress response (stressors or stress perception). Therefore, there may be confusion between the stressor and the dependent variable being asked about, e.g., the physiological stress response (Contrada, 2011; Semmer et al., 2005). In addition, it is worth reiterating here that self-reported data are usually collected retrospectively and may be subject to various biases, such as personality traits (Sutin & Terracciano, 2016) or other negative aspects of life (Epel et al., 2018) as well as the willingness to express these negative emotions (Epel et al., 2018). However besides the mentioned assessments of psychological stress, the results can especially confirm the assumption that it is difficult to correctly assess one's own physiological and endocrine processes. To be able to verify whether the stress induction by the SECPT was successful and thus to exclude this as a reason for the surprising values of the PANAS, we look at the physiological stress responses in addition. These showed significantly increased cortisol concentrations in the experimental group after stress induction compared to the control group. Thus, on a physiological level, it can be assumed that there was sufficient stress induction by the SECPT. Therefore, the changes in cortisol concentrations in the experimental group throughout the survey are in contradiction to the experience of psychological stress. Calculating the correlations between the experience of psychological stress and the physiological stress response, there were, in line with expectations, high statistical correlations between the negative affect measures before and after stress induction across both groups as well as between the two calculations of the physiological stress response (slope and $AUC_I$). But we could find no statistical correlations between the experience of psychological stress and the physiological stress response. Previous studies show a rather inconsistent picture regarding the association of subjective and objective data. Campbell and Ehlert (2012) report in their review weak correlations between the experience of psychological stress and the physiological stress responses on average. For example, Mendes et al. (2008) only demonstrated a correlation of $r = .20$ between self-reported data and the physiological stress response. The results of the current study also fit the latter data. Authors who were able to show highly significant correlations between the experience of psychological stress and the physiological stress response usually assessed the experience of stress using explicit questions about the stressor, for example, how unpleasant, stressful and painful participants found the stress induction (e.g., Schwabe et al., 2008). This may be further evidence that individuals can assess a stressor relatively reliably but that these assessments do not reliably reflect their own physiological stress response.

Because previous research has shown that while associations of different levels of the stress responses were nonsignificant between groups, they could be found using more frequent measures and more refined statistical modeling (Ditzen et al., 2014), it would be necessary for further studies to examine more frequently the associations between the two measures within teachers.

The inconsistent results about the association between the experience of psychological stress and the physiological stress response from previous studies and from the present study – in relation to (prospective) teachers – need to be discussed, especially in light of existing research on teacher stress and teacher health. Previous studies in these areas are largely based on the experience of psychological stress, collected through self-reported data using questionnaires or on the information provided by independent observers (Krause et al., 2013; Wettstein et al., 2020). However, in order to base results in the area of teacher stress only on the experience of psychological stress, a reliable correlation between the experience of psychological stress and the physiological stress response would be essential, but this could not be shown in the present study. The results of the study suggest that physiological stress responses can occur before or without being subjectively experienced. Based on the endocrinological effect, an increased release of cortisol binds cognitive capacities and thus influences executive functions in particular. Therefore, it can be assumed that cognitive impairment can be observed even in the absence of experience of psychological stress. This would mean that teachers' cognitive functions can also be impaired without being consciously experienced. Consequently, teachers should keep this in mind when making decisions within the classroom, especially for high-stakes decisions. Such high-stakes decisions could involve, for example, educational choices for school types. In addition, stress research should be based on multiple stress

measures. This should be considered especially in studies in which the impact of stress on cognitive functions is examined – for which cortisol is crucial.

The influence of sex has often been cited as one explanation for inconsistent results in psychobiological stress measures. The sample size and the experimental design of the present study allowed us to examine the experience of psychological stress and the physiological stress response between the sexes. Regarding the experience of psychological stress, there is no significant difference between the female and male participants in the present study. Thus, the results of the present study are not consistent with the repeatedly shown findings that female participants subjectively react more stressed than male participants (Kelly et al., 2006; Kelly et al., 2008) and report more negative feelings (Kroenke & Spitze, 1998; Thomsen et al., 2005). The significant difference found in the present study in cortisol concentrations between the sexes after the experimental stress induction is consistent with previously reported study findings. In stress studies, male participants mostly showed a significantly stronger cortisol response than female participants (Chetkowski et al., 1986; Strahler et al., 2017). Both gender socialization and biological sex differences are often listed as reasons (Chetkowski et al., 1986; Strahler et al., 2017). However, a significant increase in cortisol concentration was also shown in female participants by stress induction using the SECPT. Thus, sex can be excluded in the present study as a crucial influencing factor in the experience of psychological stress.

## Limitations and Future Perspectives

Several limitations and steps for further development and research remain. Regarding the composition of the present study sample, it should be noted that studies in stress research usually recruit male participants only. As has been demonstrated in these studies, male participants show a significantly stronger cortisol response than female participants (Strahler et al., 2017). Schwabe et al. (2008) also limited their study to male participants when developing the SECPT. However, they indicated in their study the goal of replicating the results in female participants. Although the sample size of the present study is too small to draw general conclusions regarding the effectiveness of SECPT with female participants, the present study was able to show its basic effectiveness among female participants ($n$ = 47). Limitations with regard to female participants in stress research are seen, for example, in the influence of hormonal contraceptives on cortisol-binding globulin levels (Chetkowski et al., 1986). For example, the review by Strahler et al. (2017) includes 14 studies showing attenuated, two studies showing higher, and 12 studies showing comparable cortisol responses in participants taking hormonal contraceptives compared with participants not taking them. In the present study, $n$ = 16 of the female participants did not answer the question about the use of hormonal contraceptives. Therefore, the influence of hormonal contraceptives could not be controlled for in the present study. Restricting the sample of prospective teachers to male participants only was not worthwhile because currently (school year 2018/2019), 72.0% of the majority of teachers in Germany are female (Statistisches Bundesamt, 2020).

