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Relaxation During the Evening and Next-Morning Energy: The Role of Hassles, Uplifts, and Heart Rate Variability During Work

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Being able to psychologically relax after work in the evening is important to the day-to-day recovery process and should enable employees to wake up feeling energized for the next workday. Drawing on affective events theory and allostatic load theory, we expected that employees will be able to psychologically relax when they get home from work if during work (a) they experienced less work-related goal-frustration events and more work-related goal-achievement events and (b) if they were adaptively regulating physiological stress arousal (as indexed by heart rate variability). As such, this research considers that work events, as well as a physiological indicator of parasympathetic regulation, can be important antecedents to off-the-job recovery. Over the course of 5 consecutive workdays, 72 employees completed daily surveys (on waking, at work, and in the evening) and wore an ambulatory electrocardiograph to measure their heart rate variability while at work that afternoon. Multilevel mediation analyses revealed support for our hypotheses at the within-person level, except for the role of goal-attainment events. The finding that goal-frustration events and heart rate variability both contribute to evening relaxation, and then indirectly to next-morning energy, provides initial insights on how both mind and body impact off-the-job recovery.

Keywords: recovery, relaxation, heart rate variability, energy, affective work events

Off-the-job time in the evenings can act as an important source of respite, a chance for employees to unwind and relax after the pressures of the workday. For these reasons, respite has been positioned as a protective factor for employee well-being and identified as an "energy resource" (Halbesleben, Neveu, Paustian-Underdahl, & Westman, 2014). Indeed, benefits of relaxation after working are not only limited to employee well-being (Bennett, Bakker, & Field, 2018; Sonnentag, Binnewies, & Mojza, 2008; ten Brummelhuis & Bakker, 2012), but can also benefit work engagement (ten Brummelhuis & Bakker, 2012), and even crossover to benefit partner well-being as well (Park & Haun, 2017; Rodríguez-Muñoz, Sanz-Vergel, Antino, Demerouti, & Bakker, 2017). Thus, discovering ways to help employees relax after work and wake up in a positive and energized mood has many benefits for both the employer and employee.

Relaxation after work is recovery experience characterized by low activation and positively toned affect (Sonnentag & Fritz, 2007). It can result from specific leisure activities and from deliberate relaxation exercises. A review of the literature identified common relaxation activities including meditation, yoga, breathing exercises, listening to music, taking a hot bath, walking in a natural environment, and progressive muscle relaxation (Demerouti, Bakker, Geurts, & Taris, 2009). Importantly, the research to date suggests that the specific activities individuals engage in to achieve relaxation are less important to recovery than the subjective experience of relaxation (Sonnentag & Fritz, 2007; ten Brummelhuis & Bakker, 2012). Indeed, relaxation activities in and of themselves only indirectly influence recovery through the psychological state of feeling relaxed (ten Brummelhuis & Bakker, 2012). Research on relaxation as a recovery experience has been limited, as most scholars have focused on psychological detachment as the main mechanism for off-the-job recovery (Demerouti et al., 2009; Sonnentag & Fritz, 2015). Thus, the first unique contribution of this research is the focus on the psychological relaxation experience in the process of off-the job recovery.

A recent meta-analysis of the recovery literature has confirmed that job demands are negatively related to the relaxation experience (Bennett et al., 2018). However, this meta-analysis evaluated

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between-person rather than within-person effects (i.e., day-level effects) due to limited diary studies available. Certainly, chronic job demands are important to consider in work stress and recovery. However, guided by the affective events theory (AET; Weiss & Cropanzano, 1996), we consider that on a day-to-day basis, it is the tangible events of that workday (i.e., the salient negative and positive events) that have the potential to be stress-arousing or soothing, and these then impact one's relaxation experience when they get home. Limited research has been conducted to date on the carry-over of affective work events into leisure time. Thus, a second contribution of our research is that we examine the impact of affective work events, in particular events related to goal frustration and goal attainment (Ohly & Schmitt, 2015), on the psychological experience of relaxation that evening at home.

A third contribution of our research is to examine the physiological state of a person during the workday as a predictor of the psychological relaxation experience in the evening. Specifically, we use heart rate variability (HRV) as an indicator of a person's physiological state, reflecting down-regulation of stress arousal. HRV is a promising emerging methodology for occupational health psychology because it is relatively easy to use, is noninvasive, and provides information about the activity of the parasympathetic nervous system (PSNS), which is the branch of the autonomic nervous system (ANS) responsible for the regulation of stress arousal (Appelhans & Luecken, 2006; Berntson, Norman, Hawkley, & Cacioppo, 2008; Massaro & Pecchia, 2017; Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). Physiological systems, like the PSNS, automatically regulate stress arousal, yet, to date, organizational scholars have only limited knowledge about how these bodily processes are involved in many work experiences (Ganster, Crain, & Brossoit, 2018) and how they might affect psychological recovery. In our study, participants wore portable electrocardiographs (ECG) during their work, enabling assessment of HRV on a daily basis in the work setting.

Our conceptual model is presented in Figure 1. In summary, we examine how affective work events, both hassles and uplifts related to goal striving, as well as the physiological regulation of stress arousal at work, impact employees' experience of relaxation in their evenings at home, which we expect then has consequences for next-morning energy. Thus, we consider that what happens at work, and how well the body regulates stress arousal at work that day, are antecedents of day-to-day recovery. Moreover, by using a daily diary study design and multilevel modeling techniques, we are able to partition the within-person and between-person variances involved in these processes throughout the working week.

Affective Work Events and Consequences for Evening Relaxation

Originally, AET was an explanation of how emotional processes accumulate to predict stable job attitudes, like job satisfaction. However, updates to the theory consider that it offers more than this, by providing a "macrostructure" for the study of emotional processes at work (Ashkanasy & Dorris, 2017; Weiss & Beal, 2005). Arguably, one of the most important contributions of the theory has been to highlight the importance of work events and their affective consequences, which has prompted the study of these effects at the within-person level (Ashkanasy & Dorris, 2017; Ohly & Schmitt, 2015; Weiss & Beal, 2005). Indeed, research by Ohly and Schmitt has provided a useful taxonomy for the study of affective work events, which we draw on in this research, with a particular focus on daily hassles and uplifts related to goal pursuit at work.

Daily hassles are a type of negative affective work event, which are defined as impediments that happen in work settings to which employees react emotionally (Ohly & Schmitt, 2015; Weiss & Cropanzano, 1996). Qualitative and quantitative diary study research has found that time pressures, mistakes, excessive workloads, and goal disruptions are negative work events that are most frequent and have stress-arousing affective consequences (Basch & Fisher, 2000; Bono, Glomb, Shen, Kim, & Koch, 2013; Diefendorff, Richard, & Yang, 2008; Ohly & Schmitt, 2015; Zohar, Tzischinski, & Epstein, 2003). In their analysis of the types of affective events that happen during the workday, Ohly and Schmitt (2015) classified these "goal-frustration" events as types of negative work-related hindrances that undermine a worker's sense of personal agency. We consider that these *work-related goal-frustration events* have the ability to impact nonwork time because hindrances like time pressure, excessive demands, and recognizing mistakes mean that tasks were difficult and challenging and potentially went unresolved. Furthermore, these types of work-related hassles are associated with negative affective experiences, including more anger, worry, and less positive enthusiasm (Ohly & Schmitt, 2015), which would impair the ability to relax later, even when one is removed from the stressful work situation. This is consistent with the idea of "aftershocks" in the AET (Weiss &

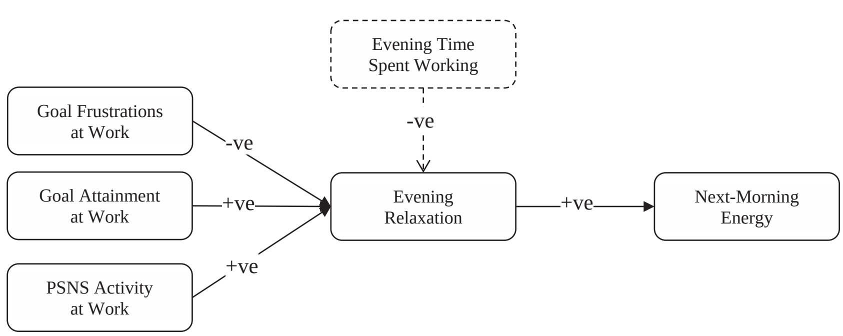

Figure 1. Conceptual model.

Cropanzano, 1996), which specifies that affective events not only cause specific emotion experiences in the moment the event is occurring but also affect later emotional episodes as the person responds and adapts to the initial shock.

