**Anmerkungen vom 29.01. Besprechung Theorie Anne & Christin**

* Mit Wearables einsteigen 🡪 hohe Akzeptanz, non-invasiv/ nicht störend/ non-intrusiv, wird von vielen getragen, Lehrer:innen tragen das sowieso, Menschen tracken ihre Parameter 🡪 welche Parameter ergeben sich daraus für Lehrpersonen (Begründung, dass wir Stress mit Fitnesstrackern erhoben haben) 🡪 Übergang zu Teacher Stress
* Verbreitung von Fitness Trackern generell in Bevölkerung (Verkaufszahlen, wie viele Leute/ Lehrpersonen tragen sie; Fitbit kann als Bsp. aufgeführt werden)
* Mehr Theorie zu Classroom Management 🡪 Kompetenz, die Lehrpersonen haben sollten (subjektive Stör- und Sicherheitserleben, Berufserfahrung, usw.) 🡪 Appraisal nicht über Self-Efficacy (SE) laufen lassen 🡪 SE komplett rauslassen
* Lazarus-Modell mehr einbinden
* über Job-Demand-Resources-Modell belesen 🡪 auch hier wird Bedeutung von Ressourcen betont, um zu untermauern, dass wir uns auf valide Sichtweise stützen
* Tobias Kärner / Kyriacou-Modell anschauen und an unser Setting anpassen (Teacher characteristics: Berufserfahrung)
* Typischer Stressor: Störung (aber gesamte Micro-Teaching-Unit betrachtend, nicht einzelne Störungen); typische Ressource: Erfahrung im Umgang damit
* First page (Introduction) vorschreiben
* Im Diskussionsteil: begründen, dass wir uns nicht einzelne Störungen angeschaut haben, sondern die Gesamtlektion (da Stress kumulativ entsteht und es zeitliche Verzögerungen gibt bei Arousal; aaaaußerdem: Daten lassen Analyse nicht zu)

**# Introduction**

In the last decade, commercial wearables have become increasingly popular and accepted among the wider population. The impact of these devices comes in concrete data: Valued at USD 61.30 billion in 2022, the market for wearable technology has experienced robust growth and is expected to continue to expand with an annual growth rate of 14.6% from 2023 to 2030 [@https://www.grandviewresearch.com/industry-analysis/wearable-technology-market]. International Data Corporation (IDC), a global provider of market research and advisory services for the technology industry, reports that the substantial growth in the wearable market has primarily been driven by smartwatches and wrist-worn fitness trackers [@richter2018global]. The most frequently used wearables in research projects are Fitbit, Garmin, Misfit, Apple, and Polar. These brands, already existing for several years, have shipped a substantial quantity of devices [henriksen2018using].

In addition to the ease of use, perceived usefulness, and enjoyment [@peng2022acceptance], the success of these devices is based on the fact that they are equipped with biosensors providing users with behavioral (e.g., step count, distance walked) and physiological data (e.g., HR, skin temperature). The general public is thus offered the opportunity to use low-cost, lightweight devices to monitor their physical activity and health routines in their everyday life. In contrast to occasional clinical observations, they allow the collection of big data over a longer period, whereby wrist-worn wearables are less intrusive than complex medical devices (e.g., electrocardiograms) that have to be attached to the body [@godfrey2018z].

The use of wearables has already been investigated across a wide range of domains, such as medicine [@hughes2023wearable; @yetisen2018wearables], sports [@secckin2023review; @ adesida2019exploring] or entertainment [@helmer2009smart; @cciccek2015wearable]. In educational contexts, research about the use of wearables is meager [@de2017towards].

While there are studies on how wearables can be used in the educational context to support teachers in monitoring student activity in the classroom [@quintana2016keeping; @de2017towards], there is a research gap on the use of wrist-worn wearables by teachers. Especially wrist-based fitness trackers, which are being used by a majority of the population, could offer the possibility of analyzing physiological parameters to gain deeper insights into the stress and strain experienced by teachers. HR measurements as a parameter – measured by most fitness trackers – are becoming increasingly important in research on stress experience as they offer insights into the cardiovascular system’s exertion levels in reaction to both physical and mental exertion [@sammito2015guideline]. Stress or mental and physical strain are factors that directly influence HR and lead to an increase in it [@custodis2014heart]. They represent an important physical and emotional stress indicator, as an increased workload is associated with increased HR [@sachs2014]. Furthermore, they allow a more objective recording of stress than for example self-reports without interrupting the teaching process [@donker2018; @runge2020].

