Does Better Sleep set the Stage for a Physically Active and Progressive Workday? Considerations Across the Daily Cycle of Rest, Commuting, and Work

Fiyinfunjah Adenike Dosumu

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Charles Calderwood, Chair
Ivan Hernandez
Roseanne Foti
Daniel Beal

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Abstract

This dissertation explored employee daily experiences through the lens of the resource allocation process whereby employees strive to meet their daily work and non-work demands and incorporate valuable experiences and activities into their workday. Previous research has largely focused on segmented aspects of employee daily lives. However, there is limited research on how employees' daily activities in their work and non-work lives may interrelate in a more dynamic sense. I assess how employees' recovery through nightly sleep quality may set the stage for subsequent engagement in moderate-to-vigorous physical activity, and the implications of this intensity of physical activity for job performance, specifically for employees who primarily commute to a physical work location. Using the effort-recovery model, I hypothesized that nightly sleep quality will positively covary with moderate-to-vigorous physical activity. I additionally considered a potential moderating influence of commute variability on the relationship between nightly sleep quality and moderate-to-vigorous physical activity. I then assessed moderate-to-vigorous physical activity as an antecedent of work goals progress, using the resource-based model of physical activity and job performance as my theoretical basis. My final sample consisted of 81 employees who commute to and from work at least 15 minutes each way. Using multilevel structural equation modeling, which enabled modeling at the within- and between-person level of analysis, I found that daily engagement in moderate-to-vigorous physical activity positively related to daily work goals progress. Furthermore, higher levels of engagement in moderate-to-vigorous physical activity on average influenced higher levels of

work goals progress on average. This dissertation contributes to the scientific understanding of the implications of physical activity for work criteria.

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General Audience Abstract

Recent research considering employees' experiences has largely separated aspects of employee lives with limited research on how home and work experiences may interrelate. As employees manage their time and energy across different demands at work and home, I expected that when employees experience better sleep quality at night, they may have enough energy and time to engage in higher intensity physical activity. I also expected that employees who engage in higher intensity physical activity will have better job performance by experiencing more progress towards their work goals. I also anticipated that employees whose commutes from home to work vary in duration from day to day may not be able to utilize the benefits of sleep quality towards higher intensity physical activity. I found that employees who engaged in moderate-to-vigorous physical activity (i.e., physical activity that utilizes a lot of energy, specifically 3 metabolic equivalents and higher) on a day-to-day basis also reported higher progress towards their work goals daily. Employees who engage in more moderate-to-vigorous physical activity on average also experienced higher progress towards their work goals on average.

Dedication

This dissertation is dedicated to my mum and best friend, Florence Dosumu. Thank you for pouring so much love into me, for being so supportive, and for encouraging me to go in the direction of my dreams. You inspire me!

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1 Introduction

Employees experience a daily cycle of work, home, and rest activities (Zuzanek & Smale, 1999). Work is an effortful activity that is often demanding and stressful (Zijlstra & Rook, 2008). Work recovery refers to the process through which an individual's stressful work demands temporarily cease such that their resource levels (e.g., attentiveness, energy) are restored to the baseline levels (Sonnentag et al., 2022). Thus, activities within and outside the workplace are crucial to the work recovery process (i.e., how employees regain the personal resources that are utilized during work activities; Sonnentag et al., 2017). For employees who work in a physical office, the lack of flexibility regarding the location of work may make their daily experiences complex. In other words, the lack of flexibility regarding the location of work may make them value their time and energetic resources more such that they need to fit in other activities (e.g., physical activity) within the workday, before work, or after work. Further, employees need to maintain the resources (e.g., attentiveness, energy) used to meet work goals throughout their workday. There remains a lack of knowledge about how employees' recovery may set the stage for the subsequent physical activity that they pursue across the workday, and the implications of this activity for shorter-term indicators of job performance. In this dissertation, I explored the prediction of physical activity and its short-term relevance with job performance criteria.

In this dissertation, I propose that employees who experience better quality of sleep may have more resources to engage in moderate-to-vigorous physical activity (MVPA) during the subsequent day. This physical activity in turn can be utilized towards making progress on goals at work. I focus on work goals progress as a measure of in-role work performance. Work goals progress is an indicator of work performance (Pomaki et al., 2009). I thus hypothesize that when employees experience a good quality night's sleep, they will be able to engage in more MVPA.

In turn, engaging in physical activity of such intensity will contribute to work performance, conceptualized as work goals progress (see Figure 1 for the conceptual model of my dissertation).

In terms of scientific research on employees' daily experiences, previous research has strongly focused on segmented aspects of employee daily lives (home vs work) or snapshots within the day (e.g., evening, during the workday; Sonnentag et al., 2008). However, there is limited research on the interrelationships of experiences within employees' day-to-day lives in a more dynamic sense. For example, initial levels of resources in the morning may influence how personal resources are directed throughout the day. In my dissertation, I explore employees' daily experiences through an experience sampling study that follows employees through their daily activities across 40 consecutive working days. I consider employees' previous night's experiences (nightly sleep quality), commuting to work experiences (commuting variability), within the workday experiences (work goals progress, physical activity), and experiences after the workday (physical activity; nightly sleep quality) to understand how this daily cycle of recovery, work, and performance unfolds. I start by considering the conditions that allow employees to be more intensely physically active by examining better sleep quality as an antecedent of MVPA (i.e., physical activity of 3 metabolic equivalents or higher; Rost et al., 2021) and theorize within the Effort-Recovery Model (Meijman & Mulder, 1998). I propose that higher sleep quality puts employees in a state of sufficient recovery of resources (Åkerstedt et al., 2009), which can then be directed towards MVPA engagement during the day. Physical activity is an activity that requires effort, self-regulation, and planning (Martin Ginis & Bray, 2010). MVPA is even more intense and may require higher levels of self-regulatory resources. These resources can be regained post-physical activity engagement (Nägel & Sonnnentag, 2013; Sonnentag & Fritz, 2007).

I also explore whether the proposed influence of sleep quality on MVPA is bounded by the variability of the commute. Commute variability represents the degree of unpredictability in the commute (Kluger, 1998). Commuting to work is an activity that may utilize energetic, attentional, and affective resources (Morris & Guerra, 2014; Zhou et al., 2017), and commute variability is considered a significant source of commuting strain (Evans et al., 2002; Kluger, 1998). Further, the morning commute has been found to be "particularly unpleasant" (Kahneman & Krueger, 2006, p. 12). Thus, I suggest that variable commuting durations from day-to-day can prevent employees from applying the benefits of better sleep quality towards MVPA due to the demands that car commuters encounter during the commute. Employees will typically strive to protect and conserve valuable personal resources; this process involves deciding which activities are worth directing resources towards (Hobfoll, 1989). For employees who work in a physical workplace, commuting is a required activity. Although the distance between the home and the workplace is the same, the commuting environment and the duration it takes to drive to work typically fluctuates (e.g., traffic congestion; Elfering et al., 2013). Once employees utilize resources towards variable commutes, this may be an impedance to MVPA engagement during the subsequent workday, an activity that also requires self-regulatory resources (Hagger et al., 2010). Thus, I investigated the potential of commuting experiences (i.e., variability of commute) to disrupt the ability of high-quality sleep to be translated into MVPA during the subsequent day.

Furthermore, I consider the implications of MVPA for work goals progress. I suggest that engaging in higher intensity physical activity (i.e., MVPA) will provide employees with more resources that can be applied towards meeting their goals at work. Physical activity has been linked to vigor and restoration among employees, and this can be linked to the recovery potential of physical activity engagement in addition to the temporary cessation of effortful work demands during physical activity episodes (Calderwood et al., 2021a; De Bloom et al., 2017; Sianoja et al., 2018).

Job performance is a crucial outcome of interest in organizational research. Thus, industrial-organizational psychology researchers have placed significant attention on job performance (Campbell & Wiernik, 2015). For employers, there is also emphasis on the job performance of employees, with increasing focus on how workplace initiatives contribute to the bottom-line (i.e., organizational productivity and performance). In the past, researchers have focused on factors within the workplace that contribute to job performance (Kahya, 2007). However, research on occupational health psychology has shown that employees typically carry burdens of the home to the workplace and vice versa, defined as spillover (Sanz-Vergel et al., 2015). Thus, there has been more focus on how home processes may relate to work processes in recent years (Kossek & Lee, 2017). For employees who work in a physical office environment, they typically have daily cycles of waking up, commuting to work, engaging in work, and engaging in other activities (e.g., physical activity) within and outside the workplace. Thus, it is crucial to explore how these personal resource-dependent daily activities can influence job performance.

In mapping the processes through which employee daily activities can influence job performance, an important research consideration is to match fluctuations in daily activity levels with potential fluctuations in performance (i.e., short-term performance). Although general levels of performance are relevant in the workplace, short-time performance measurement aligns more with the focus of this dissertation on the daily experiences of employees. Thus, dynamic factors are expected to influence short-term performance changes, in terms of work goals progress.

In terms of precursors of job performance, physical activity has been theorized to influence job performance (Calderwood et al., 2021b). Thus, employee physical activity is a variable of interest to both researchers and practitioners. Due to the daily demands and experiences of employees, it is important to understand the daily activities that may enhance or impede employees' ability to engage in more intense physical activity. Thus, in this dissertation, I seek to examine the conditions that leave employees able to engage in more intense physical activity (e.g., after a high-quality night's sleep) and map the process through which more intense physical activity can influence subsequent job performance. Due to the focus on daily experiences of employees, I seek to understand how home-to-work morning commuting experiences (i.e., commute variability) may moderate the proposed relationship between sleep quality and intensity of physical activity. For employees who work in a physical office, the commute is a potentially relevant dynamic in being able to translate the resource replenishment gained from sleep quality into intense physical activity.

I leverage the Effort-Recovery Model (Meijman & Mulder, 1998) and the resource-based model of physical activity job performance (Calderwood et al., 2021b) as guiding theoretical frameworks for the proposed relationships investigated in this dissertation. To examine the hypotheses, I utilized an experience sampling methodology and objective measures of sleep quality and intensity of physical activity via actigraphy. Commute variability was estimated using a naturalistic driving approach via micro data acquisition system (MicroDAS; Dingus et al., 2006) equipment installed in participants' cars. In combination with these objective tracking methods, I utilized a daily diary study design via self-report of work goals progress across 40 consecutive workdays. To quantitatively analyze my data, I utilized multilevel structural equation modeling (MSEM). This data analytical technique allows for modeling at the within- and between-person levels of measurement for intensity of physical activity.

I begin the introduction section by highlighting the intended contributions of my dissertation. I then elaborate on the theoretical frameworks I draw upon and how they inform my hypotheses. Finally, I combine the theoretical underpinnings with empirical evidence in the literature to develop my hypotheses, before then describing the proposed methodology and analytic approach undertaken to evaluate my hypotheses.

1.1 Intended Contributions

This dissertation focuses on an antecedent of and an outcome of physical activity intensity and offers theoretical and practical contributions to the organizational literature. The first intended contribution is the consideration of sleep quality as an antecedent of physical activity. Previous literature has suggested that there exists a bi-directional relationship between physical activity and sleep. Most research considering this bi-directional relationship has strongly focused on physical activity as a precursor of sleep indicators. For example, Pesonen et al. (2022) found that sleep duration and physical activity have bi-directional relationships only for vigorous physical activity. However, this dissertation utilizes a resource-based framework to examine how sleep quality may set the stage to subsequently enhance engagement in more intense levels of physical activity (i.e., MVPA). This is theoretically beneficial as this dissertation proposes to demonstrate how sleep quality may provide resources that are valuable to both individuals in terms of physical activity engagement and the downstream implications for job performance, which is a valued outcome for organizations. There is little insight in the literature regarding whether and when sleep quality may translate into moderate-to-vigorous physical activity levels. This knowledge is vital to how a restorative activity at home can influence engagement in MVPA the next day by considering the associations of employees' daily activities, with a focus on recovery frameworks.

The second theoretical contribution that I propose to make through this dissertation is to focus on commute variability as a moderator of the relationship between sleep quality and physical activity intensity. Specifically, I hypothesize that employees who have more generally aversive commutes (i.e., variable commuting duration) in the morning may not gain the full benefits of translating nightly sleep quality into subsequent physical activity due to the demands of the commute. On the other hand, I expect that the relationship between sleep quality and physical activity intensity will be stronger for employees with generally less aversive morning commuting experiences (i.e., less variable commuting duration). This proposition is in alignment with the dissertation focus on employee daily experiences of waking up, going to work (i.e., commuting) and engaging in physical activity across the workday and beyond. My dissertation advances the well-being literature by suggesting that there can be well-being costs to more variable commutes, especially when considering the cumulative daily experiences of employees. This contribution will enrich theoretical understanding of how going to work experiences (i.e., commuting) may have implications for employees' inability to engage in other beneficial activities during the day. Practically, interventions aimed at enriching the total experience of employees from day-to-day might focus on how to reduce commuting issues for employees (e.g., providing more flexibility regarding work location).

Practically, I seek to establish that nightly sleep quality can enhance employees' ability to engage in higher levels of MVPA, which has been demonstrated to help individuals accrue more benefits from physical activity engagement (Chomistek et al., 2017; van Hooff et al., 2019). This suggests that when employees have good quality sleep, they should make efforts to direct the potential benefits they have gained to enhance their wellbeing and potentially, job performance, by deciding to engage in MVPA the next day. Furthermore, support for the boundary condition I suggested in this dissertation, commute variability, could suggest that employers need to provide more flexibility for employees in terms of physical location, to enable them to fit in MVPA into their day. Alternatively, employers can provide flexible work hours that would reduce the time pressure experienced by employees during their commute to work. When considering the potential gains from higher sleep quality and MVPA engagement, employers can allow employees to build physical activity into their workday, if the benefits of sleep quality and MVPA towards job performance is demonstrated in this dissertation.

Methodologically speaking, this dissertation provides insights that can be applied to the commuting literature from the application of the naturalistic driving methodology. Previous research on commuting has largely focused on self-reports, Google maps estimates using postal codes, and other methods, (Elfering et al., 2020; Pereira et al., 2016) which have limitations in failing to capture the real experience of the commute due to reliance on participants' memory of their commutes or their general assessment of the commute rather than potential daily fluctuations in the commute. Commuting duration was objectively measured using a system that stores naturalistic driving data and provides precise time stamps for each individual driving. Additionally, these objectively assessed commuting trips were matched with time-stamped daily surveys that participants completed before their commute to work and before their commute back home. This combination of two methods enhances data quality and provides new insights into how commutes can be captured objectively to provide a full range of data that can be combined with employees' subjective perception to strengthen methodology.

1.2 Effort Recovery Model

Researchers studying recovery from stressful work demands have often utilized the Effort-Recovery Model (Meijman & Mulder, 1998) as a theoretical basis for their propositions. According to the Effort-Recovery Model, work is an effortful and demanding activity and is an essential part of adult life. Employees utilize energetic and attentional resources to be able to fulfill work demands. Thus, work is physiologically and psychologically taxing to employees. In addition, the Effort-Recovery Model states that individuals need to restore the resources that are utilized towards work. Restoration of resources can be made possible through social activities, physical activities, and relaxation activities, among others (Sonnentag, 2001; Rook & Zijlstra, 2006). Initially, research on recovery assumes that the restoration of resources needs to happen during non-work time (e.g., evenings, weekends, vacations; Fritz & Sonnentag, 2006; Sonnentag et al., 2008). However, there have been recent developments regarding how activities within the workplace can help employees recover from stressful work demands (e.g., microbreaks; Calderwood et al., 2021a; Kim et al., 2017). Based on the Effort-Recovery model, for restoration of resources to occur, the demands that tap into these resources need to cease temporarily. Continuous demands on resources without sufficient recovery impairs employee wellbeing and performance, according to the Effort-Recovery Model.

In considering factors that facilitate recovery, sleep quality is a non-work rest activity that has the potential to help employees recuperate energetic and attentional resources. Previous research has shown that sleep serves a restorative function and poor sleep quality has been associated with fatigue and depletion (Åkerstedt et al., 2002; Rost et al., 2021). Accordingly, the theorizing surrounding the Effort-Recovery Model (Meijman & Mulder, 1998) aligns with the focus of my dissertation on the restorative functions of sleep quality (Barnes, 2012) and how the resources gained from sleep quality can be directed towards intense physical activity and the downstream implications of sleep quality for job performance. Sleep has been theorized to help conserve and promote physical energy that is relevant for both physical and cognitive activities in the work and non-work domains (Crain et al., 2018).

Physical activity has been considered in the literature as an activity that utilizes resources but has the potential to help employees both maintain and build more resources through recovery experiences (Sonnetag & Fritz, 2007). When considering the proposed relationship between sleep quality and MVPA in this dissertation, sleep quality can provide employees with resources (e.g., physical energy; Crain et al., 2018) that can enable them to engage in such intensity of physical activity. Nightly sleep quality can make employees feel that they have sufficient resources to pursue high intensity physical activity, thus motivation to engage in MVPA may be heightened by sleep quality. High sleep quality has been associated with increased performance in Crossfit athletes (Klier et al., 2021). For employees who particularly work in a physical office, nightly sleep quality may enhance the perception that they can fit MVPA into their day's schedule. Accordingly, the arguments with the ERM can explain how experiencing a high-quality night's sleep can enhance employees' ability to engage in MVPA during the subsequent day.

As previously highlighted, I consider nightly sleep quality as a precursor of engagement in MVPA in this dissertation. Building on the point regarding employees' direction of personal resources, I propose that commuting experiences (i.e., commute variability) will moderate the potential positive relationship between nightly sleep quality and engagement in intense physical activity with specific focus on car commuters who work in a physical office location. Commuting is a necessary activity for employees who work in an office location and the commute may be perceived as aversive and typically requires regulatory control (Kahneman & Krueger, 2006; Zhou et al., 2017). For example, driving below the speed limit requires self-regulation especially if an employee is already late for work or has additional stops to make along the way (e.g., dropping off a child at school). Additionally, commuting via car is typically more appraised as more stressful than other modes of commuting, due to delays and other road users (Gatersleben & Uzzell, 2007). Aversive pre-work commutes may reduce subsequent availability of resources for MVPA. Thus, daily pre-work commute variability was explored as a boundary condition between the relationship of nightly sleep quality and intense physical activity.

