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# Investigating Relationships Between Work and Sleep and Their Mutual Consequences for Well-Being: An Actigraphy-Based Ambulatory Assessment Approach

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# Abstract

In five studies, this dissertation pursues three main objectives including (1) the investigation of work-related antecedents of (poor) sleep, (2) the investigation of mutual consequences of time spent working and time spent sleeping for well-being, and (3) a methodological examination of actigraphy as a more objective measurement of sleep.

Specifically, in Studies 1 (a two-wave online study), 2 and 3 (7-day ambulatory assessment studies with a morning and an evening survey each day, including actigraphy as an objective measurement of sleep in addition to self-reports), I investigated the relationships between job demands, work-related rumination and sleep. Consistently across these three studies, results showed that work-related rumination mediates the relationship between job demands and subjective sleep quality, but not sleep duration. In Study 4 (a 7-day ambulatory assessment study with morning surveys each day, including actigraphy), I investigated the effects of time spent working and time spent sleeping on emotional exhaustion as an indicator of well-being, using a compositional data analysis approach. Results showed that time spent working is positively related to emotional exhaustion, but there was no significant association between time spent sleeping and emotional exhaustion. Finally, in Study 5 (14-day field experiment including actigraphy), I investigated reactivity to the actigraphic measurement of sleep by manipulating the communicated measurement intention (sleep vs. physical activity). Results showed no evidence for reactivity to measurement in the context of the actigraphic measurement of sleep. Therefore, results obtained from actigraphy in this dissertation (cf., *Studies 2, 3, & 4*) can be deemed reliable with regards to measurement reactivity, and the same applies to actigraphy as a more objective measurement of sleep in general.

In sum, the results of Studies 1-4 point out the importance of a healthy work-environment (i.e., job demands not too high, working hours not too long) for an individual's health and well-being (i.e., sleep quality & emotional exhaustion) and emphasize the potentially detrimental effects of unsuccessful psychological detachment from work in the form of work-related rumination during non-work time.

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# Chapter 1: General Introduction

*“A ruffled mind makes a restless pillow.”*

— Charlotte Brontë

“Did you sleep well?” – A common phrase in everyday life. We often talk with others about sleep, reflect on our own sleep, and try to find the perfect sleep rhythm – yet many people suffer from sleep problems. About 30 to 35% of adults worldwide report insomnia symptoms such as difficulties falling asleep or feelings of unrestful sleep, with about 10% even struggling with insomnia disorder (Morin et al., 2015). Beyond the immediate discomfort that sleep problems cause, they are also associated with a broad range of further health problems, such as cardiovascular disease, obesity, depression, or neurodegenerative diseases (Hale et al., 2020). Despite these potentially severe consequences of poor sleep, sleep remains an insufficiently understood phenomenon, including its still obscure biological purpose (National Institute of Neurological Disorders and Stroke, 2017). However, research has intensively investigated potential antecedents of poor sleep and identified factors that are to the disadvantage of sleep on different levels, including, for example, individual behavioral factors (e.g., sleep habits) and interpersonal factors (e.g., relationships; Hale et al., 2020). Thereby, research especially emphasizes the work domain as related to sleep (e.g., Åkerstedt, 2006): In a quantitative (i.e., temporal) manner, time spent working and time spent sleeping are negatively correlated (e.g., Barnes et al., 2012; Basner et al., 2007). Also, studies have identified various characteristics of work as crucial for the development of sleep disorders (e.g., Åkerstedt et al., 2002; Kim et al., 2011; van Laethem et al., 2013).

Based on the state of research, this dissertation pursues three main objectives including (1) the investigation of work-related antecedents of (poor) sleep, (2) the investigation of mutual consequences of time spent working and time spent sleeping on well-being, and (3) a methodological examination of actigraphy as a more objective measurement of sleep. In the following, these three objectives will briefly be outlined.

Regarding the associations between work and sleep, the demands experienced at work have particularly received much attention. Job demands are concordantly considered to be risk factors for sleep problems and sleep disorders (Åkerstedt, 2006; van Laethem et al., 2013). Going beyond that, previous research has investigated the underlying mechanisms of the associations between job demands and sleep, and brought psychological detachment as a potential mechanism into focus. Psychological detachment from work refers to mental disengagement from work during non-work time and is crucial for successful recovery (Sonnentag & Fritz, 2015). In line with that, previous studies identified perseverative cognitive

processes (i.e., a lack of psychological detachment) as a mediator for the relationship between job demands and sleep: Job demands are positively related to cognitive representations of work-related stressors during non-work time, which in turn are negatively related to sleep quality (e.g., van Laethem et al., 2015; 2018). However, regarding work-related rumination – a specific kind of perseverative cognition that focuses on past instead of future work stressors (Clancy et al., 2020) – there are still inconclusive results regarding its mediating role (e.g., Radstaak et al., 2014; Vahle-Hinz et al., 2014). Based on this, as the centerpiece of this dissertation, I am investigating work-related rumination as a mediator for the relation between job demands and sleep. To this end, I apply different study designs including ambulatory assessment and actigraphy as a more objective measurement of sleep.

With previous research having established a strong relationship between work and sleep (e.g., Åkerstedt, 2006), it is, furthermore, important to look at mutual consequences of these two activities. Work and sleep constitute two of the most time-consuming domains in most adults' daily lives. For both time spent working and time spent sleeping, previous research has repeatedly shown associations with well-being: Specifically, time spent working is positively related to emotional exhaustion (e.g., Nishimura et al., 2014), whereas time spent sleeping is negatively related to emotional exhaustion (e.g., Söderström et al., 2012). However, previous research has mostly not taken the compositional nature of such time-use components into account, but rather examined work and sleep independently, that is, in separate studies. I am, therefore, investigating mutual effects of time spent working and time spent sleeping on well-being (i.e., emotional exhaustion) simultaneously, that is, under consideration of the interdependence of these two activities.

For the investigation of (1) relationships between job demands, work-related rumination, and sleep as well as (2) mutual effects of time spent working and time spent sleeping on emotional exhaustion, I use ambulatory assessment designs and, in particular, actigraphy as an objective measurement of sleep in addition to self-reports. Digital and objective measures such as actigraphy are able to overcome potential limitations of self-report measures such as recall bias or social desirability bias. However, these methods are still prone to the occurrence of measurement reactivity which might also lead to distorted results (König et al., 2022). Therefore, I am ultimately investigating potential reactivity to measurement in the context of the actigraphic assessment of sleep in order to examine the reliability of results obtained from actigraphy.

## Dissertation Outline: Research Goals and Contribution

This dissertation comprises five empirical studies in three chapters (see Table 1 for an overview of the empirical studies): Chapter 2 (*Studies 1, 2, & 3*) builds the centerpiece of this dissertation by examining the mediating role of work-related rumination in the relationship between job demands and sleep. Chapter 3 (*Study 4*) focuses on the investigation of the mutual effects of time spent working and time spent sleeping on emotional exhaustion. Finally, Chapter 4 (*Study 5*) comprises an examination of reactivity to measurement in the context of the actigraphic assessment of sleep. Studies 1, 2 and 3 are currently under revision at the *Journal of Occupational and Organizational Psychology* (revise and resubmit request). Study 4 has been published in the *International Journal of Environmental Research and Public Health* (Janurek et al., 2018), whereas Study 5 is in preparation. This dissertation makes three key contributions to the literature:

First, the focal aim of this dissertation is to investigate the mediating role of work-related rumination in the relationship between job demands and sleep (*Studies 1, 2, & 3*). Work-related stressors have been shown to be related to perseverative cognition which, in turn, has a negative impact on sleep (e.g., van Laethem et al., 2018). However, regarding work-related rumination as a mediator, previous studies provide inconclusive results (e.g., Syrek et al., 2017; Vahle-Hinz et al., 2014). In this context, two issues are essential to be recognized, but previous research has mostly missed out on considering them: (a) Self-reported and actigraph-measured sleep parameters constitute different aspects of sleep. Thus, these two kinds of parameters are not suitable to substitute one another (i.e., the characteristics of one of these parameters do not necessarily provide reliable information about the characteristics of the other parameter; e.g., Landry et al., 2015; Lauderdale et al., 2008). In order to get meaningful insights into sleep and to understand which aspects of sleep are affected by job demands and work-related rumination, it is important to consider both self-reported and actigraph-measured parameters of sleep quality and sleep duration. (b) The within-person level and the between-person level constitute categorically different aspects of the relationships between job demands, work-related rumination and sleep, both providing important insights: The day level informs about highly dynamic psychological mechanisms that occur as an immediate response to acute job demands. However, in order to gain insights into psychological responses that are more stable on an inter-individual level and, thus, are also important for (long-term) well-being, the person-level perspective is of higher significance. Gaining knowledge about the temporal dynamics of the investigated associations can help to make more accurate predictions, which might again facilitate the formulation of practical implications, for example, regarding the use of intervention methods in order to reduce work-related rumination or to promote sleep health. Addressing these issues and advancing previous research, I report a series of three studies with different designs (see Table 1) in

order to investigate the mediating role of work-related rumination for the relationship between job demands and sleep. These studies include both within-person and between-person effects, and both self-reported and actigraph-measured parameters of sleep duration and sleep quality.

Second, and subsequent to the investigation of the relationship between work and sleep, this dissertation focuses on the mutual consequences of time spent working and time spent sleeping on well-being, i.e., emotional exhaustion (*Study 4*, see Table 1). Previous research identified time spent working (e.g., Nishimura et al., 2014) and time spent sleeping (e.g., Söderström et al., 2012) as predictors of emotional exhaustion. However, so far, these predictors have only been examined independently, that is, in separate studies. Thereby, previous studies neglected the interdependence of different activities carried out throughout the day that arises from the daily 24-hour time limit: When time is used for one specific activity (e.g., work), it is not available for any other activity (e.g., sleep) and vice versa. The investigation of such temporal interdependencies is essential in order to understand how time use (i.e., how an individual allocates his or her time during the 24 hours of a day) is related to well-being. Addressing this issue, I investigate the effects of time spent working and time spent sleeping on emotional exhaustion whilst taking the compositional nature of work and sleep into account. In order to do so, I use a compositional data analysis approach (see Chapter 3 for a detailed description).

Throughout this dissertation, I use actigraphy as an objective way to measure sleep parameters in addition to self-report measures (*Studies 2, 3, & 4*). In doing so, I aim to overcome several limitations of self-report measures such as recall bias or social desirability bias (König et al., 2022). Even though self-report measures are especially prone to the potential problem of reactivity to measurement (see Miles et al., 2020, for a review), studies on health behavior give rise to the assumption that measurement reactivity might also occur when using digital and objective collection methods (see König et al., 2022, for a review). However, these studies have not considered sleep as an outcome. As a third contribution to the literature, I investigate reactivity to measurement in the context of the actigraphic assessment of sleep (*Study 5*, see Table 1) in order to examine the reliability of results I obtained from actigraphy. These investigations provide deeper insights into whether individuals do actively modify their sleep (i.e., quality and duration) during digital data assessment.

**Table 1**

*Overview of the Empirical Part of the Dissertation*

| | Scope | Methods | Main Findings |
|---|---|---|---|
| **Chapter 2** (*Studies 1, 2, & 3*) | Examining the mediating role of work-related rumination for the relationship between job demands and sleep | - Two-wave online study with a retest interval of four weeks (*Study 1*), 7-day ambulatory assessment studies with two surveys a day, in the morning and in the evening (*Studies 2 & 3*), 7-day field experiment including a manipulation of work-related rumination by the use of an intervention (*Study 3*)<br>- Assessment of job demands, work-related rumination, self-reported and actigraph-measured (*Studies 2 & 3*) sleep quality and sleep duration | - Work-related rumination mediated the relationship between job demands and subjective sleep quality<br>- No mediation regarding (self-reported and actigraph-measured) sleep duration<br>- In Studies 2 and 3, these relationships unfolded on the person level as well as on the day level<br>- No moderating effect of the applied intervention |
| **Chapter 3** (*Study 4*) | Examining the associations of time spent working and sleeping with emotional exhaustion using a compositional approach | - 7-day ambulatory assessment study with morning surveys each day<br>- Assessment of work (operationalized as study time), emotional exhaustion and actigraph-measured sleep and physical activity | - Time spent working was positively related to emotional exhaustion, relative to the remaining two time-use components (i.e., sleep, physical activity)<br>- Time spent sleeping was not significantly related to emotional exhaustion |
| **Chapter 4** (*Study 5*) | Examining reactivity to measurement in the context of the actigraphic assessment of sleep | - 14-day field experiment, within-person factor: Communicated measurement intention (sleep vs. physical activity)<br>- Assessment of actigraph-measured sleep | - No significant effect of the communicated measurement intention regarding actigraph-measured sleep (i.e., sleep efficiency, sleep duration) |

# Chapter 2: Job Demands, Work-Related Rumination, and Sleep (Studies 1, 2, & 3)

## Theoretical Background

### *Job Demands and Sleep*

The *job-demand-control model* (JDC model; Karasek, 1979; Karasek & Theorell, 1990) and the *job-demands-resources model* (JDR model; Demerouti et al., 2001) are two of the most influential models in occupational health psychology, focusing on psychosocial work stress and the categorization of (health-damaging) job characteristics. Both models emphasize the potentially detrimental effects of job demands on physical health and psychological well-being. Job demands refer to cognitive, physical, as well as emotional stressors experienced at work (Karasek & Theorell, 1990). A variety of previous studies support the models' assumptions regarding the risks arising from high job demands, as they are able to cause severe health problems such as cardiovascular diseases, depression, and burnout, to name just a few (see de Lange et al., 2003; Häusser et al., 2010, for reviews of the JDC model, Lesener et al., 2019; Schaufeli & Taris, 2014, for reviews of the JDR model). Regarding sleep as a key indicator of health and well-being, various characteristics of work, such as job insecurity (Kim et al., 2011) or shift work (Åkerstedt et al., 2002), have been identified as associated with the development of sleep disorders. However, especially one aspect of the job stands out to be of crucial importance for sleep: Several studies show that high job demands can affect and impair sleep, including quality and quantity parameters of sleep (e.g., Åkerstedt, 2006; van Laethem et al., 2013).

Sleep constitutes a homeostatic process that arises from the sleep drive accumulated during wakefulness. This process is also influenced by circadian rhythm (Saper et al., 2005). During sleep, neuronal activities are reorganized, which affects a restoration of the brain (Hobson, 2005). These fundamental functions of sleep provide an explanation for its crucial role regarding long-term health (see Åkerstedt, 2006, for a review), whereby different parameters of sleep are important, including both sleep quality and sleep duration (Grossi et al., 2021). Nevertheless, approximately 30-35% of adults worldwide report insomnia symptoms such as dissatisfaction with sleep quality, difficulties with falling asleep, frequent or early awakenings, and about 10% even suffer from diagnosed insomnia disorder (Morin et al., 2015). Besides the discomfort caused by sleep disorders themselves, they are also associated with the development of further health problems, especially cardiovascular disease, obesity, depression, and neurodegenerative diseases, such as Alzheimer's disease or Parkinson's disease (see Hale et al., 2020, for an overview).

In conclusion, the possible consequences of (poor) sleep are multifaceted and potentially serious. One obvious explanation for the associations of sleep with several aspects of health and well-being lies in its crucial function as a recovery mechanism (e.g., de Lange et al., 2009), which will be further elucidated in the next section.

### *The Process of Recovery*

Recovery from work is the process of reducing or eliminating physical and psychological strain symptoms that occur in reaction to job stressors (Craig & Cooper, 1992; Meijman & Mulder, 1998). Thereby, the psychophysiological systems that are activated during effort expenditure return to and stabilize at a baseline level (Geurts & Sonnentag, 2006). Effort expenditure at work unavoidably leads to load reactions (e.g., fatigue). In order to reduce these load reactions and prevent detrimental effects of job demands on health and well-being, adequate recovery is necessary, as described in the *effort-recovery model* (Meijman & Mulder, 1998). However, according to the model, when the exposure to workload continues, resulting in an insufficient or inadequate recovery process, the psychophysiological systems remain activated and do not have the chance to settle down at a baseline level. As a consequence, compensatory effort is necessary in order to still perform adequately at work, which leads to an increased intensity of load reactions and an even higher demand on subsequent recovery processes (Geurts & Sonnentag, 2006).

In summary, recovery is a crucial factor in the relationship between acute strain reactions to (stressful) work characteristics and health. Its important role has been investigated in various studies: Research shows that recovery is associated with (short-term as well as long-term) well-being, motivation and performance (see Sonnentag et al., 2022, for an overview), and that incomplete recovery can result in chronic health problems (Geurts & Sonnentag, 2006). Still, there are circumstances under which recovery from work can be impaired. In the following, I will elucidate conditions to the disadvantage of successful recovery.

### *Impaired Recovery*

As suggested by Geurts and Sonnentag (2006), the process of recovery from work is at risk of being impaired by two kinds of circumstantial factors that can be differentiated into a quantity and a quality aspect. First, in a quantitative manner, the available recovery time can be limited through prolonged exposure to job demands. If the – already limited – time for recovery is further shortened by prolonged activation of the psychophysiological systems that are activated during work, recovery will be incomplete. Supporting this assumption, studies show that longer working hours are associated with more emotional exhaustion (Iskera-Golec et al., 1996). This issue will be addressed in more detail in Chapter 3 (*Study 4*), focusing on the role of time spent working and time spent sleeping for well-being.

Second, even if there is enough time to recover (i.e., job demands are no longer present), effective use of the available recovery time can be impaired in a qualitative manner due to cognitive processes: Even if stressors are no longer present, the psychophysiological systems can still be activated through cognitive representations of the stressors (Brosschot et al., 2005). This problem is described in the *stressor-detachment model* (Sonnentag & Fritz, 2015), which postulates that a lack of psychological detachment from work has a detrimental effect on successful recovery. Psychological detachment is the process of mentally disengaging from activities and cognitions that are related to one's job during non-work time. When detachment fails, strain reactions will (further) be increased and prolonged, thus, resulting in an impairment of health and well-being (Sonnentag & Fritz, 2015). Regarding the link between job stressors and a lack of detachment, Brosschot et al. (2005; 2006) emphasize the role of perseverative cognitive processes. Perseverative cognition is defined as "the repeated or chronic activation of the cognitive representation of stress-related content" (Brosschot et al., 2005, p. 1045), and is reflected in cognitive processes such as worry or rumination. The *perseverative cognition hypothesis* (Brosschot et al., 2005; 2006) argues that perseverative cognition, if still activated during non-work time, causes a prolonged activation of the stressor (or its representation) into non-work time and, thereby, impairs detachment.

This latter form of qualitatively impaired recovery due to a lack of psychological detachment from work will be the focus of Studies 1, 2 and 3 as a potential mediator for the relationship between job demands and sleep.