To date, the studies measuring teachers’ HR in teaching-learning settings mostly use very expensive and intrusive electrocardiographs [@sperka1995; @scheuch1997psychophysische; @donker2018; @junker2021; @huang2022class], revealing that teacher-centered activities and typical stressors are leading to an increase in HR. @scheuch1997psychophysische, for example, assessed the HR of 67 teachers during five real lessons, with results showing that the highest HR occurred during organizational activities, followed by teaching activities where the teacher directed the interaction.

Other studies that have recorded HR using wearables have shown that HR decreases during a learning unit [@Darnell2019] and increases before induced stress tasks [@chalmers2021]. It should be noted that not teachers’ but college students’ HRs were assessed in these studies.

Accordingly, robust studies on whether wearable such as fitness trackers are efficient, low-cost, and robust measurements for assessing teachers’ physiological stress during teaching remain a desideratum. However, research on teacher stress is particularly relevant due to the increased stress levels in the teaching profession [@johnson2005experience]. @kieschke2008professional revealed that German teachers tend to show an “excessive commitment coupled with inadequate coping resources; and […] are too exhausted to be capable of big efforts” (p. 435). One of the reasons for this is that teachers are confronted with a multitude of demands in their everyday work, some of which exceed their available resources and therefore make it difficult to cope with various stressors [@montgomery2005meta]. In particular, the unpredictability of events such as classroom disruptions during lessons are typical stressors and can be very overwhelming for teachers.

Stress therefore occurs when stressors accumulate [@mann2021cumulative], although the extent of the strain depends on the subjective appraisal of the objective demands placed on the individual about available resources [@kyriacou2001]. It is therefore particularly important for teachers in the teaching profession to have sufficient personal and professional resources at their disposal [@cramer2018belastung], whereby, for example, professional knowledge about classroom management reduces the risk of stress [@klusmann2012berufliche]. Teachers’ characteristics such as professional experience in turn have an impact on the development of classroom management skills and thus also on the appraisal processes, as these skills develop during professional experience [@ophardt2017klassenmanagement; @wolff2015keeping].

To gain deeper insights into the links between stressors such as classroom disruption, appraisal processes, and stress responses such as increased HR, it would be beneficial in educational research to capture teachers’ HR using low-cost and non-intrusive instruments such as fitness trackers. Therefore, this study examined HR measures assessed by wrist-based fitness trackers are a suitable and effective method for mapping teachers’ HR over the course of a five-phase lab study, including a micro-teaching unit. Considering the relevance of appraisal processes in classroom management, we additionally tested whether variance in HR measures can be explained by teachers’ teaching experience, and by self-reported cognitive appraisal (disruption appraisal and confidence appraisal) of classroom events.

**## Wearable Devices**

Wearables (also referred to as wearable devices, wearable computers, or wearable electronics, @cciccek2015wearable) are defined as electronic devices that are either directly worn on the body or loosely attached to a person and integrated into clothing or accessories to serve as a convenient all-in-one solution [@godfrey2018z]. Essentially, wearables are designed to be worn continuously by users, gathering data such as location, movements, and vital signs via wireless sensors enabling users to interact with these devices anytime and anywhere [@cheng2017underlying].

Attempts to classify wearables reveal different approaches in the literature: The IDC (2017) for example divided wearables into six categories: basic wristbands (fitness bands), basic watches (hybrid watches as the evolution of fitness bands), smartwatches (advanced watches with for example integrated apps), clothing (e.g., step-counting shoes), earwear and others [@idc2017shipments]. In contrast, @cciccek2015wearable classified wearables into three categories (wearable health technologies, wearable textile technologies, and wearable consumer electronics) and stated that wearables must be characterized by attributes such as hands-free operatable, portable, useful, reliable, practical, multi-functional, mobile, socially acceptable, etc. (p. 46).