1.3 The Resource-Based Model of Physical Activity and Job Performance

The resource-based model of physical activity and job performance (Calderwood et al., 2021b) connects daily engagement in physical activity to possible variability in performance which makes it align with the focus of this dissertation on employees' daily experiences. According to the resource-based model, engaging in physical activity may have downstream implications for job performance through the generation of valuable personal resources. Physical activity is proposed to help employees restore and regenerate valuable personal resources that are crucial to job performance. The resource-based model proposes both volatile and structural influences. In my dissertation, I explored the volatile aspects of the propositions due to the within-person nature of the daily influences in this dissertation. To be able to accomplish work tasks, employees need to focus their attention and other resources on work. When employees focus on other activities outside their immediate work task, performance is bound to be impaired. Performance is determined jointly by the availability of resources and the allocation of these resources to work tasks (Hobfoll, 1989), which is in line with the overall conceptual framework of this dissertation. Accordingly, the resource-based model of physical activity and job performance can serve as a theoretical basis for the proposed relationship between MVPA and end-of-workday work goals progress.

2 Literature Review

2.1 Sleep Quality

Sleep is an important rest activity in employees' daily lives (Burgard & Ailshire, 2009) and serves recovery functions (Krueger et al., 2016). Furthermore, sleep has been established to help individuals conserve energy, promote immune functioning, clear wastes in the brain, and enhance cognitive functioning (Besedovsky et al., 2012; Diekelmann, 2014; Zielinski et al., 2016). Thus, sleep quality provides employees with sufficient resources that are useful throughout the day due to its restorative function (Barnes, 2012). Previous research has shown that sufficient sleep is crucial for recovery promotion among employees (Takahashi, 2012). Sleep impairments have been linked to reduced cognitive performance and executive functioning (Elmenhorst et al., 2009; Nilsson et al., 2005; Pilcher & Huffcutt, 1996) and these associations have been found even for short-term sleep loss. Further, attention allocation in tasks involving working memory has been found to be impaired due to sleep loss (Smith et al., 2002). On the other hand, researchers suggest that sleep provides cognitive benefits (Ellenbogen, 2005). Experiencing good quality sleep has been suggested to enhance self-regulatory resources (Barnes, 2012), resources that are crucial towards MVPA engagement. Thus, sleep may serve the function of helping to restore self-regulatory resources (Barber et al., 2010). Availability of resources may enhance employee engagement in physical activity of the intensity under consideration.

This dissertation focuses on sleep quality as a recovery resource that enhances employees' ability to engage in intense physical activity. Within individuals, poor sleep has been found to relate to increased fatigue and decreased attentiveness (Åkerstedt et al., 2002; Harrison & Horne, 1999). On the other hand, sleep quality has been found to be associated with positive affect (Sonnentag et al., 2018). In addition, sleep has been theorized to promote and retain physical energy, which suggests that sleep quality may influence next-day engagement in MVPA due to the availability of resources that can be directed towards that intensity of physical activity.

2.2 Moderate-to-Vigorous Physical Activity

Physical activity provides an opportunity for employees to recover from work stress (Oerlemans et al., 2014; van Hooff et al., 2019). Apart from the recovery potential of physical activity, this activity has been found to have important associations with physical and mental health (Macdonald et al. 2008; Vankim & Nelson, 2012) and is highly recommended globally (World Health Organization, 2022). For example, the Office of Disease Prevention and Health Promotion provides physical activity guidelines for Americans with the suggestion that regular engagement in physical activity may improve health (U.S. Department of Health and Human Services, 2023). Further, the intensity of physical activity matters. The physical activity recommendation for adults is either 150 minutes of moderate-intensity physical activity, at least 75 minutes of vigorous-intensity physical activity, or a combination of moderate- and vigorous-intensity physical activity (Centers for Disease Control and Prevention, 2022). Despite these guidelines, reports show that more than a quarter of the world's adult population do not meet the physical activity recommendations and physical inactivity is more prevalent in high-income countries (World Health Organization, 2022). Employees form a high percentage of the adult population and spend most of their waking hours at work (U.S. Bureau of Labor Statistics, 2022). Although the burden of well-being is typically placed on employees, lack of wellness in employees (e.g., insufficient physical activity) may have negative impacts on the organization through performance decrements and increased health-related compensations.

Previous research on physical activity focuses more on the physical and mental health implications of physical activity (Macdonald et al. 2008; Vankim & Nelson, 2012). Additionally, there exists an extensive research base for the recovery potential of physical activity engagement with stronger focus on physical activity outside of work (Oerlemans et al., 2014; Ten Brummelhuis & Bakker, 2012). However, physical activity within and outside the workplace has the potential to enhance affective and energetic resources that may help employees improve their work. For example, recent research has shown associations of physical activity during the workday with vigor, restoration, and reduced fatigue (Calderwood et al., 2021a; De Bloom et al., 2017; Sianoja et al., 2018). Engaging in physical activity may enhance the replenishment of resources that are utilized towards work. Furthermore, physical activity may prevent further resource loss, thus enhancing the resource bank of employees. However, there is limited empirical research on whether physical activity is beneficial for work performance.

Although research has established the benefits of physical activity, there are propositions in the literature that physical activity of higher intensity helps individuals accrue the most benefits (Gerber et al., 2014). For example, Lee and Paffenbarger (2000) found that moderate and vigorous physical activity levels are associated with longevity. Similarly, van Hooff et al. (2019) suggested that to enjoy the benefits of physical activity in terms of recovery, individuals should engage in high intensity physical activity. Thus, this dissertation focuses on MVPA, moderate physical activity refers to physical activity that is above three metabolic equivalents of task (MET) and vigorous physical activity refers to physical activity that is greater than 6 MET

(Pate et al., 1995). MVPA thus refers to physical activity of 3 metabolic equivalents or higher (Rost et al., 2021). Examples of MVPA include activities like running, bicycling, and playing tennis (Ainsworth et al., 2000).

Empirical evidence suggests that MVPA is associated with health-related quality of life (Loprinzi & Davis, 2016) and reduced risk of cardiovascular diseases (Liu et al., 2020). In addition, MVPA has been linked to mortality risk reduction (Saint-Maurice et al., 2018) even in doses that are lower than the recommended activity levels (Hupin et al., 2015). In a similar vein, MVPA has been found to be associated with better health outcomes, associations that were not found with light physical activity (Phillips et al., 2017). Fanning et al. (2017) compared the influences of light physical activity and MVPA and found that MVPA influenced executive functioning and self-regulatory behavior, but this pattern of result was not found for light physical activity. MVPA has also been found to relate to detachment from daily demands (Rost et al., 2021), suggesting that there are potential recovery gains from engaging in physical activity of such intensity.

2.3 Commuting Experiences

Commuting is an important activity of employee daily life (Calderwood & Mitropoulos, 2021). According to a recent report, almost 140 million employees in the United States regularly commuted to work in 2022 and about 15 percent of employees work from home (Burrows & Burd, 2024), which suggests that commuting is still a relevant variable in organizational research. Commuting to work is an effortful activity that is typically perceived as stressful by employees (Kahneman & Krueger, 2006). The commuting environment itself may be demanding for car commuters. Stressors during the commute refer to experiences that are demanding while strain is defined as negative reactions engendered by the commute (Calderwood & Mitropoulos, 2021). Strain reactions induced by the commute may be physiological (e.g., musculoskeletal pain), affective (e.g., negative affect), or cognitive (e.g., self-regulation) (Calderwood & Mitropoulos, 2021; Morris & Guerra, 2014; Urhonen et al., 2016; Zhou et al., 2017). Thus, commuting is an effortful activity that utilizes regulatory resources (Baumeister & Vohs, 2007). This dissertation focuses on car commuting as driving is the most utilized form of commuting (Buehler & Hamre, 2016; Burrows & Burd, 2024). In organizational research, commuting time has been found to relate positively to absenteeism (VandenHeuvel & Wooden, 1995). Further, commuting stress has been found to negatively relate to interpersonal helping (Santhosh, 2015) and aversive morning commutes have been found to indirectly relate to subjective performance and intrapersonal organizational citizenship behavior (Gerpott et al., 2022). In addition, Zhou et al. (2017) found that morning commute stressors had an influence on self-regulation at work, further bolstering the argument that commuting utilizes self-regulatory resources.

Furthermore, more variables commutes have been found to induce strain (Kluger, 1998) and previous literature suggests that commute predictability may moderate the relationship between subjective impedance and stress (Koslowsky et al., 1995). Predictability of the commute is negatively associated with commuting stress (Sposato et al., 2012). Commuting by car has also been found to be more stressful than other modes of transport (e.g., train) due to the effortful nature of car commuting and its unpredictability (Wener & Evans, 2011). This suggests that variable commutes may require more self-regulatory efforts and resources and induce strain in car commuters, thereby reducing the resources available for commuters to direct towards other effortful activities. According to Kluger (1998), commute variability is related to strain even after controlling for commute length. Thus, a lengthy commute may not induce strain if it is regular and expected. However, the unpredictability associated with variable commutes may make it stressful for commuters, especially as they strive to transition to work and face work demands for the day. This aligns with the proposition of this dissertation that commute variability moderates the relationship between nightly sleep quality and MVPA.

2.4 Work Goals Progress

Job performance, defined as behaviors of employees that are crucial for attaining organizational goals (Dalal et al., 2020) has been argued to be the most important phenomenon in organizational psychology and organizational behavior (Campbell & Wiernik, 2015). Organizational scholars have examined different dimensions of job performance. Organizational scholars have examined task performance and contextual performance as performance types. Task performance refers to behaviors that relate to technical aspects of an employee's job and accomplishment of work tasks (Griffin et al., 2007), while contextual performance refers to behaviors that are not formally required by the organization but contribute to the social and psychological functioning of the work environment (Borman & Motowildo, 1993; Koopmans et al., 2011).

Work goals progress falls under the task performance category and is defined as perceptions of employees regarding whether the goals they have set for their work have been achieved (Kehr, 2003; Klug & Maier, 2015). Thus, goal monitoring is suggested to be a self-regulatory process (Chang et al., 2017) that influences goals attainment (Harkin et al., 2016). Goal setting among employees further suggests a proactive approach towards performance and career management (Greco & Kraimer, 2020). Previous research on work goals progress has largely focused on the motivational and wellbeing benefits of work goals progress, with assertions that goals progress relates to subjective well-being and enhanced self-efficacy (Klug & Maeir, 2015; Pomaki et al., 2009). Furthermore, Kronenwett and Rigotti (2022) found that goals progress lessens the negative influence of hindrance appraisal on emotional and motivational well-being, suggesting that goals progress is a crucial resource for employees. Within the workplace, work goals progress has been found to be associated with work engagement (Bipp et al., 2021) and decreased turnover intention (Holtschlag et al., 2020).

In addition, individuals may set multiple goals for their work and need to allocate resources towards meeting these goals, amidst environmental influences (Schmidt et al., 2009). Self-regulation, defined as the effortful alteration of actions, feelings, thoughts, desires, and performance (Baumeister et al., 1994), is a central part of human processes that enhances goals pursuit and regulates motivational tendencies (Inzlicht et al., 2021). Employees need to balance the volatile work environment that typically requires their attention with meeting the goals they have set for their work. Thus, availability of resources and allocation of these resources to work tasks may influence work goals progress. Goal setting and pursuit thus requires conscious effort and intention to engage in goal-relevant behaviors (Aarts et al., 2007). The focus of this dissertation on work goals progress as a measure of performance aligns with the self-regulatory resource replenishment propositions in the mediation model.

2.5 Hypothesis Development

As previously highlighted, the Effort-Recovery Model (Meijman & Mulder, 1998) posits that work is an effortful activity and demands of work need to cease for recovery to occur. Sleep is an off job restorative activity that can enhance recovery of resources (Krueger et al., 2016). Nightly sleep quality may thus enhance recovery such that employees have enough resources to engage in daily MVPA the next day. Previous research on sleep and physical activity has found that there is a bidirectional relationship between these variables (e.g., Pesonen et al., 2022). This may be because sleep and physical activity are both considered as wellbeing variables.

Analytically, both sleep and physical activity are typically examined jointly as outcomes, predictors, or moderator variables. For example, Nägel and Sonnentag (2013) found that post-work physical activity positively associated with next day personal resources on days when sleep duration was longer.

In this dissertation, I focus on the resource perspective to propose that better sleep quality will enhance employees' ability to engage in MVPA the next day. Researchers that have previously considered the recovery potential of sleep quality have found that sleep quality positively influenced daily promotion-oriented job crafting through increased feelings of recovery in the morning (Hur & Shin, 2023), which suggests that sleep quality enhances the restoration of personal resources. In line with this view, Rivkin et al. (2023) found that the availability of regulatory resources (cognitive and affective resources) mediated the relationship between sleep duration and work engagement, and the relationship of sleep duration to both in-role and extra-role performance. This self-regulatory resource perspective (Silva et al., 2023) bolsters my argument that resources gained from nightly sleep quality can be directed towards MVPA, an activity that requires self-regulation (Martin Ginis & Bray, 2010). There is limited research on sleep quality as a precursor of physical activity. When comparing sleep quality and sleep quantity, sleep quality has been proposed to be more relevant to health and functioning (Kohyama, 2021) and recommendations regarding sleep focus on improving sleep quality (Ohayon et al., 2017) rather than sleep quantity. Measuring both sleep quality and physical activity objectively via actigraphy, Tang and Sanborn (2014) found that daily sleep quality predicted subsequent physical activity engagement. The researchers suggested that improving sleep quality may enhance the ability of individuals to engage in physical activity during the workday. Combining the ERM based theorizing with this empirical evidence, I thus expect that:

Hypothesis 1: Nightly sleep quality positively co-varies with higher MVPA the next day.

The process through which sleep quality enhances engagement in MVPA may be moderated by general levels of commuting experience, specifically more variable commutes. According to the ego depletion theory (Baumeister et al., 2000), depletion of resources may occur from self-control. To prevent further depletion and an eventual state of exhaustion, individuals may conserve self-regulatory resources when self-control strength is low. Considering commuting experiences, which has been previously argued to utilize personal resources and induce strain (Gottholmseder et al., 2009; Morris & Guerra, 2014; Urhonen et al., 2016), employees may not be able to direct resources gained from sleep quality towards higher intensity physical activity when their commuting experiences are negative. Previous research has found that morning commute stressors negatively associated with self-regulation at work (Zhou et al., 2017), suggesting that self-regulatory resources may be depleted by commuting experiences. Further, commute-related demands have been found to be associated with start-of-work-time fatigue (Dettmers et al., 2020). Additionally, previous research suggests that commute unpredictability relates to higher stress levels among rail commuters (Evans et al., 2002) and commute variability induces strain in commuters (Kluger, 1998). For car commuters on their way to work, unpredictable commutes may even be more aversive as both morning commutes and car commutes are typically appraised as more stressful and unpleasant than other timing or modes of commuting (Gatersleben & Uzzell, 2007; Kahneman & Krueger, 2006). Commuting impedance has also been found to influence negative affective states upon arrival at work (Novaco et al., 1979), further bolstering the argument that aversive commutes may deplete personal resources. Commute predictability has been found to negatively relate to commuting stress (Sposato et al., 2012) and car commutes are appraised as more stressful due to unpredictability of the commute (Wener & Evans, 2011). These findings suggest that more variable commutes may indeed impede employees' ability to engage in MVPA, a physical activity intensity that requires self-regulatory resources. Therefore, I hypothesize that:

Hypothesis 2: Commute variability will moderate the relationship of nightly sleep quality with MVPA the next day such that the relationship will be weaker for more variable commute-to-work and stronger for less variable commute-to-work.

Increased engagement in physical activity should be beneficial in enhancing the progress of employees towards their work goals throughout the workday. According to the resource-based model of physical activity and job performance (Calderwood et al., 2021b), physical activity engagement serves a function in restoring valuable personal resources that have implications for job performance. Physical activity provides an opportunity to disengage from stressful work demands (Yeung, 1996) and renew personal resources (Nägel & Sonnnentag, 2013). When employees have sufficient personal resources stemming from engagement in physical activities, they may direct these resources (Hobfoll, 1989) towards work tasks to meet work goals. Additionally, physical activity is important for work goals progress as it can help employees stay committed to their work goals due to the self-regulatory benefits of physical activity. Engagement in physical exercise has been found to improve self-regulatory capacity in other areas of life (Oaten & Cheng, 2006), thus supporting the argument that self-regulatory commitment to work goals can be enhanced by physical activity engagement. In a randomized controlled exercise trial focused on changing sedentary behaviors and replacing them with more physical activity, Fanning et al. (2017) found that substituting sedentary behaviors with MVPA related to higher accuracy on spatial working memory tasks, faster reaction times on different tasks, and global reaction time switch costs, tasks that demonstrate both self-regulatory capabilities and executive functioning.

Previous empirical studies have found associations between physical activity and work focus (Ten Brummelhuis et al., 2021). Physical activity is crucial to job performance as it has the potential to generate physical, affective, and cognitive resources that are important for job performance (Calderwood et al., 2021b; Li et al., 2023). In support of this view, Li et al. (2024) found that daily physical exercise covaries with both self- and leader-rated in-role job performance and self-rated extra role performance (i.e., organizational citizenship behavior) through the mediational influence of positive affect and work engagement. Thus, the states that employees experience through physical activity engagement may signal to employees that they have enough resources to engage in effortful work activities and meet up with their work goals. Therefore, I hypothesize that:

Hypothesis 3: MVPA positively co-varies with work goals progress.