### *Job Demands, Work-Related Rumination, and Sleep*

In line with the idea that recovery can be impaired in a qualitative manner, and following the assumptions of the *stressor-detachment model* and the *perseverative cognition hypothesis*, previous research has shown that perseverative cognition functions as a mediator for the relationship between work-related stress and sleep (e.g., van Laethem et al., 2015; 2018). However, there are inconclusive results regarding work-related rumination as a mediator: Some studies found that the relation between work stressors and sleep is mediated by work-related rumination (e.g., Radstaak et al., 2014; Syrek et al., 2017), whereas others did not find this mediation (e.g., Cropley et al., 2006; Vahle-Hinz et al., 2014). Work-related rumination constitutes a specific type of perseverative cognition by comprising (a) repetitive thoughts that explicitly refer to work-related issues (Cropley & Zijlstra, 2011) and (b) thoughts about past issues, in contrast to worry that mainly comprises thoughts about the future (Clancy et al., 2020). Extending previous research, I investigate the relationship between job demands and sleep and the mediating role of work-related rumination for this relationship in a series of three studies (*Study 1, 2, & 3*; total $N = 406$). The results of these studies are presented in the following article.

**Article: "Sorrow till Tomorrow: Work-Related Rumination Mediates the Relationship Between Job Demands and Sleep Quality but not Quantity"**[1]

A huge amount of our lifetime is spent working. Therefore, designing healthy work environments should be of top priority. However, many people are faced with unfavorable or hazardous job characteristics (American Psychological Association, 2018), and previous research has identified high job demands as a particular risk factor for poor health and well-being (see Häusser et al., 2010; Schaufeli & Taris, 2014, for reviews). Also, high job demands can affect and impair various sleep parameters, such as sleep quality or sleep duration (e.g., Åkerstedt, 2006; van Laethem et al., 2013). Sleep, in turn, is related to occupational outcomes, such as job satisfaction and performance (e.g., Kucharczyk et al., 2012; Scott & Judge, 2006), and well-being, for example, burnout (Giorgi et al., 2018). Building on the *stressor-detachment model* (Sonnentag & Fritz, 2015), we propose that high job demands are linked to poor sleep, due to work-related rumination impairing sufficient job detachment. We argue that this relationship unfolds on the day level (within person), as well as on the person level (between individuals). Moreover, we deem it important to differentiate between quantitative (sleep duration) and qualitative (sleep quality) aspects of sleep when examining these relationships. We test our predictions in a series of three preregistered studies (total $N = 406$) using different operationalizations of sleep indicators, including the use of accelerometry.

**Perseverative Cognitions as a Mechanism Linking Job Demands to Sleep.** The *stressor-detachment model* (Sonnentag & Fritz, 2015) provides an explanatory framework for the influence of job demands on sleep, postulating a lack of psychological detachment from work as an underlying mechanism of their relationship. Psychological detachment refers to mental disengagement from job-related activities and cognitions during non-work time and, thereby, constitutes an important recovery experience. The process of recovery from work, defined by the reduction or elimination of physical and psychological strain symptoms caused by job stressors (Craig & Cooper, 1992; Meijman & Mulder, 1998), is crucial in order to prevent detrimental effects of job demands on health and well-being (e.g., Sonnentag et al., 2010). Thereby, the exposure to job demands impedes psychological detachment from work during non-work time, especially because of the negative and persistent activation caused by these demands. The resulting lack of detachment will, in turn, (further) increase and prolong strain reactions and impair health and well-being (Sonnentag & Fritz, 2015). Rather than mentally switching off from work, individuals with higher job demands continue to ruminate (i.e., to consciously think around a specific theme or issue, although there is no acute environmental demand for these thoughts; Martin & Tesser, 1996) about their workplace.

[1] This project was conducted together with N. M. Junker and J. A. Häusser and is currently under revision at the *Journal of Occupational and Organizational Psychology* (revise and resubmit request).

Building on the *stressor-detachment model*, we examine the mediating role of work-related rumination at night for the relationship between job demands and sleep (quantity and quality). We focus on work-related rumination as a specific kind of perseverative cognition as this construct refers to (a) explicitly work-related thoughts, that is, repetitive thoughts about issues related to work (Cropley & Zijlstra, 2011), and (b) past stressors (Clancy et al., 2020), i.e., in our case, the preceding work day. Therefore, we deem work-related rumination very likely to impair work detachment and to contribute to poor sleep.

Indeed, initial studies examined the relation between work stress and sleep, mediated by rumination, using different study designs. A few cross-sectional (e.g., Berset et al., 2011; Demsky et al., 2019; Fritz et al., 2019) and longitudinal studies (e.g., van Laethem et al., 2015; 2018; 2019) found that the relation between work stressors and sleep is mediated by perseverative cognition or, more specifically, rumination. However, research regarding short-term, within-person relations between job demands, rumination and sleep is still scarce and led to inconclusive results: Some studies did not find a mediation of work-related rumination for the relation between work and sleep (Cropley et al., 2006; Vahle-Hinz et al., 2014), others provide support for this mediation (Radstaak et al., 2014; Syrek et al., 2017; van Laethem et al., 2016). Moreover, the existing studies have some limitations concerning their study designs: Some studies examined relations between the end of the workweek and the weekend (Syrek et al., 2017; Vahle-Hinz et al., 2014). Hence, though these studies tested within-person relationships, sleep quality and patterns during the weekend are strongly determined by other non-work factors (e.g., Vitale et al., 2015). Other studies considered only one (Cropley et al., 2006) or three consecutive work days (Radstaak et al., 2014) instead of a full working week, thereby potentially limiting within-person variance. For instance, certain job demands, such as meetings, might not take place every day of the week, making an assessment on a specific day less representative of the individual's typical experiences. Moreover, only two studies (Radstaak et al., 2014; van Laethem et al., 2016) used actigraphy as an objective measure of sleep.

**Person-level Versus Day-level Relationships.** In advancing these studies, we used a daily-diary design and examined both within-person and between-person effects simultaneously. We deem this approach reasonable as the different levels provide information about different aspects of the relationship between job demands, rumination and sleep: The day-level perspective is important for gaining knowledge about highly dynamic immediate psychological responses to acute job demands. However, a day-level perspective focuses on single events and is therefore of minor relevance for well-being, if these events (or series of events) do not translate into stable inter-individual differences in sleep. Hence, the person-level perspective is important to monitor relationships that are more stable over time, also informing about whether certain job characteristics (such as high job demands) entail higher

risks for poor sleep. Also, the consequences of acute in contrast to general sleep impairment differ significantly: Short-term sleep impairment relates to less concentration (e.g., van der Heijden et al., 2018) and an increased risk for workplace injuries (e.g., Kling et al., 2010), whereas longer-term sleep problems can lead to chronic health impairments such as hypertension or cardiovascular disease (see Medic et al., 2017, for a review).

In order to achieve an appropriate amount of day-level variance in the variables of interest, our study design extends over the course of a whole working week (Studies 2 and 3). This approach accounts for potential variation in demands over the week (e.g., Butler et al., 2005), and increases test power due to an increased number of data points. Moreover, certain events do not happen on a daily basis (e.g., conflicts at work, weekly meetings). To our knowledge, no previous studies have investigated day-to-day relations over the course of more than three consecutive work days, while examining within-person and between-person effects simultaneously and using subjective as well as objective measures of sleep.

**Indicators of Sleep.** Sleep is a yet poorly understood multi-faceted phenomenon (National Institute of Neurological Disorders and Stroke, 2017). In order to provide a broad picture of sleep, we examine sleep quality as well as sleep quantity (duration). Self-reported and actigraph-measured, and thus objective, sleep duration are only moderately correlated, whereby self-reports tend to over-report sleep duration (e.g., Lauderdale et al., 2008). Likewise, previous studies suggest that subjective and objective measures of sleep quality depict different aspects of sleep, which are not suitable to substitute one another (e.g., Landry et al., 2015) For these reasons, we included both self-reports as well as actigraph-reported measures of sleep in our studies. Regarding sleep quality, we measured self-reported sleep quality and actigraphy-based sleep efficiency (i.e., the relative amount of time in bed spent sleeping). For sleep quantity, we use self-reported sleep duration and actigraphy-based sleep duration calculated from accelerometry.

**Hypotheses and Present Research.** Based on the theoretical arguments above, we postulate the following hypotheses:

Hypothesis 1: *Mediation effect of work-related rumination for the relationship between job demands and sleep quality: Job demands are positively related to work-related rumination at night, which in turn is negatively related to sleep quality. This effect will unfold on the person level (H1a) as well as on the day level (H1b).*

Hypothesis 2: *Mediation effect of work-related rumination for the relationship between job demands and sleep duration: Job demands are positively related to work-related rumination at night, which in turn is negatively related to sleep duration. This effect will unfold on the person level (H2a) as well as on the day level (H2b).*

The mediation effects proposed in H1 and H2 will be examined in Study 1 and 2 using a mediation-by-measurement design. However, because this approach is prone to bias by

reciprocal or reversed causation, in Study 3, we additionally conduct an experimental mediator test:

Hypothesis 3: *Moderated mediation in terms of an experimental mediator test: The application of an intervention (person level) has a moderating effect on the relationship between job demands and sleep through work-related rumination (day level); the relationship between job demands and sleep, mediated through work-related rumination will only show in the waiting control group, but not in the experimental group.*

Our research aims at closing several gaps: (a) In contrast to previous studies, we are simultaneously examining person-level and day-level effects, (b) the day-level effects are investigated over the course of a whole working week, (c) in order to depict a broad picture of sleep we include both quality and quantity parameters of sleep, and (d) we use both self-reports as well as actigraphy-based measures. Thereby, Study 1 was designed to establish the mediation (test of H1/H2) using self-report measures of sleep quality and duration, whereas Studies 2 and 3 will simultaneously test for person-level (H1a/H2a) and day-level (H1b/H2b) effects using self-report and additional actigraphy-based indicators of sleep.

## *Study 1*

### Methods.

***Participants and Design*.** We conducted a two-wave online study with a retest interval of four weeks. A sample of British employees was recruited via the panel provider *Prolific.* A power analysis using *G*Power* revealed that, to detect small to medium effects ($f^2 < 0.06$) for the proposed mediations with alpha = .05 and a power of .80 (Faul et al., 2007), a sample of $N = 178$ was required. Expecting a drop-out rate of about 30% between measurement points, we recruited 300 participants for the first wave. Seventy-three participants from the first wave did not match one or more of the predefined inclusion criteria: Working regularly at the time of data collection (e.g., no vacation), no diagnosed sleep disorders, not working after 8 p.m.[2] These and five further participants that did not pass the attention check were excluded. One participant ID appeared twice, so we deleted the second one. Out of the 221 persons invited for time 2, 188 participants took part (15% dropout). At time 2, a further 10 participants had to be excluded because of not fulfilling the inclusion criteria. Two participants did not pass the attention check. In the end, the number of participants that could be included in the analyses was $N = 176$ (72% female; mean age = 37.73 years, $SD = 10.86$). Participants gave their informed consent and received £1.25 for participation at time 1 and another £1.50 for time 2. The questionnaires were identical at both measurement times. The study was conducted in

[2] Although further exclusion criteria were announced in the preregistration of this study (regular intake of sleep medication, working less than part-time), we decided to include the respective data sets in the analyses to prevent an undersized sample (the pattern of results was similar with and without exclusion).

accordance with the Declaration of Helsinki and was preregistered (see at https://osf.io/hdwc6/?view_only=5c1cd63602fb4fa588a60171e6cadf37).

***Measures[3].*** Data were collected using questionnaires provided via the online platform *SoSci Survey* (Leiner, 2021). For the analysis, we used the measures on job demands (predictor) and sleep (control variable) from Time 1 and the measures on work-related rumination (mediator) and sleep (outcome) from Time 2.

*Job Demands (Time 1).* We assessed job demands as a broad construct retrospectively for the past four weeks using ten items from the *Copenhagen Psychosocial Questionnaire* (Nübling et al., 2005), e.g., "Did you have to work very fast?". The internal consistency of the job demands scale was Cronbach's α = .87. For the assessment, a 5-point Likert scale was used.

*Work-Related Rumination (Time 2)*. We assessed work-related rumination retrospectively for the past four weeks with six items adapted from a questionnaire by Du et al. (2018). Two items had to be excluded because they were not eligible with regards to the time of day that we aimed to assess ("thoughts before going to sleep"). All items were adapted to the work-to-home rumination context (e.g., "I thought about work issues that happened during the day") and answered on a 7-point Likert scale. The internal consistency of the work-related rumination scale was Cronbach's α = .90.

*Sleep (Time 1 + 2).* We assessed subjective sleep quality of the past four weeks with a single item ("During the past month, how would you rate your sleep quality overall?") from the *Pittsburgh Sleep Quality Index* (Buysse et al., 1989) and a 4-point Likert scale. We assessed sleep quantity by asking participants to indicate how many hours of actual sleep they got on average per night during the last month.

***Statistical Analysis.*** We conducted mediation analysis using *IBM SPSS Statistics 27* and the add-on *PROCESS v3.5*, Model 4 (Hayes, 2020). In all analyses, Time 1 outcome measures were included as control variables.

**Results.** Means, standard deviations, and correlations between the variables can be found in Table 2.

***Test of Hypotheses: Mediation Effect of Work-Related Rumination for the Relationship Between Job Demands and Sleep Quality.*** Table 3 shows estimates for mediation models predicting the effects of job demands on sleep parameters via work-related rumination.

[3] For educational and explorative purposes, further constructs were measured that are beyond the scope of the present paper: General health, somatic well-being, job control, and social support.

**Table 2**

*Study 1: Means, Standard Deviations, and Correlations Between Study Variables*

| Variable | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age T1 | 37.73 | 10.86 | - | | | | | | | | | | | |
| 2. Gender T1 † | 0.73 | 0.46 | .05 | - | | | | | | | | | | |
| 3. Children T1 ‡ | 0.47 | 0.50 | **.41**** | -.03 | - | | | | | | | | | |
| 4. Working hours per week T1 | 36.70 | 7.36 | -.14 | **-.33**** | **-.18*** | - | | | | | | | | |
| 5. Educational achievement T1 § | 3.99 | 1.57 | **-.18*** | **.17*** | **-.29**** | .03 | - | | | | | | | |
| 6. Current occupation T1 ¶ | 4.14 | 0.78 | **.15*** | -.01 | -.02 | .08 | -.04 | - | | | | | | |
| 7. Demands T1 (1-5) | 2.71 | 0.73 | .02 | .13 | -.01 | .14 | .03 | -.11 | *.87* | | | | | |
| 8. Rumination T2 (1-7) | 4.18 | 1.43 | .03 | .08 | -.06 | .07 | -.06 | -.02 | **.47**** | *.90* | | | | |
| 9. Subjective sleep quality T1 (1-4) | 2.65 | 0.71 | -.03 | .08 | .06 | .04 | .11 | -.06 | **-.24**** | **-.34**** | - | | | |
| 10. Subjective sleep quality T2 (1-4) | 2.71 | 0.74 | -.08 | -.03 | -.02 | .06 | .02 | -.04 | **-.25**** | **-.38**** | **.58**** | - | | |
| 11. Self-reported sleep duration T1 | 8.91 | 29.67 | .11 | .05 | -.07 | -.05 | -.04 | -.01 | -.08 | .13 | **-.16*** | -.06 | - | |
| 12. Self-reported sleep duration T2 | 9.10 | 31.92 | .03 | .04 | .08 | .01 | .05 | -.02 | .10 | .06 | **-.16*** | **-.16*** | -.01 | - |

*Note. N* = 176. Significant correlations are highlighted in bold. In italics: Cronbach's alpha.

† 0 = male, 1 = female, 2 = diverse. ‡ 0 = no, 1 = yes. § Middle school, high school, college degree, associates degree, bachelor, master, Ph.D., vocational degree coded from 1 to 8. ¶ Student, in education, university student, employee, civil servant, self-employed, unemployed, other coded from 1 to 8.

**p* < .05. ***p* < .01.

**Table 3**

*Study 1: Estimates for Mediation Models Predicting Effects of Job Demands on Sleep Parameters via Rumination*

| | *a* (demands → rumination) | | *b* (rumination → sleep) | | Indirect effect *a*b* | | Direct effect *c'* | |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI |
| Subjective sleep quality | 0.81*** (0.13) | [0.56; 1.07] | -0.10* (0.04) | [-0.17; -0.03] | -0.08* (0.03) | [-0.15; -0.02] | -0.05 (0.07) | [-0.18; 0.09] |
| | $R^2$ = .38; $F$(3,172) = 34.58; $p$ < .001 | | | | | | | |
| Self-reported sleep duration | 0.95*** (0.13) | [0.70; 1.21] | 0.42 (1.96) | [-3.45; 4.30] | 0.40 (0.59) | [-0.35; 1.79] | 3.78 (3.83) | [-3.77; 11.34] |
| | $R^2$ = .01; $F$(3,172) = 0.55; $p$ = .649 | | | | | | | |

*Note.* CI = Confidence interval.

**p* < .05. ****p* < .001.

The model containing job demands, work-related rumination and T1 subjective sleep quality as predictor variables explained about 38% of the variance of T2 subjective sleep quality, $F(3,172) = 34.58$, $p < .001$. Results showed a significant mediation effect for work-related rumination (indirect effect = -0.08, 95% CI [-0.15; -0.02]), supporting Hypothesis 1. Job demands and rumination were positively related (a-path = 0.81, $p < .001$), whereas rumination and subjective sleep quality were negatively related (b-path = -0.10, $p = .009$).

***Test of Hypotheses: Mediation Effect of Work-Related Rumination for the Relationship Between Job Demands and Sleep Duration.*** The model containing job demands, work-related rumination and T1 self-reported sleep duration as predictor variables explained about 1% of the variance of T2 self-reported sleep duration, $F(3,172) = 0.55$, $p = .649$. No significant mediation effect for work-related rumination was found (indirect effect = 0.40, 95% CI [-0.35; 1.79]), rejecting Hypothesis 2.

**Discussion Study 1.** The results of Study 1 show that work-related rumination mediates the relationship between job demands and subjective sleep quality, but not sleep duration. In Study 1, we assessed sleep quality and sleep duration via self-reports. Regarding sleep quality that is by definition highly subjective in nature, it is conceivable that the assessment via self-report represents an adequate approach to this kind of parameter (cf., Radstaak et al., 2014; van Laethem et al., 2016). By contrast, it might be difficult for participants to self-assess their sleep duration. Moreover, previous studies showed that self-reported and actigraphy-assessed time spent asleep are only moderately correlated (e.g., Lauderdale et al., 2008). To test the robustness of our findings, we therefore conducted a second study, in which we used actigraphy to obtain more objective measures for sleep parameters (i.e., sleep efficiency, sleep duration).