Furthermore, the low reliabilities of the negative affect of the questionnaire PANAS have to be pointed out. One possible explanation for the low internal consistency could be the small number of items (ten items for the survey of negative affect) since Cronbach's α reacts very sensitively to item numbers. With regard to the low reliability of the scale of the PANAS questionnaire, it must be added that the level of Cronbach's α can be influenced by the tendency to tick further to the right or further to the left on the scale of the questionnaire. However, alternatives to Cronbach's α, such as test-retest reliability or parallel test reliability, could not be used in the present study. In the case of test-retest reliability, the participants would have had to take the test several times. This was not possible due to the scope of the survey and would have influenced the validity of the test instruments due to possible bias effects. Parallel test reliability was determined for the negative affect scale of the questionnaire PANAS, because there was no way of ensuring a second test procedure design that measures the same characteristic and shows the same error variance. Test-half reliability was not a suitable alternative due to the insufficient sample size (Blanz, 2015). Because the PANAS questionnaire can be considered an established instrument for measuring physiological stress, one aim of further research on teacher stress should be to better adapt the questionnaire and so improve the reliability with samples of teachers.

The present study was conducted in a laboratory setting for reasons of standardization and controllability of influencing factors. By randomly assigning participants to a stress group and a control group, the greatest possible avoidance of potentially confounding variables could be ensured (Dean & Voss, 1999). Therefore, the internal validity of the stress induction in the present study can be interpreted as high. However, it should be noted restrictively that not all factors which may have an influence on cortisol levels were controllable. For example, in the present study, it was not possible to check the participants' instructed abstention from food and coffee, brushing their teeth, or chewing gum one hour before their survey and the saliva samples. Since none of the saliva samples showed any contamination, this can be largely ruled out. Even so, the effects of long-term intensive stressors, such as traumatic experiences or chronic stressors, could not be excluded.

Due to the experimental design of the study, a goal of future studies should be to replicate the results in a real classroom and everyday teacher contexts. It is expected that physiological stress response, for example, due to the high density of interactions in the classroom, implies the same physiological response as induced by the SECPT. However, the cortisol levels of teachers in the classroom are not available yet. Up to now, measures of teacher stress during lessons have been largely based on self-reported data, which are collected retrospectively and thus susceptible to bias in addition to subjectivity (Wettstein et al., 2020). In a pilot study at the University of Teacher Education in Bern, the experience of psychological stress and the physiological stress response of teachers on days off and workdays have already been investigated with a small sample. The results revealed significantly higher morning cortisol on workdays compared to their free days. The results now need to be replicated on a larger sample. Furthermore, it would be interesting to compare the experience of psychological stress and the physiological stress response not only on days off and on workdays but also within a lesson, with a view to elucidating possible stressors. The following studies should investigate which classroom disturbances cause which particular experience of psychological stress and physiological stress responses. Moreover, there is a need to investigate how these experiences of psychological stress and physiological stress responses influence the teaching process itself and the learning by the students.

A central implication can be derived for the fields of teacher stress and teacher health research based on the research results presented. Long-term consequences of stress on health were not investigated in the present study. The influence of stress on health always becomes problematic if it is triggered permanently or too often. Under these circumstances, the cortisol concentration in the organism remains permanently elevated. The adrenal gland produces insufficient hormones to regulate the stress reaction due to the permanently elevated cortisol concentration so that appropriate stress response can no longer take place. Additionally, too little adrenaline is produced, which leads to complete exhaustion of the affected person. Consequences can be inner restlessness, excitability, concentration disorders, memory problems, depression, weakening of the immune system, and chronic states of exhaustion, such as burnout (Kirschbaum & Heinrichs, 2011). The long-term consequences of repeated acute stress responses should therefore be included in research on teacher stress and teacher health. Since the present study results suggest that teachers cannot adequately self-assess their experience of psychological stress, it can be assumed that teachers are already exposed to physiological stress responses before or without subjectively perceiving them or that stress induction could also be experienced positively by some participants. Common to both lines of reasoning is that the physiological stress response captures more information than the experience of psychological stress. Therefore, it would be important to integrate physiological stress measures in studies of teacher health and teacher stress.

## Conclusions

The present study is one of the first which aims to associate the experience of psychological stress with the physiological stress response of prospective teachers. To do this, we considered self-reported data through a questionnaire and saliva samples in regard to cortisol concentrations. In summary, our findings show no association between the experience of psychological stress, and the physiological stress response of prospective teachers. The results of the study suggest that a stress response should be validated not only based on the experience of psychological stress, but also based on the physiological stress response. This is especially relevant, given the short influence on cognitive functions and the long-term influence on health. Our results may provide the first important contribution to testing a stress response in future studies in the field of stress research within teachers, and we see a need for further research in the field of stress.

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