Indeed, previous research has shown that negative affective work events, particularly "goal disruptions," increase fatigue in the moment, and although this effect is lessened and somewhat dependent on existing workload levels, the relationship is still present at the end of the workday (Zohar et al., 2003). Moreover, it also has been found that affective work events from that workday can carry over onto experiences in evening leisure time. For instance, one daily diary study has found a positive association between negative work events at work that day and after-work fatigue in the evening (Gross et al., 2011). Moreover, another daily diary study has shown that negative work events that day can impair people's ability to psychologically detach from work in the evening (Bono et al., 2013). Although some studies have examined "nonwork hassles" during recovery time (Fritz, Sonnentag, Spector, & McInroe, 2010), the relationship between work-related hassles and off-the-job relaxation experience is yet to be explored. Thus, it remains unclear if and how negative affective work events impact relaxation during after-work hours.

Looking further afield, research has begun to show that work stress assessed in the afternoon can predict greater work-related rumination in the evenings (Vahle-Hinz, Bamberg, Dettmers, Friedrich, & Keller, 2014) and that thoughts of unfinished tasks can leave employees feeling stressed and in a state of heightened arousal after work (Syrek & Antoni, 2014). Thus, there are promising insights to cognitive processes (e.g., rumination) that could underlie the relationship between goal-frustration events from that day and relaxation experiences later on that evening. Guided by these insights, and also by the idea of "aftershocks" of negative events in the AET, we expected that work-related goal frustrations are likely to interfere with employees' ability to "kick back," engage in leisure, and subjectively relax when they get home that evening.

> *Hypothesis 1:* Within-person, work-related goal-frustration events are negatively related to evening relaxation.

Daily uplifts are a type of positive affective work event (Ohly & Schmitt, 2015; Weiss & Cropanzano, 1996). Qualitative and quantitative diary study research has identified a broad range of positive work events, but the most commonly occurring, with the greatest impact on affective reactions, are events related to goal attainment, for example, success on tasks, problem-solving, goal progress, and achieving goals (Basch & Fisher, 2000; Bono et al., 2013; Ohly & Schmitt, 2015; Zohar et al., 2003). In particular, the research by Ohly and Schmitt (2015) revealed that, at the time of the event, these types of "goal attainment" events are positively associated with high- and low-activation positive mood, and less anger, worry, and exhaustion. However, other research has observed that positive affective work events are less predictive of affective experiences in comparison with negative events (Miner, Glomb, & Hulin, 2005). In the studies by Ohly and Schmitt, positive affective work events classified as goal-attainment events had the strongest associations with momentary affect, compared to other types of positive work events. Thus, it might be possible that when previous research has not disentangled the specific types of positive work events (i.e., in particular, the element of goal striving), then this approach might have limited the potential for associations with affective experiences to be revealed.

Overall, research into the effects of work-related daily uplifts has been more limited than that of hassles (see Bono et al., 2013 for a review of this issue). There are a few noteworthy daily diary studies on this topic. First, Zohar and colleagues (2003) examined "goal-enhancing" events (in addition to disruptive events). Although they found limited impact of goal-enhancing events on momentary fatigue (in comparison with goal-disruptive events), they did find that goal-enhancing events were important for mitigating end-of-day fatigue, especially on days with high workload. Thus, Zohar and colleagues' research suggests that it is important to study both goal disruption and goal enhancement simultaneously, especially given the greater potential for lagged effects of goal-enhancing events on end-of-day fatigue. Indeed, Bono and colleagues (2013) found that beneficial effects of positive affective work events that day were directly related to low blood pressure and high psychological detachment from work assessed in the evening, indicating that positive work events can have a calming influence and improve recovery processes that evening. However, contrary to this, Gross and colleagues (2011) found no direct impact of positive affective work events (unlike negative events) on after-work fatigue in the evenings.

It is important to note that the studies by Gross et al. (2011) and Bono et al. (2013) grouped several specific types of work events into positive and negative categories, which is not uncommon in the AET literature. Hence, these previous studies did not tease apart the events related to goal striving (i.e., goal attainment vs. goal frustration; the *agency* dimension identified by Ohly & Schmitt, 2015), which makes it difficult to understand the potential carry-over effects of uplifts. Thus, given that daily uplifts indicative of goal attainment should spur a range of positive affective experiences (and lessen negative affective experiences; Ohly & Schmitt, 2015; Zohar et al., 2003), and given that some of these affective experiences can be long-lasting and carry over into off-the-job time (Bono et al., 2013), which would be beneficial for relaxation, we expected that *work-related goal-attainment events* would positively influence employees ability to relax when they get home from work.

> *Hypothesis 2:* Within-person, work-related goal-attainment events are positively related to evening relaxation.

Autonomic Regulation at Work and Consequences for Evening Relaxation

In addition to affective work events, we also anticipated a role for a physiological process during that workday for the prediction of psychological relaxation experiences during the evening. Previous research has shown that poor work design (e.g., low job control or jobs both high on demand and low on control) can impair *physiological unwinding in off-the-job time* (e.g., using measures of blood pressure; Steptoe, Cropley, & Joekes, 1999; Steptoe & Willemsen, 2004). However, in our research, we focus on whether *regulation of physiological arousal at work* (as indexed by HRV as an indicator of PSNS activity) is an antecedent to the process of off-the-job recovery, that is, experiencing a relaxing evening and waking up feeling more energized. We draw

on allostatic load theory (McEwen, 1998), which has emerged as the dominant theory of physiological stress (Ganster & Rosen, 2013), to understand physiological adjustments at work.

Allostatic load theory describes how the body adapts to environmental stressors via a process of adjusting physiological systems; for example, a primary load adjustment could include heart rate acceleration during a stressful encounter, to enable the organism to respond to the demands of the situation, and then, once the threat is gone, return to a normal set-point for cardiovascular activity. Such adjustments are adaptive in the short term, enabling the organism to cope with the situation, but if stressors go unresolved over an extended period of time, there can be longer term health consequences, that is, secondary and tertiary load adjustments, through an inability to return to a normal state of functioning (see Ganster et al., 2018, for a recent review of the theory, as it pertains to work stress).

According to allostatic load theory, an important *primary allostatic* system is the hypothalamic–pituitary–adrenal axis, which plays an important role in regulating cardiovascular activity (and stress hormones) trigged by the nervous system when faced with a demanding or stressful situation. Advances in HRV analysis have enabled organizational scholars to draw inferences on the outflow of ANS activity (Massaro & Pecchia, 2017), one part of the nervous system involved in "instant control of visceral function, internal regulation, and adaptation to external challenges" (Massaro & Pecchia, 2017, p. 3). In particular, some calculations of HRV can reflect PSNS activity, the branch of the ANS that downregulates stress arousal. If greater PSNS activity at work reflects better regulation of stress arousal in that context, then this should be an important indicator of the primary allostatic load for that day and could also act as a precursor to one's ability to recover in their off-the-job time. In this section, we will outline why PSNS down-regulation at work will act as an antecedent in the process of day-to-day recovery. However, first, we describe more specifically what HRV is and what is known about its associations with work stress.

Put simply, HRV is variation in the beat-to-beat changes of the heart rate. There are several ways to compute HRV, based on this interbeat interval, which are associated with different activity of the ANS (Berntson et al., 1997). HRV derived by the root mean squared standard deviation (r-MSSD) of successive interbeat intervals and HRV derived by spectral power analysis in the high frequency (HRV-HF) are thought to be the main indicators that reflect PSNS control of the heart (Berntson et al., 2008; Heathers, 2014; Shaffer & Ginsberg, 2017; Thayer et al., 2012). These indicators have been used in research on the association of HRV and work stress (see Togo & Takahashi, 2009, for a review), and although HRV-HF is more commonly used (Zahn et al., 2016), there are reasons to select r-MSSD, especially for HRV assessment in work settings (Loerbroks et al., 2010; Uusitalo et al., 2011). However, when normalized, both are considered to capture "vagally mediated" activity of the PSNS, in particular down-regulation or suppression by the PSNS of the sympathetic nervous system (Berntson et al., 2008; Shaffer & Ginsberg, 2017). As the sympathetic nervous system increases adrenaline and the "stress response" (increasing blood and oxygen flow to muscles), greater regulation by the PSNS suggests the organism is more adaptively managing physiological stress arousal. Indeed, considerable research has shown that HRV indicates PSNS output in this way and is thus useful for understanding not just the stress response (Kim, Cheon, Bai, Lee, & Koo, 2018) or emotional responding (Berntson et al., 2008), but, also emotion regulation (Appelhans & Luecken, 2006; Geisler, Vennewald, Kubiak, & Weber, 2010; see Balzarotti, Biassoni, Colombo, & Ciceri, 2017, for a recent meta-review) and more generally, self-regulatory processes (Segerstrom & Nes, 2007; see Holzman & Bridgett, 2017 and Zahn et al., 2016, for recent meta-analyses).

Previous research demonstrates a fairly reliable negative association between work stress (i.e., as measured via job strain or effort–reward imbalance) and HRV indicators of PSNS activity/capacity at the *between-person* level (see Chandola, Heraclides, & Kumari, 2010 and Togo & Takahashi, 2009 for reviews). Collectively, this research suggests that work stress can undermine individuals' physiological capacity to regulate stress arousal, which is theorized to have longer term implications for physical health through secondary and even tertiary allostatic load adjustments (Ganster et al., 2018; Ganster & Rosen, 2013; Thayer et al., 2012). However, much of this research is based on cross-sectional designs and uses either 24-hr HRV assessments or short-term (e.g., 5-min) baseline or laboratory assessments, which are then postulated to represent a trait-like value.