In the last decades, wearable technologies such as fitness trackers have become widely popular and accepted as a mass product by the population [@park2020user]. Several factors contribute to the widespread acceptance of these devices: Wearable technologies such as fitness trackers excel at monitoring various aspects of physical activity, including HR measurements, distance traveled, steps taken, or calories burned. This data provides users with valuable insights into their daily activity and cardiovascular health levels in their natural everyday lives, supporting them in setting personalized fitness and health goals [@nuss2021effects] or providing information about stress levels [@hao2018chrv]. Further advantages are the portable, non-invasive nature of these devices, the ease of use, and especially, the low costs compared to complex laboratory methods for determining vital parameters (e.g., HR, blood pressure, skin temperature, physical activity), @hajj2023].

The combination of these factors makes wearable devices such as fitness trackers an ideal technology for utilization in different domains such as healthcare, entertainment, and fitness purposes [sinha2019taxonomy]. Considering the features, benefits, and rapid adoption of these devices in recent years, some studies have also investigated their potential use in education as they represent a promising new technology that can offer additional advantages for formal and informal learning environments for both students and teachers [@koutromanos2020use].

@de2017towards pointed out that despite the scarcity of existing literature on wearables in the educational context, two different approaches can be identified: (1) On the one hand, there is research on wearables as educational tools to create particular projects and investigate their potential in teaching and learning situations @shadiev2018study, for example, showed that students performed best in learning English when using smartwatches. (2) On the other hand, there are studies using wearables to analyze physiological data from users in teaching-learning contexts to detect students' skills and improve their performance profiles. byun2018feasibility evaluated the practicality and effectiveness of an intervention with wearable fitness tracker devises to promote physical activity among preschoolers. Students utilizing the wearable device exhibited notably reduced sedentary behavior and increased overall physical activity levels.

However, in most studies, the focus is on students, especially to support their learning [@koutromanos2020use]. Despite the enormous potential of wearables, there is a desideratum of studies that deal with important recorded parameters and in particular their significance for teachers.

**# HR as a Vital Parameter and Indicator of Stress**

One important health parameter assessed by most wrist wearables is HR measurement. HR indicates the number of heartbeats within a certain time interval, which is usually heartbeats per minute and is therefore expressed in min-1 or beats per minute (BPM) [@hottenrott2007]. HR can be detected and measured using various methods via wearables, including sensors based on electrocardiogram (ECG) or phonocardiogram (PCG) [@mukhopadhyay2017wearable]. Another smart technique used by most fitness trackers on the market is photoplethysmography (PPG) which is an optical method with an inexpensive and non-intrusive technique to assess HR by flashing green lights to measure changes in blood volume [@allen2007photoplethysmography].

@sammito2015guideline stated in his guidelines for the application of HR the following points: At rest, the average HR (HRrest) of adults typically ranges from 60 to 80 BPM. The maximum HR (HRmax) can be reached during physical activity or exertion, but varies depending on individual factors such as age, sex, and fitness level and decreases with age. With the suggested formula *HRmax = 207 – 0.7 × age*, the HRmax of a 31-year-old person would be around 185 BPM, whereas sex or fitness level has not been considered in this formula.

Physiologically, HR is regulated and influenced on short-time intervals by the autonomic nervous system which is divided into two distinct components: the sympathetic and the parasympathetic nervous system [@pham2021]. An increase in the activity of the sympathetic, known as the “quick response” system, results in HR being speeded up (“fight or flight”). Increased activity of the parasympathetic as the counterpart known as the “relaxed response” system, has the effect of slowing down the HR (“rest and digest”) [@battipaglia2015].

In addition to the autonomic nervous system and genetic factors, human HR is influenced by numerous external factors such as social, personal, psychological, environmental, and behavioral factors [@wang2022] and depends largely on the intensity of strain “in response to physical and mental workload” [@sammito2015guideline, p. 1]. Physical and mental strain are therefore factors that directly influence HR and lead to an increase in HR [@custodis2014heart]. This can be explained by the fact that short-term or acute psychological stress activates the hypothalamic-pituitary-adrenal axis. The production of glucocorticoids by the adrenal glands then stimulates the cardiovascular tissue and provides feedback to the central nervous system to prevent activation of the hypothalamic-pituitary-adrenal axis. At the same time, stimulation of the cardiovascular tissue during stress causes an increased HR [@junker2021]. Accordingly, it can be assumed that stress-induced excitation of the sympathetic nervous system leads to activation of the cardiovascular system, which is why an increasing HR can be regarded as an indicator of increasing stress on the cardiovascular system [@kyriacou1978].