Based on the arguments drawn from the Effort-Recovery Model (Meijman & Mulder, 1998) and the resource-based model of physical activity and job performance (Calderwood et al., 2021b), I expect that nightly sleep quality will influence next-day engagement in MVPA. In turn, I expect that MVPA will have positive implications for work goals progress. Nightly sleep quality has been theorized to help employees recover valuable resources that can be directed towards MVPA engagement. Within the resource-based model, physical activity can generate personal resources that have downstream implications for job performance. Combining my arguments drawn from theoretical propositions and empirical evidence, I expect that nightly sleep quality will indirectly influence daily work goals progress through the mediational influence of MVPA. Therefore, I hypothesize the following:

Hypothesis 4: Sleep quality will indirectly influence work goals progress through MVPA.

2.6 Summary of Conceptual Model

In this dissertation, I propose that MVPA will mediate the relationship between sleep quality and work goals progress, with commute variability serving as a boundary condition between sleep quality and MVPA in this process model (Figure 1). In this model, I assessed whether experiencing better sleep quality will influence next-day engagement in moderate-to-vigorous physical activity. As discussed above, there exists theoretical and empirical evidence for this prediction. Additionally, I draw on the resource-based model to propose that engaging in MVPA may provide resources that employees can direct toward their work such that they perceive higher levels of work goals progress.

3 Method

3.1 Study Overview

Data collection for this dissertation is part of a larger study sponsored by the National Institute for Occupational Safety and Health under the Centers for Disease Control and Prevention (CDC). Participants were recruited through a combination of strategies including the following: (1) direct emailing to potential participants, (2) flyers in the New River Valley and Northern Virginia areas, (3) Facebook advertisements, LinkedIn posts, and Twitter posts, (4) blog posts, and (5) newspaper advertisements. Participants were required to 1) be at least 18 years old, 2) be a licensed driver, 3) commute to and from a physical workplace by car at least four out of five weekdays (Monday – Friday), 4) commute to work with an average commute time of at least 15 minutes each way, 5) drive themselves to and from work when commuting, 6) plan to use the same car to commute to and from work each workday during an eight week study period, and to 7) live close enough to one of the installation garage sites (Blacksburg, Virginia and Manassas, Virginia) such that they could reasonably bring their car to the location for in-vehicle equipment installation. Data were collected in two study sites that reflected both rural and urban commuting characteristics. The first study site was in the New River Valley area in Virginia and participants in this area were required to attend the vehicle installation appointment in Blacksburg, Virginia. The second study site was in the Northern Virginia area and the installation garage was in Manassas, Virginia. The New River Valley area represented the rural commuting conditions, while the Northern Virginia area represented the urban commuting conditions. Individuals were ineligible to participate if they 1) are undergraduate or graduate students, 2) work in a job in which driving is a part of their central job duties, 3) have an extended planned time off from work, 4) are carpooling, 5) do not hold a valid, U.S. driver's license that they can present when they enroll in the study, 6) do not have regular access to the internet / email, 7) indicate that their primary vehicle is an Audi, Jaguar, Mercedes, or Volkswagen, as these vehicles have installation limitations with the MicroDAS equipment, 8) cannot avoid driving into areas where videotaping is not allowed, such as military installations, high security areas, or border crossings, or 9) anticipate any life events during the next 8 weeks that may alter their normal driving pattern (e.g., changing employment, extended time off work).

3.2 Procedure

The study components (see Figure 2) included (1) an eligibility screening call, (2) completion of an online opt-in survey, (3) completion of an informed consent document and tax forms for compensation purposes, (4) installation of in-vehicle naturalistic driving equipment used to objectively track commuting behaviors across the study period, (5) participant training and instructions for how to use an actigraph device used to objectively track physical activity and sleep, (6) an eight-week daily survey period which included naturalistic driving monitoring

(Dingus et al., 2006) and physical activity and sleep monitoring via actigraphy, and (7) a return to the installation garage for equipment deinstallation and actigraph return after study completion. I describe each of these steps in more detail in the paragraphs below.

Participants first went through a screening call to determine their eligibility for participation in the study. This screening call (see Appendix A for a copy of the questions that were used to determine participant eligibility), which was conducted via telephone by trained undergraduate and graduate research assistants, included an overall description of the study procedure followed by attainment of verbal confirmation that a participant meets each of the study eligibility criteria. During the screening call, an equipment installation appointment was set up once eligibility was confirmed. Next, participants received a link to an online opt-in survey (see Table 2 for a list of measures contained in the different survey-based components of the measurement assay for the larger data collection which this project is drawn from), which they were asked to complete before their scheduled equipment installation appointment date. The opt-in survey was estimated to take approximately 30 minutes to complete and contained an online informed consent document that was supplemented with either an online Zoom informed consent before their installation appointment or an in-person informed consent on the day of their equipment installation in which written signed consent to participate was provided. Participants wore a wrist-worn actigraph device which was used to objectively track physical activity and sleep across the eight-week study interval. This eight-week daily study interval began on the Monday following the equipment installation appointment and lasted for eight consecutive weeks, during which participants completed a start-of-day survey and an end-of-workday survey on every working day across this time period.

Participants were expected to complete the start-of-day survey before beginning their commute to work each workday (Monday – Friday). This survey was estimated to take approximately 10 minutes to complete and collected information regarding sleep quality and sleep quantity, affective states, and previous night's recovery experiences. Participants took the end-of-workday survey before starting their commute back home from work each workday, and this survey was estimated to take about 10 minutes to complete. This survey collected information about state sleepiness, affective states, daily challenge and hindrance work stress exposure, daily attentional failures, and daily work goals progress.

Participants received between $30 and $500 in compensation, depending on the extent of their participation. Participants were compensated $30 for the combination of completing the opt-in survey and attending the in-person installation appointment, with an additional $50 provided towards transportation costs to and from the installation garage. Participants were compensated $8 for each day in which they completed both the start-of-day and the end-of-workday surveys, which totals up to $320 for the eight-week daily survey period. Participants also could receive a $50 perfect compliance bonus for completing all daily surveys and a $50 equipment return bonus if they returned all study equipment (i.e., the Micro-data acquisition system [micro-DAS; described in greater detail subsequently]) used to objectively track driving behaviors and the actigraph device used to objectively track physical activity and sleep across the eight-week study period).

The compensation was structured to encourage participant engagement in the study. Additionally, participants received weekly reminders about their participation in the study, in addition to the e-mails they received each day containing the start-of-day and end-of-workday survey links. Undergraduate and graduate research assistants managed the emails sent to the participants. The opt-in survey, the start-of-day survey, and the end-of-workday survey were all collected via Qualtrics, a survey management tool. The MicroDAS device used to track driving behaviors across the eight-week study interval is a tool that uses a universal serial bus (USB) or internet protocol (IP) cameras to create and store time-synced video streams (Virginia Tech Transportation Institute, 2024a) and driving behavior information. The MicroDAS stores naturalistic driving data including video (forward roadway and driver’s face), location (global positioning system; GPS), and other sensors that record speed, acceleration, and kinematic data (Virginia Tech Transportation Institute, 2024b) for every driving trip that participants take while the equipment is installed in their vehicle. In terms of time stamps, the Qualtrics survey management tool provides the exact time that participants completed each survey. In addition, the MicroDAS equipment provides time stamps which allow commuting trips to be identified and matched to survey data. Accordingly, trained undergraduate and graduate research assistants followed a process to identify pre-work commuting trip durations (recorded automatically for each trip by the MicroDAS system) using a combination of survey-based and MicroDAS based time stamp information.

Participants received training regarding the study protocol when they attend the equipment installation appointment from trained research personnel working at an equipment installation site staffed with experienced and trained Virginia Tech Transportation Institute (VTTI) research personnel and technicians. The VTTI research personnel reviewed the consent form with the prospective participant upon arrival at the equipment installation appointment and verified that the participant possesses the capacity to provide informed consent. The participant then signed the consent form once the capacity to provide informed consent has been verified by the research personnel and any questions the participant may have about the study protocol were answered. The research team member also took a photograph of the participant at this initial equipment installation appointment to identify the participant as the driver during the study on the naturalistic driving video feed data. Finally, participants completed a W-9 tax form as part of the study compensation paperwork. Participants received a wrist-worn device that was used to track physical activity and sleep during the study period at this equipment installation appointment, in addition to a device used to charge the wrist-worn device's battery. Participants also received a ClinCard during their appointment, which was used to compensate participants throughout the study. The ClinCard is a management system for clinical trials with a reloadable debit card (Greenphire, 2024) that allowed participants to be compensated on a weekly basis throughout the daily survey period.

After the eight-week study period, participants returned to the installation garage for the deinstallation of the MicroDAS equipment, at which point they also returned the actigraph device. The VTTI research personnel informed the participants at this de-installation appointment whether they had qualified for both the equipment return bonus and the perfect compliance bonus. Participants were asked to keep the ClinCard as any remaining compensation to be distributed was received through their ClinCard within the next several days after their deinstallation appointment. The deinstallation appointment concluded the participant's engagement in the study.

3.3 Sample and Statistical Power Analysis

3.3.1 Sample

A total of 129 participants completed the opt-in survey after the study staff determined their eligibility via a screening call. Of those individuals, 35 participants did not proceed with their study participation prior to beginning the daily survey period for several reasons, including an inability to install the MicroDAS equipment in their vehicle due to technical issues with their vehicle (e.g., low car battery, other mechanical issues that prevented installation, $n = 3$), failing to attend the equipment installation appointment ($n = 30$), or withdrawing from the study upon receiving further details ($n = 2$). Of the 96 participants who participated in the eight-week daily survey and naturalistic driving monitoring period, participants were screened out if they failed to comply with the study protocol (e.g., consistently completing the surveys intended to be done before their commute well after their commute; $n = 9$), had missing data on the actigraph device due to data recording failures or not returning the device ($n = 2$), or had missing commuting data due to equipment failures or vehicle issues (e.g., the car had to go to the shop for multiple days during the study period; $n = 4$).

The final Level 2 sample size consisted of 81 participants ($N = 81$) who had valid commuting, actigraphy, and daily survey data for at least 10 study days across the eight-week study period. A majority of participants were female (61.7%), with a mean age of 43 years ($M = 43.09$, $SD = 11.24$). Participants reported working an average weekly work hours of 43 hours ($M = 43.45$, $SD = 8.01$), an average job tenure of approximately 6 years ($M = 6.30$, $SD = 8.10$), and had been working in their current organization for roughly 7 years ($M = 7.56$, $SD = 6.78$). Most participants were White (84%), and the remaining participants were Black or African American (9.9%), Asian (1.2%), more than one race (2.1%), or did not specify their race (1.2%). Participants demonstrated an average morning commute duration of 34 minutes based on observed naturalistic driving data ($M = 34.57$, $SD = 14.11$), which aligned closely with the self-reported one-way average commute of 35 minutes ($M = 35.52$, $SD = 22.01$) that participants provided in the opt-in survey.

In terms of the Level 1 data, I took a few data cleaning steps specifically for the actigraph device that assesses physical activity and sleep to screen out cases that indicated either non-compliance with the actigraphy data recording protocol or potential data recording failures. In terms of the actigraph device, data was retained on days when participants had a wear percentage of at least 10 hours, based on the recommendations of Mathews et al. (2008). Regarding the measure of sleep quality, Level 1 data were screened out on days when participants have overly long sleep periods with an efficiency of 100% (e.g., 12 hours), which is suggestive of inactivity of the device during these long time periods (i.e., potentially just setting their device aside rather than wearing it on a given night). Sleep periods recorded during the workday (i.e., between completion of the pre-work or post-work commute) were screened out as they were considered to be naps and were not coded as nightly sleep, which is the focus of this dissertation. Additionally, unrealistic variable values were screened out as errors (e.g., 55 hours of self-reported nightly sleep duration). Finally, because the focus of this dissertation was on temporal issues relating to the daily cycles of sleep, work, physical activity, and commuting, data were screened out on days when participants reported that they did not commute to work (e.g., vacationing, working from home).

I also conducted an outlier analysis for the main study variables (i.e., those study variables included in the hypothesized conceptual model). For example, some extreme values were observed on MVPA that seemed unrealistic and may be due to improper calibration of the actigraph device for some participants. I screened out participants' day-level observations on study days in which they reported or exhibited observed values that are greater than 3 standard deviations above or below the mean on a given indicator. The number of observations and percentage retained valid, observed data for all Level 1 for all other study variables is presented in Table 1. The average response or observed rate across all study variables and control variables is 78.94%, with commuting duration having the lowest observed data rate (68.80%). The rate of observed commuting trips is lower than the other variables for a variety of reasons, including participant non-compliance with the study protocol and technical failures relating to participants' personal vehicles or study equipment.

3.3.2 Statistical Power Analysis

To determine the power to detect a medium-sized effect (i.e., 0.20; Muthén & Muthén, 2002) corresponding to each of my hypotheses, I conducted a post-hoc power analysis based on the final sample size of 81 participants. I specified the missing data rate for each variable in the Monte Carlo simulation to be 20% to approximate the average missing data rate across the study variables (see Appendix B for the Monte Carlo input syntax). I estimated the statistical power to detect a medium sized multilevel cross-level moderation to be .263 and the statistical power to detect a medium sized multilevel indirect effect to be .99, based on the results of this Monte Carlo statistical power analysis (Muthén & Muthén, 2002). Given the relatively low estimated statistical power to detect a cross-level interaction, I will be careful not to over-interpret or over-analyze a non-statistically significant cross-level interaction pathway in light of the heightened Type II error rate.

3.4 Measures

3.4.1 Sleep Quality

Sleep quality was assessed objectively via wrist-worn Actigraph WGT3X-BT devices (Actigraph, 2024), which were worn throughout the eight-week study period. This device collects information about sleep efficiency, the number of awakenings, and average awakening in minutes across the observed sleep period. Higher scores on sleep efficiency indicate higher sleep quality and were used in the statistical data analysis. Sleep efficiency is calculated using three values including total time in bed, total sleep time, and wake after sleep onset. This calculation incorporates elements relevant to both sleep duration and sleep fragmentation and is a valid measure of sleep quality (Khan & Woodward, 2018). The actigraph device has been extensively validated and shown to accurately assess sleep quality (Marino et al., 2013; Slater et al., 2015). These devices have also been used in past organizational research that examined the relationships between work-family conflict, family-supportive supervisor behaviors, and sleep outcomes (Crain et al., 2014) and another organizational research study that considered sleep quality as a potential mediator of the relationship between supervisor undermining and home undermining among employees (Barber et al., 2017).

Reviews and validation of actigraph devices show that this assessment method provides accurate estimates of sleep and wake cycles for individuals with healthy sleep. However, the device has limitations in accurately capturing sleep disorders (Ancoli-Israel et al., 2003; Taibi et al., 2013). Despite this limitation in capturing sleep issues associated with clinical disorders, actigraph devices accurately measure sleep in natural settings (Fekedulegn et al., 2020; Lujan et al., 2021).

3.4.2 Moderate-to-Vigorous Physical Activity

Moderate-to-vigorous physical activity was assessed using a summation of minutes of moderate, vigorous, and very vigorous intensity physical activity each day, estimated via wrist-worn Actigraph WGT3X-BT devices (Actigraph, 2024). This device utilizes a composite vector magnitude of three axes to estimate the intensity and duration of physical activity (Sasaki et al., 2011) throughout the day. The estimates of the number of minutes of physical activity at different levels of intensity are provided on a minute-by-minute basis, which makes it possible to assess the specific times within the day in which participants engaged in each intensity level of physical activity. MVPA refers to physical activity that is of 3 metabolic equivalents or higher (Rost et al., 2021). Actigraph WGT3X-BT devices have been validated and shown to track physical activity accurately in a wide range of past empirical research across many different populations (Lee et al., 2015; Whitaker et al., 2018). This measure of physical activity has been used in previous experience sampling studies that combine objective actigraphy measures of physical activity with survey data (e.g., Li et al., 2023; Rost et al., 2021).

To estimate MVPA, I utilized a computation of the minutes of moderate, vigorous, and very vigorous physical activity to arrive at a score for minutes of MVPA across the whole day. The actigraph device accurately estimates and provides data for minutes of physical activity intensity (Sasaki et al., 2011). The actigraph device has also been found to provide more accurate measures than other technologies (Middelweerd et al., 2017; Semanik et al., 2020). In general, there is a strong research base for the validation evidence of actigraphy devices in accurately assessing physical activity (Kelly et al., 2013).

3.4.3 Commuting Variability

The duration of the commute was assessed using the MicroDAS equipment, a component of the widely validated naturalistic driving approach (Dingus et al., 2006). The MicroDAS utilizes Universal Serial Bus or Internet Protocol cameras to store time-synced video data including the forward roadway and the driver's face. The equipment also has sensors that provide information about location, speed, and acceleration during driving (Virginia Tech Transportation Institute, 2024b). There exists extensive validation evidence for the MicroDAS naturalistic driving equipment (Klauer et al., 2006) and the measurement approach has been used in a wide range of empirical research encompassing many different devices (Dingus et al., 2016). The commuting duration data was extracted from the MicroDAS equipment that was installed in participants' cars when they commenced their participation. The driving trips are time-stamped in terms of duration and this information was combined with the start-of-day survey time stamps to identify the duration of the commuting trips for all pre-work commuting trips. I computed the standard deviation of the commuting duration across the eight-week study as a between-person metric of commute variability for each participant.

3.4.4 Work Goals Progress

Daily work goals progress was assessed using one item, adapted from Mun et al. (2015): "I made good progress on my work goals today." Participants indicated the extent to which they agreed or disagreed with the statement as it applied to their "workday today" within the end-of-workday survey on a 6-point Likert-type scale ranging from 1 (*Strongly disagree*) to 6 (*Strongly agree*). The original one-item measure was worded as a question: "How much progress have you made on your work goals today since the last time we talked with you?", and this was question adapted to a statement in this project. Organizational researchers have established that single item measures can have good reliability and validity and provide useful information about a construct (Fisher et al., 2015; Matthews et al., 2022). This is particularly relevant for experience sampling studies as researchers try to reduce the burden on participants by using more efficient measures of variables (Gabriel et al., 2019). Specifically, single item measures are relevant to the assessment of self-reported facts such as events as work, rather than psychological constructs (Gabriel et al., 2019). Work goals progress falls within the category of self-reported facts as employees have the knowledge of the goals they have set for their work and whether they have been able to meet these goals throughout the workday.