At the same time, it is theorized that *within-person* differences in HRV have the potential to be indicative of *primary allostatic* load adjustments while adapting to work stressors (Ganster et al., 2018); however, this area of research is still emerging. Such a proposition is supported by findings from laboratory based research that shows sensitive changes in HRV in response to changes in mental workload (Hoover, Singh, Fishel-Brown, & Muth, 2012; Jorna, 1992) and, with practice-coping with a demanding-work simulation (Parker, Laurie, Newton, & Jimmieson, 2014). However, to date, field research using *repeated assessments of HRV in work contexts*, for instance, on a day-to-day basis, is limited.

To our knowledge, there is one diary study over 3 workdays showing a negative association of HRV with work-related worry (with all data collected in the evenings after work; Cropley et al., 2017) and another diary study over 2 workdays and 1 day of the weekend demonstrating a negative association of nocturnal HRV with rumination (on the Saturday assessment only; Vahle-Hinz et al., 2014). In addition, we have observed some studies conducted over 1 or 2 days that classify HRV into work, leisure, and/or sleep periods and compare these assessments against participant reports on their job strain or effort–reward imbalance (Loerbroks et al., 2010; Uusitalo et al., 2011). However, as identified in a recent review (Ganster et al., 2018), other field-based organizational research using repeated daily repeated assessments of HRV is limited, and it is still considered an emergent area (Uusitalo et al., 2011). This is in contrast to research using blood pressure assessment, for which there are exemplar studies using repeated assessments over 10 workdays (Ilies, Dimotakis, & Watson, 2010). Thus, we do not know to what extent HRV, in particular, indicators of PSNS activity, could be indicative of day-to-day primary allostatic load (nor even more fine-grained adjustments within the workday), nor what the consequences are of daily variation in HRV for day-to-day recovery processes.

If we consider that higher PSNS activity at work that day indicates that the employee has been effectively physiologically regulating the stress arousal of the day, that is, the mental effort and emotion occurring at work, then we could consider that the

primary allostatic load for that workday is not too high and/or is manageable. On such days, the employee should be better positioned to transition to off-the-job time and take advantage of opportunities for relaxation during that important period of respite, and that this is because psychophysiological arousal is less likely to carry over and disrupt the evening relaxation experience. Thus, we might expect then that HRV at work will relate positively to the psychological experience of relaxation that evening at home. Conversely, lower HRV will indicate restricted PSNS activity on that workday, which suggests that daily experiences at work have been particularly straining (Hoover et al., 2012; Jorna, 1992; Uusitalo et al., 2011), with heightened mental effort and emotion that has been difficult to regulate. On such days, there would be a negative deviation from the organism's set point for PSNS activity, and thus we expect that the effects of this heightened psychophysiological arousal are likely to be difficult to recover from and will carry over into off-the-job time. As such, we expect that it will be harder to psychologically relax that evening at home.

> *Hypothesis 3:* Within-person, HRV (i.e., r-MSSD and HRV-HF) at work is positively related to evening relaxation.

From Evening Relaxation to Feeling Energized the Next Day

The opportunity to relax in one's off-job time should aid the process of unwinding before bed, providing the optimum context in which to restore one's energy resources in preparation for work the next day (Halbesleben et al., 2014). This recovery process can occur through many mechanisms (see Demerouti et al., 2009, for a review). For instance, relaxation experiences can help to reduce psychophysiological stress arousal, thereby reducing allostatic load that evening (Demerouti et al., 2009). Relaxation, as compared with other experiences in off-job time, also has the potential to restore personal resources because the leisure activities typically involved in relaxation consume very few resources to be enacted (Demerouti et al., 2009; Halbesleben et al., 2014; ten Brummelhuis & Bakker, 2012). Moreover, relaxation can improve sleep quality, which has many benefits for psychological functioning (Friedrich & Schlarb, 2018). However, it is important to note that relaxation in the evening after work can improve on-waking affect even when controlling for sleep quality (Sonnentag et al., 2008). Thus, we expect that when employees experience relaxation after work, there are many benefits that should lead one to wake up in a more energized mood the next workday.

> *Hypothesis 4:* Within-person, evening relaxation is positively related to next-morning energy.

Finally, given our earlier propositions, we also expect the following indirect effects:

> *Hypothesis 5:* Within-person, there will be a negative indirect effect of goal-frustration events at work on next-morning energy via evening relaxation.

> *Hypothesis 6:* Within-person, there will be a positive indirect effect of goal-attainment events at work on next-morning energy via evening relaxation.

> *Hypothesis 7:* Within-person, there will be a positive indirect effect of HRV (i.e., r-MSSD and HRV-HF) at work on next-morning energy via evening relaxation.

Method

Design and Procedure

We used a press release for recruitment. Participants were included if they were 18 years or older, full-time employed, and free of health/medication issues that would invalidate the interpretation of heart rate data. We followed guidelines for diary research (Bolger, Davis, & Rafaeli, 2003; Ohly, Sonnentag, Niessen, & Zapf, 2010) regarding use of brief online surveys to lessen demand on participants and used incentives (i.e., a personalized feedback report; entry into a prize draw for a chance to win an AUD500 gift card) to improve participation and compliance.

Participants completed three diaries (i.e., "on waking," "at work," and "evening") daily for 5 consecutive workdays (on Monday morning through Saturday morning inclusive). The "on waking" diary was sent at 4 a.m. each day, and participants were instructed to complete it within 30 min of waking. The "at work" diary was sent to participants at about 4 p.m., so that it was available for them to complete at the end of the workday before they left work. The "evening" diary was sent to participants each evening at about 8 p.m., which they were instructed to complete within 30 min before going to bed. Surveys not submitted within the timeframes specified were not included in the analysis.

Participants were inducted into the study, which included training on how to connect themselves to a heart rate monitor. They were provided with all the resources (e.g., electrode pads, connection instructions, a form to log their activities, and a reply paid postbag to return these materials) needed to be able to participate in heart rate monitoring over the course of 1 work week. They also had the primary researcher's contact details in case they needed help with use of the ECG monitor. Participants were instructed to go about their normal activities during the recording period, and to note their main activities, as well as transitions from home to work, and posture, on an easy-to-use pen and paper activity form, which was designed to fold up and store in the carry pouch of the ECG monitor.

Participants

Eighty-six participants started the study. Of these, 72 were retained for analyses as they had less than 20% missing data across the surveys and ECG recordings. For the 72 retained participants, compliance rates for the diaries ranged from 94% ("at work" diary) to 98% ("on waking" diary), and 93% of ECG assessments were retained for HRV analysis.

Among the 72 participants, approximately 61% were female, with a mean age of 43.13 years ($SD = 10.60$), working 40 hr per week on average ($SD = 4.85$), with a tenure of 5.37 years on average ($SD = 7.17$). Most had tertiary-level qualifications (86%). Participants' mean body mass index (BMI) was 24.44 ($SD = 3.83$). Participants were from diverse professions, organizations, and industries, but all were doing office-based work (i.e., not physically active). Occupation titles were coded and included 37.5% professionals, 31.9% managers, 13.9% community and per-

sonal service workers, 12.5% administrative and clerical workers, and 4.2% technicians and trade workers.

Measures

Heart rate variability. The heart rate recorders were a Schiller Medilog "AR12plus" portable ECG monitor (1000 Hz sampling rate). Leads were positioned on the torso to minimize muscle artifacts and maximize amplitude.

As noted earlier, there are several ways to calculate HRV values that reflect PSNS activity. We used HRV-HF as our primary indicator, as it is the most popular measure of HRV, both among psychologists (Zahn et al., 2016) and within occupational-stress research in particular (Togo & Takahashi, 2009). Moreover, HRV-HF is considered the best indicator of PSNS (Thayer et al., 2012) and is reportedly superior in quantifying PSNS activity, as well as correlating this with psychological states (Massaro & Pecchia, 2017), especially when it is normalized, as there is some evidence it can then reflect 'vagally mediated' PSNS activity (see Shaffer & Ginsberg, 2017, for a review of HRV measures). However, current advice for HRV researchers is to undertake their analyses on multiple indicators of HRV (Massaro & Pecchia, 2017). Thus, because HRV-HF is a frequency-based calculation of HRV, we also tested our model using an alternative time-based calculation, that being r-MSSD. According to reviews, r-MSSD is the second most commonly used indicator of HRV in psychological research on self-regulation (Zahn et al., 2016), and there is a demonstrated association of r-MSSD and occupational stress across at least seven studies (Togo & Takahashi, 2009). It also is considered the best indicator of PSNS activity that is vagally mediated (Shaffer & Ginsberg, 2017), and some argue it could be more suited for research in field settings (Loerbroks et al., 2010; Uusitalo et al., 2011).