Moreover, the design of Study 1 did not allow us to disentangle more stable between-person and highly dynamic within-person relationships between job demands, rumination and sleep. Therefore, we used a one-week daily-diary approach in Study 2, allowing for testing the proposed relationships at the day level and at the person level.

### *Study 2*

#### Methods.

***Participants and Design.*** Meeting the sample size recommendations for multilevel analysis (Nezlek et al., 2006), a total of 130 incoming psychology students at a German university took part in this study. Participants received course credit. Two participants cancelled their participation during data collection, one data set could not be matched and a further eight participants had to be excluded from analyses because they did not match one or more of our inclusion criteria: Participating in an ongoing exam period, not working after 10

p.m.[4] The final sample comprised 119 participants (78% female) with an average age of 21.49 years (*SD* = 3.93). Participants gave their informed consent. The study was conducted in accordance with the Declaration of Helsinki, approved by the local ethics committee and preregistered (see at https://osf.io/68nuf/?view_only=4e480ece574a4938948f484268ec3e89).

We conducted a one-week ambulatory assessment study. For eight consecutive days, participants continuously wore an accelerometer for the objective assessment of sleep parameters and answered short questionnaires on their smartphones every morning immediately after waking up as well as every night right before going to sleep. Surveys were provided via the online platform *SoSci Survey* (Leiner, 2021). Compliance to the protocol was very good, with participants answering on average 98.4% of all daily questionnaires.

***Measures.*[5]**

*Daily Study Demands (Bedtime Survey).* We assessed daily study demands using the German version of the demands scale used in Study 1 (Nübling et al., 2005). One item had to be excluded because it did not match our student sample. The remaining nine items were adapted to the day level and the student sample (e.g., “Did you have to work very fast today?”) and presented together with a 5-point Likert scale. The internal consistency of the study demands scale was Cronbach’s α = .91 on the between-person level, and α = .87 on the within-person level.

*Daily Study-Related Rumination (Morning Survey).* We assessed study-related rumination experienced the previous night using the same scale as in Study 1 (Du et al., 2018). The six items were adapted to the day level and the student sample (e.g., “I thought about study issues that happened yesterday.”) and presented together with a 7-point Likert scale. The internal consistency of the rumination scale was Cronbach’s α = .93 on the between-person level, and α = .89 on the within-person level.

*Daily Subjective Sleep Quality (Morning Survey).* We assessed subjective sleep quality, consistent with Study 1, with a single item (“How would you rate your sleep quality during the past night overall?”) from the *Pittsburgh Sleep Quality Index* (Buysse et al., 1989) on a 4-point Likert scale.

[4] Although further exclusion criteria were announced in the preregistration of this study (< 100% of actigraphy data, < 80% of daily questionnaires), we decided to include the respective data sets in the analyses to prevent an undersized sample (the pattern of results was similar with and without exclusion).

[5] For educational and explorative purposes, further constructs were measured. In the baseline assessment: Chronotype, general health, sleep parameters, social support, meaning of work, pressure to perform, performance standard, social identity, emotional detachment, general propensity for rumination. On the day level: Mood, psychological stress, somatic well-being, job control, social support.

*Daily Objective Sleep Parameters.* Objective sleep parameters were assessed using accelerometry (*ActiSleep+* and *wGT3X-BT* devices; ActiGraph LLC). The small and lightweight accelerometer devices monitor spatial movements (Tryon, 2011). Devices were attached to participants' non-dominant body side in order to avoid overestimation of movement behavior (Dieu et al., 2017). We chose to attach the accelerometers to the wrist using disposable wristbands to ensure better compliance to wearing the devices continuously (as compared to attaching them to the hip, cf., Rosenberger et al., 2013). Participants wore the accelerometers for eight consecutive days, resulting in seven monitored nights per person. In sum, we detected and analyzed 817 (out of a possible maximum of 833) sleep periods.

The computation of sleep parameters was carried out using the software *ActiLife 6* (ActiGraph Software Department, 2020). Sleep periods were estimated by the software using established algorithms (Cole et al., 1992), and were adjusted with participants' self-reports about their in-bed and out-of-bed times. After detecting sleep periods, the parameters sleep duration and sleep efficiency were calculated. Sleep duration as a quantitative indicator of sleep is defined by the total number of minutes scored as "asleep" by the algorithm. Sleep efficiency was used as an objective qualitative indicator of sleep in addition to subjectively assessed sleep quality. Sleep efficiency is defined as the number of sleep minutes divided by the total number of minutes the participant was in bed (ActiGraph Software Department, 2012); hence, as a percentage of time in bed spent sleeping.

***Statistical Analysis.*** Study 2 provided day-level information over the course of one week with a nested data structure (day-level data nested in the person level). We conducted multilevel mediation analyses using *IBM SPSS Statistics 27* and the add-on *MLmed* (Hayes & Rockwood, 2020), because this procedure accounts for the interdependent nature of the two levels (Hox, 2002). We handled missing data with pair-wise deletion. All models are presented with random intercepts and fixed slopes.

**Results.**

***Preliminary Analysis.*** Means, standard deviations, and correlations between the variables can be found in Table 4. Dividing the total variance into variance between and within persons showed that a high share of the total variance of subjective sleep quality (71%), sleep efficiency (69%), and sleep duration (82%) can be attributed to within-person variations. This illustrates the utility of the daily-diary design and the multilevel-analytical approach.

***Test of Hypotheses.***

*Mediation Effect of Work-Related Rumination for the Relationship Between Study Demands and Sleep Quality.* Table 5 shows the multilevel estimates for mediation models predicting the effects of study demands on sleep parameters via study-related rumination.

**Table 4**

*Study 2: Means, Standard Deviations, and Correlations Between Study Variables*

| Variable | *M* | *SD* | *ICC* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age | 21.49 | 3.93 | | - | **-.13**** | **.72**** | **.22**** | **.10**** | **.14**** | **-.18**** | .02 | **-.10**** |
| 2. Gender † | 0.78 | 0.42 | | -.13 | - | **.05*** | **.09**** | .04 | **.07*** | .06 | **.17**** | **.07*** |
| 3. Children ‡ | 0.01 | 0.09 | | **.72**** | .05 | - | **.13**** | .04 | **.12**** | **-.09*** | .02 | -.03 |
| 4. Side job § | 0.35 | 0.48 | | **.22*** | .09 | .13 | - | **.12**** | .06 | -.03 | **.09**** | -.04 |
| 5. Demands (1-5) | 2.76 | 0.81 | | .14 | .06 | .07 | .16 | *.87/.91* | **.46**** | **-.21**** | .04 | **-.10**** |
| 6. Rumination (1-7) | 3.28 | 1.44 | | **.18*** | .10 | .16 | .08 | **.59**** | *.89/.93* | **-.35**** | -.03 | -.00 |
| 7. Subjective sleep quality (1-4) | 2.81 | 0.70 | .711 | **-.28**** | .08 | -.14 | -.04 | **-.34**** | **-.53**** | - | **.16**** | **.19**** |
| 8. Sleep efficiency | 89.23 | 5.58 | .694 | .04 | **.27**** | .03 | .15 | .07 | -.06 | .09 | - | **.23**** |
| 9. Sleep duration | 425.90 | 73.95 | .816 | -.18 | .05 | -.06 | -.12 | **-.23*** | .01 | .08 | **-.30**** | - |

*Note.* Values below the diagonal are correlations between person-level variables (*N* = 119). Values above the diagonal are correlations between day-level variables (*N* = 817-824). Significant correlations are highlighted in bold. In italics: Cronbach's alpha within/between.

† 0 = male, 1 = female. ‡ 0 = no, 1 = yes. § 0 = no, 1 = yes.

**p* < .05. ***p* < .01.

**Table 5**

*Study 2: Multilevel Estimates for Mediation Models Predicting Effects of Demands on Sleep Parameters via Rumination*

| | *a* (demands → rumination) | | *b* (rumination → sleep) | | Indirect effect *a*b* | | Direct effect *c'* | |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI |
| Within level | | | | | | | | |
| Subjective sleep quality | 0.50*** (0.06) | [0.38; 0.62] | -0.11*** (0.02) | [-0.16; -0.07] | -0.06*** (0.01) | [-0.08; -0.03] | -0.04 (0.04) | [-0.11; 0.04] |
| Sleep efficiency | 0.50*** (0.06) | [0.38; 0.62] | -0.04 (0.18) | [-0.40; 0.32] | -0.02 (0.09) | [-0.20; 0.16] | 0.20 (0.31) | [-0.41; 0.80] |
| Sleep duration | 0.50*** (0.06) | [0.38; 0.62] | 1.62 (2.64) | [-3.56; 6.81] | 0.81 (1.34) | [-1.76; 3.40] | -3.39 (4.39) | [-12.02; 5.23] |
| Between level | | | | | | | | |
| Subjective sleep quality | 1.11*** (0.14) | [0.84; 1.39] | -0.20*** (0.04) | [-0.28; -0.12] | -0.23*** (0.05) | [-0.34; -0.13] | -0.04 (0.07) | [-0.19; 0.10] |
| Sleep efficiency | 1.11*** (0.14) | [0.84; 1.39] | -0.48 (0.37) | [-1.22; 0.26] | -0.54 (0.43) | [-1.39; 0.28] | 1.02 (0.70) | [-0.38; 2.42] |
| Sleep duration | 1.11*** (0.14) | [0.84; 1.39] | 6.41 (4.21) | [-1.93; 14.74] | 7.15 (4.81) | [-1.92; 16.94] | -22.66* (7.93) | [-38.36; -6.97] |

*Note.* CI = Confidence interval.

**p* < .05. ****p* < .001.

The fit indices for the model containing study demands as a predictor, rumination as a mediator and subjective sleep quality as an outcome were -2LL = 4017.65, AIC = 4025.65 and BIC = 4047.19. Supporting Hypothesis 1a (person level), results showed a significant mediation effect of study-related rumination on the person level (indirect effect = -0.23, $p$ < .001): Person-level study demands were positively related to person-level study-related rumination at night (a-path = 1.11, $p$ < .001), whereas person-level study-related rumination was negatively related to person-level subjective sleep quality (b-path = -0.20, $p$ < .001). Supporting Hypothesis 1b (day level), the mediation effect of study-related rumination was also significant on the day level (indirect effect = -0.06, $p$ < .001): Day-level study demands were positively related to day-level study-related rumination (a-path = 0.50, $p$ < .001), whereas day-level study-related rumination was negatively related to day-level subjective sleep quality (b-path = -0.11, $p$ < .001).

The fit indices for the model containing study demands as a predictor, rumination as a mediator and sleep efficiency as an outcome were -2LL = 7317.99, AIC = 7325.99 and BIC = 7347.50. We did not find a mediation regarding sleep efficiency as the outcome, neither on the between-person level (indirect effect = -0.54, $p$ = .207, rejecting Hypothesis 1a) nor on the within-person level (indirect effect = -0.02, $p$ = .832, rejecting Hypothesis 1b).

*Mediation Effect of Work-Related Rumination for the Relationship Between Study Demands and Sleep Duration.* The fit indices for the model containing study demands as a predictor, rumination as a mediator and sleep duration as an outcome were -2LL = 11481.87, AIC = 11489.87 and BIC = 11511.38. No mediation was found for sleep duration, neither on the between-person level (indirect effect = 7.15, $p$ = .138, rejecting Hypothesis 2a) nor on the within-person level (indirect effect = 0.81, $p$ = .543, rejecting Hypothesis 2b). Nevertheless, on the between-person level, we found a significant negative relationship between study demands and sleep duration (direct effect = -22.66, $p$ = .005), that was not mediated by rumination.

**Discussion Study 2.** The results of Study 2 replicated the findings of Study 1 by showing that rumination functions as a mediator in the relationship between study demands and subjective sleep quality, but not sleep duration. Extending this finding, in Study 2, we show that this effect unfolds on a person level, but also on a day level. In Study 2, in addition to subjective sleep quality, we used actigraphy-monitored sleep efficiency as a second indicator of sleep quality. However, for this outcome we did not find the proposed mediation effect. We will return to this issue in the General Discussion.

With respect to sleep duration, we replicated the finding from Study 1 that sleep duration was not affected by demands via rumination, while using an objective measure of sleep duration in Study 2. Thus, the null finding from Study 1 is unlikely to be due to an unreliable measure of sleep duration. Instead, our findings are robust in that they show that

mere quantity parameters like sleep duration are not impaired by demands via rumination. Interestingly, we still found a direct negative effect of study demands on sleep duration. We will come back to this issue in the General Discussion.

Beyond the replication of the findings from Study 1, Study 2 revealed new findings: (a) We found the proposed mediation for subjective sleep quality on both the person level as well as the day level, (b) no effect was found for sleep efficiency as an indicator of sleep quality, and (c) we found a direct effect of demands on sleep duration. In order to examine the robustness of these new results, these analyses will be repeated in Study 3. Moreover, Study 1 and 2 used mediation-by-measurement designs, making it prone to common method bias and limiting the possibilities to infer causation from the relationships found (Asay et al., 2019). Therefore, we used an experimental mediator test in Study 3.

### *Study 3*

In Study 3, we implemented a manipulation of study-related rumination in the study design. The experimental group was encouraged to apply an intervention designed to suppress undesired rumination ("thought-stopping technique"; see Tyron, 2015). The waiting control group did not get instructions on this intervention. We supposed that the relationship between study demands and sleep quality through study-related rumination, as postulated in Hypothesis 1 and found in the results of Studies 1 and 2, would show only in the waiting control condition. In the experimental group we expected that the relationship between job demands and subjective sleep quality through work-related rumination would be diminished.

#### Methods.

***Participants and Design.*** Meeting the sample size recommendations for multilevel analysis (Nezlek et al., 2006), a total of 119 incoming psychology and sports science students at a German university took part in Study 3. Participants received course credit. Three participants cancelled their participation during data collection, four data sets could not be matched, and one participant had to be excluded because of our inclusion criteria (equal to Study 2).[6] The final sample comprised $N$ = 111 participants (85% female) with an average age of 22.23 years ($SD$ = 5.60). On day 8 of data collection, participants were randomly assigned to an experimental and a waiting control group. At the end of data collection, four participants of the experimental group reported that they had not used the thought-stopping technique on any day of week 2, although they had experienced study-related ruminative thoughts on at least one day of week 2. Therefore, these participants were excluded from the experimental mediation test. The final sample comprised 107 participants divided into an experimental ($n$ =

[6] Although further exclusion criteria were announced in the preregistration of this study (< 100% of actigraphy data, < 80% of daily questionnaires), we decided to include the respective data sets in the analyses to prevent an undersized sample (the pattern of results was similar with and without exclusion).

53; 83% female, average age = 22.38, *SD* = 4.16) and a waiting control group (*n* = 54; 87% female; average age = 21.65, *SD* = 5.42). Participants gave their informed consent. The study was conducted in accordance with the Declaration of Helsinki, was approved by the local ethics committee and was preregistered (see at https://osf.io/6rfj7/?view_only=d8b0f2a35b394529bfeb7abc75ab99ed).

We used a similar study design as in Study 2. However, the ambulatory assessment was conducted over a period of 14 days, with the manipulation being introduced after the first week. We decided on an assessment period of 14 days because Study 3 comprised two phases: (a) The first week as a direct replication of Study 2, (b) the second week for the experimental mediation test under similar circumstances as during week 1.

***Experimental Mediation Test.*** On day 8 of data collection, participants in the experimental group received specific instructions for an intervention designed to stop ruminative thoughts ("thought-stopping technique", see below). Instructions on the thought-stopping technique were provided by well-trained examiners. Afterwards, the experimental group was encouraged to apply the thought-stopping technique over the course of the second week of data assessment anytime a study-related ruminative thought appeared. The waiting control group did not get instructions on the intervention on day 8, but only the battery levels of the accelerometers were checked.

The thought-stopping technique is designed to suppress undesirable thoughts in the moment of their appearance by imagining or pronouncing the word "stop". It is said to function as a relief when having difficulties with perseverative, ruminative thoughts. This intervention is, among others, used in the context of phobias and compulsive behavior (Tyron, 2015). A major reason for choosing the thought-stopping technique for this study was that it is easy to apply by oneself. It was, therefore, suitable for our experimental setting in which the time for practicing an intervention method was short and participants were encouraged to apply this technique by themselves.

***Measures.***[7] The collection of data (via questionnaires and actigraphy) was identical to Study 2. Participants answered on average 97.5% and 94.4% of all daily questionnaires during assessment weeks 1 and 2, respectively. Including assessment weeks 1 and 2 as well as the person level and the day level, Cronbach's α of the daily study demands scale ranged between .86 and .92. Cronbach's α of the daily study-related rumination scale ranged between .91 and .94. Regarding objective sleep parameters, we detected and analyzed 764 (out of a possible

[7] For educational and explorative purposes, further constructs were measured. In the baseline assessment: Chronotype, general health, sleep parameters, social support, meaning of work, pressure to perform, performance standard, social identity, emotional detachment, general propensity for rumination. On the day level: Mood, psychological stress, somatic well-being, job control, social support.

maximum of 777) sleep periods regarding week 1 and 743 (out of a possible maximum of 749) regarding week 2.

***Statistical Analysis.*** The two weeks of assessment were analyzed separately. For week 1, in terms of replicating the findings from Study 2, we ran multilevel mediation models identically to Study 2. For week 2, in terms of an experimental mediation test, we conducted a moderated multilevel mediation analysis, including the group variable (experimental vs. waiting control group, level 2) as a moderator on the relationship between study demands and study-related rumination (first-stage moderated mediation).

**Results.**

***Preliminary Analyses.*** Means, standard deviations, and correlations between the variables regarding assessment week 1 can be found in Table 6. For assessment week 1, a high share of the total variance of subjective sleep quality (80%), sleep efficiency (57%), and sleep duration (83%) could be attributed to within-person variations. Similarly high proportions of within-person variance can be found for subjective sleep quality (71%), sleep efficiency (54%), and sleep duration (89%), looking at assessment week 2.

***Test of Hypotheses.***

*Week 1: Mediation Effect of Study-Related Rumination for the Relationship Between Study Demands and Sleep Quality.* Table 7 shows multilevel estimates for mediation models predicting the effects of study demands on sleep parameters via study-related rumination for assessment week 1.