Due to the availability of longitudinal data across the eight-week study period, I estimated the test-retest reliability of the one-item work goals progress scale using the univariate stable trait, autoregressive trait, and state (STARTS) model utilized by Ock (2020) and proposed by Donnellan et al. (2012). According to Ock (2020), "in the univariate STARTS model, reliability is estimated at the ratio of the sum of the stable trait variance and autoregressive trait variance over the total variance" (p. 300). The univariate STARTS test-retest reliability estimate for the work goals progress scale was 0.89.

3.5 Analytic Approach

All hypotheses were tested using multilevel structural equation modeling in MPlus Version 8 (Muthén & Muthén, 1998 – 2017), which is relevant to testing both within- and between-person aspects of the hypothesized model. The model was specified such that nightly sleep quality was modeled to predict MVPA; MVPA in turn was modeled to predict work goals progress. I included the direct effect pathway corresponding to the indirect effect relationship between sleep quality and work goals progress. Commute variability was modeled as a cross-level predictor of a random slope term indexing the relationship between nightly sleep quality and MVPA. All other pathways were modeled as fixed effects. I included a cross-level direct effect term linking commute variability and MVPA, based on the recommended best-practices for modeling cross-level interactions (e.g., Aguinis et al., 2013).

Bayesian estimation was utilized to compute the multilevel structural equation model due to its advantages over maximum likelihood estimates in terms of more precision in parameter estimation with a smaller Level 2 sample size and when the distribution of the predictor variables is non-normal (Asparouhov & Muthén, 2020). This advantage is possible because the Bayesian estimation method estimates the posterior distribution by utilizing the Markov Chain Monte

Carlo (MCMC) method (Asparouhov & Muthén, 2020), and this method also provides accurate estimates of indirect effects. I utilized the latent-mean-centering approach due to its advantages over the observed variable centering approach for multilevel structural equation modeling. This centering approach separates within-person influences from between-person influences and is suitable for multilevel structural equation modeling as it enhances interpretability of the model (Asparouhov & Muthén, 2018). Additionally, the estimates from the latent centering approach are more accurate relative to estimates obtained via maximum likelihood as this method provides more precise standard errors and mean square errors (Asparouhov & Muthén, 2018). The statistical significance of all hypothesized pathways and indirect effects were evaluated using 95% credibility intervals (*CIs*). Within this model, indirect pathways were specified using model constraint terms at both the within- and between-person level of analysis.

Hypotheses 1 – 4 were tested with a multilevel structural equation model such that MVPA mediates the relationship between sleep quality and work goals progress. Table 2 presents the metrics that I used to determine support for each hypothesis. The cross-level moderation hypothesis was tested by the addition of a random slope pathway from nightly sleep quality to next-day MVPA which was predicted from the between-person commute variability indicator. Commute variability was grand-mean centered given that it has no within-person variance and was thus not encompassed within the latent-mean centering approach. Self-reported nightly sleep quantity was added as a control variable for all hypothesized pathways to rule out the potential alternative explanation that the duration of sleep, rather than the focal sleep quality variable, was responsible for this hypothesized relationship within the model. Participants reported the number of hours of sleep that they got during the previous night in numeric values by answering the following question: “How many hours of sleep did you get last night?” As an alternative, I included day of the week, week of the study, and lagged variables as statistical control variables in a separate model. Due to issues with model convergence, the results are presented in the appendix section (see Appendix C) rather than including them as statistical control variables in the focal multilevel structural equation model.

To account for the study site, I conducted *t-tests* for two independent samples to analyze the potential for any differences recruited between participants in the New River Valley and Northern Virginia study sites. I set the *p-value* for assessing the statistical significance of the t-test value to .05. For the *t-tests*, equal variances were not assumed due to the differences in sample size between the two study sites (30.86% in the Northern Virginia study site). The number of employees in the New River Valley study site was 56 (n = 56) while the number of employees in the Northern Virginia study site is 25 (n = 25). The results of the t-test revealed that participants in the New River Valley site (M = 30.68, SD = 10.22, n = 56) and Northern Virginia sites (M = 43.27, SD = 17.60, n = 25) had significantly different scores on commute duration (t (31.47) = -3.33, p <.05, Cohen's d = -.97). Additionally, a significant difference in work goals progress (t (56.83) = -2.22, p <.05, Cohen's d = -.49) was observed between participants in the New River Valley site (M = 4.39, SD = .63, n = 56) and Northern Virginia sites (M = 4.68, SD = .51, n = 25). Due to the observed differences between the two study sites on some of the study variables (see Table 4 for the different comparisons across the two study sites), I added the study site to the multilevel structural equation model as a control variable.

4 Results

4.1 Descriptive Statistics

Table 5 contains descriptive statistics, within-person correlations, and between-person correlations for all study variables. In terms of sleep quality, the average sleep quality (in terms of sleep efficiency) was 93% (*M* = 93.22, *SD* = 2.48), with a slight standard deviation, suggesting that high sleep quality was observed generally. Similarly, participants reported an average sleep duration of 7 hours (*M* = 6.94, *SD* = 0.84). The minutes of MVPA was 211 minutes (*M* = 211.36, *SD* = 82.42), which suggests that employees in this study generally seem to engage in moderate to vigorous physical activity within a reasonable portion of their day. However, the standard deviation of MVPA seems to be large (*SD* = 82.42), suggesting that some individuals exercised a lot while others may fall within the lower range of MVPA engagement. Additionally, participants generally reported making high progress towards their work goals each day (*M* = 4.48, *SD* = 0.61).

4.2 Unconditional Model

I computed an unconditional model to decompose the within-person and between-person variance for all Level 1 study variables and ascertain the justification for the use of multilevel modeling, in alignment with recommendations for experience sampling methodologies (Gabriel et al., 2019). The estimated variance at the within-person and between-person levels of analysis for all study variables is presented in Table 6. As can be seen in this table, the within-person variance for study variables ranged from 34.00% - 77.50%. Intraclass correlations, reflecting between-person variability, for study variables ranged between .23 and .66. Across all Level 1 study variables, I observed statistically significant variance at both the between- and within-person levels of analysis (see Table 6) and thus proceeded with my plan to compute a multilevel structural equation model.

4.3 Hypotheses Testing

All coefficient estimates, posterior standard deviation, and 95% credibility intervals for the hypothesized model at both the within-person and between-person levels are presented in

Table 7. The direct effect path estimates can be seen in Figure 3. For clarity of presentation, I discussed the within-person results first, followed by the between-person pattern of results. However, I note that the within- and between-person models were estimated simultaneously in the computed multilevel structural equation model.

4.3.1 Within-Person Level of Analysis

Turning first to the within-person pattern of findings, Hypothesis 1 states that nightly sleep quality positively covaries with higher MVPA the next day., I found no evidence to support the anticipated relationship between nightly sleep quality and next-day MVPA (γ = -1.27, Posterior *SD* = 1.41, 95% *CI* = [-4.22, 1.55]), providing no support for Hypothesis 1 at the *within-person* level.

Hypothesis 2 focuses on commute variability as a moderator of the within-person relationship between nightly sleep quality and MVPA. I found no evidence to support that commute variability moderates the relationship between nightly sleep quality and MVPA (γ = -.05, Posterior *SD* = .08, 95% *CI* = [-.20, .11]), yielding no support for Hypothesis 2.

Hypothesis 3 states that MVPA positively relates to work goals progress. MVPA positively co-varied with work goals progress (γ = .001, Posterior *SD* = .000, 95% *CI* = [.000, .002]), providing support for the *within-person* portion of Hypothesis 3. This pattern of results suggests that the fluctuations of MVPA engagement from day to day are relevant to the daily progress that employees report that they made towards their work goals.

In terms of the hypothesized indirect effect of sleep quality on work goals progress through MVPA, I found no evidence to support the indirect influence of sleep quality on work goals progress via MVPA (γ = -.001, Posterior *SD* = .001, 95% *CI* = [-.004, .001]) at the *within-person* level of analysis. This pattern of findings yields no support for Hypothesis 4.

4.3.2 Between-Person Level of Analysis

Turning now to the between-person level of analysis, Hypothesis 1 states that nightly sleep quality positively covaries with higher MVPA the next day. There was no support for the relationship between nightly sleep quality and next-day MVPA (γ = -1.75, Posterior *SD* = 4.27, 95% *CI* = [-10.86, 7.36]) at this level of analysis. Thus, Hypothesis 1 was not supported at the *between-person* level of analysis.

Hypothesis 3 stated that MVPA positively relates to work goals progress. MVPA was positively related to work goals progress (γ = .001, Posterior *SD* = .001, 95% *CI* = [.000, .003]), yielding support for Hypothesis 3 at the *between-person* level of analysis. This pattern of results suggests that employees who tend to engage in higher levels of MVPA on average are more likely to report higher levels of work goals progress on average.

Hypothesis 4 states that sleep quality will indirectly influence work goals progress through MVPA. At the *between-person* level, there was no support that sleep quality indirectly influences work goals progress through MVPA (γ = -.001, Posterior *SD* = .007, 95% *CI* = [-.021, .010]); this pattern of results does not yield support for Hypothesis 4.

In summary, at the within-person level of analysis, I found no evidence for the relationship between nightly sleep quality and MVPA. There was no evidence that commute variability moderates the relationship between sleep quality and MVPA. MVPA was positively related to work goals progress at the within-person level of analysis. There was no evidence to support the indirect influence of sleep quality on work goals progress via MVPA. Based on the study results, daily fluctuations in employee MVPA engagement from day to day related to their daily work goals progress.

At the between-person level of analysis, there was no evidence to suggest that nightly sleep quality covaried with MVPA. MVPA did, however, positively covary with work goals progress, but there was no evidence to suggest that nightly sleep quality indirectly influenced work goals progress through the mediating influence of MVPA. Further, commute variability did not moderate the relationship between nightly sleep quality and MVPA. Based on the pattern of results, engaging in higher levels of MVPA on average associated with higher levels of work goals progress on average.

4.4 Supplemental Analyses

4.4.1 Between-Person Interaction

To evaluate the potential for an interaction between commute duration and sleep quality at the between-person level of analysis in predicting MVPA at the between-person level, I manually computed a grand-mean centered interaction term which was then added to the model in a supplementary comparison. This analysis was separated from the hypothesized model to avoid having two simultaneous cross-level interaction in the focal model and enhance interpretability of the interaction estimated. All coefficient estimates, posterior standard deviation, and 95% credibility intervals for the hypothesized model at both the within-person and between-person levels for this supplemental analysis are presented in Table 8. The pattern of results is similar to the main multilevel structural equation model, although there was no evidence for the relationship between MVPA and work goals progress (γ = .000, Posterior *SD* = .001, 95% *CI* = [-.001, .003]) at the *between-person* level once the between-person sleep quality – commute duration interaction term was entered. The between-person interaction term, however, was also not statistically significant (γ = .094, Posterior *SD* = .583, 95% *CI* = [-0.925, 1.351]). There was thus no evidence to suggest that the average level of MVPA depends on the joint relationship between average sleep quality and average commute variability.

4.4.2 Commute Time as Moderator

The findings in the commuting literature about the influence of commuting duration on outcomes of interest are mixed. Whereas commute time has been found to relate to perceived stress (Gottholmseder et al., 2009), the commute time may also be used by employees to prepare for the upcoming work role (Jachimowicz et al., 2021). Thus, my dissertation focuses on commute variability as it has been associated with strain (Kluger, 1998). However, to assess whether commute duration may moderate the pathway linking nightly sleep quality to MVPA, I conducted additional analysis with commute duration as the cross-level moderator. All coefficient estimates, posterior standard deviation, and 95% credibility intervals for the hypothesized model at both the within-person and between-person levels are presented in Table 9. The pattern of results is the same as the main multilevel structural equation model for all hypothesized pathways. However, I found no evidence to support that commuting time moderates the relationship between nightly sleep quality and MVPA (γ = .023, Posterior *SD* = .038, 95% *CI* = [-.057, .093]) in this supplemental analysis.

5 Discussion

The goal of this dissertation was to explore the interrelationships between the daily cycle of rest, physical activity, commuting, and work. Specifically, I sought to examine whether quality nightly sleep would positively covary with the minutes of MVPA engagement during the next day. I then focused on commute variability as a moderator of the relationship between nightly sleep quality and MVPA. I then investigated whether MVPA engagement would positively relate to work goals progress. Finally, I examined if there is an indirect effect of nightly sleep quality on work goals progress through MVPA.

At the within-person level of analysis, I found no evidence to support the hypothesized relationship between nightly sleep quality and MVPA. However, daily engagement in MVPA is positively related to daily work goals progress. The indirect influence of sleep quality on work goals progress through MVPA was not statistically significant at the within-person level of analysis.

At the between-person level of analysis, there was also no evidence for the anticipated relationship between nightly sleep quality and next-day MVPA. However, MVPA again positively covaried with work goals progress at the between-person level, suggesting that higher levels of engagement in MVPA on average is likely to influence higher levels of work goals progress reported on average. I found no evidence to support the expected indirect influence of sleep quality on work goals progress through MVPA at the between-person level of analysis. Furthermore, commute variability was not observed to moderate the relationship between sleep quality and MVPA at either the within- or between-person level of analysis. However, caution is needed in interpreting these non-statistically significant findings as the estimated statistical power to detect this interaction was quite low.

Additional analyses from the supplemental lagged variable models provided evidence to support that previous day sleep quality related to next-day sleep quality at the within-person level of analysis. In a similar vein, engagement in MVPA in a previous day covaried with MVPA engagement the next day at the within-person level of analysis. Finally, previous day work goals progress positively related to next-day work goals progress at the within-person level of analysis. At the between-person level of analysis, nightly sleep quality in a previous day was found to associate with nightly sleep quality the next day. Similarly, previous day MVPA related to next-day MVPA at the between-person level of analysis. Further, work goals progress in a previous day associated with next-day work goals progress at the between-person level of analysis.

5.1 Theoretical Implications

This investigation provides an opportunity to examine the interrelationships of employee daily activities in their work and non-work environments in a dynamic sense. Previous research has emphasized different segments of employee daily lives or time frames within the day (e.g., Sonnentag et al., 2008). However, employees direct their personal resources to different activities within the day (Hobfoll, 1989) and the resource allocation process in one segment of the day may influence the amount of resources available for a different activity later in the day. In light of the possibility for the commute to deplete some of the personal resources that employees have available (Evans et al., 2002; Kluger, 1998), this dissertation focused on employees who primarily commute to a physical work location. I sought to provide insight into how employees' recovery may set the stage for their subsequent engagement in MVPA, an activity that not only requires self-regulatory resources (Martin Ginis & Bray, 2010) but also can enhance generation of personal resources (Nägel & Sonnnentag, 2013) that can be utilized towards job performance (Calderwood et al., 2021b).

This dissertation tested the prediction of physical activity and its short- and long-term relevance with work criteria. I did find that daily engagement in MVPA positively covaried with daily work goals progress. Although the relationship between physical activity and job performance has been asserted in organizational literature (Calderwood et al., 2021b), there is limited empirical and quantitative evaluation of this prediction. As the result of my dissertation suggests, engaging in moderate to vigorous levels of physical activity within a given day could help employees perform better at work (i.e., meet their work goals) that day. This pattern of finding was similar in a more structural sense. I found that engaging in moderate to vigorous intensity of physical activity on average can enhance employee performance in general. These findings support the recovery potential of physical activity (Ten Brummelhuis & Bakker, 2012) and its relevance to restoration of resources, vigor, and reduction of fatigue in employees (Calderwood et al., 2021a; De Bloom et al., 2017; Sianoja et al., 2018). Although much of the research on MVPA has focused on the health implications of this intensity of physical activity (Liu et al., 2020; Loprinzi & Davis, 2016; Saint-Maurice et al., 2018), the results of my dissertation suggest that employees can simultaneously accrue both wellbeing and job performance benefits from engaging in MVPA.

Furthermore, I found evidence for homology (Chen et al., 2005) across the within- and between-person levels of analysis for the relationship between MVPA and work goals progress. This homology contributes insight into the dynamic and stable aspects of employee physical activity behavior and its relationship to the progress employees make toward their work goals. Additionally, the findings of my dissertation suggest that there is theoretical similarity in the MVPA – work goals progress relationship across the within- and between-person levels of analysis and this strengthens confidence in the results. This is an advantage of microlevel measurement that allows for modeling of relationships across different levels of analysis, and I observed within – and between-person variability across all study variables.

Previous literature on the sleep quality-physical activity relationship suggests a bi-directional relationship between these two variables. However, nightly sleep quality is a restorative activity that may help employees recover resources (Åkerstedt et al., 2009) that can be applied toward MVPA. Due to this restorative function of sleep (Barnes, 2012; Krueger et al., 2016), considering sleep quality using a resource recovery perspective can expand our understanding of the potential link between sleep quality and MVPA, suggesting the value of theoretically enriching understanding of the sleep quality – MVPA relationship. Although this theoretical expansion of understanding of the nature of this association was one of the goals of this dissertation, findings from this study provided no evidence to support the relationship between nightly sleep quality and next-day MVPA engagement at the within-person or between-person level of analysis. One possibility to explore in future research is that the relationship between nightly sleep quality and MVPA may be non-linear. Previous research has explored bi-directional relationships between sleep and physical activity (e.g., Pesonen et al., 2022) but non-linear relationships are underexplored. Additionally, it could be that other demographic variables not considered in this dissertation may moderate the relationships linking nightly sleep quality and MVPA. For example, employees who are parents may have family demands that prevent them from utilizing the benefits of nightly sleep quality towards MVPA.