Before generating the HRV values, we performed a visual inspection of each ECG trace and also examined validity estimates provided by the Schiller Medilog "Darwin" software program. ECG data were filtered and transformed using Medilog Darwin software, which analyzes the ECG trace adhering to accepted guidelines (Berntson et al., 1997; Malik et al., 1996). Following these guidelines, only normal beats (via R-peak detection) were used in the analysis (thus excluding artifacts and irregular beats). To derive HRV-HF, we conducted spectral power analysis of the frequency data using the discrete Fourier transform. HRV-HF was calculated by integrating the spectral power across the upper frequency band (0.15–0.40 Hz) using 2-min *epochs* (also referred to as *window widths*, used to derive HRV values over a standard length of time). To derive r-MSSD, successive interbeat intervals were analyzed across 2-min epochs. Because physiological data are significantly skewed, we normalized HRV-HF and r-MSSD using the natural log transform, as per recommendations (Berntson et al., 1997; Malik et al., 1996; Massaro & Pecchia, 2017; Shaffer & Ginsberg, 2017).

ECG data were collected each day, but we used only the epochs from *afternoon work* periods, that being from after the end of the lunch break until leaving the office each workday. In the "at work" diary, as well as the pen and paper activity form (for triangulation), we asked participants to report the time they came back from their lunch break and the time when they left the workplace, to ensure the HRV aggregate we calculated was for meaningful time periods at work each afternoon. As such, epochs retained for use in the aggregate did not include breaks, the commute home, or other personal time while at work. HRV aggregates for this time period were then calculated from epochs classified as "valid" by the Medilog Darwin software program.

Current advice is that the length of time chosen from which to compute HRV aggregates should match the research question of the study, the phenomenon under consideration, as well as the participants personal circumstances (Massaro & Pecchia, 2017). We contemplated each of these factors in determining our aggregates. Although laboratory-based research has indicated that it is useful to have short time periods (but no shorter than 5 min), limited field research has been conducted to date in the work setting, to guide the choice of aggregate length. Use of this afternoon work period for the HRV aggregate also was designed to be consistent with the time period over which we asked participants to report on the frequency of affective work events each afternoon. Because of the approach adopted in this research, the aggregates did vary in total duration (M = 3 hr and 52 min; SD = 1 hr and 30 min). By using an aggregate (i.e., mean of epochs available), we controlled for this variation in the number of epochs. Moreover, we checked that there was no systematic variation in HRV values based on the number of epochs, as the correlation of the number of epochs used in the aggregates with the HRV value of the aggregates was nonsignificant for HRV-HF, $r = .09$, $p = .120$, and for r-MSSD, $r = -.05$, $p = .396$. However, as the HRV-HF relationship was approaching significance, we elected to control for the number of epochs onto HRV values in our main analysis.

Scholars also note the need to "normalize" HRV recordings for the purposes of making comparisons within and between participants (Massaro & Pecchia, 2017). Although HRV has been found to be a sensitive state-like index that fluctuates in response to work requirements in controlled conditions (Hoover et al., 2012; Parker et al., 2014), it is, however, also trait-like, with large interindividual differences (Thayer et al., 2012). Accordingly, we attempted to normalize the HRV assessments in several ways. First, we took repeated daily assessments, to partition the variance components in multilevel modeling. Other scholars studying HRV in the work setting have done this by comparing people to a baseline assessment or to their recording during sleep (Loerbroks et al., 2010; Uusitalo et al., 2011). However, taking repeated assessments and modeling both the within and between variance components is recommended (Massaro & Pecchia, 2017; Vahle-Hinz et al., 2014). Therefore, we sampled HRV each afternoon at work over the course of 1 work week, and by doing so, we accounted for between as well as within sources of variance across assessments. Second, we sought office-working employees working relatively standard 9 a.m. to 5 p.m. work hours, in an attempt to control for physical activity and time of day effects. Third, we collected self-reports on posture. During the afternoon at work periods, participants reported sitting at their desk the majority of afternoons (73.6%), as compared with being upright (11.9%) or a mixture (14.6%). We further checked if reported posture was related to HRV values at work each afternoon. To do this, we performed an analysis of variance of the different postures (i.e., sitting, mixture, and upright) predicting HRV values, and the results revealed no significant differences, for either HRV-HF,

$F(2, 271) = 1.380$, $p = .253$, or for r-MSSD, $F(2, 271) = 1.197$, $p = .304$.

Diary measures.

Work-related goal frustration and goal attainment. To lessen burden on participants who were connected to an ECG monitor, we kept the "at work" diary brief by using single items on work events. We formulated these items based on previous qualitative research on affective work events, including insights on the content, frequency, and affective consequences of work events (Basch & Fisher, 2000; Ohly & Schmitt, 2015). In particular, our items were informed by the content analysis by Ohly and Schmitt. The work-related goal-frustration item was "Did you experience time pressure, excessive demands, or did you recognize mistakes, which resulted in difficulties to fulfil your work tasks?" The work-related goal-attainment item was "Did you solve any work-related problems, complete a work task, or did you succeed in a certain task?" Participants rated the frequency of these events *at work this afternoon* on a scale of 1 (*none of the time*) to 7 (*all of the time*).

Evening relaxation. Each evening before bed, participants completed a four-item measure on their subjective relaxation experience, for example, "Tonight, I kicked back and relaxed" (Sonnentag & Fritz, 2007). Response options ranged from 1 (*strongly disagree*) to 7 (*strongly agree*). Internal consistency for the measure was $\alpha = .95$.

We also included questions about relaxation activities to better understand participants' experiences. First, using the pen and paper activity forms, we coded activities reported by participants in their evenings that constituted deliberate attempts at relaxation. To do this, we started with a set of relaxation activities derived from the literature (i.e., meditation, yoga, breathing, listening to music, taking a bath, etc.), and also included emergent categories in which participants noted the activity was chosen for the purposes of relaxation. This revealed 11 distinct categories. The most common relaxation activity was "watching movies/TV" (53.5%), followed by "reading/Internet browsing" (25.7%), "yoga" (4.9%), and "meditation/breathing exercises" (4.5%), and then other activities occurred less frequently, such as "nonspecific relaxing activity," "gaming," "listening to music/podcasts," "napping," "bath," "painting," and "prayer."

Some evenings had no relaxation activities reported by the participants (53.8%), on other evenings there were multiple relaxation activities reported (12.6%), and the remaining evenings, at least one relaxation activity was reported (33.5%). We performed an analysis of variance to see if there were any noticeable differences in the self-reported evening relaxation experience between evenings with "none," "at least one," or "two or more" relaxation activities reported. The omnibus test was significant, $F(2, 322) = 8.539$, $p < .001$, $\eta^2 = .05$. Using the Bonferroni adjustment for multiple comparisons, evenings when no relaxation activities were reported had a significantly lower relaxation experience ($M = 4.68$; $SD = 1.54$) compared with evenings with at least one ($M = 5.23$; $SD = 1.32$), $p = .005$, 95% confidence interval [CI] [−0.96, −0.14], or two or more relaxation activities reported ($M = 5.52$; $SD = 1.10$), $p = .002$, 95% CI [−1.43, −0.24], and there was no significant difference between "one" versus "two or more" activities, $p = .809$, 95% CI [−0.91, 0.34].

Second, in the evening diary, we asked them to report on "How much time this evening did you spend on low-effort activities, such as watching TV, taking a bath, reading a magazine or fiction book, listening to music?", taken from Sonnentag (2001a). The average time reported on "low-effort" activities was 79.70 min ($SD = 66.38$). When we checked the correlation of time spent on low-effort activities with the self-reported relaxation experience, it was positive and significant, $r = .27$, $p < .001$, which is in line with previous research (ten Brummelhuis & Bakker, 2012).

Next-morning energy. On waking each morning, participants completed a four-item measure on high-arousal positive mood from Kessler and Staudinger (2009), which included the items *enthusiastic*, *elated*, *excited*, and *euphoric*. This measure reflects "energetic activation," a subjective experience of positive activation similar to the experience of vitality or vigor (Quinn, Spreitzer, & Fu Lam, 2012). Participants reported the extent to which each item best described how they feel this morning, on a scale from 1 (*not at all*) to 5 (*extremely*). Internal consistency for the measure was $\alpha = .78$.

Controlling for the continuation of work in the evenings at home. To be able to interpret the effects of affective events at work that day as a predictor of relaxation that evening, we needed to control for the continuation of work into the evening. Previous research has identified that time spent on work-related activities in off-work time has a negative impact on well-being (Sonnentag, 2001a). Thus, based on Sonnentag (2001b), we included an item in the evening diary on how much time was spent on work that evening. We asked participants to report the number of minutes spent on "Work-related activities, such as finishing or preparing for work-duties, doing one's private administration, or answering / writing emails."