**Table 6**

*Study 3, Week 1: Means, Standard Deviations, and Correlations Between Study Variables*

| Variable | *M* | *SD* | *ICC* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age | 22.23 | 5.60 | | - | **-.32**** | **.63**** | **.18**** | -.06 | -.01 | -.07 | -.05 | -.05 |
| 2. Gender † | 0.85 | 0.36 | | **-.32**** | - | **-.12**** | **-.12**** | **.16**** | **.10**** | **-.08*** | **.16**** | **.11**** |
| 3. Children ‡ | 0.05 | 0.23 | | **.63**** | -.12 | - | **.09**** | -.03 | **-.09*** | **-.12**** | -.05 | .00 |
| 4. Side job § | 0.33 | 0.47 | | .18 | -.12 | .09 | - | -.06 | .01 | -.07 | -.04 | -.01 |
| 5. Demands (1-5) | 2.70 | 0.80 | | -.08 | **.20*** | -.05 | -.07 | *.86/.92* | **.54**** | **-.19**** | -.01 | -.07 |
| 6. Rumination (1-7) | 3.27 | 1.48 | | -.01 | .13 | -.11 | .02 | **.67**** | *.91/.94* | **-.32**** | -.04 | -.05 |
| 7. Subjective sleep quality (1-4) | 2.86 | 0.68 | .798 | -.12 | -.15 | **-.21*** | -.13 | **-.36**** | **-.39**** | - | **.14**** | **.17**** |
| 8. Sleep efficiency | 89.07 | 6.08 | .565 | -.07 | **.22*** | -.08 | -.05 | -.03 | -.01 | .06 | - | **.22**** |
| 9. Sleep duration | 418.88 | 69.33 | .834 | -.10 | **.20*** | .01 | -.04 | -.07 | -.01 | -.12 | .13 | - |

*Note.* Values below the diagonal are correlations between person-level variables (*N* = 111). Values above the diagonal are correlations between day-level variables (*N* = 752-764). Significant correlations are highlighted in bold. In italics: Cronbach's alpha within/between.

† 0 = male, 1 = female. ‡ 0 = no, 1 = yes. § 0 = no, 1 = yes.

**p* < .05. ***p* < .01.

**Table 7**

*Study 3, week 1: Multilevel Estimates for Mediation Models Predicting Effects of Demands on Sleep Parameters via Rumination*

| | *a* (demands → rumination) | | *b* (rumination → sleep) | | Indirect effect *a*b* | | Direct effect *c'* | |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI | Estimate (*SE*) | 95% CI |
| Within level | | | | | | | | |
| Subjective sleep quality | 0.63*** (0.07) | [0.50; 0.76] | -0.19*** (0.02) | [-0.24; -0.14] | -0.12*** (0.02) | [-0.16; -0.08] | 0.06 (0.04) | [-0.03; 0.14] |
| Sleep efficiency | 0.63*** (0.07) | [0.50; 0.76] | -0.41* (0.20) | [-0.80; -0.02] | -0.26* (0.13) | [-0.51; -0.02] | 0.34 (0.34) | [-0.33; 1.01] |
| Sleep duration | 0.63*** (0.07) | [0.50; 0.76] | -5.09 (2.79) | [-10.57; 0.39] | -3.20 (1.79) | [-6.82; 0.19] | -3.56 (4.80) | [-12.99; 5.88] |
| Between level | | | | | | | | |
| Subjective sleep quality | 1.28*** (0.14) | [1.01; 1.56] | -0.10* (0.04) | [-0.17; -0.02] | -0.12* (0.05) | [-0.23; -0.02] | -0.11 (0.08) | [-0.26; 0.04] |
| Sleep efficiency | 1.28*** (0.14) | [1.01; 1.56] | 0.13 (0.50) | [-0.86; 1.12] | 0.16 (0.64) | [-1.09; 1.45] | -0.32 (0.96) | [-2.22; 1.57] |
| Sleep duration | 1.28*** (0.14) | [1.01; 1.56] | 3.50 (4.11) | [-4.64; 11.64] | 4.49 (5.32) | [-5.69; 15.30] | -9.96 (7.88) | [-25.58; 5.66] |

*Note.* CI = Confidence interval.

**p* < .05. ****p* < .001.

The fit indices for the model containing study demands as a predictor, rumination as a mediator and subjective sleep quality as an outcome were -2LL = 3612.74, AIC = 3620.74 and BIC = 3641.92. Supporting Hypothesis 1a (person level), results showed a significant mediation effect of study-related rumination on the person level (indirect effect = -0.12, $p$ = .020): Person-level study demands were positively related to person-level study-related rumination at night (a-path = 1.28, $p$ < .001), whereas person-level study-related rumination was negatively related to person-level subjective sleep quality (b-path = -0.10, $p$ = .017). Supporting Hypothesis 1b (day level), the mediation effect of study-related rumination was also significant on the day level (indirect effect = -0.12, $p$ < .001): Day-level study demands were positively related to day-level study-related rumination at night (a-path = 0.63, $p$ < .001), whereas day-level study-related rumination was negatively related to day-level subjective sleep quality (b-path = -0.19, $p$ < .001).

The fit indices for the model containing study demands as a predictor, rumination as a mediator and sleep efficiency as an outcome were -2LL = 6652.78, AIC = 6660.78 and BIC = 6681.93. On the person level (H1a), we did not find a mediation effect regarding the relationship between study demands and sleep efficiency (indirect effect = 0.16, $p$ = .799). However, on the day level (H1b), results showed a significant mediation effect of study-related rumination (indirect effect = -0.26, $p$ = .043): Day-level study demands were positively related to day-level study-related rumination at night (a-path = 0.63, $p$ < .001), whereas day-level study-related rumination was negatively related to day-level sleep efficiency (b-path = -0.41, $p$ = .037).

*Week 1: Mediation Effect of Study-Related Rumination for the Relationship Between Study Demands and Sleep Duration.* The fit indices for the model containing study demands as a predictor, rumination as a mediator and sleep duration as an outcome were -2LL = 10370.89, AIC = 10378.89 and BIC = 10400.04. We did not find any mediation effect regarding sleep duration as an outcome, neither on the between-person level (indirect effect = 4.49, $p$ = .399, rejecting Hypothesis 2a) nor on the within-person level (indirect effect = -3.20, $p$ = .075, rejecting Hypothesis 2b). Finally, in contrast to Study 2, the direct effect of study demands on sleep duration on the person level was not significant (direct effect = -9.96, $p$ = .209).

*Week 2: Moderated Mediation Effect of the Intervention.* We tested the moderated mediation for subjective sleep quality, but not for sleep efficiency and sleep duration because the former analyses showed that there is no consistent indirect effect via rumination regarding these two outcomes. The fit indices for the model containing study demands as a predictor, rumination as a mediator and intervention group as a moderator (on the a-path) regarding subjective sleep quality as an outcome were -2LL = 3246.61, AIC = 3254.61 and BIC = 3275.43. We did not find a moderating effect of the intervention on the relationship between

study demands and subjective sleep quality (index of moderated mediation = 0.01, 95% CI [-0.02; 0.04]). More specifically, the results did not show a significant interaction effect of study demands and intervention group on study-related rumination on the day level (Effect = -0.08, *p* =.485, rejecting Hypothesis 3).

**Discussion Study 3.** Study 3 provides further support for rumination as a mediator in the relationship between demands and sleep quality, but not sleep duration. In line with Study 2, this mediation effect was found on the between-, as well as on the within-person level. In addition, we also found the proposed mediation for sleep efficiency on the within-person level. Since this relationship was not found in Study 2, the robustness of this result stands to reason. Again, no mediation regarding sleep duration was found (in contrast to Study 2, also no direct effect of demands on duration was found).

Regarding the experimental mediation test, we did not find the expected moderation effect of the intervention. Although the experimental and the waiting control group do show significant differences in the amount of study-related rumination they reported (experimental group: $M$ = 2.67, $SD$ = 1.45; waiting control group: $M$ = 3.22, $SD$ = 1.49; $t(700) = 4.95$, $p < .001$), the intervention did not totally suppress rumination. Hence, the "thought-stopping technique" intervention we used to conduct an experimental mediator test might not have been strong enough.

### *General Discussion Studies 1, 2, & 3*

Building on the *stressor-detachment model* (Sonnentag & Fritz, 2015), the current research examined the indirect effect of job demands on sleep through rumination. In a nutshell, across three studies we found robust evidence for the proposed mediation for subjective sleep quality, but also robust evidence for the absence of such a mediation with respect to sleep duration.

**Job Demands and Sleep Quality.** Regarding subjective sleep quality, the hypothesized mediation effect was consistently found on the person level as well as on the day level. These findings are in line with the propositions of the *stressor-detachment model* (Sonnentag & Fritz, 2015). The person-level effects illustrate that a higher average level of job demands related to more average rumination, which, in turn, related to lower average sleep quality. Thus, it shows that jobs characterized by high job demands entail the danger to result in chronic reduced sleep quality, providing further evidence for the negative effects of high job demands beyond 'traditional' domains of work-related well-being (cf., Häusser et al., 2010). In addition, the day-level relationships indicate that experiencing more job demands on a specific day related to more rumination on that day, which in turn, related to poorer sleep quality on that given day. Our findings suggest that the relations between job demands, rumination and

subjective sleep quality are of a highly dynamic nature, but that they also manifest as more stable, habitual patterns.

Regarding sleep efficiency, the hypothesized effect only appeared in Study 3, and only on the day level. Sleep efficiency is defined as the time spent sleeping divided by the total time in bed, mapping events such as sleep onset latency or awakenings at night. Thus, sleep efficiency represents a quality indicator especially regarding the initiation and maintenance of sleep, and rumination seems to be unrelated to this aspect of sleep quality. Hence, in reverse conclusion, reduced subjective sleep quality is likely to result from aspects of sleep other than problems with falling asleep and awakenings at night. The very small correlations between subjective sleep quality and sleep efficiency (day-level correlations: all $r \leq .16$; person-level correlations: all $r \leq .09$) similarly illustrate the distinctness of these two parameters. Hence, reduced subjective sleep quality is likely to result from more 'content-related' aspects of sleep, such as dream content or duration and frequency of sleep phases (e.g., REM vs. nonREM sleep), which are not represented in actigraphy data. Barnes et al. (2021) provide initial findings for the involvement of dream content in the relationship between job demands and sleep quality: They found that demands were related to dream affect via rumination. Future studies should further investigate the role of dream content or other sleep-content variables in this context.

We found that the mediation of rumination for the relation between job demands and subjective sleep quality manifests consistently on the person level and on the day level. Though, different mechanisms are likely to be accountable for the effects on the two levels. On the person level, habitual patterns should be investigated: What causes people to develop a general tendency to ruminate? And how do job demands contribute to the emergence of (problematic) sleep patterns? On the day level, the underlying mechanisms of the a-path of the mediation, i.e., the relation between job demands and rumination, are of major interest. Are there certain aspects of high job demands that promote perseverative cognition on a specific day? Referring to the Zeigarnik effect (Zeigarnik, 1938), previous research suggests that, for example, unfinished tasks trigger rumination (Syrek et al., 2017). Another potential moderator that should be investigated is the proximity of time between the end of work and the beginning of sleep.

**Job Demands and Sleep Duration.** We found robust evidence for the absence of a mediation of rumination for the relation between job demands and sleep duration, regarding the person level as well as the day level, and regarding self-reported as well as actigraph-measured sleep duration. This was due to nonsignificant associations between work-related rumination and sleep duration.

There are two potential explanations for it. First, demands as well as rumination are related to psychological and physical exhaustion (e.g., Demerouti et al., 2001; Geisler et al., 2019). This association might, as a consequence, increase the need for sleep and might even trump the potential of ruminative thoughts – despite their occurrence – to keep one awake. Second, sleep duration is a somewhat ambiguous indicator of well-being. In contrast to subjective sleep quality, sleep duration does not follow a simple 'the-more-the-merrier' function (Hirshkowitz et al., 2015). Instead, the optimum sleep duration differs between individuals, whereby some need to sleep longer hours to feel recovered, whereas others need less sleep (e.g., Åkerstedt et al., 2021). To take this into account, future studies should carefully determine participants' individual sleep duration optima prior to the study and use deviations from these optima as a sleep duration parameter to operationalize well-being. This differentiation in "undersleep" and "oversleep" might be a more meaningful indicator – in terms of well-being – than mere sleep duration.

In Study 2, however, we found a negative direct effect of job demands on actigraph-measured sleep duration on the person level: The higher the job demands in general, the lower the sleep duration. Because this effect was not mediated by rumination, other mechanisms must be accountable for it. Quite obviously, high demands might be reflected in long working hours (e.g., when a deadline is approaching), which lead to a reduction of time that can be used for sleep. The same is true when high demands require an early start of work, particularly if working hours and chronotype do not match and one's sleep habits follow chronotype preferences (e.g., an "owl" that prefers to be nocturnal and goes to bed late, still has to get up early for the morning shift, see Hittle & Gillespie, 2018, for a review). Generally, considering the daily time limit of 24 hours, the amount of time spent on working has an impact on the amount of time that is left for other activities, such as sleep (cf., Janurek et al., 2018). Nevertheless, since we did not find a direct effect on sleep duration in Study 1 and Study 3, the robustness of this result is questionable and future studies might follow up on the time conflict perspective discussed above.

**Limitations.** A few limitations of the current research have to be addressed. First, in Study 2 and Study 3, student samples were used. Since the study designs extended over the course of one or two weeks, respectively, included actigraphy in both studies and the implementation of an intervention method in Study 3, the studies were quite time-consuming and therefore difficult to realize in an employee sample with good test power. We, therefore, decided to conduct the studies with undergraduate students as participants. However, the results obtained in Study 2 and Study 3 are consistent with Study 1, where the sample consisted of employees. Moreover, we have no reason to assume that the relationships

between demands, rumination and sleep should be different in students as compared to employees.

Second, because the manipulation of rumination in Study 3 (i.e., the elimination of study-related rumination in the experimental group) was not successful, no strong inferences regarding causality can be made. For the manipulation, we decided to use the thought-stopping technique because it is effective according to clinical experience (Tyron, 2015). Moreover, the thought-stopping technique is easy to self-administer by the participants without the presence of a therapist or clinician. It was, therefore, suitable for our experimental setting. However, although the experimental and the waiting control group did show differences in the amount of self-reported study-related rumination, the intervention did not fully suppress rumination, but the experimental group did still report a crucial amount of study-related rumination. It seems that the "thought-stopping technique" intervention was not strong enough. Future studies should search for more effective interventions in order to investigate causality assumptions.

**Practical Implications.** Our results consistently show that rumination mediates the relation between job demands and subjective sleep quality at the day level and at the person level. Subjective sleep quality, in turn, is related to occupational outcomes, such as job satisfaction, engagement, and performance (e.g., Kucharczyk et al., 2012; Schleupner & Kühnel, 2021), and well-being, such as burnout (Giorgi et al., 2018). Therefore, organizations should aim to reduce their employees' job demands to increase their subjective sleep quality and, in the long run, their performance and health. Besides designing healthy work environments, the reduction of perseverative cognition should be focused on. Rumination does not only have detrimental effects on subjective sleep quality, but is also related to other outcomes concerning well-being, such as work-family conflict (Junker et al., 2021). As outlined above, intervention techniques might support detachment from work (see Karabinski et al., 2021, for a meta-analysis on interventions). Further suggestions for successful detachment are developing routines for the work-to-nonwork transition. Beyond that, it can be helpful to engage in activities that are unrelated to work together with people that are unrelated to work (Sonnentag & Fritz, 2015).

**Conclusion.** The current research examined the relations between job demands, rumination and sleep. Thereby, it adds to previous research considering (a) person-level as well as day-level effects simultaneously, (b) a whole working week for the investigation of day-level effects, (c) quality as well as quantity parameters of sleep, and (d) self-reported as well as actigraph-measured sleep parameters. Across three studies we consistently found that job demands are related to sleep quality via rumination, but are unrelated to sleep quantity.

# Chapter 3: Work, Sleep, and Emotional Exhaustion (Study 4)

## Theoretical Background

### *Work, Sleep, and Emotional Exhaustion*

The findings in Chapter 2 suggest an association between work and sleep, mediated through work-related rumination. Work and sleep constitute two time-use components that fill a huge amount of time in most adults' daily lives. Based on that, in this chapter, I am going to focus on the mutual consequences of time spent working and time spent sleeping on emotional exhaustion as an important indicator of well-being.

Emotional exhaustion comprises a state of overextension and depletion of emotional and physical resources and, thereby, constitutes the key dimension of burnout (Maslach et al., 2001). Burnout describes a "state of physical, emotional and mental exhaustion that results from long-term involvement in work situations that are emotionally demanding" (Schaufeli & Greenglass, 2001, p. 501). This definition already delivers the most prominent and best-studied predictor of burnout: On the one hand, as set out above in Chapter 2, qualitative aspects of one's job (i.e., the job demands) are strongly associated with psychological well-being (see Häusser et al., 2010; Lesener et al., 2019; Schaufeli & Taris, 2014, for reviews). On the other hand, the quantity of work (i.e., the mere amount of time spent working) has also been identified as influential for burnout. Various studies showed associations between working hours and emotional exhaustion (e.g., Gopal et al., 2005; Iskera-Golec et al., 1996; Martini et al., 2006; Nishimura et al., 2014). One potential reason for these associations has already been discussed in Chapter 2: Working long hours leads to prolonged exposure to work demands and, thus, to a reduction of available recovery time. The consequent incomplete recovery might pave the way for impairments in health and well-being (Geurts & Sonnentag, 2006). Nevertheless, besides work, a person's day is defined by several other domains.

Naturally, time spent working competes with leisure time, which is described in the so-called time-based conflict (Greenhaus & Beutell, 1985): Time spent working cannot be used for any other (off-job) activity. Besides, for example, family time, this also affects sleep – an off-job activity of high temporal dominance (i.e., it comprises a large part of an individual's day) and high importance for the maintenance of an individual's health and well-being (Åkerstedt, 2006). Although the definition of burnout implies a work relation of its predictors, sleep has also been identified as a serious risk factor. Studies have shown negative associations between sleep duration and burnout symptoms (Söderström et al., 2012; Wolf & Rosenstock, 2017). In a more recent study, Allen et al. (2021) showed a negative association between sleep duration and emotional exhaustion, and cited the importance of sufficient sleep for emotion and energy regulation as a potential reason for this association.

In summary, time spent working and time spent sleeping have both been identified as risk factors for the development of burnout or, more specifically, emotional exhaustion. However, previous studies have neglected one important characteristic of work and sleep that is associated with the time-based conflict mentioned above: The mutual dependence of these two activities due to the compositional nature of daily time.

### *Compositional Nature of Time*

Daily time is limited to 24 hours. Because of that, different activities that are carried out throughout the day are not temporally independent from one another: Time that is allocated to one activity (e.g., work) cannot be used for any other activity (e.g., sleep). Edwards and Rothbard (2000) described this issue in their considerations on time-based resource drain between the work and the non-work domain. The authors state that different domains compete for time, and that time spent with one domain naturally decreases the available time for any other domain (i.e., resource drain). Regarding work and sleep, this dependence has already been shown empirically: Basner et al. (2007) as well as Barnes et al. (2012) found that time spent working and time spent sleeping are negatively correlated.