Although there are other physiological markers of the cardiac system’s activity as more accurate indicators of stress (e.g., HR variability), research indicates a strong correlation between stress measurements such as HR and HR variability [@rieger2014heart; @ vrijkotte2000effects]. Thus, HR serves as a reliable indicator of acute psychological stress.

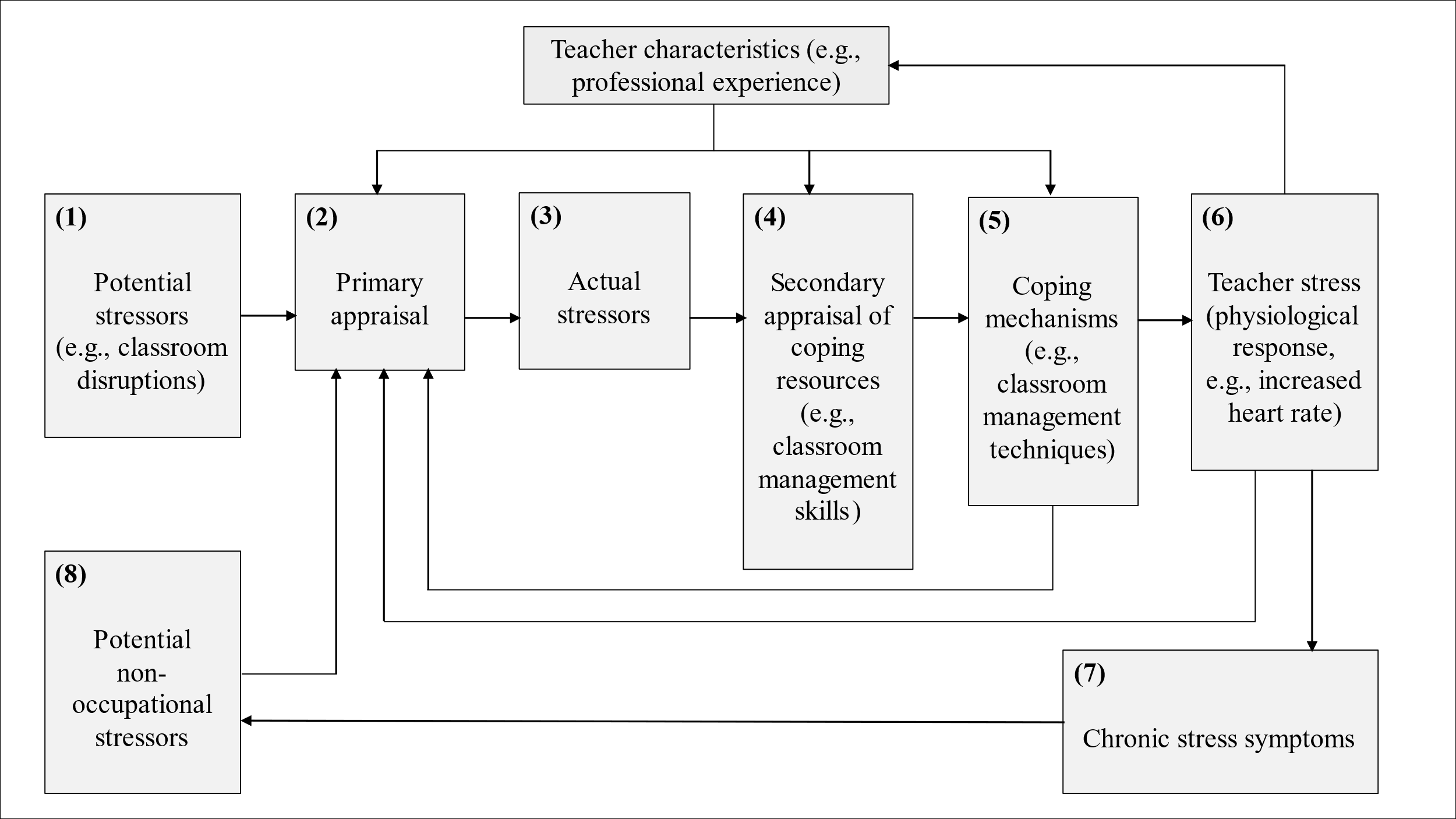
**## Stress in the Teaching Profession**

This correlation between stress and increased HR is particularly essential in the teaching-learning context, as the teaching profession is one of the most stressful professions compared to other occupational groups, facing a variety of stressors during everyday work [@smith2000; @herman2020].