Additional control variables for sensitivity analyses. Evident from the analysis by Ohly and Schmitt (2015), we recognize that private life intrusions can occur at work, thus contributing to physiological arousal in that context. Thus, to be able to assess the influence of such intrusions from private life, we also asked participants in the "at work" dairy the following item on the same scale as the other affective work events: "Did you experience any negative news or happenings in your private environment (e.g., problems concerning close friends or family, or events concerning your private life)?"

Moreover, to account for other life commitments in the evenings after work and the implications for the psychological experience of evening relaxation, we asked participants to report on time spent on household chores and time spent on physical activity in the evenings, using the same response scale as time spent on work and low-effort activities. Items were from the study by Sonnentag (2001a): "Household activities, such as cooking, doing the dishes, shopping, doing laundry, or cleaning etc.", and "How much time did you spend on physical activities, such as sports, cycling, running, going to the gym, dancing, etc."

Results

Due to the nature of the data (i.e., observations nested within individuals), the hypothesized effects were modeled at both the within-level and between-level in a multilevel mediation (MLM) path model (Preacher, Zyphur, & Zhang, 2010) using M*plus* 8. The data file was first constructed such that each row ($n = 360$) included that afternoon's HRV at work (both HRV-HF and r-MSSD indicators), that afternoon's affective work events, that evening's relaxation, and next-morning energy. Within the data

file, we also included that morning's energy and the previous evening's relaxation, the number of epochs used to derive the HRV aggregates, other controls outlined in the Method section, and various between-person controls (e.g., sex and age), for use in sensitivity analyses. Table 1 reports the correlations, descriptive statistics, and intraclass correlation coefficients (ICC).

Analyzing the variance components revealed ICCs in the range of .306 to .476 for the self-reported variables, and ICCs for HRV-HF = .835 and r-MSSD = .804. These HRV ICC values are similar to those observed in the Vahle-Hinz et al. (2014) study with three nights of HRV assessment (i.e., ICC = .82 for nocturnal r-MSSD). High ICC values for HRV are in line with research that suggests that although HRV can be a sensitive index of regulation from moment to moment, it also reflects large individual differences in a general physiological capacity to regulate arousal (Thayer et al., 2012) and highlights the importance of taking repeated assessments of HRV and modeling the variance components. It is important to note, however, that because HRV epochs were aggregated from the afternoon work period, although the within-person variation in HRV is attributable to that afternoon's PSNS activity, the between-person variance is attributable to both individual differences (i.e., capacity for regulation or secondary load adjustments; Ganster et al., 2018) and also is likely influenced by the common work context in which each individual is situated.

Test of Hypotheses With HRV-HF as an Indicator of HRV

The HRV-HF model had adequate fit, $\chi^2(42) = 130.43$, $p < .001$, comparative fit index (CFI) = .938, Tucker–Lewis index (TLI) = .907, root mean square error of approximation (RMSEA) = .024, standardized root mean square residual (SRMR) within = .065, SRMR between = .083. The MLM regression effects for both the within- and between-levels are summarized in Figure 2. In support of Hypothesis 1, work-related goal-frustration events were negatively related to evening relaxation, $b = -.13$, $SE = .051$, 95% CI [−.23, −.03], $p = .008$. Contrary to Hypothesis 2, work-related goal-attainment events were not associated with evening relaxation, $b = .04$, $SE = .055$, 95% CI [−-.07, .15], $p = .492$. In support of Hypothesis 3, HRV-HF at work was positively related to evening relaxation, $b = .42$, $SE = .133$, 95% CI [.16, .68], $p = .002$. In support of Hypothesis 4, evening relaxation was positively related to next-morning energy, $b = .06$, $SE = .030$, 95% CI [.002, .120], $p = .042$.

For the indirect effects, we applied a one-tailed test as per the recommendations of Preacher et al. (2010) for handling MLM indirect effects. Table 2 reports the indirect effects (as well as the direct effects, for full reporting). In support of Hypothesis 5, there was a negative indirect effect of goal-frustration events on next-morning energy through evening relaxation. However, contrary to Hypothesis 6, there was no indirect effect of goal-attainment events on next-morning energy. In support of Hypothesis 7, there was a positive indirect effect of HRV-HF at work on next-morning energy through evening relaxation. Thus, two of the hypothesized indirect effects were significant in the expected direction and at the within-person level. Overall, we found support for Hypotheses 1, 3, 4, 5 and 7, at the within-person level, but no support for the hypotheses pertaining to goal-attainment events at the within-person level (i.e., Hypotheses 2 and 6).

At the between-person level, the effect of goal-frustration events on evening relaxation was negative and significant, $b = -.32$, $SE = .103$, 95% CI [−.45, −.01], $p = .002$. Moreover, the effect of goal-attainment events on evening relaxation was positive and significant, $b = .57$, $SE = .153$, 95% CI [−.45, −.01], $p < .001$. However, none of the indirect effects at the between-person level were significant (Table 2).

Test of Hypotheses With r-MSSD as an Indicator of HRV

The model fit for an alternative analysis that included r-MSSD in exchange for HRV-HF was adequate, $\chi^2(42) = 125.650$, $p < .001$, CFI = .928, TLI = .891, RMSEA = .025, SRMR within = .065, SRMR between = .087. Interestingly, fit was not as good as

Table 1
Correlations and Descriptive Statistics

Variables	M_{person}	SD_{person}	M_{day}	SD_{day}	ICC	2	3	4	5	6	7	8	9	10	11	12	13
Between-person																	
1. Sex	1.61	.49	—	—	—	.06	−.03	−.04	.28	−.32	−.13	−.02	.00	−.19	−.03	−.10	−.17
2. Age	43.13	10.60	—	—	—	—	.01	.01	−.12	−.25	−.10	−.61	−.54	−.15	.13	−.06	.02
3. Body mass index	24.44	3.83	—	—	—		–	.12	.13	.16	−.00	−.07	−.11	−.19	−.16	.05	−.27
Within-person																	
4. Private life intrusions at work	1.25	.85	1.25	.84	.376	—	—	—	.60	−.06	.23	−.29	−.26	.05	−.01	−.38	−.00
5. Evening time on chores	49.10	45.99	50.06	45.78	.418	—	—	.03	—	.35	.39	−.13	−.08	−.03	.04	−.28	.02
6. Evening time on physical activity	23.02	48.03	23.73	47.81	.447	—	—	−.04	−.19	—	.42	.30	.33	−.12	−.04	.17	.10
7. Evening time on work	32.32	57.09	32.20	56.82	.435	—	—	.06	−.04	.11	—	.03	.06	.20	.00	−.35	.22
8. HRV-HF at work (ν)	5.15	.63	5.15	.90	.835	—	—	.16	−.03	−.01	.03	—	.92	.04	−.21	.09	.16
9. HRV r-MSSD at work (ν)	3.36	.40	3.36	.41	.804	—	—	.10	−.00	−.02	.04	.88	—	.06	−.13	.08	.24
10. Goal frustrations at work	2.84	1.78	2.83	1.79	.476	—	—	.08	.02	.00	.04	−.14	−.13	—	.24	−.32	−.03
11. Goal attainment at work	4.09	1.60	4.08	1.61	.306	—	—	−.02	.12	.02	.01	.08	.07	.15	—	.38	.20
12. Evening relaxation	4.90	1.53	4.89	1.53	.419	—	—	−.00	−.08	−.02	−.37	.14	.12	−.17	.02	—	.16
13. Next-morning energy	1.61	.62	1.61	.62	.476	—	—	−.01	−.22	.05	−.04	.00	−.03	.02	−.04	.16	—

Note. ν = normal units; ICC = Intraclass correlation coefficient; HRV = heart rate variability; HRV-HF = HRV derived by spectral power analysis in the high frequency domain; r-MSSD = HRV derived by the root mean squared standard deviation of successive inter-beat intervals. Correlations at the between-person level are on the upper diagonal, and correlations at the within-person level are on the lower diagonal. For descriptive purposes, we note that heart rate was $M = 76.60$ ($SD = 9.24$) and ranged from 49.33 to 115.74 beats per minute.