Although previous studies have repeatedly shown associations between time spent working and emotional exhaustion (e.g., Iskera-Golec et al., 1996) as well as time spent sleeping and emotional exhaustion (e.g., Söderström et al., 2012), these studies did not take the interdependent nature of these two activities (i.e., working and sleeping) into account that arises due to the daily time limit of 24 hours. All of the studies that have been conducted so far examined work and sleep independently, i.e., in separate study designs. This procedure can lead to erroneous results, as the compositional nature of work and sleep and their potentially compositional impact is ignored (e.g., Chastin et al., 2015): For example, even if time spent working does not per se have an impact on emotional exhaustion, long working hours inevitably result in less time that can be used for sleep which, ultimately, might result in higher levels of emotional exhaustion. Edwards and Rothbard (2000) already hypothesized that sleep time might be reduced in reaction to increased time demands at work. Barnes et al. (2012) later found evidence for this hypothesis, showing a non-linear relationship between work time and sleep time: In their study, the negative relationship between time spent working and time spent sleeping continually increased with increasing work time, and each additional hour spent working further increased the cost for time spent sleeping. Thus, beyond the impact that each predictor can individually exert on emotional exhaustion, it is conceivable that the composition of work and sleep throughout the day can also be influential. Brauchli et al. (2011) support this assumption, showing that time-based work-life conflict is strongly associated with burnout.

Derived from that, in order to adequately investigate the associations of time spent working and time spent sleeping with emotional exhaustion, I examined the two predictors simultaneously using a compositional data analysis approach (see Chastin et al., 2015; Dumuid et al., 2020, for an overview). Again, I used actigraphy as an objective measurement of sleep. Actigraphy operates through the assessment of physical movement in order to distinguish wake from sleep phases (Tryon, 2011), also obtaining information about physical activity carried out throughout the day. Besides work and sleep, physical activity has been hypothesized to be a crucial factor for well-being, as described in the *physical activity-mediated Demand-Control model* (pamDC model; Häusser & Mojzisch, 2017). Supporting this assumption, previous research repeatedly showed that physical activity and burnout are negatively related (e.g., Gerber et al., 2015; Jonsdottir et al., 2010; see Naczenski et al., 2017, for a review). To date, the underlying mechanisms of the association between physical activity and burnout are still obscure, but different pathways are discussed, including psychological (e.g., psychological detachment as a mediator between physical activity and burnout) and physiological pathways (e.g., an involvement of neurotransmitters between physical activity and energy), as well as the combination of both (Naczenski et al., 2017). Based on the findings that highlight the relevance of physical activity for well-being, I decided to investigate time spent being physically active simultaneously with time spent working and sleeping as predictors for emotional exhaustion. The results of the analysis are presented in the following article.

**Article: "The Association of the 24-Hour Distribution of Time Spent in Physical Activity, Work, and Sleep With Emotional Exhaustion"**[8]

Burnout is defined by "a state of physical, emotional and mental exhaustion that results from long-term involvement in work situations that are emotionally demanding" (Schaufeli & Greenglass, 2001, p. 501). It comprises three key dimensions: Emotional exhaustion, feelings of cynicism and detachment from the job, and feelings of ineffectiveness and missing personal accomplishment (Maslach & Jackson, 1981; Maslach & Leiter, 2016). Emotional exhaustion represents the core element of burnout, referring to "feelings of being overextended and depleted of one's emotional and physical resources" (Maslach et al., 2001, p. 399). Therefore, researchers often focus exclusively on emotional exhaustion when examining burnout (cf., Häusser et al., 2010).

Burnout affects not only employees individually by constituting a severe risk factor for mental health issues (Maslach, 2001) but also the company as a whole by increasing

[8] This section was published as Janurek, J., Abdel Hadi, S., Mojzisch, A., & Häusser, J. A. (2018). The association of the 24-hour distribution of time spent in physical activity, work, and sleep with emotional exhaustion. *International Journal of Environmental Research and Public Health, 15*(9), 1927. https://doi.org/10.3390/ijerph15091927

organizational costs. For example, in a 5-year prospective study, illness-related absence in individuals scoring high in burnout amounted to 13.9 days versus 6.0 days in individuals reporting low burnout scores (Borritz et al., 2006). Originally, burnout was considered to occur in individuals who work in the service sector (Maslach & Schaufeli, 1993). However, later it became clear that burnout also exists outside this field (Maslach & Leiter, 1997).

Various predictors for the development of emotional exhaustion have been identified, with work-related predictors being the most prominent. Research on the *job-demand-control model* (Karasek, 1979; Karasek & Theorell, 1990) identified cognitive (e.g., time pressure), physical (e.g., heavy lifting), and emotional (e.g., customer contact) job demands as influential for psychological well-being (Häusser et al., 2010). Besides qualitative differences in work characteristics, the mere amount of time spent at work (i.e., the working hours) turned out to be a strong predictor of burnout. For example, nurses working in 12 h shifts have been found to experience more emotional exhaustion than their 8 h shift colleagues (Iskera-Golec et al., 1996). Also, the number of working hours per week has been found to be positively associated with emotional exhaustion, both in a physician sample (Nishimura et al., 2014) and in a sample of nurses (Park & Lake, 2005). Furthermore, research revealed that the reduction of working hours can decrease emotional exhaustion (Gopal et al., 2005; Martini et al., 2006).

Although the original development of the burnout construct implies a work-related etiology, research also turned to identifying off-job activities as predictors (Oerlemans & Bakker, 2014). In this context, sleep is an interesting factor for at least two reasons. First, from the perspective of how much time is spent in a certain type of behavior, sleep is a highly prevalent activity. Second, sleep is essential for maintenance of physiological and psychological functioning and long-term health (Åkerstedt, 2006; de Lange et al., 2009). According to the National Sleep Foundation, for healthy adults without sleep-related diseases, the appropriate sleep duration is between 7 h and 9 h (Hirshkowitz et al., 2015). Söderström et al. (2012) conducted a prospective study and identified too little sleep (<6 h per night) at baseline as a severe risk factor for the development of burnout during the two subsequent years. This finding has been replicated in other studies (Wolf & Rosenstock, 2017).

Besides time spent working and sleeping, another activity received an increasing amount of attention as a predictor of emotional exhaustion – time spent in physical activity. Research indicates that a minimum of 30 min of moderate physical activity (e.g., riding a bike) on at least five days a week can help to promote and maintain health (World Health Organization, 2010). In line with this general finding, participants who reported levels of moderate to vigorous physical activity (MVPA) that exceeded the recommended minimum MVPA reported lower levels of burnout, as compared to individuals who failed to match the recommendation (Gerber et al., 2015). Also, research indicates that engagement in physical activity may lower the risk of developing burnout two years later (Jonsdottir et al., 2010). Regarding the underlying

mechanisms of this relation, it was shown that physical activity is related to positive affect (Feuerhahn et al., 2014) and, in combination with sufficient sleep, the revitalization of personal resources (Nägel & Sonnentag, 2013) and can also improve sleep quality (P.-Y. Yang et al., 2012) which might again contribute to the prevention of emotional exhaustion and burnout.

As outlined above, numerous empirical studies have investigated the effects of the three types of behavior (i.e., time spent working, sleeping, and being physically active) on emotional exhaustion or burnout. Surprisingly, however, in previous research the examination of the predictors was conducted independently (i.e., the three predictors were examined in separate studies). To the best of our knowledge, so far, no study has simultaneously used the three types of behavior as predictors of emotional exhaustion or burnout.

The present research aims to address this research gap. As daily time is limited to 24 h, the amounts of time spent in the different activities are not independent of each other: Time used for a specific activity (e.g., sleep or work) cannot be used for any other activity (e.g., physical activity). As a consequence, studies focusing on only one type of predictor (e.g., the number of working hours) without simultaneously considering the two other types (e.g., leisure time physical activity and sleep) are likely to yield erroneous conclusions (Chastin et al., 2015; Dumuid, Stanford, et al., 2017; Pedišić, 2014); see also Pedišić et al. (2017) for a discussion of compositional data structure and a theoretical framework to analyze this type of data. For example, it is conceivable that not high job demands (i.e., the number of working hours) per se lead to emotional exhaustion but rather the fact that high job demands are typically associated with less physical activity and less sleep. In conclusion, not only can each predictor itself have an association with emotional exhaustion – as outlined above – but also the composition of the different types of behavior carried out during a given 24 h period.

University students are a specific population of young adults as their working hours consist mostly of attending lectures and studying outside of lectures. Nonetheless, this “student work” has very similar characteristics as compared to regular work, regarding, for example, hierarchical structures or deadlines (Cotton et al., 2002). It can, therefore, be hypothesized that long studying hours, just as long working hours, act as a predictor for burnout. Research has already shown that students’ workload has a positive effect on burnout. This relationship holds for both subjectively perceived (Jacobs & Dodd, 2003) and actual workload (H.-J. Yang, 2004). No previous studies have examined study time, sleep, and physical activity as simultaneous predictors of emotional exhaustion in university students, while acknowledging the compositional properties of these time-use components. Using both compositional data analyses and multilevel analyses, the present study is the first to examine the three types of behavior (work, sleep, and physical activity) as simultaneous predictors of emotional exhaustion.

The current study aims at answering the following questions: Are the amounts of time spent in sleep, physical activity, and study related to emotional exhaustion? Are there any differences in the daily composition of sleep, physical activity, and study time between people with low and with high emotional exhaustion? Are the amounts of time spent in sleep, physical activity, and study associated with emotional exhaustion on a daily level?

### *Materials and Methods*

**Design and Participants.** We conducted a one-week daily sampling study to assess the relationship between physical activity, study time, and psychological well-being in undergraduate students, using a convenience sample. Guided by recommendations on sample size for multilevel analysis, suggesting a minimum of 50 observation units on Level 2 (Nezlek et al., 2006), we set our sample size at $N$ = 104 participants (89% female, mean age = 22.48 years, $SD$ = 4.32). As an inclusion criterion, participants had to be at least second-year students to ensure that they had already fully adapted to a daily student routine. The student sample was heterogeneous with the majority of participants (62.5%) attending psychology courses. Around 59% of the participants reported not working in part-time jobs, whilst the remaining 41.3% had an average workload of 4.24 h per week in their part-time jobs. As a compensation for participation, participants received either €25 or course credit. Data analyses were conducted after data collection was completed and no participants were excluded from the analysis. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and was approved by the local Ethics Committee of the University of Hildesheim, Hildesheim, Germany.

**Procedure.** Participants were recruited via e-mail or phone and scheduled for an appointment in our laboratory. Participants filled in a baseline questionnaire containing questions on demographic data. For the following eight days, participants wore an accelerometer continuously (see below for a detailed description) and answered paper-and-pencil questionnaires every morning regarding the previous day and night. These questions asked about in-bed time in the evening, out-of-bed time in the morning, time spent studying (in courses and individually), and emotional exhaustion. After one week the accelerometers were retrieved and participants were thanked, debriefed, and compensated. The current study was part of a larger study including additional questionnaires which are irrelevant for the current research question, and will, therefore, not be outlined in detail. Constructs measured additionally in the baseline assessment were chronic stress (*stress index*, L. Schmidt & Obergfell, 2011), life and study contentment (*life and study contentment scale*, Holm-Hadulla & Hofmann, 2007), study demands and control (*job content questionnaire – studies*, L. Schmidt & Obergfell, 2011), and resilience (*resilience scale*, Schumacher et al., 2005), as well as questions on consumption

behavior and sports. Constructs measured additionally on a daily level were subjective sleep quality (*Pittsburgh Sleep Quality Index*, Buysse et al., 1989) and study demands and control (*job content questionnaire – studies*, L. Schmidt & Obergfell, 2011).

**Assessment of Composition of the Day.** For the analyses, we considered the amounts of time spent in the following components of the 24 h day: Sleep, moderate to vigorous physical activity (MVPA), and study time. Sleep and MVPA were assessed using accelerometry (*ActiSleep+*; ActiGraph LLC, Pensacola, FL, USA). Accelerometers are small, lightweight devices designed to monitor spatial movements in three dimensions (Tryon, 2011). Participants wore the accelerometers continuously (day and night) for eight days on the wrist of their nondominant body side. We chose to attach the devices to the nondominant body side in order to avoid overestimation of movement behavior, since the dominant arm is in general used more often than the nondominant arm (Dieu et al., 2017). It should be mentioned that wrist-worn accelerometers are likely to entail the risk of overestimating movement behavior as the wrist is the most active site during wakefulness being involved in rather inactive types of behavior in contrast to, for example, the waist (Tryon, 2011). Nevertheless, we chose to attach the accelerometers to the wrist to ensure better compliance to wearing the devices continuously (Rosenberger et al., 2013). The Choi wear time validation (Choi et al., 2011) then served as an additional compliance check by identifying non-wear times. Following recommendations by Katapally and Muhajarine (2014) that only data with a wear time ≥10 h a day should be considered, no data had to be excluded from analyses. The mean wear time per person per day amounted to 23.99 h in our study.

The marginal days that were not monitored completely (the first and the last day of data assessment) were excluded from analysis, leaving six full days of 24 h for each participant. The computation of times spent in sleep and MVPA was carried out using the software *ActiLife 6* (ActiGraph Software Department, 2020). Sleep periods were detected automatically by the software using established algorithms (Sadeh et al., 1994), and were adjusted with participants' self-reports about their in-bed and out-of-bed times. Furthermore, for the computation of time spent in MVPA, every 60 s interval with ≥1952 counts (sample rate 30 Hz) was categorized as moderate to vigorous activity, using an algorithm developed by Freedson, Melanson, and Sirard (1998). Counts are derived by summing raw accelerometer data into epoch "chunks", wherein the values of the counts vary depending on the frequency and intensity of the raw accelerometer data (ActiGraph LLC, November 8th, 2018). Study time was measured via self-report every morning retrospectively for the previous day. Participants answered the following two questions: "How much time did you spend at university attending lectures yesterday?" and "How much time did you spend studying apart from attending lecture yesterday (e.g., home exams, preparing for exams)?". Participants indicated the respective times in hours. Both values were summed up to build the factor "study time".

Times spent in each of the three types of behavior (sleep, MVPA, study) were transformed into minutes per day and were averaged over all six days of data assessment. These proportions of time spent in sleep, MVPA, and study were then expressed as percentages of 24 h so that their sum (+ remaining, not-considered residual) equaled 100%.

**Assessment of Emotional Exhaustion.** To assess emotional exhaustion on a daily level, we constructed a German three-item short scale with items derived from two established scales for the assessment of burnout: The *Maslach Burnout Inventory* (MBI; Maslach et al., 1986) and the *Oldenburg Burnout Inventory* (OLBI; Demerouti et al., 2003). Items were adapted to the day level – "Did you feel emotionally exhausted yesterday?", "Did you feel worn out yesterday?", and "Last night, did you have the feeling of not having done enough, although you worked hard?" – and answered on a five-point Likert scale. The internal consistency of the emotional exhaustion scale was Cronbach's $\alpha = .85$. To obtain information about what the composition of the day looked like for participants reporting high or low emotional exhaustion, we divided participants into two groups of different levels of emotional exhaustion using a median split. Since the scale for emotional exhaustion ranged from 1 to 5 with higher values representing higher emotional exhaustion, participants with values <2.22 (median) were categorized as "lowly emotionally exhausted" and participants with values >2.22 were categorized as "highly emotionally exhausted".

**Socio-Demographic Data and Covariates.** Participants answered questions on socio-demographic variables (age, gender, children, field of study, semester, part-time job) during the first appointment in our laboratory directly before starting their one-week data assessment. In all following analyses, we included age and gender as covariates.

**Data Analysis Strategy.** Data analysis followed the compositional data approach suggested by Chastin et al. (2015). As an appropriate method of descriptive analysis of compositional data, the compositional mean was calculated. Furthermore, a variation matrix was used as a measure of dispersion. It shows the variability structure of the data by means of log-ratio variances (variances of the logs of all pairwise ratios between types of behavior), thereby accounting for the interdependent nature of compositional data (Chastin et al., 2015).

The daily proportions of time spent in sleep, MVPA, and study, as well as the daily measurements of emotional exhaustion, were averaged per person over all six days of data assessment. For the examination of the associations between proportions of time spent in the three types of behavior and emotional exhaustion, linear regression models were then computed.

In order to take the interdependence of the three different types of behavior into account, a compositional analysis based on isometric log-ratio (ilr) transformation (adapted from Hron et al., 2012, as suggested by Chastin et al., 2015) was implemented. In this approach, the composition of the daily time spent in sleep, MVPA, and study, rather than the individual types

of behavior, acts as the predictor variable (Chastin et al., 2015). All compositional analyses were conducted using the open source software *Physical Activity CoDa Regression Model* (PACRM) developed by McGregor et al. (2018).

Our study provides day-level information over the course of one week with a nested data structure (days nested in persons). Therefore, we further conducted a stepwise two-level hierarchical analysis using raw data. As day-level data (Level 1) are nested within the person level (Level 2) in our study, this procedure accounts for the interdependent nature of the two levels (Hox, 2002). In the multilevel analysis, regarding MVPA and study time, data from the same six days were used as in the compositional analysis, whereas sleep data were used from each previous night. To estimate variance components on both levels, we started with calculating an intercept-only model (null model) for emotional exhaustion. Model 1 includes the control variables age and gender (on Level 2), the Level 1 predictor variables (i.e., sleep duration, MVPA, and study time), and the averaged continuous Level 1 predictor variables to estimate the between-person relationships (Level 2). Finally, in a more exploratory manner, in Model 2, we additionally entered the interaction terms of the predictor variables of sleep duration, MVPA, and study time. We centered all day-level variables at the respective person mean and person-level variables at the grand mean (cf., Sonnentag et al., 2008). All models are presented with random intercepts and fixed slopes. All multilevel analyses were conducted using *Stata/IC 15.1* (StataCorp, 2017).

All multivariate analyses were adjusted for age and gender. Furthermore, regression assumptions were examined a priori. Table 8 displays means, standard deviations, and correlations between the variables. Predictors' means and standard deviations on Level 2 can be found in Table 9.

**Table 8**

*Means, Standard Deviations, and Correlations Between Study Variables*

| | | ***SD*** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|---|
| **1. Sleep** (Level 1, in minutes) | *M* = 400.57 | 79.92 | - | **-.27** | -.06 | -.03 | | |
| **2. MVPA** (Level 1, in minutes) | *M* = 184.58 | 75.12 | **-.31** | - | **-.23** | **-.13** | | |
| **3. Study** (Level 1, in minutes) | *M* = 259.95 | 183.73 | -.09 | **-.30** | - | **.26** | | |
| **4. Emotional Exhaustion** (Level 1) | *M* = 2.25 | 0.92 | -.01 | -.17 | **.29** | - | | |
| **5. Age** | *M* = 22.48 | 4.32 | -.07 | .18 | -.04 | -.05 | - | |
| **6. Gender**: Female | % = 89 | | -.13 | -.10 | -.06 | -.02 | -.05 | - |

*Note.* Correlations below the diagonal are person-level correlations (*N* = 104). Correlations above the diagonal are day-level correlations (*N* = 624). Correlations highlighted in bold are significant at $p < .01$. MVPA: Moderate to vigorous physical activity.