However, we need to clarify what stress means and how it is caused. According to @kyriacou1978, teacher stress can be defined as

“a response of negative affect […] usually accompanied by potentially pathogenic physiological and biochemical changes (such as increased heart rate […]) resulting from aspects of the teacher's job and mediated by the perception that the demands made upon the teacher constitute a threat to his self-esteem or well-being and by coping mechanisms activated to reduce the perceived threat.” (p. 2).

This definition of teacher stress is based on the ideas of the integrative framework of the transactional stress model by Lazarus and colleagues [@lazarus1981stressbezogene; @lazarus1984stress]. Lazarus' stress theory initially served as a model, which @kyriacou1978 subsequently modified and tailored to the teaching-learning environment [@dick2013belastung]. For our study, we adopted the model of @van2006stress who made slight modifications to the model of @kyriacou1978.

*Figure 1* A model of teacher stress (adapted from van Dick 2006, p.37, modified by the author)

The model highlights the interaction between an individual and the environment, whereby stress refers to any event that exceeds a person's adaptive resources [@lazarus1990theory]. This model will be explained using an example (based on @dick2013belastung): A teaching unit with classroom demands such as classroom disruptions [@karner2021teachers] is an objective aspect of a teacher's work and represents potential occupational stress factors in the teaching profession (box 1). If classroom disruptions occur, the teacher first evaluates the situation (box 2) either positively as a challenge, considers the disruption to be irrelevant, or negatively as a potential threat. The stress model is only relevant in the last case when potential stressors are evaluated as actual stressors (box 3). In the next step, during the second appraisal (box 4), the teacher considers whether he/she has sufficient resources available to deal with the stressors. In the best case, the teacher has both external (e.g., supportive colleagues) and internal (e.g., classroom management skills) resources at his/her disposal. During both primary and secondary appraisal processes, the individual characteristics of the teacher, such as teaching experience, play a particularly important role. Based on the evaluation of resources and his/her characteristics, the teacher will try to cope with the situation (box 5) and, for example, use classroom management strategies to stop the disruption. If the teacher is unable to cope, he/she experiences stress (box 6). Teacher stress is mainly characterized as a reaction to negative affect (e.g., anger or depression), which is generally followed by other symptoms that can be seen as reactions to teacher stress. The response of negative affect can be a psychological (e.g., job dissatisfaction), physiological (e.g., increased HR), and behavioral (e.g., absenteeism) stress reaction [huang2022class; @kyriacou1978]. Over the long term, if classroom disruptions occur again and again during teaching lessons and the teacher is unable to successfully manage the classroom due to insufficient effective classroom strategies, the result is chronic stress reactions (box 7). In addition, there may be burdens that are not directly related to the job (e.g., illness, financial difficulties) which, in addition to the professional demands, exhaust the teacher's resources and thus make it more difficult to cope with potential stressors (box 8).

For our research goals, we are particularly interested in potential stressors in the classroom such as classroom disruptions (box 1), and their impact on the physiological component in terms of an increased HR (box 6), which can be interpreted as an indicator of stress based on existing research [@clays2011perception; @schubert2009effects]. In order to better understand the interlinking of these aspects, the HR during teaching as a stress reaction will be discussed in more detail.