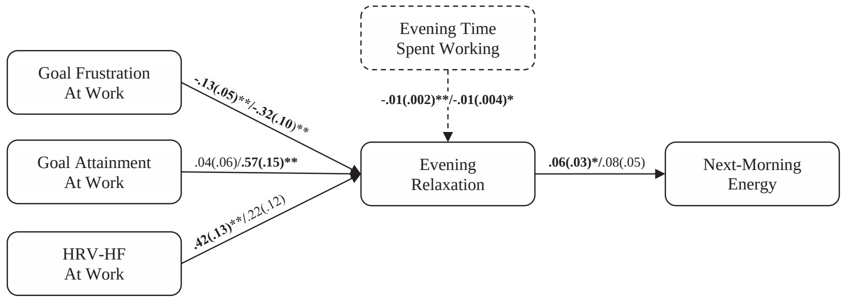

Figure 2. Regression paths from multilevel model analysis with within- and between-person estimates reported (HRV-HF model). Within-person estimate (standard error)/between-person estimate (standard error). Estimates are unstandardized. Number of epochs used to derive heart rate variability values is controlled. * $p < .05$. ** $p < .01$.

that using HRV-HF, which could be due to lower correlations of r-MSSD with psychological constructs (Table 1), consistent with observations by Massaro and Pecchia (2017). All the effects involving affective work events, evening relaxation, and next-morning energy that we have previously reported were retained in this alternative model, and no new effects emerged (Figure 3; Table 3). Of note, at the within-person level, the effect of r-MSSD onto evening relaxation was positive and significant, $b = .733$, $SE = .306$, 95% CI [.01, .04], $p = .017$, and the indirect effect was significant (Table 3), providing further support for the hypotheses pertaining to HRV on this alternative indicator of PSNS activity (i.e., Hypotheses 3 and 7). Identical to the model tested with HRV-HF, there was a similar pattern of findings, whereby, there were limited effects at the between-persons level, and these pertained to work events and not HRV.

Overall, support for the hypotheses at the within-person level, and the relative absence of significant effects at the between-person level, suggests the observed relationships are due to day-to-day intraindividual processes, at least over the period of 1 work week, rather than interindividual differences. Finally, it is important to note that evening time spent on work was a significant negative predictor of evening relaxation, at both the between- and within-persons level and for each HRV model assessed (Figures 2 and 3), demonstrating that it was important to take account of the continuation of work into the evening in the analyses.

Supplementary Analyses

We controlled for that morning's energy to determine if this addition changed the results reported. Here, we specified a regres-

Table 2
Summary of Indirect and Direct Effects With HRV-HF as the Heart Rate Variability Indicator

Within-person level	Estimate (*SE*) [90% confidence interval]
Indirect effects	
Goal-Frustration Events > Evening Relaxation > Next-Morning Energy	−.008 (.005) [−.016, −.001]**
Goal-Attainment Events > Evening Relaxation > Next-Morning Energy	.002 (.003) [−.003, .008]
HRV-HF At Work > Evening Relaxation > Next-Morning Energy	.025 (.014) [.003, .048]**
Direct effects	
Goal-Frustration Events > Next-Morning Energy	.022 (.027) [−.032, .075]
Goal-Attainment Events > Next-Morning Energy	−.019 (.030) [−.077, .040]
HRV-HF at Work > Next-Morning Energy	−.021 (.086) [−.191, .148]
Between-person level	**Estimate (*SE*) [90% confidence interval]**
Indirect effects	
Goal-Frustration Events > Evening Relaxation > Next-Morning Energy	−.025 (.018) [−.055, .005]
Goal-Attainment Events > Evening Relaxation > Next-Morning Energy	.045 (.033) [−.009, .099]
HRV-HF at Work > Evening Relaxation > Next-Morning Energy	.017 (.015) [−.008, .043]
Direct effects	
Goal-Frustration Events > Next-Morning Energy	−.037 (.063) [−.161, .087]
Goal-Attainment Events > Next-Morning Energy	.126 (.113) [−.096, .349]
HRV-HF at Work > Next-Morning Energy	.090 (.086) [−.078, .258]

Note. HRV-HF = HRV derived by spectral power analysis in the high frequency domain. Estimates are unstandardized. Confidence intervals for the multilevel model indirect effects are at the 90% confidence interval, as per the Preacher, Zyphur, and Zhang (2010) recommendations.
* $p < .10$. ** $p < .075$.

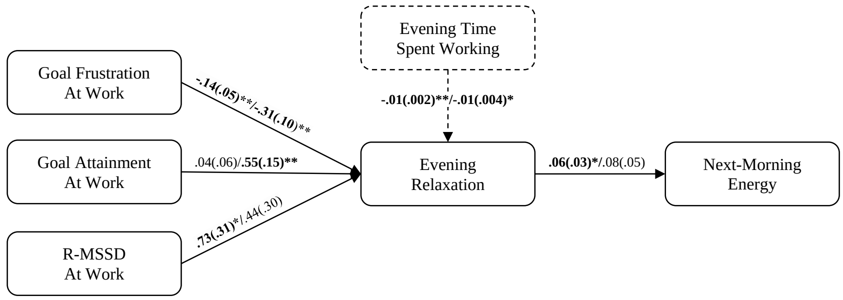

Figure 3. Regression paths from multilevel model analysis with within- and between-person estimates reported (r-MSSD model). Within-person estimate (standard error)/between-person estimate (standard error). Estimates are unstandardized. Number of epochs used to derive heart rate variability values is controlled. * $p < .05$. ** $p < .01$.

sion path from energy that morning onto next-morning energy, at both the within-person and the between-person levels. The rationale for checking this was that inclusion of on-waking energy at the start of the day as a predictor of next-morning energy, at the within-person level, should account for any systematic changes in energy levels day-to-day across the work week, beyond those attributed to between-person variance and other study variables. This lagged effect from morning energy to next-morning energy was nonsignificant at the within-person level (i.e., for both HRV-HF and r-MSSD models, the effect was the same: $b = -.02$, $SE = .045$, 95% CI [−.10, .07], $p = .743$. Inclusion of these paths did not improve the model fit indices, neither for the HRV-HF model, $\chi^2(56) = 277.560$, $p < .001$, CFI = .924, TLI = .894, RMSEA = .035, SRMR within = .062, SRMR between = .099, nor for the r-MSSD model, $\chi^2(56) = 272.326$, $p < .001$, CFI = .910, TLI = .874, RMSEA = .037, SRMR within = .063, SRMR between = .106.

Similarly, we checked for changes in evening relaxation day to day across the week by including previous evening relaxation as a predictor of evening relaxation. Although this lagged effect from relaxation during the previous evening on relaxation during this evening was significant at the within-person level (i.e., HRV-HF model: $b = -.21$, $SE = .075$, 95% CI [−.36, −.06], $p = .005$; r-MSSD model: $b = -.21$, $SE = .074$, 95% CI [−.36, −.07], $p = .004$), the inclusion of this path did not improve the model fit indices, i.e., HRV-HF model: $\chi^2(56) = 296.18$, $p < .001$, CFI = .904, TLI = .866, RMSEA = .040, SRMR within = .059, SRMR between = .145; r-MSSD model: $\chi^2(56) = 290.765$, $p < .001$, CFI = .899, TLI = .859, RMSEA = .041, SRMR within = .059, SRMR between = .146.

Table 3
Summary of Indirect and Direct Effects With r-MSSD as the Heart Rate Variability Indicator

Within-person level	Estimate (*SE*) [90% confidence interval]
Indirect effects	
Goal-Frustration Events > Evening Relaxation > Next-Morning Energy	−.008 (005) [−.016, −.001]*
Goal-Attainment Events > Evening Relaxation > Next-Morning Energy	.002 (.003) [−.003, .008]
r-MSSD at Work > Evening Relaxation > Next-Morning Energy	.045 (.027) [.001, .089]*
Direct effects	
Goal-Frustration Events > Next-Morning Energy	.020 (.028) [−.025, .066]
Goal-Attainment Events > Next-Morning Energy	−.018 (.030) [−.067, .031]
r-MSSD at Work > Next-Morning Energy	−.084 (.175) [−.371, .203]
Between-person level	**Estimate (*SE*) [90% confidence interval]**
Indirect effects	
Goal-Frustration Events > Evening Relaxation > Next-Morning Energy	−.025 (.018) [−.055, .005]
Goal-Attainment Events > Evening Relaxation > Next-Morning Energy	.044 (.033) [−.010, .097]
r-MSSD at Work > Evening Relaxation > Next-Morning Energy	.035 (.034) [−.021, .091]
Direct effects	
Goal-Frustration Events > Next-Morning Energy	−.037 (.105) [−.138, .064]
Goal-Attainment Events > Next-Morning Energy	.121 (.061) [−.052, .293]
r-MSSD at Work > Next-Morning Energy	.292 (.223) [−.074, .658]

Note. Estimates are unstandardized; r-MSSD = HRV derived by the root mean squared standard deviation of successive inter-beat intervals. Confidence intervals for the multilevel model indirect effects are at the 90% confidence interval, as per the Preacher et al. (2010) recommendations.
* $p < .10$. ** $p < .075$.

In each of these supplementary analyses, all the effects previously reported were retained, and no new effects emerged. Thus, these results suggest that day-to-day changes in morning energy and evening relaxation are not affecting the results reported, which involved within-level effects occurring over the afternoon to evening to next morning. However, it is an interesting observation that participants reported less relaxation on an evening if the previous evening was relaxing.