**Table 9**

*Standard and Compositional Descriptive Measures of the Proportions of Time Spent in Sleep, MVPA, and Studying: Arithmetic Mean (Standard Deviation in Parentheses) and Compositional Mean. Results Expressed in Percentage of 24 h*

| | Sleep | MVPA | Study |
|---|---|---|---|
| Arithmetic Mean | 27.91% (2.79) | 12.82% (3.77) | 18.05% (7.42) |
| Compositional Mean | 27.77% | 12.25% | 16.42% |

### *Results*

**Descriptive Statistics.** Standard and compositional descriptive statistics of the proportions of time (percentage of 24 h) spent in the three types of behavior (sleep, MVPA, study) were calculated and are displayed in Table 9. The compositional means are smaller compared with standard arithmetic means, which indicates an overestimation by standard descriptive statistics in compositional data. For example, the mean relative amount of time spent studying is overestimated by the arithmetic mean as compared with the compositional mean by 1.63% of the day, that is, by approximately 23 min a day.

As a measure of dispersion for compositional data, a variation matrix was calculated (see Table 10), where the variability of the data is represented by means of pairwise log-ratio variances. If a value is close to zero, the times spent in the two types of behavior involved in the ratio are highly proportional (Chastin et al., 2015). The variance of log(sleep/MVPA) = 0.12 is closest to zero in comparison with the other pairs of types of behavior. Thus, the highest proportional relationship or interdependence in the data exists between sleep and MVPA.

**Table 10**

*Compositional Variation Matrix of Time Spent in Sleep, MVPA, and Study: Pairwise Log-Ratio Variances*

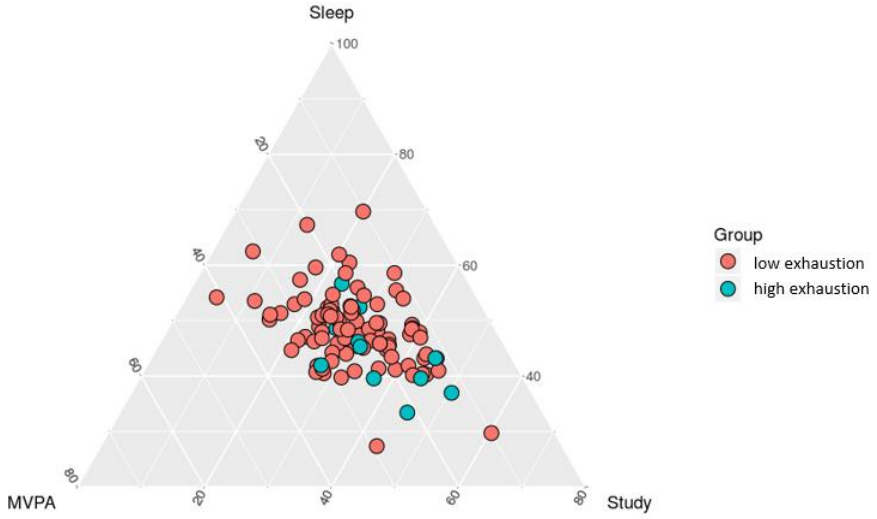
| | Sleep | MVPA | Study |
|---|---|---|---|
| **Sleep** | 0 | 0.12 | 0.24 |
| **MVPA** | 0.12 | 0 | 0.40 |
| **Study** | 0.24 | 0.40 | 0 |

Equivalent to scatterplots in standard descriptive statistics, ternary plots provide an overview of the distribution of compositional data (Chastin et al., 2015). Figure 1 displays a ternary plot of the distribution of the sample composition of time spent in sleep, MVPA, and

study. Participants with low (red) and high (blue) emotional exhaustion are displayed in different colors.

**Figure 1**

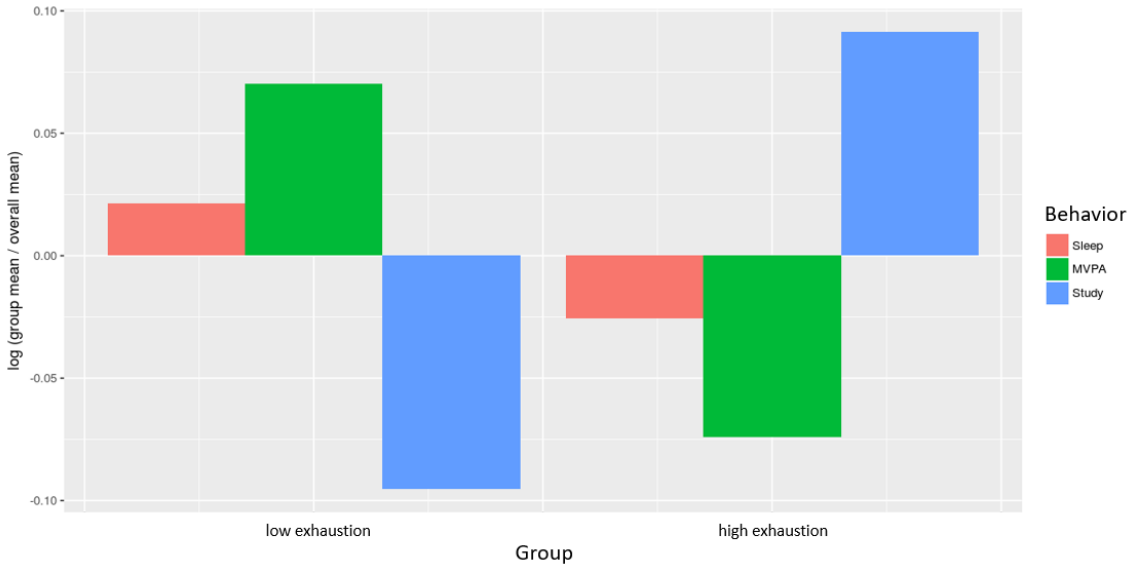
*Ternary Plot of the Sample Composition of Time Spent in Sleep, MVPA, and Study. Colored Points Represent Groups of Low (**red**) and High Emotional Exhaustion (**blue**)*




**Composition of the Day by Groups.** The composition of the day for the two different groups of lowly emotionally exhausted and highly emotionally exhausted participants is shown in Figure 2. For the compositional analysis of the relative distribution of times spent in the three types of behavior, for each group, the log-ratio between the group compositional mean and the overall compositional mean of the complete sample after centering the data was used (Chastin et al., 2015). Results show that for highly emotionally exhausted participants, time spent studying is around 9% higher (exp (0.09) = 1.094), whereas for lowly emotionally exhausted participants it is around 9% lower relative to the overall mean composition. For MVPA, an opposite effect occurs: for highly emotionally exhausted participants, time spent in moderate to vigorous physical activity is around 7% lower, whereas for lowly emotionally exhausted participants, it is around 7% higher relative to the overall mean composition.

**Figure 2**

*Composition of the Day by Groups of Low and High Emotional Exhaustion (Median Split) as Compositional Analysis of the Relative Importance of the Group Mean Time Spent in Sleep, MVPA, and Study with Respect to the Overall Mean Time Composition. The y Axis Displays the Log-Ratio Value*




**Linear Regression Models: Compositional Analysis.** The model with age and gender as covariates and proportions of sleep, MVPA, and study time as predictor variables explains the variance for emotional exhaustion ($R^2$ = .09). As a compositional method of analysis, the proportion of time spent in each type of behavior relative to the other two types of behavior was computed, and its impact on emotional exhaustion was tested. The proportion of time spent in MVPA relative to the other two types of behavior was significantly negatively related to emotional exhaustion (β = −0.29, *p* = .007), whereas the proportion of time spent studying was significantly positively related to emotional exhaustion (β = 0.45, *p* = .003). By contrast, there was no significant association between the proportion of time spent sleeping (relative to the other two types of behavior) and emotional exhaustion (β = −0.16, *p* = .141).

**Linear Regression Models: Multilevel Analysis.** Before conducting multilevel analyses, we calculated intraclass correlations to examine if emotional exhaustion varied within persons. Dividing the total variance into variance between and within persons showed that 52% of the total variance of emotional exhaustion can be attributed to within-person variations. Hence, in our study, a substantial part of the total variance lies within persons, emphasizing the volatility of emotional exhaustion and the benefit of an additional multilevel analysis (cf., Bakker et al., 2014). Table 11 shows information on model fit (differences of −2 × log) as well as estimates for fixed and random parameters. Model 1, which contained the

control variables age and gender as well as the predictor variables sleep duration, MVPA, and study time (on both Levels 1 and 2), showed significantly better model fit than the null model, which only contained the intercept, $\triangle -2 \times \log = 22.11$; $df = 8$; $p < .001$. Study time was a positive predictor of emotional exhaustion on the day level ($b = 0.001$, $p < .001$) and on the person level ($b = 0.002$, $p = .012$). However, sleep duration and MVPA did not show significant associations with emotional exhaustion (sleep Level 1: $b = -0.000$, $p = .240$, Level 2: $b = -0.000$, $p = .795$; MVPA Level 1: $b = -0.001$, $p = .173$, Level 2: $b = 0.001$, $p = .377$). For exploratory analyses, Model 2 additionally included interaction terms for the predictors, but did not show significantly better model fit than Model 1, $\triangle -2 \times \log = 4.21$; $df = 6$; $p = .209$. Study time still acted as a significant predictor of emotional exhaustion on Level 1, $b = 0.001$, $p < .001$, but not on Level 2, $b = 0.001$, $p = .055$. No other main effects were shown to be significant, and significant interaction effects were found neither between nor within persons (all $p > .05$).

**Table 11**

*Multilevel Estimates for Models Predicting Day-Level Emotional Exhaustion*

| | **Null Model** | | **Model 1** | | **Model 2** | |
|---|---|---|---|---|---|---|
| **Variable** | ***b*** | ***SE*** | ***b*** | ***SE*** | ***b*** | ***SE*** |
| Intercept | 2.254*** | 0.068 | 2.408*** | 0.434 | 2.331*** | 0.425 |
| Age | | | −0.005 | 0.015 | −0.005 | 0.015 |
| Gender | | | −0.046 | 0.218 | −0.013 | 0.215 |
| Sleep (Level 1) | | | −0.000 | 0.000 | −0.001 | 0.000 |
| Sleep (Level 2) | | | −0.000 | 0.002 | −0.000 | 0.002 |
| MVPA (Level 1) | | | −0.001 | 0.001 | −0.001 | 0.001 |
| MVPA (Level 2) | | | 0.001 | 0.001 | 0.002 | 0.001 |
| Study (Level 1) | | | 0.001*** | 0.000 | 0.001*** | 0.000 |
| Study (Level 2) | | | 0.002* | 0.001 | 0.001 | 0.001 |
| Sleep (Level 1) × MVPA (Level 1) | | | | | −0.000 | 0.019 |
| Sleep (Level 2) × MVPA (Level 2) | | | | | 0.000 | 0.000 |
| MVPA (Level 1) × Study (Level 1) | | | | | −0.013 | 0.010 |
| MVPA (Level 2) × Study (Level 2) | | | | | −0.004 | 0.000 |
| Study (Level 1) × Sleep (Level 1) | | | | | −0.003 | 0.007 |
| Study (Level 2) × Sleep (Level 2) | | | | | −0.000 | 0.000 |
| −2 × log(lh) | −729.91 | | −707.80 | | −703.59 | |
| Difference of −2 × log(lh) | | | 22.11*** | | 4.21 | |
| df | | | 8 | | 14 | |

*Note.* * $p < 0.05$. *** $p < 0.001$.

### *Discussion*

Research has identified time spent in physical activity, sleeping, and working as important predictors of emotional exhaustion and burnout (Nishimura et al., 2014; Söderström et al., 2012; Jonsdottir et al., 2010). The present study is the first to examine these three types of behavior as simultaneous predictors of emotional exhaustion. Since standard regression analyses are not able to take into account the compositional nature of such a data structure, a compositional approach based on isometric log-ratio (ilr) transformation was used (Chastin et al., 2015; Hron et al., 2012).

Our results show that the amount of time spent physically active (relative to the amount of time spent sleeping or studying) was significantly negatively related to emotional exhaustion. This finding is perfectly in line with earlier theorizing and empirical findings, supporting the assumption that physical activity may prevent burnout (Gerber et al., 2015; Häusser & Mojzisch, 2017). Furthermore, the amount of time spent studying (relative to the amount of time spent sleeping or in physical activity) was significantly positively related to emotional exhaustion. Thus, our study supports the hypothesis that long working hours may increase the risk of developing burnout symptoms (Iskera-Golec et al., 1996). By contrast, the results do not show any significant relation between the amount of time spent sleeping and emotional exhaustion, although sleep has already been shown to have an effect on mental health in earlier research (Söderström et al., 2012). Potential reasons for this inconsistency will be discussed in the Limitations section.

Since our study also provides day-level information over the course of one week, we conducted an additional stepwise multilevel analysis. On a more general level, this approach also contributes to the literature on effects of job demands on emotional exhaustion, as studies conducted in this field typically adopt a between-person perspective (see Häusser et al., 2010, for an overview). The day-level approach used in our study accounts for intra-individual fluctuations in work characteristics and well-being. The results of the multilevel analyses revealed that study time is significantly related to emotional exhaustion on both the person level and the day level. Hence, individuals spending higher amounts of time studying are at higher risk of developing emotional exhaustion. However, also within persons, long study days increase the immediate experience of emotional exhaustion. By contrast, neither sleep nor physical activity showed significant effects on emotional exhaustion.

In summary, both compositional and multilevel analyses show that the amount of time spent studying (attending lectures as well as studying apart from lectures) acts as a significant predictor for emotional exhaustion. By contrast, regarding physical activity, results from compositional analyses and multilevel analyses diverge: Physical activity was a significant predictor variable for emotional exhaustion in the compositional analysis, but not in the multilevel analysis. Albeit speculatively, a possible explanation could be that physical activity

does not instantly affect emotional exhaustion. Instead, physical activity may pay off in the long run: By regularly engaging in physical activity at any time during the week, one may build and maintain a steady level of fitness and resilience, which, in turn, may prevent the detrimental effects of (job) stress on psychological strain, as shown by, for example, Schmidt et al. (2016). It is further conceivable that the correlative relationship between physical activity and emotional exhaustion shown in the compositional analysis results from a reverse causation: people suffering from mental strain may overall engage less in physical activity (Roshanaei-Moghaddam et al., 2009).

Previous research has already shown that workload in student samples, similar to regular work, has an impact on burnout (Jacobs & Dodd, 2003; H.-J. Yang, 2004). Our study contributes to and extends these findings by showing that study time is positively associated with emotional exhaustion. In addition to studies identifying job characteristics as influential for psychological well-being (Häusser et al., 2010), and especially the amount of time spent working (Iskera-Golec et al., 1996), other studies suggest that off-job activities are also powerful predictors of burnout (Oerlemans & Bakker, 2014). Our results support this multicausal perspective on burnout by showing that off-job physical activity is negatively related to emotional exhaustion. The current study thereby emphasizes the importance of a healthy work-life balance and engagement in off-job activities, especially physical activity, as a compensation for work.

**Limitations.** Some limitations of our study have to be pointed out. The first limitation concerns the time lags between the predictor variables. To recap, participants filled in the questionnaires every morning regarding their study time on the previous day as well as emotional exhaustion on the previous evening. Time spent sleeping and in physical activity were continuously assessed using accelerometry. Conducting multilevel analysis, we examined the effects of time spent sleeping the previous night as well as time spent in physical activity and study during the ongoing day on emotional exhaustion on the subsequent evening. Therefore, the time lags between the different predictor variables and the outcome variable are not equally long in duration. Although it has to be noted that in daily diary studies different time lags are common, this may still have influenced the impact of the predictors under study and contributed to the fact that our results are not completely in line with earlier research, showing no significant effects of sleep and physical activity on emotional exhaustion. For example, sleep might be more predictive for well-being in the morning (cf., Sonnentag et al., 2008) as compared to well-being in the evening whereas study duration should be more predictive for well-being before going to bed.

Another limitation of our study is that rather low levels of emotional exhaustion were reported in our sample. For the illustration of the composition of the day by groups of lowly and highly emotionally exhausted participants, we therefore decided to use a median split of

the emotional exhaustion values. A partition of the sample by the center of the scale would not have been reasonable since the “highly emotionally exhausted” group would have contained considerably fewer participants (*N* = 12) than the “lowly emotionally exhausted” group (*N* = 92). This circumstance may be another reason for the absent effects of sleep on emotional exhaustion in the compositional analysis as well as of sleep and physical activity in the multilevel analysis. While study time is closely linked to emotional exhaustion – both conceptually and regarding measurement with self-report questionnaires – sleep and MVPA are not. Sleep and MVPA might be of particular importance as resilience and recovery factors when emotional exhaustion is more pronounced. In contrast, differences in study time might already have effects on low to medium levels of burnout, as it more directly translates into (self-reported) exhaustion. Although university students are a specific population of young adults, the prevalence of sleep deprivation was not unusually high as compared to a working population (Schoenborn & Adams, 2010). Since the average sleep duration of the study sample was 6.68 h per night, it is rather unlikely that the absence of relationships is due to floor effects in levels of sleep.

Furthermore, it should be mentioned that wrist-worn accelerometers are likely to overestimate movement behavior (see Tudor-Locke et al., 2015, for a comparison of step counts between waist- and wrist-worn accelerometers) as the wrist is the most active body part during wakefulness, being also involved in rather inactive behaviors in contrast to the waist (Tryon, 2011). Nevertheless, we decided to attach the accelerometers to the wrist as we assumed higher acceptance of and compliance to wearing the devices continuously during a whole week (Rosenberger et al., 2013). For the analysis of sleep and physical activity, we used an algorithm, developed by Freedson and colleagues (1998), that is suitable for the wrist as the wear site on the recommendation of the manufacturer (Willis, A., ActiGraph LLC, personal communication, March 20th, 2018). Still, we cannot rule out that physical activity measured in our study is somewhat overestimated and noisy (which might also explain the lack of an effect in the multilevel analyses).

Finally, study time and MVPA are not necessarily mutually exclusive time-use components, as time spent in MVPA and time spent studying may overlap. However, since there were no sports students included in our sample (or other students with physical exercise classes), we assume that there should be only little overlap between these two factors in our study.