**## HR in Teaching-Learning Contexts**

In the educational context, there is a particular interest in finding adequate indicators and quantitatively measurable parameters for teacher stress and burnout [@fisher2011; @ junker2021]. Previous research on teacher stress often focused on the psychological experience of stress using self-report questionnaires with single-item measures (“I find teaching to be very stressful‖”) [@chaplain2008; @goker2012] or questionnaires with multiple scales (e. g. Teacher Stress Inventory; @fimian1990; @liu2020]. However, self-reported data in the measurement of stress raises concerns about the validity and accuracy of causal inferences for several reasons, including response biases such as social desirability [@razavi2001self] or recall bias [@van2016accuracy]. Because self-reported data fail to capture actual physiological stress responses in real-life situations, ambulatory assessment methods using a variety of assessments are recommended e.g., collecting additional physiological measures such as HR as objective data [@trull2013ambulatory; @ wettstein2020ambulatory]. Furthermore, HR as a physiological measurement provides researchers with objective insights into teachers’ affectivity and stress levels without interrupting the teaching process [@donker2018; @runge2020]. To gain a more detailed insight into teacher stress, @wettstein2021 recommend, for example, measuring physiological parameters before, during as well as after teaching.

Despite this potential of HR measurements, there are only a few studies that investigated HR as a physiological indicator of teacher stress. The studies recorded teachers’ HR using expensive and intrusive electrocardiographs (ECG devices). The results revealed that HR as an indicator of stress can be used to map different HR courses during teaching depending on the teachers’ activity. The HR increased especially during teacher-centered activities when teachers had to take a leading position in the student-teacher interaction [@sperka1995; @scheuch1997psychophysische; @donker2018; @junker2021]. @sperka1995 for example recorded the HR of 16 pre-service teachers during their first lesson. The results showed that the first lesson is linked to significantly increased psychophysiological activation in terms of an increased HR. The activation effect was particularly prominent at the beginning of the lesson and decreased in the course of the lesson due to the pre-service teachers’ active coping processes, meaning that the active management of the interaction with the students helped the teachers regulate their HR.

Other studies that measured teachers’ HR using electrocardiographs identified typical potential predictors for increased HR values such as typical stressors, e.g., class size [@huang2022class] or low student engagement and motivation [@junker2021]. @junker2021 for example recorded the HR of 40 teachers using an Ambulatory Monitoring System with seven electrodes during a real classroom lesson to find out to what extent main stressors within the classroom (e.g., low student engagement and motivation, teacher-centered activities) can predict teachers’ HR as an indicator of physiological stress during teaching. @junker2021 proved that teacher stress caused by those stressors during teaching can be quantitatively measured by an increase in HR.

In addition to these studies that measured HR using cost-intensive and intrusive ECG devices, there are a few studies that used low-cost, wrist-worn fitness trackers to investigate HR trends in teaching-learning situations [@Darnell2019; @chalmers2021]. However, it is very important to note that these studies did not measure teachers’, but college students’ HR. @Darnell2019 for example measured the HRs of 15 medical college students using wrist-worn devices during lecture classes. The analysis revealed a constant decrease in HR from the beginning to the end of a lecture, whereas the HR peak was reached during active learning sessions. The researchers proposed the first robust measurements of HR changes during lectures and recommended using personal fitness trackers during various phases of learning and teaching. @chalmers2021 examined the usability of the average HR measured with a Fitbit fitness tracker of 30 medical students and 30 normative participants to identify physiological changes during stress tasks, whereas the average HR increased significantly between the resting and stress phases for both groups.

So far, only one study known to the author has combined both aspects (hand-worn wearable and recording of teachers’ HR): In the study conducted by @runge2020, HR was one of several parameters used to identify stress in four teachers based on physical characteristics using a Fitbit fitness tracker. Another aim was to determine to what extent affordable fitness trackers and the provided parameters can be used to measure teacher stress. @runge2020 concluded that stress in the teaching profession can be mapped using fitness trackers' indicators. In particular, it was found that the combination of a high number of steps, a high HR, and short sleep is an indicator of stress and that poor student behavior is the stressor that is perceived most frequently. It should be noted that the generalizability of the results is limited due to the small sample size of four participants.

The studies show that the HR of teachers (and students) changes depending on the activity and stressors during teaching, whereby teacher-centered phases and less engaged students in particular lead to an increase in the HR. Furthermore, it could be shown that HR increases even before stress occurs. To gain a more detailed insight into these processes of the development of teacher stress, it is relevant to look at the individual phases in particular the potential stressors such as classroom disruptions (box 1) in the model (see Fig. 1).