We further conducted several sensitivity checks. First, we checked the influence of negative private life events occurring that work afternoon as a predictor of HRV values, to partition out variance attributable to private life events. For the analysis with HRV-HF, at the within-person level, the effect of private life events was significant, $b = .09$, $SE = .043$, 95% CI [.00, .17], $p = .044$, but for the analysis with r-MSSD, it was not, $b = .02$, $SE = .019$, 95% CI [−.01, .06], $p = .213$. However, and importantly, inclusion of this variable did not change the results reported (i.e., the relationship of HRV, both HRV-HF and r-MSSD, onto evening relaxation remained, as did the indirect effects involving HRV and next-morning energy, and no new effects emerged). In addition, we accounted for the impact of other activities in the evening at home on the relaxation experience. Although we controlled for time spent on work at home, there are factors that could disrupt the ability to relax in the evenings that are not work related. Thus, we also checked if time spent on household chores and time spent on physical exercise that evening had any bearing on the results. Neither of these variables were significant predictors of evening relaxation at the within-person level in either HRV model tested (ps $> .919$), and their inclusion did not improve model fit or change the results already reported.

In light of the nonsignificant results for goal-attainment events at the within-person level, we performed one further exploratory analysis. Although we did not make specific predictions about the interaction of negative and positive work events, there is some evidence that positive events might be predictive of affective experiences in conjunction with greater negative events or work demands (Gross et al., 2011; Zohar et al., 2003). As such, we checked if there was a significant interaction of negative and positive work events (i.e., goal frustrations by goal attainment). For example, goal attainment might be beneficial only on days when goal frustrations are high. However, this interaction was nonsignificant in both HRV models (ps $> .708$). Importantly, accounting for this interaction effect did not eliminate the significant effects for HRV-HF, $b = .41$, $SE = .134$, 95% CI [.15, .68], $p = .002$, nor r-MSSD, $b = .73$, $SE = .307$, 95% CI [0.13, 1.33], $p = .018$, onto evening relaxation, nor the indirect effects reported.

Finally, we examined the potential influence of sex, age, and BMI at the between-person level, as these are known correlates of HRV (Massaro & Pecchia, 2017). Only age was a significant predictor of HRV-HF, $b = -.08$, $SE = .021$, 95% CI [−.12, −.04], $p < .001$, and r-MSSD, $b = -.03$, $SE = .029$, 95% CI [−.05, −.01], $p = .014$, whereas sex and BMI were nonsignificant for both HRV indicators (ps $> .150$), and there was no sex by age interaction (ps $> .117$; Britton et al., 2007). Inclusion of these predictors had no bearing on the results previously reported. No new effects emerged from controlling for these variables.[1]

Discussion

On days with poorer PSNS regulation of physiological stress (as indexed by lower HRV) and more work-related goal-frustration events, participants experienced less relaxation that evening at home, which meant they were less likely to wake up feeling energized. Interestingly, work-related goal-attainment events did not contribute to evening relaxation or next-morning energy at the within-persons level. The two main insights from this research include the study of (a) HRV as an antecedent to a psychological recovery experience, that being relaxation, and (b) the finding that affective work events related to goal striving (in particular, goal frustration) can undermine the recovery process.

HRV as an Antecedent to Recovery

Our study showed that PSNS regulation of stress at work, as indexed by HRV, relates to the experience of relaxation when one gets home. Most previous research on recovery experiences has relied on self-reported antecedents of mainly psychological concepts (Bennett et al., 2018). Our study demonstrated that regulation of stress arousal while still being at work—as an important physiological process—adds to the prediction of psychological recovery experiences in the evening. Until now, only a handful of studies has assessed and specifically analyzed HRV values from the work context (Loerbroks et al., 2010; Uusitalo et al., 2011). Previous research that has incorporated repeated assessments of HRV (i.e., beyond the typical 24-hr assessment paradigm) in the study of off-the-job recovery processes has assessed HRV in off-the-job time or during sleep. For example, in a study by Vahle-Hinz et al. (2014) on rumination, there were no significant effects of work-related stress or work-related rumination on nocturnal HRV for the 2 workdays assessed. However, they did find that work-related rumination on the weekend was associated with higher HRV during sleep on a Saturday evening. To the contrary, Cropley et al. (2017) found that "high ruminators" had lower HRV in the evenings after work (aggregated over 3 consecutive workdays). Although these previous studies show promising, yet conflicting, insights into the effect of after-work cognitive processes concomitant with HRV, these studies have been limited by the number of assessments of HRV (less than three assessments) as well as sample sizes ($N = 50$ or less). Moreover, as suggested by Cropley et al. (2017), it is possible that an affective component of rumination is more important for parasympathetic suppression.

Thus, we extend on these initial HRV studies methodologically, and also theoretically, by studying HRV at work as an antecedent to the psychological experience of relaxation, an important aspect of off-the-job recovery. We have shown that PSNS activity at work, which suggests physiological regulation of stress arousal in that context, is associated with greater relaxation experience that evening when home. Related research on self-reported emotion regulation suggests that the need to regulate emotions at work has negative consequences for recovery in the evenings. For example, greater daily surface acting at work results in a greater need for recovery and impairs relaxation and then vigor the next workday (Xanthopoulou, Bakker, Oerlemans, & Koszucka, 2018). On days

[1] The authors thank the Editor and anonymous reviewers for suggesting many of these additional sensitivity checks.

when employees report greater threat emotions that morning, they have greater difficulty relaxing after work (Michel, Turgut, Hoppe, & Sonntag, 2016). Indeed, on days with more illegitimate tasks, through lowered self-esteem, employees experience less psychological detachment from work that evening (Sonnentag & Lischetzke, 2018). Also, it has been found that daily difficulties in emotion regulation impaired well-being (at work and at home), especially when nurses did not have the chance to relax in the evening (Blanco-Donoso, Garrosa, Demerouti, & Moreno-Jimenez, 2017). We contribute to this research by demonstrating that a physiological indicator of emotion regulation (Balzarotti et al., 2017), in the form of HRV, is directly associated with evening relaxation and indirectly associated with next-morning energy.

Using HRV as an antecedent is a novel departure from current thinking and approaches on how to use HRV assessment in occupational health psychology. It is important to consider that physiological processes not only are the end-state to a process of work stress but also are concomitant and dynamic in nature. Importantly, these physiological processes seem to play an important role for subsequent recovery. Developing a deeper understanding of the body's role in regulating stress is particularly important to advance our understanding on how to intervene. This approach has been adopted in other research areas. For example, in defense personnel, higher HRV (through training) improves stress responses to simulated combat (Lewis et al., 2015), and in athletes, HRV has been shown to be a preperformance physiological state important to shooting performance (Ortega & Wang, 2018). To sum up, our research contributes support for the use of HRV assessment to inform stress and recovery phenomenon. We hope it encourages the use of HRV in occupational health research, noting that this certainly can be studied in response to stressful work but can also be considered as an antecedent to recovery.

Work-Related Events and Evening Relaxation at Home

Although it was novel and interesting to include a physiological measure, study of a physiological process alone does not reveal insights on "what happened at work that day." Thus, we drew on AET, in particular, a more recent taxonomy on the different types of affective work events (Ohly & Schmitt, 2015), to understand what types of events might carry over and impact recovery in off-the-job time. Previous research on affective work events and their "aftershock" in the evening is limited (see Bono et al., 2013 and Gross et al., 2011 for exceptions). Although scholars have theorized, and also demonstrated empirically, that hassles offer more in the prediction of burnout than "classic" role demands (Zohar, 1997), except for a few seminal studies (Ohly & Schmitt, 2015; Zohar et al., 2003), researchers have neglected to study these "emotionally laden" work events specifically and the consequences of these events after they have ended or during off-the-job time.

We were able to demonstrate that daily hassles related to goal frustration (e.g., *excessive demands, mistakes, and goal disruptions*) are negatively related to the psychological relaxation experience that evening (while accounting for time spent on work that evening and also the primary allostatic load of that workday, as indexed by HRV). Our findings extend the work of Zohar et al. (2003) who found that goal disruptions were associated with fatigue at the end of the workday. It also extends work by Gross et al. (2011) and Bono et al. (2013) on the impact of negative work events into affective and cognitive recovery processes in the evenings after work. However, here, we note that using more specific work events, guided by Ohly and Schmitt (2015), was potentially quite useful. Comparing our results with those of Zohar et al. (2003), it is important to consider events in relation to the implications for goal striving (or *agency* as described by Ohly & Schmitt, 2015), rather than combining together all types of events based solely on their valence (i.e., negative vs. positive).

We did not observe effects of goal-attainment events on evening relaxation at the within-person level of analysis. Thus, it seems that the benefits of such work events during the workday do not carry over to influence evening relaxation experiences. We did, however, observe that goal attainment, much like goal frustration, had between-level effects on evening relaxation. This pattern of finding highlights the importance of studying empirical relationships both at the within-person and between-person level and demonstrates that homology (i.e., the identical pattern of relationships across levels of analysis) should not be taken for granted (Gabriel et al., 2018). Our findings at the between-person level suggests that those individuals who have more goal attainment over the week experience more evening relaxation over the week, without goal-attainment events being reflected in higher relaxation levels on the evening of the same day. The significant between-person associations do not necessarily imply that goal attainment causes relaxation. The empirical association at the between-person level could be due to third variables or might even reflect reverse causality.