Although previous research has found that variable commutes have been associated with strain (Kluger, 1998), which may reduce the self-regulatory resource available to pursue moderate-to-vigorous intensity of physical activity, the results of my dissertation provided no evidence that commute variability serves as a boundary condition between nightly sleep quality and MVPA. Interestingly, one unanticipated contributor to this pattern findings was that the descriptive pattern of findings suggested that employees exhibited relatively small between-person variability in their commute duration across the 40-study days. It is possible that commuting time generally remains stable for employees and the commute is less variable, with the exception of major events that disrupt commuting patterns such as traffic accidents or unexpected road constructions. Further, employees may have resources that help them prepare for their commute before leaving home. For example, Google maps can provide information about potential traffic disruptions and suggest alternative routes. Future research utilizing video / objective commuting data can explore whether employees use similar routes across a study period or vary their home-to-work routes based on prior knowledge of potential disruptions to their commute. To extend consideration of aspects relevant to the commute, I considered the duration of the commute (rather than the variability of the commute) as a potential cross-level moderator of the link between nightly sleep quality and MVPA in a supplementary analysis. However, I also found no evidence that commute duration moderated the relationship between nightly sleep quality and next-day MVPA. Another potential explanation for the non-statistically significant results is the low estimated statistical power to detect a cross-level interaction in this dissertation. That said, there is a need for increased attention on the experiences of employees during their travel to work and how this may relate to both work and non-work criteria (i.e., commuting spillover; Calderwood & Mitropoulos, 2021), especially when viewing these relationships from a temporal perspective (Sandberg et al., 2023). Future research should explore the potential cross-level influences of commuting characteristics on sleep – MVPA associations with a more robust Level 2 sample size. For example, considerations across rural and urban commuting conditions may influence the pattern of these relationships. Additionally, objectively assessing commuting demands (e.g., traffic congestion, aberrant drivers) and exploring how these demands influence the proposed relationships is a consideration for future research.

5.2 Practical Implications

The major practical contributions of this dissertation focus on the benefits of MVPA engagement towards work goals progress. In this dissertation, I found that MVPA positively related to work-goals progress at the within-person level of analysis. Daily engagement in MVPA influenced daily work goals progress. This suggests that acute engagement in MVPA can influence work-related criteria in the short-term (Calderwood et al., 2021b). It is crucial for both employers and employees to understand the benefits of this intensity of physical activity and implement strategies to promote physical activity engagement among employees. Through workplace support programs that may include active work breaks, employees can harness the benefits of physical activity. Previous research has found that prior to end-of-workday physical activity related to end-of-workday vigor (Calderwood et al., 2021a). Employment practices that encourage employees to pursue physical activity both within (e.g., physical activity microbreaks) and outside of the workplace can be helpful (e.g., not intruding in employees' leisure time by discouraging after-hours work demands) in harnessing both the wellbeing and work performance benefits of moderate to vigorous physical activity engagement.

I also found that MVPA positively covaried with work goals progress at the between-person level of analysis. Higher levels of MVPA engagement on average is associated with higher levels of work goals progress. In alignment with the short-term influences of physical activity, physical activity also has long-term implications for job performance (Calderwood et al., 2021b). Empirically, physical activity has been found to be associated with work focus among regular exercisers (Ten Brummelhuis et al., 2021). Thus, regular exercise is beneficial for employees in the long run as it is associated with work criteria. These findings suggest that moderate to vigorous physical activity doses are more beneficial for employees and cumulative experiences of employees' daily physical activity choices serve long-term job performance benefits. Thus, it would be relevant for employees to engage in regular physical activity rather than focusing on bursts of physical activity that deviate from their typical physical activity levels, to leverage the full benefits of physical activity. Employees can benefit from incorporating exercise into their daily life such that they can gain both short-term and long-term benefits from this activity.

Methodologically, this dissertation contributes to the commuting literature by applying the naturalistic driving methodology (Dingus et al., 2006) to objectively assess the duration of commuting trips. This methodology has been widely used to study driving behaviors more generally. However, the broader project within which my dissertation is embedded advance the application of this naturalistic driving methodology by considering the context of personal vehicle commuting, which makes it relevant to daily commuting among employees. To further strengthen this methodology, the time-stamped commutes were matched with time-stamped daily surveys to enhance data quality. Rather than relying on participants' memories of their commutes or their subjective perceptions, objectively measuring the commuting variable is a methodological strength that this dissertation offers to the commuting literature.

5.3 Limitations and Future Directions

One limitation of this dissertation is the low estimated statistical power to detect the hypothesized cross-level interaction of commute variability on the sleep quality – MVPA relationship. Future studies should consider the sample size that will be robust enough to allow for estimation of potential cross-level moderation. The power analysis I conducted in this dissertation was a post-hoc power analysis. Researchers should strive to estimate the sample size that will enhance statistical power analysis before data collection as this may be relevant to the data collection planning process and allow researchers to collect enough data that will enhance statistical power.

Another limitation of this dissertation concerns potential differences across the study sites where data were collected. The two study sites had differences due to rural and urban commuting environments. Furthermore, I observed some differences in study variables based on the study site of the participants. These differences called for an in-depth consideration of the location dynamic, but the sample size in the Northern Virginia study side was small compared to the New River Valley study site, which prevented any further evaluation of the differences between participants based on location. To accommodate this limitation, I included the study site as a control variable in the hypothesized model. Future research could extend the study to incorporate similar number of participants across different commuting conditions or environments, in addition to assessing whether these differences are perceived or real through data analytic techniques.

Furthermore, the descriptive statistics information in this dissertation reflects some potential self-selection bias in the sample, especially for an intensive longitudinal study that requires a high amount of participant engagement. Participants exhibited or reported high scores on the study variables in general. Due to the rigorous study protocol, it is possible that the study may be biased towards individuals who are conscientious and more willing to engage in intensive longitudinal studies (Scollon et al., 2003). Additionally, repeated measures across the 40-day study period have the potential of increasing participant burden and fatigue. Related to data collection, I observed a high average MVPA ($M = 211.36$, $SD = 82.42$), and this suggests that the actigraph devices may be too sensitive in the tracking of physical activity engagement.

Furthermore, I was unable to consider the different measures of sleep quality that the actigraph device provides (e.g., number of awakenings) due to lack of methodological backing for how measures of sleep fragmentation can be used in combination with measures of sleep efficiency. Thus, I utilized only sleep efficiency as the measure of sleep quality due to its incorporation of sleep duration (total time in bed) and sleep fragmentation (wake after sleep onset). Sleep quality can be measured objectively through other variables including sleep patterns and sleep changes, sleep latency, duration, efficiency and fragmentation (Landry et al., 2015; Sadeh, 2011). This limitation calls for more validation and methodological research on sleep measurement using actigraph devices. There is a need for validation studies that specifically consider the full range of sleep data that the actigraph device collects.

An additional limitation of my dissertation is the generalizability of the sample size and their commuting experiences. A majority of participants were female and White with generally average commute duration (M = 34.57, SD = 14.11) and little variability in their commutes. The findings in this study may not extend to the general population in the United States.

6 Conclusion

This dissertation utilized a combination of objective measures of sleep quality, physical activity, and commuting, in addition to self-reported work criteria to investigate the daily cycles of rest, physical activity, commuting, and work. Combining the Effort-Recovery Model (Meijman & Mulder, 1998) with the resource-based model of physical activity job performance (Calderwood et al., 2021b), I anticipated that nightly sleep quality will influence MVPA, which in turn will influence work goals progress. I also expected that sleep quality will indirectly influence work goals progress through the mediating influence of MVPA. Furthermore, I anticipated that commute variability will moderate the relationship between nightly sleep quality and MVPA. Using multilevel structural equation modeling, I found that MVPA covaried with work goals progress, both acutely and structurally. I did not find support for the remaining hypothesized pathways. These results suggest that the resource-based framework is relevant to the understanding of relationships between employee health behaviors and work criteria. Future research should continue to explore how daily influences of rest and self-regulatory activities relate to temporal dynamics within the commute and work-related criteria.

References

Aarts, H., Custers, R., & Holland, R. W. (2007). The nonconscious cessation of goal pursuit: when goals and negative affect are coactivated. *Journal of Personality and Social Psychology*, *92*(2), 165–178.

Actigraph. (2024). https://theactigraph.com/

Aguinis, H., Gottfredson, R. K., & Culpepper, S. A. (2013). Best-practice recommendations for estimating cross-level interaction effects using multilevel modeling. *Journal of Management*, *39*(6), 1490-1528.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., O'Brien, W. L., Bassett, D. R., Schmitz, K. H., Emplaincourt, P. O., Jacobs, D. R., & Leon, A. S. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise*, *32*(9 Suppl), S498–504.

Åkerstedt, T. (1990). Psychological and psychophysiological effects of shift work. *Scandinavian Journal of Work, Environment & Health*, 67-73.

Åkerstedt, T., Fredlund, P., Gillberg, M., & Jansson, B. (2002). A prospective study of fatal occupational accidents–relationship to sleeping difficulties and occupational factors. *Journal of Sleep Research*, *11*(1), 69-71.

Åkerstedt, T., Nilsson, P. M., & Kecklund, G. (2009). Sleep and recovery. In *Current perspectives on job-stress recovery* (pp. 205-247). Emerald Group Publishing Limited.

Ancoli-Israel, S., Cole, R., Alessi, C., Chambers, M., Moorcroft, W., & Pollak, C. P. (2003). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*, *26*(3), 342-392.

Asparouhov, T., & Muthén, B. (2018). Latent Variable Centering of Predictors and Mediators in Multilevel and Time-Series Models. *Structural Equation Modeling: A Multidisciplinary Journal*, *26*(1), 119–142.

Asparouhov, T., & Muthén, B. (2020). Bayesian estimation of single and multilevel models with latent variable interactions. *Structural Equation Modeling: A Multidisciplinary Journal*, *28*(2), 314–328.

Barber, L. K., Munz, D. C., Bagsby, P. G., & Powell, E. D. (2010). Sleep consistency and sufficiency: Are both necessary for less psychological strain? *Stress and Health*, *26*(3), 186-193.

Barber, L. K., Taylor, S. G., Burton, J. P., & Bailey, S. F. (2017). A self-regulatory perspective of work-to-home undermining spillover/crossover: Examining the roles of sleep and exercise. *Journal of Applied Psychology, 102*(5), 753–763.

Barnes, C. M. (2012). Working in our sleep: Sleep and self-regulation in organizations. *Organizational Psychology Review*, *2*(3), 234-257.

Baumeister, R.F., Heatherton, T.F., & Tice, D.M. (1994). Introduction: Self-regulation failure in social and theoretical context. In R.F. Baumeister, T.F. Heatherton, & D.M. Tice (Eds.), *Losing control: How and why people fail at self-regulation* (pp. 3-13). San Diego: Academic Press

Baumeister, R. F., Muraven, M., & Tice, D. M. (2000). Ego depletion: A resource model of volition, self-regulation, and controlled processing. *Social Cognition*, *18*(2), 130-150.

Baumeister, R. F., & Vohs, K. D. (2007). Self-regulation, ego depletion, and motivation. Social and *Personality Psychology Compass, 1*(1), 115–128.

Besedovsky, L., Lange, T., & Born, J. (2012). Sleep and immune function. *Pflügers Archiv-European Journal of Physiology*, *463*(1), 121-137.

Bipp, T., Kleingeld, A., & Schelp, L. (2021). Achievement goals and goal progress as drivers of work engagement. *Psychological Reports*, *124*(5), 2180-2202.

Borman, W. C., & Motowidlo, S. M. (1993). Expanding the criterion domain to include elements of contextual performance. In: N. Schmitt & W. C. Borman (Eds.), *Personnel Selection in Organizations* (pp. 71-98). San Francisco, CA: Jossey Bass.

Buehler, R., & Hamre, A. (2016). An examination of recent trends in multimodal travel behavior among American motorists. *International Journal of Sustainable Transportation, 10*(4), 354-364.

Burgard, S. A., & Ailshire, J. A. (2009). Putting work to bed: stressful experiences on the job and sleep quality. *Journal of Health and Social Behavior*, *50*(4), 476-492.

Burrows, M., & Burd, C. (2024). *Commuting in the United States:2022.* American Community Survey Briefs, ACSBR-108, U.S. Census Bureau, Washington, DC.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*, 193-213.

Calderwood, C., Ackerman, P. L., & Conklin, E. M. (2014). What else do college students "do" while studying? An investigation of multitasking. *Computers & Education*, *75*, 19-29.

Calderwood, C., Gabriel, A. S., Ten Brummelhuis, L. L., Rosen, C. C., & Rost, E. A. (2021a). Understanding the relationship between prior to end-of-workday physical activity and work–life balance: A within-person approach. *Journal of Applied Psychology*, *106*(8), 1239.

Calderwood, C., & Mitropoulos, T. (2021). Commuting spillover: A systematic review and agenda for research. *Journal of Organizational Behavior*, *42*(2), 162-187.

Calderwood, C., ten Brummelhuis, L. L., Patel, A. S., Watkins, T., Gabriel, A. S., & Rosen, C. C. (2021b). Employee physical activity: A multidisciplinary integrative review. *Journal of Management*, *47*(1), 144-170.

Campbell, J. P., & Wiernik, B. M. (2015). The modeling and assessment of work performance. *Annual Review of Organizational Psychology and Organizational Behavior*, *2*(1), 47-74.

Centers for Disease Control and Prevention (2022). How much physical activity do adults need? https://www.cdc.gov/physicalactivity/basics/adults/index.htm

Chang, B. P. I., Webb, T. L., Benn, Y., & Stride, C. B. (2017). Which Factors Are Associated with Monitoring Goal Progress? *Frontiers in Psychology*, *8*, 434.

Chen, G., Bliese, P. D., & Mathieu, J. E. (2005). Conceptual Framework and Statistical Procedures for Delineating and Testing Multilevel Theories of Homology. *Organizational Research Methods, 8*(4), 375–409.

Chomistek, A. K., Yuan, C., Matthews, C. E., Troiano, R. P., Bowles, H. R., Rood, J., Barnett, J. B., Willett, W. C., Rimm, E. B., & Bassett, D. R. (2017). Physical Activity Assessment with the ActiGraph GT3X and Doubly Labeled Water. *Medicine and Science in Sports and Exercise*, *49*(9), 1935–1944.

Cohen, S., & Williamson, G. (1988). Perceived stress in a probability sample of the United States. In S. Spacapan & S. Oskamp (Eds.), *The social psychology of health* (pp. 31– 67). Newbury Park, CA: Sage.

Crain, T. L., Brossoit, R. M., & Fisher, G. G. (2018). Work, nonwork, and sleep (WNS): A review and conceptual framework. *Journal of Business and Psychology*, *33*, 675-697.

Crain, T. L., Hammer, L. B., Bodner, T., Kossek, E. E., Moen, P., Lilienthal, R., & Buxton, O. M. (2014). Work-family conflict, family-supportive supervisor behaviors (FSSB), and sleep outcomes. *Journal of Occupational Health Psychology, 19*(2), 155–167.

Cropley, M., Michalianou, G., Pravettoni, G., & Millward, L. J. (2012). The relation of post-work ruminative thinking with eating behaviour. *Stress and Health*, *28*(1), 23-30.

Dalal, R. S., Alaybek, B., & Lievens, F. (2020). Within-person job performance variability over short timeframes: theory, empirical research, and practice. *Annual Review of Organizational Psychology and Organizational Behavior*, *7*, 421–449.

De Bloom, J., Sianoja, M., Korpela, K., Tuomisto, M., Lilja, A., Geurts, S., & Kinnunen, U. (2017). Effects of park walks and relaxation exercises during lunch breaks on recovery from job stress: Two randomized controlled trials. *Journal of Environmental Psychology*, *51*, 14-30.

Dettmers, J., Wendt, C., & Biemelt, J. (2020). Already exhausted when arriving at work? A diary study of morning demands, start-of-work-day fatigue and job performance and the buffering role of temporal flexibility. *European Journal of Work and Organizational Psychology*, *29*(6), 809-821.

Diekelmann, S. (2014). Sleep for cognitive enhancement. *Frontiers in Systems Neuroscience*, *8*, 46.

Dingus, T. A., Guo, F., Lee, S., Antin, J. F., Perez, M., Buchanan-King, M., & Hankey, J. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences*, *113*(10), 2636-2641.

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., &

Knipling, R. R. (2006). The 100-car naturalistic driving study, Phase II-results of the 100-car field experiment (No. DOT-HS-810-593). United States. Department of Transportation. National Highway Traffic Safety Administration.

Donnellan, M. B., Kenny, D. A., Trzesniewski, K. H., Lucas, R. E., & Conger, R. D. (2012). Using trait–state models to evaluate the longitudinal consistency of global self-esteem from adolescence to adulthood. *Journal of Research in Personality*, *46*(6), 634-645.

Elfering, A., Grebner, S., & de Tribolet-Hardy, F. (2013). The long arm of time pressure at work: Cognitive failure and commuting near-accidents. *European Journal of Work and Organizational Psychology*, *22*(6), 737-749.

Elfering, A., Igic, I., Kritzer, R., & Semmer, N. K. (2020). Commuting as a work-related demand: Effects on work-to-family conflict, affective commitment, and intention to quit. *PsyCh Journal*, *9*(4), 562-577.

Ellenbogen, J. M. (2005). Cognitive benefits of sleep and their loss due to sleep deprivation. *Neurology*, *64*(7).

Elmenhorst, D., Elmenhorst, E.-M., Luks, N., Maass, H., Mueller, E.-W., Vejvoda, M., Wenzel, J., & Samel, A. (2009). Performance impairment during four days partial sleep deprivation compared with the acute effects of alcohol and hypoxia. *Sleep Medicine*, *10*(2), 189–197.

Enders, C. K. (2001). The impact of nonnormality on full information maximum-likelihood estimation for structural equation models with missing data. *Psychological Methods, 6*(4), 352–370.

Evans, G. W., Wener, R. E., & Phillips, D. (2002). The morning rush hour: Predictability and commuter stress. *Environment and Behavior, 34*(4), 521–530.

Fanning, J., Porter, G., Awick, E. A., Ehlers, D. K., Roberts, S. A., Cooke, G., Burzynska, A. Z., Voss, M. W., Kramer, A. F., & McAuley, E. (2017). Replacing sedentary time with sleep, light, or moderate-to-vigorous physical activity: effects on self-regulation and executive functioning. *Journal of Behavioral Medicine*, *40*(2), 332–342.