**## Classroom Disruptions as Potential Stressors**

The causes of teacher stress are diverse and the investigation of these is relevant, as it has been shown that there are important connections between stress and resources on the one hand and stress-induced health issues on the other [@krause2013messung]. Student misbehavior such as classroom disruptions, disrespect, and disciplinary problems is one of the most influential stressors and key risk factors for teacher health [@boyle1995structural; @aloe2014multivariate]. @ aldrup2018misbehavior revealed in their study that teachers who perceive more misbehavior also reported decreased work enthusiasm and increased emotional exhaustion. A positive relationship between teachers and students is therefore crucial for the professional well-being of teachers and thus also influences the perception of stress and strain.

In contrast to disciplinary conflicts and disrespect, classroom disruptions are linked to the teaching process. They can be defined as “events that impair, interrupt or make the teaching-learning process impossible by partially or completely overriding the conditions under which teaching and learning can take place” [own translation, @lohmann2007schulern, 13]. Classroom disruptions can be differentiated according to various aspects, e.g., intensity and severity [@steins2010], active and passive disruptions [@scherzinger2018aggressive], focusing on the teaching-learning process [@lohmann2007schulern].

@eckstein2022 emphasizes that the term *classroom disruption* can be used when at least one person involved in the teaching-learning process is disturbed in their thought process or emotional experience. A teaching disruption can therefore be regarded as a co-constructivist phenomenon [@eckstein2022]. Classroom disruption can occur in the context of a multifactorial structure, whereby two fundamental processes interact with each other: behavior that deviates from the norm and the subjective perception of disruption. Whether an incident is perceived as a classroom disruption depends on the subjective appraisal of the recipient, whereas the context, the teaching experience, and the personality traits of the disrupted and the disruptive person need to be taken into account [@eckstein2016].

In this regard, parallels to the transactional stress model emerge very clearly: When faced with stressors such as classroom disruptions, teachers assess both the stressors’ relevance (primary appraisal) and their capacity for overcoming stress (secondary appraisal). How teachers evaluate the demands placed on them also depends on the interaction between their characteristics such as biographical details (e.g., teaching experience) and their perception of the demands. Primary and secondary appraisals are regarded to have an impact on teachers coping mechanisms. Coping strategies in turn have an impact on the immediate stress reaction, long-term health, psychological well-being, and social functioning [@kyriacou2001; @obbarius2021].

**## Classroom Management Skills and Professional Experience as Resources**

The relevance of resources and coping strategies such as classroom management skills and professional experience should be emphasized at this point, as they are crucial for the appraisal processes. The consequences of a lack of resources and coping mechanisms are fatal: If teachers are exposed to a teaching-learning environment that they evaluate as stressful or disruptive (primary appraisal) over a long period and if they do not feel confident to deal with these disruptive classroom situations (secondary appraisal) because they have no sufficient resources and coping strategies, it can lead to negative personal and vocational consequences such as burnout, high turnover, and premature retirement [@jalongo2006; @unterbrink2007; @aloe2014].

These correlations are not surprising, as teaching is characterized as multidimensional, simultaneous, immediate, unpredictable, public, and shared [@doyle2013ecological]. Lessons and, in particular, classroom disruptions are unpredictable and multifaceted. All of these circumstances place several demands on teachers and require a high level of knowledge and competence from the teacher [@klieme2008concept]. These professional competencies encompass, among other things, teachers' specific knowledge and skills about classroom management and can be understood as a diverse toolbox of strategies, techniques, and measures for the teacher to navigate the challenging environment of the classroom [@konig2016teacher]. Based on @doyle1986classroom, a distinction can be made between structure-oriented and process-oriented measures. Process-oriented measures include (1) the monitoring of student activities and (2) the smooth structure of lessons. While these measures relate directly to events in the teaching process, structure-oriented measures, such as (3) the establishment of rules, routines, and rituals, have a longer-term effect. The three aspects of effective classroom management aim to maximize students' active learning time and reduce classroom disruption [@emmer2003classroom].

Thus, effective classroom management skills are considered an important personal resource for teachers to reduce classroom disruption [@cramer2018belastung] and it has been shown, that professional knowledge about classroom management reduces the risk of strain and stress [klusmann2012berufliche]. In their intervention study, @schelske1994coping showed that providing training in coping and classroom management skills enhanced student teachers’ competency in handling classroom challenges and coping with stressors, contributing to their professional development. The positive outcomes of effective classroom management include better teacher-student relationships, an improved classroom climate, and more cooperative and less disruptive learners [@eichhorn2015foresight; @marzano2003classroom]. Thus, effective classroom management techniques can be used to develop resources for the health of both teachers and students [@hascher2004wohlbefinden].