Previous research has revealed mixed results for positive affective work events. Indeed, studies usually only find an effect in conjunction with moderators (Gross et al., 2011; Zohar et al., 2003), with the exception of Bono et al. (2013), who reported a small effect onto psychological detachment. Thus, it is possible that positive work events do not have direct effects, but rather conditional effects. However, although other researchers have observed that positive work events might be able to offset the negative implications of negative work events (Gross et al., 2011), we did not observe this for the evening relaxation experience. In line with previous research (Bono et al., 2013; Miner et al., 2005), we found that although positive events can be more frequent than negative events (as per the mean reported in Table 1), it is the negative events that have the stronger implications for subsequent experiences.

In summary, we extend theorizing on the AET, by demonstrating work-related goal frustrations at work can impair relaxation as a recovery experience that evening, but work-related goal attainment that day is unrelated to evening relaxation. There have been calls for research on the impact of negative work events for recovery experiences (Sonnentag & Fritz, 2015), and we have shown such consequences for the relaxation experience. Negative work events can certainly impact the ability to "mentally switch-off" after work (i.e., through reduced psychological detachment as per Bono et al., 2013 but also possibly due to work-related worry; Cropley et al., 2017). However, in addition to these relatively more cognitive processes, as we observed in our research, there are implications for the resource-restoring potential of relaxation experiences as well. Thus, we encourage scholars interested in the recovery process to consider the AET, and in particular, the work of

Ohly and Schmitt (2015), in understanding the emotionality of what happens at work that day, and the potential emotional "aftershocks" that can occur and impair recovery.

Limitations and Future Research

One limitation of this research was the use of single items for assessing work events. Research suggests use of single items can be reliable and valid in the occupational stress field (Fisher, Matthews, & Gibbons, 2016) and can help increase survey completion rates within diary study designs (Ohly et al., 2010), which we did observe with higher than normal completion rates of our "at work" diary. However, the use of single items, and also, one reflection on the whole afternoon at the end of the workday, is a limitation. Development of a validated measure of specific work events would be worthwhile for future research. Also a more fine-grained analysis of the relationships between specific events and physiological processes during the workday would be beneficial. One option could be to use event sampling while hassles or uplifts are occurring. However, such an approach would need to be sensitive to the constraints placed on employees at work (i.e., limited ability to respond to frequent surveys, especially while coping with an ongoing stressful event).

Another limitation is that we did not examine affective experiences at work and home. Affective experiences could potentially act as a mechanism between work events and evening relaxation. Related to this point, we measured neither the mechanisms between evening relaxation and next-morning energy (e.g., reduction in allostatic load that evening, positive experiences that evening, supportive social interactions that evening, and objective sleep quality) nor other potential barriers to relaxation at home (e.g., stressful events in the home environment and specific types of media consumption). Our research establishes goal frustrations and HRV as antecedents to the recovery process, and hopefully this observation will prompt further research on the exact mechanisms and boundary conditions involved. In relation to the mechanism of sleep quality, it is important to note we had intended to use a measure of HRV during sleep (similar to Vahle-Hinz et al., 2014) as an indicator of sleep quality. However, research has revealed that concurrent measurement of EEG or actigraphy would be required to detect changes in HRV that occur with changes in sleep cycles (Werner et al., 2015). In our research, as is the case in most research on recovery, we have inferred that feeling relaxed in the evening and then waking up energized the next day is due to a variety of factors, including but not limited to having a good night's sleep. However, future research could explore these mechanisms.

Finally, we note some limitations to our approach to HRV assessment, which involved naturalistic monitoring. First, although we checked for the impact of posture and number of epochs (i.e., varying lengths of aggregates) on HRV values, the average length of HRV aggregates was approximately 4 hr. Coupled with the high ICC values observed, this indicates that there is substantial between-person variance present in these aggregates. Although this variance was partitioned out of the within-person analyses, and is similar to ICC values observed by Vahle-Hinz et al. (2014), future research might consider shorter aggregates of HRV. However, in relation to this suggestion, we note there is criticism of research that relies on very short assessments of HRV in field settings (see Heathers, Brown, Coyne, & Friedman, 2015, for a critique on Kok and colleagues; see also Shaffer & Ginsberg, 2017 for general advice on the length of aggregates in HRV research). Second, we elected to use 2-min epochs from which to derive our HRV aggregates. A recent review suggests it is appropriate to go as short as 1 min for HRV-HF and r-MSSD; however, there is a lot of variation in the epoch length selected by researchers (i.e., including 30 secs, 1 min, 2 min, 3 min, and 5 min; Chandola et al., 2010; Shaffer & Ginsberg, 2017). Thus, we would advise researchers to carefully consider their epoch length in relation to the HRV indicators they plan to use and the research questions of their study (Massaro & Pecchia, 2017). Third, we had originally intended to use a measure of HRV each evening as an indication of physiological unwinding (or physiological recovery) from work that day to use alongside the self-reported psychological experience of relaxation. However, we observed that the HRV recordings from this period were not "normalized," as Massaro and Pecchia (2017) would describe it. As the focus of our study was on the evening relaxation experience, we elected not to disrupt participants' evening time with instructions on when and what to do. A consequence of this decision is that participants went about their normal leisure routines in the evening and, to varying extents, engaged in physical exercise, other physically active household chores, consumed food, and drank alcohol, all of which are all factors that can affect heart rate, and as such, HRV. Indeed, Cropley et al. (2017) also allowed participants to go about their normal activities in the evening while assessing HRV (via a wrist monitor). As a consequence, measurement artifacts were frequent, and the authors could only use data from approximately 36% of their original participants.

Thus, another suggestion for future research could be use of actigraphy monitors to control for physical activity (Uusitalo et al., 2011). In addition, instructions could help to create "normalization" similar to laboratory-based settings. However, researchers interested in pursuing HRV assessment in work settings will need to consider the trade-offs between naturalistic monitoring and "experimental" control in relation to their specific research questions. HRV measurement decisions do vary study by study, and there is a need for "harmonization of methodologies" (Chandola et al., 2010). We hope our study offers insights, both on the advantages and disadvantages of naturalistic monitoring and the choice of aggregates for organizational researchers interested in designing HRV studies in work settings.

Practical Implications and Conclusions

One might assume HRV, as it reflects output of the ANS, is something people do not have conscious control over. According to allostatic load theory, although many physiological adjustments are autonomic, these also are under the control of the central nervous system, especially allostatic systems like the hypothalamic-pituitary-adrenal axis and, as such, can also be anticipatory, that is, influenced by previous knowledge, experience, and anticipated demands of the environment (Ganster & Rosen, 2013). In which case, what can we recommend individuals and organizations do to improve HRV at work as they come to the end of each workday? People can, to a certain extent, influence the heart's behavior through efferent processes, which means, strategies they have discovered through practice that they know can help them to

physiologically relax, such as thinking positive thoughts, breathing exercises, and progressive muscle relaxation (for reviews, see De Pascalis, Palumbo, & Ronchitelli, 1991; Lacroix & Gowen, 1981). Indeed, research suggests mindful meditation also can improve HRV (i.e., with practice over a 10-day time period; Krygier et al., 2013). Moreover, relaxation training designed to enhance HRV improved defense personnel reactions to combat simulation (Lewis et al., 2015). However, interventions, like the examples described here, are yet to be thoroughly tested in work settings, which is a worthwhile future research endeavor.

Practical implications from this research include organizing the work afternoon so that work-related hassles, especially goal frustrations, are mitigated, aiming to lessen the stress arousal and mental effort experienced toward the end of the workday. Individuals can engage in a number of activities while at work to manage work stress (e.g., time management, micro breaks, and job crafting). However, these efforts can be constrained by the design of the job or nature of the work. In such instances, employees need to reserve time in the evenings to recover, away from the physical and psychological sources of stress experienced in their workplace. However, as found here, and outlined in recent theorizing on the recovery paradox (Sonnentag, 2018), sometimes those who have a high need for recovery can find it difficult to enact behaviors to support their recovery. Thus, it is not just the responsibility of individual employees to attempt to craft their work afternoons and evenings in a way that they avoid negative arousal, but, of course, supervisor training and job redesign initiatives in the workplace are crucial. It is important to create a work environment where negative work events, like goal frustrations, are reduced and work does not negatively impact off-the-job time. Protecting off-the-job time and its potential for relaxation experiences is an important consideration for how work is designed, not just for individuals' sense of well-being but also for work performance (Binnewies, Sonnentag, & Mojza, 2009).

Overall, our findings provide insights on the relaxation experience and its recovery potential, more specifically, the impact of affective work events and PSNS activity (i.e., as reflected by HRV) at work that day. Importantly, the association between HRV and evening relaxation was present when accounting for self-reported work events that day, time spent on other activities that evening, and between-person variance associated with these variables. Seemingly, there is an important role for the body in regulating stress at work and then being able to recover from the stress of the workday, to wake up the next morning more energized.

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