Fekedulegn, D., Andrew, M. E., Shi, M., Violanti, J. M., Knox, S., & Innes, K. E. (2020). Actigraphy-based assessment of sleep parameters. *Annals of Work Exposures and Health*, *64*(4), 350-367.

Fisher, G. G., Matthews, R. A., & Gibbons, A. M. (2015). Developing and investigating the use of single-item measures in organizational research. *Journal of Occupational Health Psychology*, *21*(1), 3.

Fritz, C., & Sonnentag, S. (2006). Recovery, well-being, and performance-related outcomes: the role of workload and vacation experiences. *Journal of Applied Psychology*, *91*(4), 936 – 945.

Gabriel, A. S., Podsakoff, N. P., Beal, D. J., Scott, B. A., Sonnentag, S., Trougakos, J. P., & Butts, M. M. (2019). Experience sampling methods: A discussion of critical trends and considerations for scholarly advancement. *Organizational Research Methods*, *22*(4), 969-1006.

Gatersleben, B., & Uzzell, D. (2007). Affective appraisals of the daily commute: Comparing perceptions of drivers, cyclists, walkers, and users of public transport. *Environment and Behavior, 39*(3), 416–431.

Gerber, M., Brand, S., Herrmann, C., Colledge, F., Holsboer-Trachsler, E., & Pühse, U. (2014). Increased objectively assessed vigorous-intensity exercise is associated with reduced stress, increased mental health and good objective and subjective sleep in young adults. *Physiology & Behavior*, *135*, 17-24.

Gerpott, F. H., Rivkin, W., & Unger, D. (2022). Stop and go, where is my flow? How and when daily aversive morning commutes are negatively related to employees' motivational states and behavior at work. *Journal of Applied Psychology*, *107*(2), 169-192.

Goldberg, L. R. (1992). The development of markers for the Big-Five factor tructure. *Psychological Assessment*, *4*(1), 26 – 42.

Gottholmseder, G., Nowotny, K., Pruckner, G. J., & Theurl, E. (2009). Stress perception and commuting. *Health Economics, 18*(5), 559-576.

Greco, L. M., & Kraimer, M. L. (2020). Goal-setting in the career management process: An identity theory perspective. *The Journal of Applied Psychology*, *105*(1), 40–57.

Greenphire. (2024). https://greenphire.com/participant-payments/

Griffin, M. A., Neal, A., & Parker, S. K. (2007). A new model of work role performance: positive behavior in uncertain and interdependent contexts. *The Academy of Management Journal*, *50*(2), 327–347.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*(2), 348 – 362.

Hagger, M. S., Wood, C. W., Stiff, C., & Chatzisarantis, N. L. (2010). Self-regulation and self-control in exercise: The strength-energy model. *International Review of Sport and Exercise Psychology*, *3*(1), 62-86.

Harkin B., Webb T.L., Chang B.P.I., Benn Y., Prestwich A., Conner M., Kellar I., & Sheeran P. (2016). Does monitoring goal progress promote goal attainment? A meta-analysis of the experimental evidence. *Psychological Bulletin*, *142*(2), 198–229.

Harrison, Y., & Horne, J. A. (1999). One night of sleep loss impairs innovative thinking and flexible decision making. *Organizational Behavior and Human Decision Processes*, *78*(2), 128-145.

Hobfoll, S. E. (1989). Conservation of resources: a new attempt at conceptualizing stress. *American Psychologist*, *44*(3), 513.

Holtschlag, C., Masuda, A. D., Reiche, B. S., & Morales, C. (2020). Why do millennials stay in their jobs? The roles of protean career orientation, goal progress and organizational career management. *Journal of Vocational Behavior*, *118*, 103366.

Hupin, D., Roche, F., Gremeaux, V., Chatard, J.-C., Oriol, M., Gaspoz, J.-M., Barthélémy, J.-C., & Edouard, P. (2015). Even a low-dose of moderate-to-vigorous physical activity reduces mortality by 22% in adults aged ≥60 years: a systematic review and meta-analysis. *British Journal of Sports Medicine*, *49*(19), 1262–1267.

Hur, W. M., & Shin, Y. (2023). Is resting and sleeping well helpful to job crafting? Daily relationship between recovery experiences, sleep quality, feelings of recovery, and job crafting. *Applied Psychology*, *72*(4), 1608-1623.

Inzlicht, M., Werner, K. M., Briskin, J. L., & Roberts, B. W. (2021). Integrating models of self-regulation. *Annual Review of Psychology*, *72*, 319-345.

Jachimowicz, J. M., Cunningham, J. L., Staats, B. R., Gino, F., & Menges, J. I. (2021). Between home and work: Commuting as an opportunity for role transitions. *Organization Science, 32*(1), 64–85.

Johns, M. W. (1991). A new method for measuring daytime sleepiness: The Epworth sleepiness scale. *Sleep*, *14*(6), 540-545.

Kahneman, D. & Krueger, A. B. (2006). Developments in the measurement of subjective well-being. *Journal of Economic Perspectives, 20*(1), 3–24.

Kahya, E. (2007). The effects of job characteristics and working conditions on job performance. *International Journal of Industrial Ergonomics, 37*(6), 515-523.

Kehr, H. M. (2003). Goal conflicts, attainment of new goals, and well-being among managers. *Journal of Occupational Health Psychology, 8*(3), 195.

Kelly, L. A., McMillan, D. G., Anderson, A., Fippinger, M., Fillerup, G., & Rider, J. (2013). Validity of Actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC Medical Physics*, *13*, 5–5.

Khan, C. T., & Woodward, S. H. (2018). Calibrating actigraphy to improve sleep efficiency estimates. *Journal of Sleep Research*, *27*(4), 1-7.

Kim, S., Park, Y., & Niu, Q. (2017). Micro-break activities at work to recover from daily work demands. *Journal of Organizational Behavior*, *38*(1), 28-44.

Klauer, C., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data.

Klier, K., Dörr, S., & Schmidt, A. (2021). High sleep quality can increase the performance of CrossFit® athletes in highly technical-and cognitive-demanding categories. *BMC Sports Science, Medicine and Rehabilitation*, *13*, 1-10.

Klug, H. J., & Maier, G. W. (2015). Linking goal progress and subjective well-being: A meta-analysis. *Journal of Happiness Studies, 16*, 37-65.

Kluger, A. (1998). Commute variability and strain. *Journal of Organizational Behavior, 19*(2), 147–165.

Kohyama, J. (2021). Which is more important for health: sleep quantity or sleep quality? *Children*, *8*(7), 542.

Koopmans, L., Bernaards, C. M., Hildebrandt, V. H., Schaufeli, W. B., De Vet, H. C., & Van Der Beek, A. J. (2011). Conceptual frameworks of individual work performance: A systematic review. *Journal of Occupational and Environmental Medicine, 53*(8) 856-866.

Koslowsky, M., Kluger, A. N., & Reich, M. (1995). *Commuting stress: causes, effects, and methods of coping*. Plenum Press.

Kossek, E. E., & Lee, K. H. (2017). Work-family conflict and work-life conflict. In *Oxford research encyclopedia of business and management*.

Kronenwett, M., & Rigotti, T. (2022). All's well that ends well!? Moderating effects of goal progress on the relation between challenge and hindrance appraisal and well-being. *Journal of Managerial Psychology*, *37*(5), 444-466.

Krueger, J. M., Frank, M. G., Wisor, J. P., & Roy, S. (2016). Sleep function: Toward elucidating an enigma. *Sleep Medicine Reviews*, *28*, 46-54.

Landry, G. J., Best, J. R., & Liu-Ambrose, T. (2015). Measuring sleep quality in older adults: a comparison using subjective and objective methods. *Frontiers in Aging Neuroscience*, *7*, 166.

Lee, I. M., & Paffenbarger Jr, R. S. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity: the Harvard Alumni Health Study. *American Journal of Epidemiology*, *151*(3), 293-299.

Lee, J. A., Williams, S. M., Brown, D. D., & Laurson, K. R. (2015). Concurrent validation of the Actigraph gt3x+, Polar Active accelerometer, Omron HJ-720 and Yamax Digiwalker SW-701 pedometer step counts in lab-based and free-living settings. *Journal of Sports Sciences*, *33*(10), 991-1000.

Li, Y. N., Cheng, B. H., Yu, B., & Zhu, J. N. Y. (2023). Let's get physical! A time-lagged examination of the motivation for daily physical activity and implications for next-day performance and health. *Personnel Psychology*.

Li, Y. N., Zhu, J. N. Y., Su, Q., & Xu, Q. (2024). A daily exercise prescription when work gets tough: The moderating effect of work demands on the relationship between daily physical exercise and next-day well-being and job performance. *Journal of Occupational Health Psychology, 29*(5), 342–358.

Liu, Q., Liu, F.-C., Huang, K.-Y., Li, J.-X., Yang, X.-L., Wang, X.-Y., Chen, J.-C., Liu, X.-Q., Cao, J., Shen, C., Yu, L., Lu, F.-H., Wu, X.-P., Zhao, L.-C., Li, Y., Hu, D.-S., Lu, X.-F., Huang, J.-F., & Gu, D.-F. (2020). Beneficial effects of moderate to vigorous physical activity on cardiovascular disease among Chinese adults. *Journal of Geriatric Cardiology: JGC*, *17*(2), 85–95.

Loprinzi, P. D., & Davis, R. E. (2016). Bouted and non-bouted moderate-to-vigorous physical activity with health-related quality of life. *Preventive Medicine Reports*, *3*, 46-48.

Lujan, M. R., Perez-Pozuelo, I., & Grandner, M. A. (2021). Past, present, and future of multisensory wearable technology to monitor sleep and circadian rhythms. *Frontiers in Digital Health*, *3*, 721919.

Macdonald, H. M., Kontulainen, S. A., Petit, M. A., Beck, T. J., Khan, K. M., & McKay, H. A. (2008). Does a novel school-based physical activity model benefit femoral neck bone strength in pre- and early pubertal children? *Osteoporosis International: With Other Metabolic Bone Diseases*, *19*(10), 1445–1456.

Marino, M., Li, Y., Rueschman, M. N., Winkelman, J. W., Ellenbogen, J. M., Solet, J. M., Dulin, H., Berkman, L. F., & Buxton, O. M. (2013). Measuring Sleep: Accuracy, Sensitivity, and Specificity of Wrist Actigraphy Compared to Polysomnography. *Sleep*, *36*(11), 1747–1755.

Martin Ginis, K. A., & Bray, S. R. (2010). Application of the limited strength model of self-regulation to understanding exercise effort, planning and adherence. *Psychology and Health*, *25*(10), 1147-1160.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., & Troiano, R. P. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *American Journal of Epidemiology*, *167*(7), 875–881.

Matthews, R. A., Pineault, L., & Hong, Y. H. (2022). Normalizing the use of single-item measures: Validation of the single-item compendium for organizational psychology. *Journal of Business and Psychology*, *37*(4), 639-673.

Meijman, T. F., & Mulder, G. (1998). Psychological aspects of workload. In P. J. D. Drenth, H. Thierry, & C. J. deWolff (Eds.), Handbook of work and organisational psychology: Vol. 2. Work psychology (2nd ed., pp. 5 – 33). Hove, UK: Psychology Press

Middelweerd, A., Van Der Ploeg, H. P., Van Halteren, A., Twisk, J. W., Brug, J., & Te Velde, S. J. (2017). A validation study of the Fitbit One in daily life using different time intervals. *Medicine and Science in Sports and Exercise*, *49*(6), 1270-1279.

Morris, E. A. & Guerra, E. (2014). Mood and mode: Does how we travel affect how we feel? *Transportation, 42*(1), 25–43.

Motowidlo, S. J., Packard, J. S., & Manning, M. R. (1986). Occupational stress: Its causes and consequences for job performance. *Journal of Applied Psychology, 71*, 618 – 629.

Mun, C. J., Karoly, P., & Okun, M. A. (2015). Effects of daily pain intensity, positive affect, and individual differences in pain acceptance on work goal interference and progress. *Pain*, *156*(11), 2276-2285.

Muthén, B., Asparouhov, T., & Keijsers, L. (2025). Dynamic structural equation modeling with cycles. *Structural Equation Modeling: A Multidisciplinary Journal*, *32*(2), 264-286.

Muthén, L.K., & Muthén, B.O. (1998–2017). MPlus user's guide (8th edn.). Los Angeles, CA: Muthén & Muthén.

Muthén, L. K., & Muthén, B. O. (2002). How to use a Monte Carlo study to decide on sample size and determine power. *Structural Equation Modeling*, *9*(4), 599-620.

Nägel, I. J., & Sonnentag, S. (2013). Exercise and sleep predict personal resources in employees' daily lives. *Applied Psychology: Health and Well-Being*, *5*(3), 348-368.

Nilsson, J. P., Söderström, M., Karlsson, A. U., Lekander, M., Akerstedt, T., Lindroth, N. E., & Axelsson, J. (2005). Less effective executive functioning after one night's sleep deprivation. *Journal of Sleep Research*, *14*(1), 1–6.

Novaco, R. W., Stokols, D., Campbell, J., & Stokols, J. (1979). Transportation, stress, and community psychology. *American Journal of Community Psychology*, *7*(4), 361-380.

Oaten, M., & Cheng, K. (2006). Longitudinal gains in self-regulation from regular physical exercise. *British journal of Health Psychology*, *11*(4), 717-733.

Ock, J. (2020). How satisfied are you with your job? Estimating the reliability of scores on a single-item job satisfaction measure. *International Journal of Selection and Assessment*, *28*(3), 297-309.

Oerlemans, W. G., Bakker, A. B., & Demerouti, E. (2014). How feeling happy during off-job activities helps successful recovery from work: A day reconstruction study. *Work and Stress*, *28*(2), 198-216.

Ohayon, M., Wickwire, E. M., Hirshkowitz, M., Albert, S. M., Avidan, A., Daly, F. J., Dauvilliers, Y., Ferri, R., Fung, C., Gozal, D., Hazen, N., Krystal, A., Lichstein, K., Mallampalli, M., Plazzi, G., Rawding, R., Scheer, F. A., Somers, V., & Vitiello, M. V. (2017). National Sleep Foundation's sleep quality recommendations: first report. *Sleep Health*, *3*(1), 6–19.

Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., Buchner, D., Ettinger, W., Heath, G. W., & King, A. C. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*, *273*(5), 402–407.

Peeters, M. C. W., Montgomery, A. J., Bakker, A. B., & Schaufeli, W. B. (2005). Balancing work and home: How job and home demands are related to burnout. *International Journal of Stress Management, 12*, 43– 61.

Pereira, D., Bucher, S., & Elfering, A. (2016). Daily impaired detachment and short-term effects of impaired sleep quality on next-day commuting near-accidents–an ambulatory diary study. *Ergonomics*, *59*(8), 1121-1131.

Pesonen, A.-K., Kahn, M., Kuula, L., Korhonen, T., Leinonen, L., Martinmäki, K., Gradisar, M., & Lipsanen, J. (2022). Sleep and physical activity – the dynamics of bi-directional influences over a fortnight. *BMC Public Health*, *22*(1).

Phillips, C. M., Dillon, C. B., & Perry, I. J. (2017). Does replacing sedentary behaviour with light or moderate to vigorous physical activity modulate inflammatory status in adults? *International Journal of Behavioral Nutrition and Physical Activity*, *14*, 1-12.

Pilcher, J. J., & Huffcutt, A. I. (1996). Effects of sleep deprivation on performance: a meta-analysis. *Sleep*, *19*(4), 318-326.

Pomaki, G., Karoly, P., & Maes, S. (2009). Linking goal progress to subjective well-being at work: The moderating role of goal-related self-efficacy and attainability. *Journal of Occupational Health Psychology, 14*(2), 206.

Rigotti, T., Schyns, B., & Mohr, G. (2008). A short version of the occupational self-efficacy scale: Structural and construct validity across five countries. *Journal of Career Assessment*, *16*(2), 238-255.

Rivkin, W., Diestel, S., Stollberger, J., & Sacramento, C. (2023). The role of regulatory, affective, and motivational resources in the adverse spillover of sleep in the home domain to employee effectiveness in the work domain. *Human Relations*, *76*(2), 199-232.

Rodell, J. B., & Judge, T. A. (2009). Can “good” stressors spark “bad” behaviors? The mediating role of emotions in links of challenge and hindrance stressors with citizenship and counterproductive behaviors. *Journal of Applied Psychology*, *94*(6), 1438 – 1451.

Rook, J., & Zijlstra, F. (2006). The contribution of various types of activities to recovery. *European Journal of Work and Organizational Psychology, 15*(2), 218–240.

Rost, E. A., Glasgow, T. E., & Calderwood, C. (2021). Active today, replenished tomorrow? How daily physical activity diminishes next-morning depletion. *Applied Psychology: Health and Well-Being*, *13*(1), 219-238.

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: An update. *Sleep Medicine Reviews*, *15*(4), 259–267

Saint-Maurice, P. F., Troiano, R. P., Matthews, C. E., & Kraus, W. E. (2018). Moderate-to-vigorous physical activity and all-cause mortality: do bouts matter? *Journal of the American Heart Association*, *7*(6).

Sandberg, B., Hurmerinta, L., Leino, H. M., Lehtonen, E., & Lyytimäki, J. (2023). Time-related aspects of commute well-being. *Transportation Research Part F: Traffic Psychology and Behaviour*, *95*, 177-187.

Santhosh, V. A. (2015). A study on the impact of workplace commuting on citizenship behaviour of employees working with public and private sector organizations. *Vision*, *19*(1), 13-24.

Sanz-Vergel, A. I., Rodríguez-Muñoz, A., & Nielsen, K. (2015). The thin line between work and home: The spillover and crossover of daily conflicts. *Journal of Occupational and Organizational Psychology*, *88*(1), 1-18.

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport*, *14*(5), 411–416.

Schaufeli, W. B., Bakker, A. B., & Salanova, M. (2006). The measurement of work engagement with a short questionnaire: A cross-national study. *Educational and Psychological Measurement*, *66*(4), 701-716.

Schmidt, A. M., Dolis, C. M., & Tolli, A. P. (2009). A matter of time: individual differences, contextual dynamics, and goal progress effects on multiple-goal self-regulation. *Journal of Applied Psychology*, *94*(3), 692.