Professional experience as a characteristic of teachers (see Fig. 1) also has a decisive influence on classroom management skills and hence on the appraisal processes, as particularly teachers with less teaching experience are overwhelmed by the simultaneity and complexity of teaching [@ophardt2017klassenmanagement; @wolff2015keeping; @ klusmann2012berufliche]. Skills in dealing with teaching events are closely related to the cognitive load of teachers. These classroom management skills develop, among other things, through growing teaching experience, as teachers attempt to cluster experienced classroom events into patterns and formulate appropriate action alternatives. According to @ wolff2021classroom, such cognitive processes can be understood as mental classroom management scripts. Accordingly, especially for beginning teachers, the teaching profession seems to be very demanding and stressful. In particular the first five years, between 40 and 50 percent of beginning teachers change careers for a variety of reasons such as disciplinary problems with students [@ingersoll2003]. @fisher2011 investigated the extent to which age or teaching experience and job dissatisfaction are associated with an increased risk of burnout and stress among teachers. The results revealed that teachers with less professional experience had higher burnout scores. @fisher2011 concluded that years of professional experience, burnout, and satisfaction in the teaching profession are statistically significant predictors of teacher stress.

**## Present Investigation**

The present investigation was part of a larger project targeting the development of professional vision in teachers. The study was carried out in a classroom at the university that served as the lab.

Within the time frame of approximately two hours, we distinguished five phases of our study: In the (1) pre-teaching phase, the participants were welcomed, prepared for the following micro-teaching unit, and familiarized with the setting. During the (2) teaching phase, the participants taught a 15-minute self-prepared micro-teaching unit to a "class" of three actors that performed nine (possibly disruptive) classroom events (e.g., chatting with a neighbor, heckling, looking at the phone; see Table ## in the supplementary material for an overview and categorization of all events; also see Fig## for a depiction of the laboratory setting of the micro-teaching unit). The actors received standardized instructions on a screen (only visible to the actors, but not to the participants) to perform a classroom event every one and a half minutes. While teaching, participants wore eye-tracking glasses, and additionally, their lessons were recorded by cameras. In the (3) post-teaching phase, the participants answered several questionnaires, followed by the (4) interview phase, in which they watched the video of their 15-minute unit and answered questions about the (disruptive) classroom events. In the (5) end phase, the participant answered another questionnaire. These conditions were identical for all participants.

During the entire study, the participants wore a fitness tracker, while the HR measurements provided the database for the present investigation. Previous research found that fitness trackers can be used as a low-cost, non-invasive method of measuring HR [hajj2022wrist; @fuller2020reliability] and that fitness trackers can help to detect differences in mean HR between different teaching phases [@donker2020associations; @junker2021potential]. However, XXX

Thus, the goals of the present study were twofold:

(1) The first research goal was to investigate whether HR measures assessed by wrist-based fitness trackers are a suitable and effective method for mapping teachers’ HR over the course of a five-phase lab study, including a micro-teaching unit.

In the first step, we therefore exploratively described the participants’ overall HR trend during the two-hour study interval and examined whether z-standardization of the participants’ mean HR can serve as a useful method to account for individual differences in baseline HR. Regarding the HR trend of the entire course of the study, we expected participants´ HR to gradually increase during the pre-teaching phase, to peak during the teaching phase, and to gradually decrease during the remaining time interval. Furthermore, we expected to observe the same trends in both standardized and non-standardized mean HR values.

In the second step, we selected five corresponding intervals with a length of ten minutes each out of the five phases and examined the levels of and the changes in HR of the five intervals separately. We presumed the highest HR levels in the micro-teaching unit and regarding HR changes, we expected an increase at the beginning of the study and a decrease in the following phases.

(2) The second research goal was to examine whether variance in HR measures can be explained by teachers’ teaching experience, and by self-reported cognitive appraisal (disruption appraisal and confidence appraisal) of classroom events. We expected all three variables (teaching experience, disruption appraisal, and confidence appraisal) to be significant predictors for the HR measurements in the different phases.