**Implications for Future Research and Practice.** Our study focused on the compositional effect of time spent in physical activity, sleep, and study on emotional exhaustion. Although compositional analysis makes it possible to examine time spent in different activities during a 24 h period, we did not examine every single behavior carried out that day. The accelerometers used are indeed capable of monitoring a whole period of 24 h,

splitting the day into time spent sleeping, sedentary, and in light, moderate, and vigorous physical activity. In our study, we examined time spent studying which should have considerable overlaps with sedentary behavior. We, therefore, did not examine all possible classifications the accelerometry provides, but rather focused on self-reported study time, sleep, and moderate to vigorous physical activity. Nevertheless, future research could investigate the effects of 24 h movement behavior, including sleep, sedentary time, and time spent in light, moderate, and vigorous physical activity, on emotional exhaustion. Chastin and colleagues (2015), among others (Dumuid, Pedišić, et al., 2017; Hunt et al., 2018), already examined the associations of 24 h movement behavior with physical health. To our knowledge, no studies have been conducted examining the effects of 24 h movement behavior on psychological well-being and mental health in healthy adults so far (see Wong et al., 2017, for a study with adolescents). More generally, we like to emphasize that when examining movement behavior, it is important to account for the psychological quality of the specific behavior. For example, sedentary behavior is present while relaxing in an armchair, as well as while having a stressful job interview. Vigorous physical activity is present while jogging, as well as while running for the train (or away from the notorious sabretooth tiger). Hence, although identical from a mere physiological perspective, the specific reason for a physical activity might moderate its psychological effect on well-being and health. We strongly recommend future studies to account not only for the quantity and intensity of movement behavior but to also take reasons for movement and psychological quality into account.

The sample of the current study consisted of undergraduate students who overall scored rather low on emotional exhaustion, as outlined above. A suggestion for future research is to examine study populations with a broader range of emotional exhaustion, which would allow us to investigate whether factors that are more indirectly (e.g., via recovery) linked to emotional exhaustion, such as sleep, are of better predictive value when it comes to the upper end of the exhaustion continuum. Furthermore, the gender distribution in our student sample was unbalanced (89% female). Due to the small case numbers of male participants, we were not able to conduct meaningful analyses of gender effects. However, we have no (theoretical) reason to assume considerable gender effects regarding the interplay between study time, physical activity, and emotional exhaustion. Nonetheless, future studies should ensure an equal distribution of female and male participants.

Our findings are also of practical relevance. Our results suggest that it may be beneficial for mental health to carefully determine the appropriate amount of time spent working. Research has shown that a restriction of working hours can decrease emotional exhaustion (Gopal et al., 2005; Martini et al., 2006). Our study highlights that the same applies to workload in students. Hence, when developing study schedules at universities, it should be taken into account that studying is structurally similar to work and care should be taken to keep the

workload at a level that does not entail the risk of producing burnout. Furthermore, our results highlight the importance of time spent in physical activity for psychological well-being. It is, therefore, advisable to meet the public health recommendations for physical activity and engage in a minimum of 30 min of moderate physical activity on at least five days a week (World Health Organization, 2010). Universities and companies should be encouraged to provide possibilities to be physically active, for example, in the form of gym courses, running groups, or bike sharing programs to support students' and employees' health. On a societal level, policy-makers are challenged to develop work regulations that are suited to maintaining psychological well-being and that reduce work-life interferences.

**Conclusions.** In summary, our results show that considering the interdependent nature of different activities carried out during the day (i.e., sleeping, studying, and being physically active), time spent in physical activity is negatively related to emotional exhaustion. In addition, study time is positively associated with emotional exhaustion, both on a between-person level and on a day level within a person. In conclusion, these findings suggest that emotional exhaustion is not only associated with work-related factors, but also with off-job activities – more specifically, engagement in physical activity. As a consequence, the composition of one's day is important for the prevention of emotional exhaustion and, therefore, for the maintenance of psychological well-being and mental health.

# Chapter 4: Reactivity to Actigraphy-Based Measurement of Sleep (Study 5)

In psychological research, behavior is often measured using self-reports. In doing so, researchers have to face several difficulties potentially distorting their results, such as recall bias or social desirability bias (König et al., 2022). Besides that, another potential problem is the occurrence of reactivity to measurement. Reactivity to measurement refers to the circumstance that participants, as a reaction to their knowledge on being observed, may alter their behavior, emotions or cognitions (D. P. French & Sutton, 2010).

For sleep as a research subject, the outlined biases are not unlikely to occur: In terms of a recall bias, participants might simply not remember their sleep times correctly, especially when asked retrospectively (Coughlin, 1990). But even if they do remember, being aware of the common conventions for sleep (e.g., a sleep duration between 7h and 9h for healthy adults; Hirshkowitz et al., 2015), it is conceivable that participants are tempted to answer in a socially desirable way, which could lead to both an over- and underestimation of their actual sleep duration. With regards to measurement reactivity, participants might alter their sleep habits during the study as a consequence of their awareness of being observed, and, thereby, distort the results. However, similarly to a social desirability bias, the direction of the alteration is equivocal: For sleep duration, on the one hand, “the more, the better” is not always valid. According to the National Sleep Foundation, for healthy adults, sleep durations of less than six or more than ten hours are not recommended (Hirshkowitz et al., 2015). Therefore, depending on participants’ usual sleep duration, measurement reactivity might result in either an over- or an underestimation. For sleep quality, on the other hand, the “right” direction is not as ambiguous as for sleep duration, but it is much more difficult to control. Still, it is conceivable that measurement reactivity occurs in the way that participants try to eliminate potentially disturbing factors such as irregular sleep times, exercising shortly before going to bed, or the intake of caffeine or alcohol in the evening (i.e., methods of sleep hygiene, cf., Stepanski & Wyatt, 2003) in order to increase their sleep quality.

A crucial advantage of objective measures is their potential to overcome several limitations of self-report measures including recall bias or social desirability bias (König et al., 2022). Also, especially self-report measures are prone to measurement reactivity (see Miles et al., 2020, for a review) which is why the use of (more) objective measures is advised in many cases. Nevertheless, studies on health behavior come to the conclusion that measurement reactivity might also be a problem – at least to a small degree – when using digital and objective collection methods. These studies mostly focus on physical activity as an outcome (see König et al., 2022, for a review), but have yet to consider sleep as an outcome.

Derived from the review by König and colleagues (2022) and the considerations above, reactivity might also occur when using portable measurement devices such as actigraphy in order to ambulatory assess sleep (as in *Studies 2, 3, & 4*), that is, participants might alter their sleep habits as a consequence of their awareness of being observed. Still, it is questionable if these alterations are, ultimately, reflected in distorted results: Sleep quality is quite difficult to control, limiting the possibility of measurement reactivity. Sleep duration, on the other hand, can more easily be altered, though, there is no unambiguously "right" direction for the alteration of sleep duration (cf., Hirshkowitz et al., 2015). In order to address this research gap, I conducted a separate study for the investigation of measurement reactivity in the context of the actigraphic assessment of sleep.

Actigraphs are small, lightweight devices that monitor spatial movements in three dimensions and that can be worn on different body sites, whereby most often the wrist, the waist or the ankle are used. The decision on the site of attachment is usually made depending on the behavior of interest. In this project (i.e., *Studies 2, 3, & 4*), devices were attached to the wrist, since the wrist – being the most active body part during wakefulness – is the site of choice for the assessment of sleep (Tryon, 2011). As a positive side effect, the wrist as wear site increased participants' compliance with wearing the devices continuously throughout the assessment due to disposable wristbands that could not be occasionally taken off.

**Methods**

One-hundred and eight undergraduate students took part in a two-week field experiment with continuous ambulatory assessment of sleep using actigraphy (*ActiSleep+* and *wGT3X-BT* devices, ActiGraph LLC). Similar to Studies 2, 3, and 4, devices were worn on the wrist of the non-dominant body side. As a within-person factor in a one-factorial experimental design, the communicated measurement intention was manipulated. To this end, actigraphs of different colors were used: In one week, participants received a black device (*ActiSleep+*) and were informed that it would monitor sleep. In the other week, participants received a red device (*wGT3X-BT*) and were informed that it would monitor physical activity. Actually, devices of both colors monitored both physical activity and sleep and only differed in their color. The order of the communicated measurement intention was randomized between participants. As an intensification of the manipulation, participants answered short daily questionnaires that asked questions about either their sleep (when wearing a black device) or their physical activity (when wearing a red device) on each day. All participants gave their informed consent. As compensation for their participation, they received 20 €. Seventeen participants had to be excluded from the analysis because of incomplete data sets. The final sample comprised ninety-one undergraduate students (92% female) with an average age of 21.62 years (*SD* =

4.71). This study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee.

I used the software *ActiLife 6* (ActiGraph Software Department, 2020) and established algorithms (Cole et al., 1992) to estimate sleep periods and to calculate two indicators of sleep, sleep efficiency and sleep duration, as these two indicators were also used in Studies 2, 3 and 4. Sleep duration constitutes the total number of minutes scored as "asleep", and sleep efficiency is defined by the number of sleep minutes divided by the total number of minutes the participant was in bed (ActiGraph Software Department, 2012). Sleep parameters were averaged per person over all seven days of assessment week 1 and assessment week 2, respectively. Participants slept on average $M$ = 429.49 minutes ($SD$ = 47.10) in the "sleep" week (i.e., when the communicated measurement intention was sleep), and $M$ = 432.78 minutes ($SD$ = 53.48) in the "physical activity" week. Sleep efficiency amounted to $M$ = 91.30% ($SD$ = 3.18) in the "sleep" week and $M$ = 91.27% ($SD$ = 3.24) in the "physical activity" week. I conducted paired $t$-tests (two-tailed) and calculated Bayes factors using *JASP* (version 0.14.1; JASP Team, 2020) in order to investigate potential effects of the communicated measurement intention on the outcome variables (i.e., sleep duration and sleep efficiency).

**Results**

Results showed no significant effect of the communicated measurement intention, neither regarding sleep efficiency, $t(90) = -0.13$, $p = .901$, nor regarding sleep duration, $t(90) = 0.64$, $p = .522$. The corresponding Bayes factors are clearly in favor of the null hypotheses ($BF_{01} = 8.57$ for sleep efficiency, $BF_{01} = 7.06$ for sleep duration).[9]

**Discussion**

Regarding the assessment of health behavior, previous research gave rise to the assumption that measurement reactivity might not only occur in self-reports, but also when using digital and (more) objective data collection methods such as actigraphy. Thereby, most of these studies focused on physical activity as an outcome: In their review, König et al. (2022) report a small, but significant pooled effect size (Cohen's $d$ = 0.27) regarding reactivity to measurement in digital assessment of physical activity. However, previous studies did not take sleep as an outcome into account. Thus, I aimed at closing this research gap.

The results of this study show no reactivity to the actigraphic measurement of sleep (i.e., sleep efficiency and sleep duration). These findings suggest that results obtained from actigraphy in Studies 2, 3, and 4, as well as results obtained from actigraphy in general, can

[9] In Study 4, actigraphy was used as an objective measurement of physical activity as well. Therefore, besides sleep parameters, I also investigated time spent in moderate to vigorous physical activity (MVPA) as an outcome. Results showed no significant effect of the communicated measurement intention regarding MVPA, $t(90) = -0.91$, $p = .364$, $BF_{01} = 5.78$, indicating an absence of measurement reactivity regarding physical activity in the context of actigraphic assessment.

be deemed reliable in terms of measurement reactivity. Actigraphy seems to constitute a reliable way for a more objective assessment of sleep parameters in addition to self-reports. The absence of reactivity to measurement might possibly be explained due to the fact that sleep parameters are either less controllable (cf., sleep quality) or equivocal in the direction they should be altered to (cf., sleep duration: both too short and too long sleep durations are not recommended, Hirshkowitz et al., 2015), as compared to other health behaviors such as physical activity.

This study comprises some methodological advantages. In order to investigate reactivity to measurement in the context of the actigraphic assessment of sleep, I manipulated the communicated measurement intention (sleep vs. physical activity) in a within-subject design. For the investigation of measurement reactivity in the context of digital and objective assessment of health behavior, previous studies mostly used observational within-subject designs and tested whether behavior changed across the study period. Some studies also compared different types of devices in an experimental design, either between or within participants, with most of them concealing the actual use of the device, at least in the first part of the study (see König et al., 2022, for a review). For my field-experimental within-subject design, I used different actigraph devices (ActiGraph LLC) that looked identical except for their color (i.e., black or red) in order to manipulate the communicated measurement intention. Both black and red devices continuously assessed sleep and physical activity. Unlike previous studies, the measurement intention (sleep vs. physical activity) was communicated openly to participants, and participants answered daily questionnaires on either their sleep or their physical activity, intensifying the manipulation. These advantages in design reduce the danger of reciprocal or reversed causation. Additionally, the naturalistic setting of this study increases the validity of its results. Future studies should extend this research, for example, by using fitness trackers that offer the possibility of providing participants with feedback during data assessment in order to investigate whether reactivity occurs when the manipulation is further intensified.

# Chapter 5: General Discussion

This dissertation comprises three major research goals:

(1) The investigation of work-related antecedents of (poor) sleep. Specifically, I investigated the relationship between job demands and sleep as well as the mediating role of work-related rumination for this relationship. Work-related stressors have been shown to be related to perseverative cognition which, in turn, is related to sleep (e.g., van Laethem et al., 2018). However, for work-related rumination as a specific type of perseverative cognition, previous studies provide inconclusive results regarding its mediating role (e.g., Syrek et al., 2017; Vahle-Hinz et al., 2014). In order to address shortcomings of these previous studies, I considered both self-reported and actigraph-measured sleep quality and sleep duration, and examined both within-person and between-person effects.

(2) The investigation of mutual consequences of time spent working and time spent sleeping on emotional exhaustion. Previous research identified time spent working (e.g., Nishimura et al., 2014) and time spent sleeping (e.g., Söderström et al., 2012) as predictors of emotional exhaustion, but these studies examined the two predictors separately. In order to consider the compositional nature of time-use components such as work and sleep, I investigated the relations between time spent working and time spent sleeping with emotional exhaustion simultaneously using a compositional data analysis approach.

(3) A methodological examination of actigraphy as an objective measurement of sleep, that is, an investigation of potential reactivity to the actigraphic measurement of sleep. Objective measurements such as actigraphy yield the potential of overcoming several limitations of self-report measurements such as recall bias or social desirability bias, but results might still be biased due to reactivity to measurement (König et al., 2022). Regarding sleep as an outcome, reactivity to measurement in the context of actigraphy has not been investigated to date, thus, I aimed to close this research gap.

## Summary of Results and Theoretical Contributions

### *Reactivity to Actigraphy-Based Measurement of Sleep* (Study 5)

Throughout this dissertation, I used actigraphy (*ActiSleep+* and *wGT3X-BT* devices, ActiGraph LLC) as an objective measurement of sleep in addition to self-reports. In particular, I examined sleep duration and sleep efficiency as objective sleep parameters. In order to test the reliability of actigraphy as an objective method of measurement, I investigated potential reactivity to measurement in the context of the actigraphic assessment of sleep in Study 5, conducting a field experiment. The results of this study showed no measurement reactivity regarding actigraph-measured sleep parameters (i.e., sleep duration, sleep efficiency). These findings support the assumption that actigraphy constitutes a reliable method in terms of

measurement reactivity and, thus, can be deemed useful in order to measure sleep in a more objective manner. As a consequence, results obtained from actigraphy in this dissertation (cf., *Studies 2, 3, & 4*) can be deemed reliable with regard to measurement reactivity.

***Job Demands, Work-Related Rumination, and Sleep* (Studies 1, 2, & 3)**

In the following, the results obtained from Studies 1, 2, and 3 will be discussed separately for the outcome variables subjective sleep quality[10] and sleep duration.

**Subjective Sleep Quality.** Constituting the main finding of this dissertation, across three studies (*Studies 1, 2, & 3*), I found robust evidence for an indirect effect of job demands on subjective sleep quality through work-related rumination. This finding is in line with previous research showing that perseverative cognition mediates the relationship between work-related stress and sleep (e.g., van Laethem et al., 2015, 2018). Sleep constitutes an important recovery mechanism (de Lange et al., 2009). As described in the *stressor-detachment model* (Sonnentag & Fritz, 2015) and the *perseverative cognition hypothesis* (Brosschot et al., 2005, 2006), perseverative cognitive representations of work-related stressors during non-work time impede psychological detachment from work. Thus, even if recovery time is sufficient in a quantitative manner, the available recovery time is qualitatively impaired (Geurts & Sonnentag, 2006). In agreement with these theoretical considerations, the results of Studies 1, 2, and 3 show that strain reactions caused by job demands are prone to be prolonged in the form of work-related rumination in the evening and even further in the form of reduced subjective sleep quality during the night.

For an explanation of the indirect effect of job demands on subjective sleep quality via work-related rumination, potential underlying mechanisms need to be discussed. Thereby, both the a-path and the b-path need to be focused on. Regarding the a-path (i.e., the relation between job demands and work-related rumination), it might play an important role if individuals have the chance to finish their (highly demanding) work tasks within the work day: As research indicates, prolonged activation of a work stressor in the form of rumination during non-work time is especially fostered by unfinished tasks at the end of a work day (Syrek et al., 2017). Regarding the b-path (i.e., the relation between work-related rumination and subjective sleep quality), it might be important how individuals spend their leisure time between the end of the work day and the beginning of sleep. A recent study showed that, for example, physical activity after work can suppress ruminative processes (Junker et al., 2022). Hence, spending leisure time physically active could help to prevent the translation of work-related rumination

[10] For sleep efficiency as an objective parameter of sleep quality, the mediation of work-related rumination only appeared in Study 3, and only on the day level. This inconsistent pattern of results regarding sleep efficiency as an outcome is discussed in the article in Chapter 2: “Sorrow till Tomorrow: Work-Related Rumination Mediates the Relationship Between Job Demands and Sleep Quality but not Quantity”.

into reduced subjective sleep quality. In addition to these considerations, moderator variables on the person level should be addressed: Studies give rise to the assumption that certain person characteristics such as negative affectivity or neuroticism are negatively associated with detachment (Wendsche & Lohmann-Haislah, 2017). Directions for future research to shed further light on the underlying mechanisms of the relations will be further discussed in the *Limitations and Implications for Future Research* section.

***Person-level versus day-level effects.*** The mediation consistently unfolded on the person level as well as on the day level (cf., *Studies 2 & 3*). Thus, on the one hand, there are highly dynamic associations between job demands, work-related rumination and subjective sleep quality: Job demands experienced on a specific day are positively related to work-related rumination before going to bed that day, which, in turn, is negatively related to subjective sleep quality of the subsequent night. Additionally, there are more stable and habitual associations on the inter-individual level: Generally higher job demands are related to generally higher work-related rumination, which in turn is related to generally lower sleep quality.