Scollon, C. N., Kim-Prieto, C., & Diener, E. (2003). Experience sampling: Promises and pitfalls, strengths and weaknesses. *Journal of Happiness studies*, *4*(1), 5-34.

Semanik, P., Lee, J., Pellegrini, C. A., Song, J., Dunlop, D. D., & Chang, R. W. (2020). Comparison of physical activity measures derived from the Fitbit flex and the Actigraph GT3X+ in an employee population with chronic knee symptoms. *ACR Open Rheumatology*, *2*(1), 48–52.

Sianoja, M., Syrek, C. J., de Bloom, J., Korpela, K., & Kinnunen, U. (2018). Enhancing daily well-being at work through lunchtime park walks and relaxation exercises: Recovery experiences as mediators. *Journal of Occupational Health Psychology*, *23*(3), 428.

Silva, A. J., Mosteo, L., & Rueff, R. (2023). The non-sleepy neurotic: the role of a good night's sleep for daily self-regulatory resources and vitality at work. *International Journal of Organizational Analysis*.

Slater, J. A., Botsis, T., Walsh, J., King, S., Straker, L. M., & Eastwood, P. R. (2015). Assessing sleep using hip and wrist actigraphy. *Sleep and Biological Rhythms*, *13*(2), 172–180.

Smith, M. E., McEvoy, L. K., & Gevins, A. (2002). The impact of moderate sleep loss on neurophysiologic signals during working-memory task performance. *Sleep*, *25*(7), 56-66.

Sonnentag, S. (2001). Work, recovery activities, and individual well-being: a diary study. *Journal of Occupational Health Psychology*, *6*(3), 196–210.

Sonnentag, S., Binnewies, C., & Mojza, E. J. (2008). " Did you have a nice evening?" A day-level study on recovery experiences, sleep, and affect. *Journal of Applied Psychology*, *93*(3), 674.

Sonnentag, S., Cheng, B. H., & Parker, S. L. (2022). Recovery from work: Advancing the field toward the future. *Annual Review of Organizational Psychology and Organizational Behavior*, *9*(1), 33-60.

Sonnentag, S., & Fritz, C. (2007). The Recovery Experience Questionnaire: development and validation of a measure for assessing recuperation and unwinding from work. *Journal of Occupational Health Psychology*, *12*(3), 204.

Sonnentag, S., Venz, L., & Casper, A. (2017). Advances in recovery research: What have we learned? What should be done next? *Journal of Occupational Health Psychology*, *22*(3), 365.

Sposato, R. G., Röderer, K., & Cervinka, R. (2012). The influence of control and related variables on commuting stress. *Transportation Research Part F: Traffic Psychology and Behaviour, 15*(5), 581–587.

Taibi, D. M., Landis, C. A., & Vitiello, M. V. (2013). Concordance of Polysomnographic and Actigraphic Measurement of Sleep and Wake in Older Women with Insomnia. *Journal of Clinical Sleep Medicine*, *9*(3), 217–225.

Takahashi, M., Iwasaki, K., Sasaki, T., Kubo, T., Mori, I., & Otsuka, Y. (2012). Sleep, Fatigue, Recovery, and Depression After Change in Work Time Control: A One-year Follow-Up Study. *Journal of Occupational and Environmental Medicine*, *54*(9), 1078–1085.

Tang, N. K., & Sanborn, A. N. (2014). Better quality sleep promotes daytime physical activity in patients with chronic pain? A multilevel analysis of the within-person relationship. *PLOS ONE*, *9*(3), e92158.

Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory—scale construct and validation. *Accident Analysis & Prevention*, *36*, 323-332.

Ten Brummelhuis, L. L., & Bakker, A. B. (2012). Staying engaged during the week: the effect of off-job activities on next day work engagement. *Journal of Occupational Health Psychology*, *17*(4), 445.

Ten Brummelhuis, L. L., Calderwood, C., Rosen, C. C., & Gabriel, A. S. (2021). Is physical activity before the end of the workday a drain or a gain? Daily implications on work focus in regular exercisers. *Journal of Applied Psychology, 107*(10), 1864–1877.

Urhonen, T., Lie, A., & Aamodt, G. (2016). Associations between long commutes and subjective health complaints among railway workers in Norway. *Preventive Medicine Reports, 4*, 490-495.

U.S. Bureau of Labor Statistics (2022). Average hours per day spent in selected activities on days worked by employment status and sex. https://www.bls.gov/charts/american-time-use/activity-by-work.htm

U.S. Department of Health and Human Services (2023). Physical activity guidelines for Americans. https://health.gov/our-work/nutrition-physical-activity/physical-activity-guidelines

Useche, S. A., Cendales, B., Lijarcio, I., & Llamazares, F. J. (2021). Validation of the F-DBQ: A short (and accurate) risky driving behavior questionnaire for long-haul professional drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *82*, 190-201.

VandenHeuvel, A., & Wooden, M. (1995). Do Explanations of Absenteeism Differ for Men and Women? *Human Relations, 48*(11), 1309–1329.

van Hooff, M. L., Benthem de Grave, R. M., & Geurts, S. A. (2019). No pain, no gain? Recovery and strenuousness of physical activity. *Journal of Occupational Health Psychology*, *24*(5), 499.

VanKim, N. A., & Nelson, T. F. (2012). Vigorous physical activity, mental health, perceived stress, and socializing among college students. *American Journal of Health Promotion, 28*(1), 7-15.

Virginia Tech Transportation Institute. (2024a). https://www.vtti.vt.edu/projects/microdas.html

Virginia Tech Transportation Institute. (2024b). https://www.vtti.vt.edu/facilities/labs-das.html

Wallace, J. C., & Chen, G. (2005). Development and validation of a work-specific measure of cognitive failure: Implications for occupational safety. *Journal of Occupational and Organizational Psychology*, *78*(4), 615-632.

Watson, D., & Clark, L. A. (1994). The PANAS-X: Manual for the Positive and Negative Affect Schedule—Expanded Form.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070

Wener, R. E., & Evans, G. W. (2011). Comparing stress of car and train commuters. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*(2), 111–116.

Whitaker, K. M., Gabriel, K. P., Jacobs Jr, D. R., Sidney, S., & Sternfeld, B. (2018). Comparison of two generations of ActiGraph accelerometers: the CARDIA study. *Medicine and Science in Sports and Exercise*, *50*(6), 1333 – 1340.

World Health Organization (2022). Physical activity. https://www.who.int/news-room/fact-sheets/detail/physical-activity

Yeung, R. R. (1996). The acute effects of exercise on mood state. *Journal of Psychosomatic Research, 40*(2), 123 – 141.

Zhou, L., Wang, M., Chang, C., Liu, S., Zhan, Y., & Shi, J. (2017). Commuting stress process and self-regulation at work: Moderating roles of daily task significance, family interference with work, and commuting means efficacy. *Personnel Psychology, 70*(4), 891–922.

Zhou, L., Wang, M., & Zhang, Z. (2021). Intensive longitudinal data analyses with dynamic structural equation modeling. *Organizational Research Methods*, *24*(2), 219-250.

Zielinski, M. R., McKenna, J. T., & McCarley, R. W. (2016). Functions and mechanisms of sleep. *AIMS Neuroscience*, *3*(1), 67.

Zijlstra, F. R., & Rook, J. W. (2008). The weekly cycle of work and rest: A diary study. In *Time in Organizational Research* (pp. 84-101). Routledge.

Zuzanek, J., & Smale, B. J. (1999). Life-cycle and across-the-week allocation of time to daily activities. In *Time use research in the social sciences* (pp. 127-153). Boston, MA: Springer US.

Table 1

Overview of number and percentage of data retained for Level 1 study variables

Variable	Number Retained	Percentage Retained
Sleep Quality	2493	76.94%
MVPA	2749	84.85%
Daily Commuting Duration	2229	68.80%
Self-Reported Sleep Quantity	2660	82.10%
Work Goals Progress	2657	82.01%

Table 2

Overview of how support for each hypothesis was evaluated within this analytic approach

Hypotheses	Analytic Approach	Expectation
Hypothesis 1	Multilevel structural equation modeling	I expect a positive standardized regression coefficient for the relationship between nightly sleep quality and next-day MVPA
Hypothesis 2	Multilevel structural equation modeling with the addition of a random pathway from nightly sleep quality to next-day MVPA to test cross-level moderation	I expect that the proposed positive relationship between nightly sleep quality and next-day MVPA will be weaker for longer commute-to-work and stronger for shorter commute-to-work
Hypothesis 3	Multilevel structural equation modeling	I expect a positive coefficient for the relationship between MVPA and work goals progress
Hypothesis 4	Multilevel structural equation modeling	I expect statistically significant indirect effects for the relationship between sleep quality and work goals progress through MVPA

Table 3

List of Measures in the Surveys

Opt-In Survey	Start-of-Day Survey	End-of-Workday Survey
Positive and Negative Affect Schedule (Watson et al., 1988)	**Previous Night's Sleep Quantity**, Sleep Quality, and State Sleepiness (Buysse et al., 1989; Åkerstedt, 1990)	State Sleepiness (Åkerstedt, 1990)
Trait Fatigue (adapted from Calderwood et al., 2014)	State Positive Affect, Negative Affect, Attentiveness, Anger, Anxiety, Vigor, and Fatigue (Watson et al., 1988; Watson & Clark, 1994; Schaufeli et al., 2006; Calderwood et al., 2014)	State Positive Affect, Negative Affect, Attentiveness, Anger, Anxiety, Vigor, and Fatigue (Watson et al., 1988; Watson & Clark, 1994; Schaufeli et al., 2006; Calderwood et al., 2014)
Perceived Stress Scale (Cohen & Williamson, 1988)	State Distractibility (New Scale)	State Distractibility (New Scale)
Emotional Home Demands (Peeters et al., 2005)	Previous Night's Recovery Experiences (Sonnentag & Fritz, 2007)	Daily Challenge and Hindrance Stressor Exposure (Rodell & Judge, 2009)
Chronic Job Stress (Motowidlo et al., 1986)	Previous Night's Affective Rumination (Cropley et al., 2012)	**Daily Work Goals Progress (Mun et al., 2015)**
Recovery Experiences Questionnaire (Sonnentag & Fritz, 2007)		Daily Attentional Failures (Wallace & Chen, 2005)
Commuting Experiences Scale (New; To Be Validated in this Data Collection)		
Neuroticism, Conscientiousness, Agreeableness (Goldberg, 1992)		
Emotion Regulation (Gross & John, 2003)		
Occupational Self-Efficacy (Rigotti et al., 2008)		

Driver Behavior Questionnaire – Short Version (Useche et al., 2021)
Multidimensional Driving Style Inventory (Taubman-Ben-Ari & Skvirsky, 2004)
Prior Driving History (Dingus et al., 2016)
Epworth Sleepiness Scale (Johns, 1991)
Situational Awareness Rating
Demographics

Note. Previous night's sleep quantity in the start-of-day survey was used as a control variable. Work goals progress in the end-of-workday survey was used as the outcome variable.
The variables that were in bold were used in the context of this dissertation.

Table 4

t-tests Comparing Employees from the New River Valley Study Site and Employees from the Northern Virginia Study Site

Variable	*n*	*M*	*SD*	*t-value (df)*	*Cohen's d*	*p*
1. Sleep Quality						
New River Valley	56	93.00	2.34			
Northern Virginia	25	93.72	2.75	-1.15 (40.21)	-.29	.26
2. Sleep Quantity						
New River Valley	56	6.92	.74			
Northern Virginia	25	6.98	1.04	-.27 (35.47)	-.07	.79
3. MVPA						
New River Valley	56	209.65	77.27			
Northern Virginia	25	215.19	94.54	-.26 (38.94)	-.07	.80
4. Work Goals Progress						
New River Valley	56	4.39	0.63			
Northern Virginia	25	4.68	0.51	-2.22 (56.83)	-.49	.03
5. Morning Commute Variability						
New River Valley	56	8.80	5.46			
Northern Virginia	25	10.50	6.47	-1.15 (39.93)	-.29	.26
6. Morning Commute Duration						
New River Valley	56	30.68	10.22			
Northern Virginia	25	43.27	17.60	-3.33 (31.47)	-.97	.00

Note. $N = 81$. Two-sided p values are reported. Equal variance was not assumed.

Table 5

Descriptive Statistics and Correlations for Study Variables

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Sleep Quality	93.22	2.48	–	.03	-.00	.01	–	.01	–	–	–	–	–	–	.08**
2. Sleep Quantity	6.94	.84	.09	–	-.04	.04	–	-.02	–	–	–	–	–	–	.50**
3. MVPA	211.36	82.42	-.14	-.29*	–	.04*	–	-.01	–	–	–	–	–	–	.00
4. Work Goals Progress	4.48	.61	.19	.03	.16	–	–	.02	–	–	–	–	–	–	.04*
5. Commute Variability	9.32	5.81	.08	-.19	-.07	.15	–	–	–	–	–	–	–	–	–
6. Commute Duration	34. 57	14.11	.18	-.22	-.00	.10	.45**	–	–	–	–	–	–	–	-.02
7. Gender	-	-	-.08	.01	.05	.01	-.19	-.15	–	–	–	–	–	–	–
8. Age	43.09	11.24	.06	.09	.07	-.07	.01	.15	.08	–	–	–	–	–	–
9. Race	-	-	-.13	-.01	-.01	.19	.06	-.10	.18	-.35**	–	–	–	–	–
10. Job Tenure	6.30	8.10	.15	-.09	.13	.11	-.06	.08	.04	.32**	-.16	–	–	–	–
11. Organizational Tenure	7.56	6.78	.11	.03	.16	-.10	-.07	-.08	.16	.37**	-.20	.64**	–	–	–
12. Work Hours	43.35	8.01	-.01	-.17	.20	-.19	-.02	.03	.03	.11	-.11	-.07	-.04	–	–
13. Self-Reported Sleep Quality	2.90	.35	.14	.29**	.01	.34**	.17	.05	-.04	.13	.05	.04	.14	-.11	–

Note. $N = 81$. Within-person correlations are in the upper diagonal, between-person correlations are in the lower diagonal. The Level 1 sample sizes on which the within-person correlational relationships were based on ranged from 1844 (for the relationship between sleep quality and commute duration) to 2657 (for the relationship between sleep quantity and self-reported sleep quality).

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

Table 6

Estimated Variance at the Within-Person and Between-Person Levels of Analysis

			Within-Person		Between-Person	
Variable	ICC	1-ICC	*Estimate*	*S.E.*	*Estimate*	*S.E.*
Sleep Quality	.337	.663	10.882	.793**	5.500	.992**
Sleep Quantity	.439	.561	.845	.059**	.661	.140**
MVPA	.660	.340	3335.866	222.025**	6450.792	1102.487**
Work Goals Progress	.225	.775	1.129	.079**	.328	.050**

Note. $N = 81$. ICC = Intraclass correlation reflecting the between-person variability. 1- ICC is the variability of the variables at the within-person level of analysis.

** $p < .01$.

* $p < .05$

Table 7

Empirical Test of the Hypothesized Model

	MVPA			Work Goals Progress		
Predictor	γ	Posterior *SD*	*95% CI*	γ	Posterior *SD*	*95% CI*
Intercept	571.029	389.816	[-348.992, 1246.583]	-1.910	2.864	[-7.694, 3.455]
<u>Within-Person Level</u>						
<u>Control Variable</u>						
Sleep Quantity	-1.946	1.422	[-4.646, 0.662]	.045	.025	[-.003, .092]
<u>Predictor Variables</u>						
Sleep Quality	-1.268	1.413	[-4.216, 1.552]	.004	.008	[-.012, .018]
MVPA				.001	.000	[.000, .002] *
<u>Between-Person Level</u>						
<u>Control Variable</u>						
Sleep Quantity	-32.685	11.825	[-55.746, -10.018] *	.034	.095	[-.138, .227]
<u>Predictor Variables</u>						
Sleep Quality	-1.750	4.274	[-10.856, 7.356]	.063	.030	[.002, .121] *
MVPA				.001	.001	[.000, .003] *
<u>Level 2 Predictor (Slope)</u>						
Commute Variability → Sleep Quality				-.048	.079	[-.202, .105]
<u>Within-Person Mediator</u>						
Sleep Quality➔MVPA				-.001	.001	[-.004, .001]
<u>Between-Person Mediator</u>						
Sleep Quality➔MVPA				-.001	.007	[-.021, .010]

Note. $N = 81$. There were 2999 day-level time points available for statistical analysis ($n = 2999$). Reported coefficients are unstandardized. Level 2 predictors were grand-mean centered. Variables with both within- and between-person variance were latent-mean centered. CI is credibility interval. Coefficient estimates were obtained using Bayesian estimation.

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

Table 8

Empirical Test of the Model with a Between-Person Interaction Term for Sleep Quality and Commute Duration

	MVPA			Work Goals Progress		
Predictor	γ	Posterior *SD*	*95% CI*	γ	Posterior *SD*	*95% CI*
Intercept	610.429	416.746	[-398.866, 1304.147]	-2.163	2.822	[-7.889, 3.701]
Within-Person Level						
Control Variable						
Sleep Quantity	-1.926	1.428	[-4.695, 0.660]	.045	.025	[-.003, .092]
Predictor Variables						
Sleep Quality	-1.514	1.196	[-3.914, 1.184]	.004	.008	[-.012, .018]
MVPA				.001	.000	[.000, .002] *
Between-Person Level						
Control Variable						
Sleep Quantity	-32.806	11.906	[-55.696, -10.199] *	.053	.087	[-.129, .225]
Predictor Variables						
Sleep Quality	-2.032	4.538	[-11.941, 7.140]	.062	.030	[.002, .117] *
MVPA				.001	.001	[-.000, .003]
Interaction Effect						
Commute Variability*Sleep Quality				.094	.583	[-.925, 1.351]
Within-Person Mediator						
Sleep Quality→MVPA				-.001	.002	[-.005, .001]
Between-Person Mediator						
Sleep Quality→MVPA				-.002	.009	[-.021, .015]

Note. $N = 81$. There were 2999 day-level time points available for statistical analysis ($n = 2999$). Reported coefficients are unstandardized. Level 2 predictors were grand-mean centered. Variables with both within- and between-person variance were latent-mean centered. CI is credibility interval. Coefficient estimates were obtained using Bayesian estimation.

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

Table 9

Empirical Test of the Model with Commute Duration as a Cross-Level Moderator

	MVPA			Work Goals Progress		
Predictor	γ	Posterior *SD*	*95% CI*	γ	Posterior *SD*	*95% CI*
Intercept	539.841	398.252	[-409.607, 1208.312]	-1.904	2.867	[-7.703, 3.428]
Within-Person Level						
Control Variable						
Sleep Quantity	-1.956	1.422	[-4.654, .743]	.045	.025	[-.003, .092]
Predictor Variables						
Sleep Quality	-.935	1.477	[-3.814, 2.299]	.004	.008	[-.012, .018]
MVPA				.001	.000	[.000, .002] *
Between-Person Level						
Control Variable						
Sleep Quantity	-33.045	12.146	[-55.044, -10.438] *	.034	.095	[-.138, .227]
Predictor Variables						
Sleep Quality	-1.377	4.383	[-10.825, 8.156]	.062	.030	[.002, .121] *
MVPA				.001	.001	[.000, .003] *
Level 2 Predictor (Slope)						
Commute Duration → Sleep Quality				.023	.038	[-.057, .093]
Within-Person Mediator						
Sleep Quality➔MVPA				-.001	.002	[-.004, .002]
Between-Person Mediator						
Sleep Quality➔MVPA				-.001	.007	[-.020, .010]

Note. $N = 81$. There were 2999 day-level time points available for statistical analysis ($n = 2999$). Reported coefficients are unstandardized. Level 2 predictors were grand-mean centered. Variables with both within- and between-person variance were latent-mean centered. CI is credibility interval. Coefficient estimates were obtained using Bayesian estimation.

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

Table 10

Empirical Test of the Model with Day of the Week, Week of the Study, and Lagged Variables as Control Variables

	MVPA			Work Goals Progress		
Predictor	*γ*	Posterior *SD*	*95% CI*	*γ*	Posterior *SD*	*95% CI*
Intercept	-4.813	1311.643	[-1587.964, 2151.054]	-.460	29.429	[-56.536, 49.023]
Control Variables (Within-Person)						
Sleep Quantity	-1.779	1.345	[-4.402, .854]	.041	.024	[-.005, .088]
Day of the Week	-1.118	.778	[-2.641, .409]	.010	.015	[-.018, .039]
Study Week	-1.266	.486	[-2.226, -.322] *	-.011	.009	[-.028, .007]
Lagged MVPA	.112	.019	[.074, .150] *	-	-	-
Lagged Work Goals Progress	-	-	-	.156	.020	[.116, .196] *
Control Variables (Between-Person)						
Sleep Quantity	1.100	5.729	[-7.647, 8.831]	.004	.117	[-.208, .205]
Day of the Week	6.355	418.904	[-702.699, 518.568]	.088	9.413	[-15.329, 18.322]
Study Week	2.574	146.259	[-245.402, 182.628]	.031	3.266	[-5.304. 6.396]
Lagged MVPA	1.031	.071	[.907, 1.120] *	-	-	-
Lagged Work Goals Progress	-	-	-	1.005	.124	[.774, 1.192] *
Within-Person Level						
Sleep Quality	-1.174	1.318	[-3.735, 1.455]	.003	.007	[-.012, .017]
MVPA				.001	.000	[.000, .002] *
Between-Person Level						
Sleep Quality	-.521	6.996	[-9.279, 11.490]	-.001	.153	[-.300, .239]
MVPA				.000	.002	[-.002, .003]
Level 2 Predictor (Slope) Commute Variability → Sleep Quality				-.034	.080	[-.189, .124]
Within-Person Mediator						
Sleep Quality➔MVPA				-.001	.001	[-.004, .001]
Between-Person Mediator						
Sleep Quality➔MVPA				-.000	.052	[-.016, .015]

Note. $N = 81$. There were 2999 day-level time points available for statistical analysis ($n = 2999$). Reported coefficients are unstandardized. Level 2 predictors were grand-mean centered. Variables with both within- and between-person variance were latent-mean centered. CI is credibility interval. Coefficient estimates were obtained using Bayesian estimation.

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

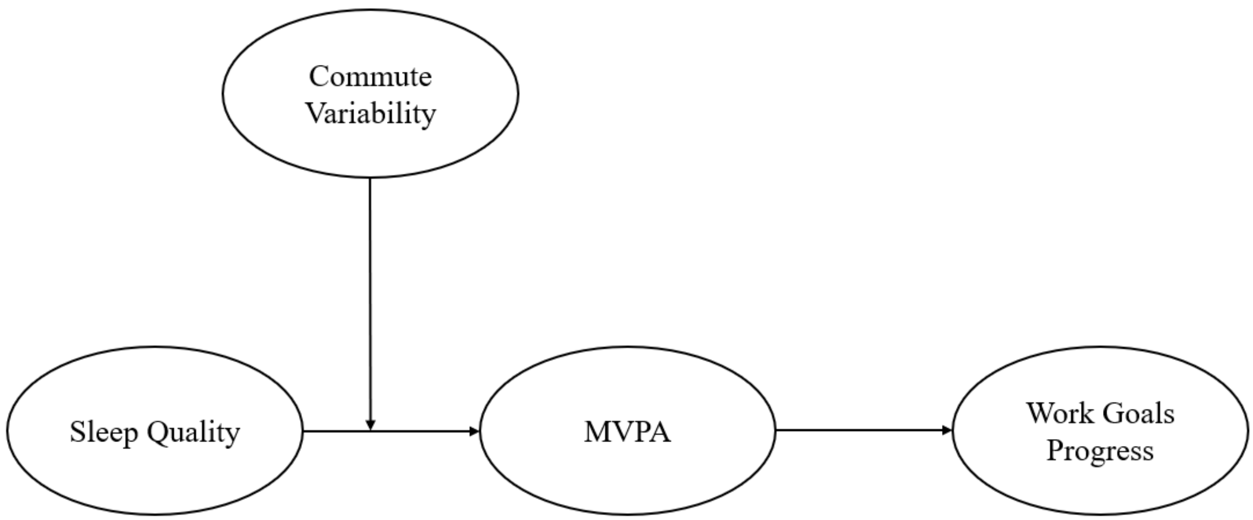

Figure 1. Conceptual model

Note. MVPA refers to moderate-to-vigorous physical activity.

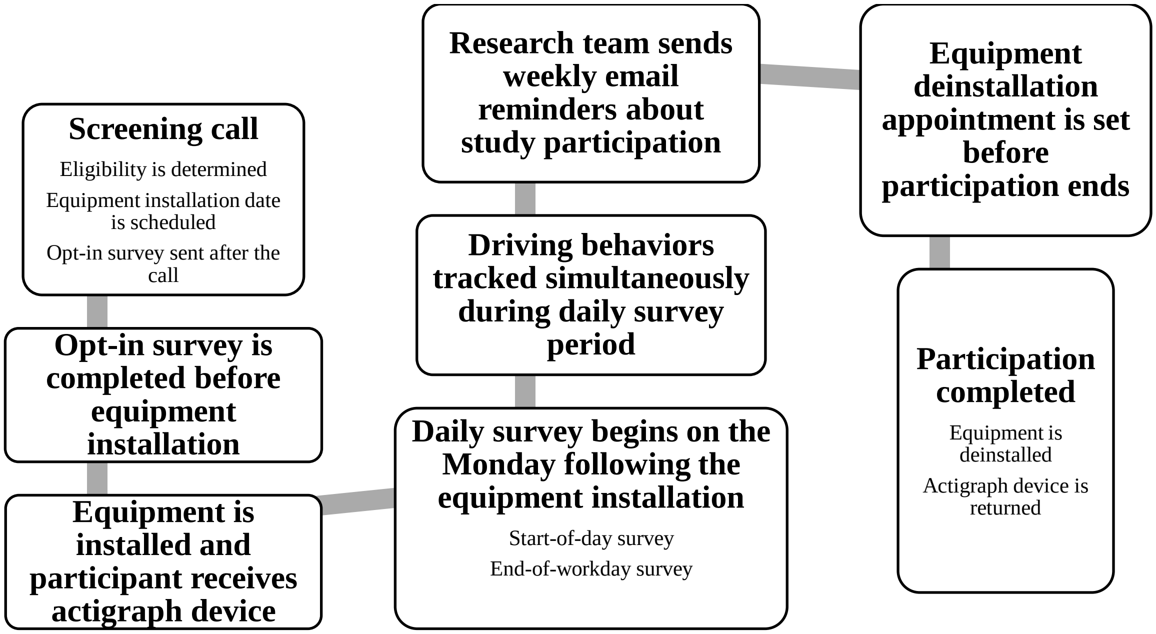

Figure 2. Summary of research procedure

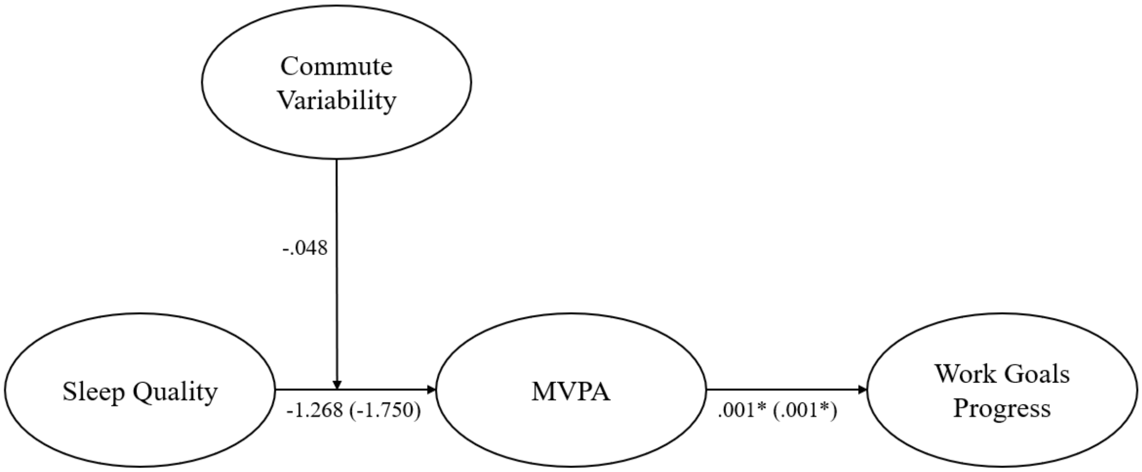

Figure 3. Multilevel structural equation model including parameter estimates for direct effects. Within-person results are reported first, and between-person results are reported in parentheses.

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

Note. MVPA refers to moderate-to-vigorous physical activity.

Appendix A: Questions Used to Determine Participant Eligibility

1. **Are you at least 18 years old?** [Need YES answer to continue]

2. **Are you a licensed driver?** [Need YES answer to continue]

3. **Are you an undergraduate or a graduate student?** [Need NO answer to continue]

4. **Do you commute to and from your physical workplace by car five days a week (Monday – Friday)?** [Need YES answer to continue]

5. **Do you drive yourself to and from work when commuting (i.e., you are not carpooling)?** [Need YES answer to continue]

6. **Are you planning to use the same car to commute to and from work each workday for the next eight weeks?** [Need YES answer to continue]

7. **Do you commute to work with an average commute time of at least 15 minutes each way?** [Need YES answer to continue]

8. **Do you work in a job in which driving is not part of your central job duties (i.e., not a bus driver, truck driver, etc.)?** [Need YES answer to continue]

9. **Do you live close enough to Blacksburg, Virginia such that you could feasibly bring your car to a garage in this location to have in-vehicle recording equipment installed?** [Need YES answer to continue; be sure to note which research site they are making an appointment for on the study tracking sheet. URAs are recommended to have a maps application open on one of the lab computers, so that they can provide a time estimate if the participant asks how far a specific location is from Blacksburg for purposes of planning their transportation]

10. **Do you have regular access to the Internet/email? We ask this question because there will be daily surveys that you will be asked to complete as part of this study that require Internet access.** [Need YES answer to continue]

11. **Do you currently hold a valid, U.S. driver's license that you can present when you enroll?** [Need YES answer to continue]

12. **Are you a U.S. citizen?** [If YES, ask Question 12. If no, ask Question 11a below]

    a. **If NO, do you have a valid Green Card with permanent resident status which allows you to work anywhere in the U.S. with no limitations?** [Need YES answer to continue]

13. **If you are eligible for this study, you will be required to fill out a W-9 form for compensation purposes that will require your social security number, full name, and address. Are you willing to provide this information and complete a W-9 to participate in this study?** [Need YES answer to continue]

14. **Do you own, co-own, or lease the primary vehicle you drive? Please note that the registration for the car must have your name on it in order to participate and you will be asked to provide documentation at the time of installation or the owner of the vehicle must be willing to sign an owner permission form allowing you to use the car for the study.** [If YES, ask Question 14. If NO, ask Question 13a]

a. **If the vehicle is owned by someone else, will they be willing to sign an owner permission form that gives VTTI permission to install the equipment for the study?** [Need YES answer to continue]

15. **What is the make, model, and year of the primary vehicle you usually drive that you might be willing to have instrumented for this study?** [Continue unless they indicate an Audi, Jaguar, Mercedes, or Volkswagen vehicle which are excluded due to installation limitations with the microDAS. It is important to note the vehicle information in the study tracking sheet, as VTTI will need this information when planning the equipment installation]

Make: ________________ Model: __________________

Year: ______________

16. **Does anyone else drive this vehicle on a regular basis?**

a**. If YES, what percentage of time do others drive the vehicle?** (Must be less than 75%; Otherwise they are ineligible to participate)

17. **If you enroll in this study, can you avoid driving into areas where videotaping is not allowed, such as military installations, high security areas, or border crossings?** [Need YES answer to continue]

18. **Do you anticipate any life events during the next 8 weeks that may alter your normal driving pattern, causing you to drive less? For example, an upcoming surgery, going out of town for an extended period of time, changing employment, moving, etc.?** [Need NO answer to continue]

a. If YES, ask for the dates: _____________

Will you be taking your car with you? _______ (e.g., will they be bringing their car on vacation?)

19. **Are you willing to bring your car to one of our garages so that our technicians can install data collection equipment?** [Need YES answer to continue]

20. **Are you comfortable reading, writing, and speaking in English?** [Need YES answer to continue]

Appendix B: Monte Carlo Input Syntax for Statistical Power Analysis

```
TITLE: Monte Carlo Power Analysis;
MONTECARLO: names are x y m w c;
WITHIN ARE x c;
BETWEEN ARE w;
NOBSERVATIONS=3240;
NCSIZES=1;
CSIZES=81(40);
NREPS = 10000;
SEED = 53487;
PATMISS=x(.20) y(.20) m(.20) c(.20);
PATPROB=1;
ANALYSIS: TYPE=TWOLEVEL RANDOM;
ESTIMATOR=BAYES;
MODEL MONTECARLO:
  %WITHIN%
  s1 | m ON x;
  m ON c*.10;
  y ON m*.20(a);
  y ON x*.20;
  x*.05;
  y*.05;
  m*.05;
  c*.05;
  %BETWEEN%
  s1 ON w*.20(INT);
  m ON w*.20;
  [s1*.20](s1);
  m*.05;
  w*.05;
  s1*.05;
  MODEL CONSTRAINT:
  NEW (ind);
  ind=s1*a;
  MODEL:
  %WITHIN%
  s1 | m ON x;
  m ON c*.20;
  y ON m*.20(a);
  y ON x*.20;
  x*.05;
  y*.05;
  m*.05;
```

```
c*.05;
%BETWEEN%
s1 ON w*.20(INT);
m ON w*.20;
[s1*.20](s1);
m*.05;
w*.05;
s1*.05;
```

Appendix C: Alternative Model

Day of Week, Week of Study, and Lagged Variables as Controls

I computed a model with prior day values of sleep quality, MVPA, and work goals progress as control variables in the focal multilevel structural equation model. I also included the day of the week and week of the study as statistical control variables in the model due to potential fluctuations in the study variables based on these temporal considerations, in the same model. This model initially failed to converge without substantially increasing the number of iterations, thus, I ran the model with 100,000 iterations. The initial convergence issue may be due to potential issues including cyclical considerations, autoregressive relations, and trends (Muthén at al., 2025; Zhou et al., 2021) relating to intensive longitudinal data.

All coefficient estimates, posterior standard deviation, and 95% confidence intervals for the hypothesized model at both the within-person and between-person levels are presented in Table 10. The pattern of results mirrored the observations in the main multilevel structural equation model, although I found no evidence to support the relationship between MVPA and work goals progress ($\gamma = .000$, Posterior *SD* = .002, 95% *CI* = [-.002, .003]), at the *between-person* level in the current analysis.

Additionally, previous day sleep quality related to next-day sleep quality at the *within-person* level of analysis ($\gamma = .059$, Posterior *SD* = .023, 95% *CI* = [.014, .104]). Further, previous day MVPA co-varied with next-day MVPA at the *within-person* level of analysis ($\gamma = .112$, Posterior *SD* = .019, 95% *CI* = [.074, .150]). Finally, previous day work goals progress positively related to next-day work goals progress at the *within-person* level of analysis ($\gamma = .156$, Posterior *SD* = .020, 95% *CI* = [.116, .196]).

Previous day sleep quality related to next-day sleep quality at the *between-person* level of analysis ($\gamma = .996$, Posterior *SD* = .079, 95% *CI* = [.841, 1.188]). Previous day MVPA co-varied with next-day MVPA at the *between-person* level of analysis (γ = 1.031, Posterior *SD* = .071, 95% *CI* = [.907, 1.120]). Finally, work goals progress is positively related to next-day work goals progress at the *between-person* level of analysis (γ = 1.005, Posterior *SD* = .124, 95% *CI* = [.774, 1.192]).