These findings provide insights into temporal aspects of the relations. The manifestation of the associations on the person level (cf., *Studies 1, 2, & 3*) shows that sleep quality is prone to become chronically reduced as a reaction to generally high job demands and work-related rumination, constituting a serious risk for well-being in general (Hale et al., 2020). In contrast, the day-level associations (cf., *Studies 2 & 3*) are of minor relevance for general well-being, considered in isolation: If an individual experiences low sleep quality during the night from Monday to Tuesday due to high job demands and work-related rumination on Monday, they can, nevertheless, experience high sleep quality during the night from Tuesday to Wednesday and the rest of the week if job demands and work-related rumination then are low. Thus, the short-term associations on the day level need not inevitably translate into detrimental effects in general. However, in order to prevent individuals from developing stable patterns of (impaired) sleep in the long run, an adjustment of circumstances often needs to be made on the day level, emphasizing the relevance of day-level associations. Concrete action recommendations regarding the design of healthy work environments and the reduction of work-related rumination in order to promote and maintain high sleep quality will be discussed as practical implications below.

***Experimental Mediation Test.*** Since the mediation-by-measurement design I used in Studies 1, 2, and 3 might be biased by reciprocal or reversed causation, I additionally conducted an experimental mediation test in Study 3. Therefore, I implemented a manipulation of work-related rumination by the use of an intervention designed to suppress undesired rumination (“thought-stopping technique”; see Tyron, 2015). However, the manipulation did not work as expected: Even though the amount of reported work-related rumination differed significantly between the experimental and the waiting control group, rumination was not totally

suppressed in the experimental group. Therefore, the possible inferences regarding causality are limited. I decided to use the thought-stopping technique for two reasons: First, according to clinical experience, the thought-stopping technique constitutes an effective intervention method (Tyron, 2015). Beyond that, it is simple to apply by participants themselves. However, regarding reasons for the unsuccessful manipulation, most likely the applied intervention was not strong enough. Future studies should address this and select other intervention methods that might be more effective in order to totally suppress work-related rumination, which would allow for an experimental mediator test and the investigation of causality assumptions. Besides looking out for stronger interventions that specifically target the suppression of rumination, it is also reasonable to think about other mechanisms that serve the same purpose. For example, in order to successfully detach from work during non-work time, Sonnentag and Fritz (2015) suggest engaging in activities that are unrelated to work. Physical activity has especially been hypothesized to foster psychological detachment from work (Naczenski et al., 2017). In line with that, and as mentioned above, Junker et al. (2022) showed that physical activity after work can suppress ruminative processes. In their study, affective rumination directly after work mediated the relationship between quantitative job demands and affective rumination before going to bed, but only on days without physical activity: Being physically active (i.e., going for a walk or running) after work stopped the association between affective rumination directly after work and affective rumination before going to bed. Thus, physical activity (or other low-duty off-job activities such as social activities or engaging in a hobby, cf., Sonnentag et al., 2022) might be even more effective for diminishing work-related rumination than interventions explicitly designed to suppress rumination.

**Sleep duration.** For sleep duration as an outcome, across all three studies (*Study 1, 2, & 3*) no mediation of work-related rumination was found, neither on the person level nor on the day level (cf., *Studies 2 & 3*). The non-significant mediation is not only consistent across levels, but also regarding self-reported and actigraph-measured sleep duration. In Study 1, sleep duration was assessed using self-reports, whereas Studies 2 and 3 included actigraphy as a more objective manner to assess sleep duration in order to prevent potential problems of self-reports such as recall bias (König et al., 2022). For actigraph-measured sleep duration, a previous study showed that the devices I used for the objective assessment of sleep duration in Studies 2 and 3 (ActiGraph LLC) provide comparably high accuracy regarding total sleep time in comparison with polysomnography (Quante et al., 2018). Also, the results obtained from Study 5 in this dissertation plead for an absence of reactivity to measurement in the context of the actigraphic assessment of sleep, thus, it is unlikely that the non-significant results regarding a mediation of work-related rumination for the relationship between job demands and actigraph-measured sleep duration are due to methodological reasons.

Even though job demands consistently showed significant associations with work-related rumination across all three studies (i.e., *Studies 1, 2, & 3*), work-related rumination was not significantly associated with (self-reported and actigraph-measured) sleep duration. In this context, two aspects have to be pointed out:

First, previous research indicates that both job demands and rumination can foster exhaustion (e.g., Demerouti et al., 2001; Geisler et al., 2019). Thus, in contrast to the potential of rumination to keep one awake and to delay sleep, the need for sleep might simultaneously be increased due to the exhaustion caused by job demands and rumination. These counteractive processes might, finally, result in a non-significant association between work-related rumination and sleep duration as shown in Studies 1, 2, and 3. In order to get a deeper insight into rumination and its consequences, different kinds of rumination should be considered. Cropley & Zijlstra (2011) point out that rumination indeed prevents detachment from work and, thereby, hinders recovery, but rumination is not inevitably negatively connoted. The authors differentiate between affective rumination and problem-solving pondering: Whilst affective rumination describes a state of intrusive and perseverative thoughts that are affectively negative and difficult to control, problem-solving pondering comprises constructive thoughts that can help to improve work-related situations or to solve work-related problems. Thereby, other than affective rumination, problem-solving pondering does not involve an increased negative activation and, thus, prolonged arousal (Cropley & Zijlstra, 2011). Supporting this, previous research showed that affective rumination is negatively related to the process of recovery, whereas problem-solving pondering is not (Vahle-Hinz et al., 2017). In addition, studies give rise to the assumption that only affective rumination, but not problem-solving pondering functions as a mediator for the relationship between work and sleep (e.g., Syrek et al., 2017). Thus, future studies should differentially investigate affective rumination and problem-solving pondering in order to discover their potentially divergent consequences.

Second, the ambiguity of sleep duration as an outcome needs to be discussed. Unlike sleep quality, for sleep duration as a parameter, “the more, the better” is not always valid: The National Sleep Foundation suggests a sleep duration between 7h and 9h for healthy adults and advises against sleeping less than six or more than ten hours (Hirshkowitz et al., 2015). Supporting these recommendations, Åkerstedt et al. (2021) showed a U-shaped association between sleep duration and mortality, with both short (<6.5h) and long sleep durations (≥9.5h) being potentially detrimental with regard to mortality. In addition to this, the optimum sleep duration is highly individual with some people needing much more sleep to feel recovered than others. For example, the optimum sleep duration seems to differ between groups of different ages (e.g., Åkerstedt et al., 2021). Future studies should consider participants’ sleep duration optima and assess sleep quantity as a relative instead of an absolute parameter, for example, by using deviations from these optima as an indicator for sleep duration on a daily basis.

**Job Demands, Work-Related Rumination, and Sleep: Summary.** Taken together, the findings of this dissertation suggest that job demands are related to subjective sleep quality via work-related rumination, but not to (self-reported and actigraph-measured) sleep duration. Sleep quality and sleep duration seem to depict categorically different aspects of sleep, which is also underlined by comparatively small correlations between these two parameters in my data (all $r \leq |.19|$, including subjective sleep quality x self-reported sleep duration in Study 1, and subjective sleep quality x actigraph-measured sleep duration in Study 2 and Study 3, the latter both on the person level and the day level). Even though some of these correlations are statistically significant, they do not represent strong relationships in a practical sense: Subjective sleep quality and (self-reported and actigraph-measured) sleep duration are considerably inappropriate for predicting one another. This emphasizes the importance of considering both sleep quality and sleep duration when analyzing sleep in order to obtain an overall picture.

***Work, Sleep, and Emotional Exhaustion* (Study 4)**

In addition to the main question on the relationships between job demands, work-related rumination and sleep, I examined mutual consequences of time spent working and time spent sleeping for emotional exhaustion. The results show that time spent working is positively related to emotional exhaustion, relative to the remaining two considered time-use components (i.e., time spent sleeping, time spent in physical activity). This finding is in line with earlier research showing associations between working hours and emotional exhaustion (e.g., Gopal et al., 2005; Iskera-Golec et al., 1996; Martini et al., 2006; Nishimura et al., 2014) and is also in line with the definition of burnout, already implying work to be an antecedent of burnout (Schaufeli & Greenglass, 2001). In contrast to previous research that showed negative associations between sleep duration and burnout symptoms (Söderström et al., 2012; Wolf & Rosenstock, 2017), time spent sleeping was not significantly associated with emotional exhaustion, relative to the remaining two time-use components (i.e., time spent working, time spent in physical activity). Similarly to Studies 2 and 3, I used actigraphs (ActiGraph LLC) in order to objectively assess sleep duration. Again, it is unlikely that the non-significant association between time spent sleeping and emotional exhaustion is induced by methodological reasons, since the potential occurrence of reactivity to measurement in the context of the actigraphic assessment of sleep was ruled out in Study 5. One potential reason lies in the time of day emotional exhaustion was assessed: Participants were asked about their emotional exhaustion at night, though previous research gives rise to the assumption that sleep duration might be associated with well-being in the morning rather than with well-being in the evening (Sonnentag et al., 2008).

Taken together, the results suggest that time spent working is positively related to emotional exhaustion, whereas time spent sleeping and emotional exhaustion are not significantly related. These findings emphasize the relevance of the composition of one's day for the prevention of emotional exhaustion. In comparison with a separate analysis of work and sleep, the compositional analysis of time spent working and time spent sleeping considers the interdependence of these two time-use components that arises from the daily time limit of 24 hours. Thus, compositional analysis allows for a more valid approach to understanding how time use (i.e., how an individual allocates his or her time during the 24 hours of a day) is related to well-being.

**Methodological Considerations**

This dissertation comprises several methodological considerations. For the investigation of the relations between job demands, work-related rumination and sleep, I considered methodological issues that previous research missed out on: I applied different study designs, including a whole week of ambulatory assessment, the consideration of both person-level as well as day-level effects and different operationalizations of sleep (i.e., subjective and objective sleep parameters, sleep quality and sleep duration). These considerations are important in order to gain insight into temporal aspects of the relations and to find out which parameters of sleep are specifically affected by job demands and work-related rumination.

Investigating mutual consequences of time spent working and time spent sleeping for well-being, I took the compositional nature of these two time-use components into account that arises due to the daily limit of 24 hours. Previous research examined work and sleep independently, i.e., in separate study designs, and, thereby, neglected their interdependence. In order to adequately investigate the associations of time spent working and time spent sleeping with emotional exhaustion, I examined the two predictors simultaneously using a compositional data analysis approach (see Chastin et al., 2015, for an overview).

Finally, in order to investigate potential reactivity to measurement in the context of the actigraphic assessment of sleep, I conducted a two-week field experiment using a within-subject design. I used actigraph devices (ActiGraph LLC) that continuously assessed sleep and physical activity, and that were of different colors (i.e., black or red) in order to manipulate the communicated measurement intention (i.e., sleep vs. physical activity, respectively). Unlike previous studies (see König et al., 2022, for a review), the measurement intention was communicated openly to participants, and participants answered daily questionnaires on either their sleep or their physical activity, intensifying the manipulation. These advantages in design reduce the danger of reciprocal or reversed causation. Additionally, the naturalistic setting of this study increases the validity of its results.

**Limitations and Implications for Future Research**

Some limitations of this dissertation have to be pointed out. In Studies 1, 2, and 3, I investigated the effects of job demands on work-related rumination and sleep. For these analyses, I assessed job demands as a broad construct. However, job demands comprise many different aspects of the job and are typically divided into cognitive, emotional and physical stressors (Karasek & Theorell, 1990). Cavanaugh et al. (2000) provide another classification, differentiating between challenging and hindering job demands. According to their *challenge-hindrance framework*, hindrance demands (e.g., role conflicts, bureaucracy) cause undesired constraints that impede the achievement of work-related goals, whereas challenge demands (e.g., responsibility, task complexity) are worth the discomfort they cause by also providing an opportunity to learn, to develop and to achieve work-related goals (Cavanaugh et al., 2000). Previous studies give rise to the assumption that the effects of challenge vs. hindrance demands also diverge regarding work-related rumination and sleep as outcomes (e.g., Bennett et al., 2018; K. A. French et al., 2019; van Laethem et al., 2019). Taking this into account, future studies should distinguish between challenge and hindrance demands in order to learn about their – potentially divergent – effects on work-related rumination and sleep.

The results of Studies 1, 2, and 3 show an indirect effect of job demands on subjective sleep quality through work-related rumination: The higher the job demands the participants reported, the more they experienced work-related rumination at night, and the lower they rated their sleep quality. However, regarding (self-reported and actigraph-measured) sleep duration, no indirect effect was found. Thus, sleep duration is not accountable for the reduced subjective sleep quality. The question arises as to which aspects of sleep are instead responsible for participants' subjective perception of a lower sleep quality. Regarding sleep efficiency as an outcome, there was no consistent mediation through work-related rumination. Sleep efficiency – a parameter used as an objective indicator of sleep quality – is calculated as the time spent sleeping divided by the total time spent in bed. Thereby, aspects regarding the initiation of sleep and the maintenance of sleep during the night are considered in sleep efficiency. However, these aspects seem to be unaffected by job demands and work-related rumination and, thus, cannot be responsible for participants' lower perception of sleep quality. Instead, other aspects must be accountable. Future studies should further elucidate the aspects of sleep that underlie the relationship between work-related rumination and subjective sleep quality. Thereby, different sleep phases (e.g., REM vs. nonREM sleep) and the frequency of their occurrence could be focused on, as well as dreams (i.e., dream content, dream affect, dream duration). Providing first evidence for the involvement of these more 'content-related' aspects of sleep, Barnes et al. (2021) found a mediation of rumination for the relationship between demands and dream affect.

Finally, regarding the relationship between time spent working and well-being, I focused on emotional exhaustion, which constitutes the key dimension of the burnout construct (Maslach et al., 2001), as an indicator of well-being. However, in order to broaden the picture and to generalize the results, future studies should take other indicators of well-being into account, especially because evidence on the relations between long working hours and psychological well-being is equivocal (see Ganster et al., 2018, for a review). Thereby, objective indicators of well-being should also be considered. Previous research shows small, but significant associations between long working hours and objective outcomes of well-being and health such as coronary heart disease (Ganster et al., 2018). On another note, future studies should explicitly examine work-related indicators of well-being such as job satisfaction or work-life balance. For example, Valcour (2007) showed that time spent working is negatively related to satisfaction with work-family balance. Previous studies also indicate the importance of context variables, such as individual preferences regarding the number of working hours: Lee et al. (2015) showed that congruence between the preferred and the actual number of working hours can be beneficial for job satisfaction. However, when examining associations between time spent working and well-being, including the discussed indicators, researchers should always take the compositional nature of time-use components into account and investigate working hours only in the context of time spent in other activities throughout the day.

**Practical Implications**

Subjective sleep quality and emotional exhaustion are highly relevant for further occupational and well-being outcomes: Emotional exhaustion represents the key dimension of the burnout construct (Maslach et al., 2001) and is, therefore, an important indicator of well-being. Subjective sleep quality, on the other hand, can affect and impair occupational outcomes, for example, job satisfaction, engagement, and performance (e.g., Kucharczyk et al., 2012; Schleupner & Kühnel, 2021), and is also related to well-being (Giorgi et al., 2018). In order to ensure the health and well-being of their employees, the promotion and maintenance of high subjective sleep quality as well as low emotional exhaustion should be an organization’s concern. To this end, derived from the results of this dissertation, especially two aspects need to be addressed:

(a) Healthy work environments: Organizations should promote healthy work environments that do not foster work-related rumination during non-work time. Therefore, on the one hand, qualitative aspects of work should be focused on, for example, by limiting job demands to a healthy amount (Karasek & Theorell, 1990). Furthermore, as mentioned above, Syrek et al. (2017) showed that especially unfinished tasks at the end of the week are related to affective rumination during the weekend. In order to prevent employees from ruminating

during non-work time, it might help if organizations would provide the opportunity of flexible working hours. Thus, employees might have a better chance to finish their tasks before the end of the work day. On the other hand, organizations should also keep an eye on quantitative aspects of work, that is, the mere amount of working hours. Research shows that a restriction in working hours can decrease emotional exhaustion (Gopal et al., 2005; Martini et al., 2006). However, this somewhat contrasts with the flexibility of working hours, thus, both must be carefully weighed up.

(b) Reduction of work-related rumination during non-work time: A recent study gives rise to the assumption that an employee's work-related rumination is not only triggered by the work context itself, but also by their leader's work-related rumination (Matick et al., 2022). Together with the fact that the alteration of work environments is often difficult to realize, this finding emphasizes the importance of directly focusing on the reduction of work-related rumination and the prevention of its translation into (low) sleep quality. In order to effectively reduce rumination, different mechanisms are conceivable, for example, applying an intervention explicitly designed to suppress rumination. The thought-stopping technique (Tyron, 2015) I used as an intervention for the experimental mediator test did reduce work-related rumination in the experimental group, but rumination was not totally suppressed. Thus, more effective intervention methods should be selected in order to reliably reduce work-related rumination in everyday life. Besides intervention methods specifically targeting rumination, Sonnentag and Fritz (2015) suggest other mechanisms that are not specifically designed to suppress rumination, but also have the potential to do so. These mechanisms include, for example, practicing routines for the transition from work to non-work time, spending non-work time with people that are unrelated to work and engaging in activities that are unrelated to work. As outlined above, a recent study showed that, for example, physical activity after work can buffer ruminative processes (Junker et al., 2022). Sonnentag et al. (2022) noted that, for successful recovery, not only the type of activity (i.e., low-duty instead of high-duty profile) matters, but also an individual's motivation for a certain activity. As the possibilities regarding off-job activities are manifold (e.g., physical exercise, social activities, engaging in any desired hobby), the type of activity in which to engage can individually be chosen depending on an individual's intrinsic motivation. On top of that, in cases when ruminative processes might, despite these arrangements, occur, the prevention of their translation into low sleep quality can be focused on: To this end, it might help to consider methods of sleep hygiene such as regularizing one's bedtime, engaging in relaxing activities in the evening or making a worry list before going to bed (see Stepanski & Wyatt, 2003, for an overview).

## Conclusion

This dissertation provides valuable insights into relationships between work and sleep and their mutual consequences for well-being, and comprises four key findings: (a) Work-related rumination mediates the relationship between job demands and subjective sleep quality, (b) but not sleep duration. (c) Time spent working is positively related to emotional exhaustion. (d) There is no evidence for reactivity to measurement in the context of the actigraphic assessment of sleep, thus, results obtained from actigraphy in this dissertation as well as results obtained from actigraphy in general can be considered reliable in terms of measurement reactivity.

The findings of this dissertation point to the importance of a healthy work-environment (i.e., job demands that are not too high, working hours that are not too long) for an individual's health and well-being (i.e., sleep quality & emotional exhaustion) and emphasize the detrimental effects of failed psychological detachment from work in the form of work-related rumination during non-work time.

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