2-2022

There is a time to be creative: The alignment between chronotype and time of day

Jana KUEHNEL
University of Vienna

Ronald BLEDOW
Singapore Management University, RBLEDOW@smu.edu.sg

Markus KIEFER
Universitat Ulm

Citation

KUEHNEL, Jana; BLEDOW, Ronald; and KIEFER, Markus. There is a time to be creative: The alignment between chronotype and time of day. (2022). *Academy of Management Journal*. 65, (1), 218-247.
Available at: https://ink.library.smu.edu.sg/lkcsb_research/6694

© *Academy of Management Journal*
2022, Vol. 65, No. 1, 218–247.
https://doi.org/10.5465/amj.2019.0020

THERE IS A TIME TO BE CREATIVE: THE ALIGNMENT BETWEEN CHRONOTYPE AND TIME OF DAY

JANA KÜHNEL
University of Vienna

RONALD BLEDOW
Singapore Management University

MARKUS KIEFER
Ulm University

We examine the influence of chronobiological processes on creativity, specifically the influence of a person's chronotype. Chronotype refers to the setting of a person's biological clock that gives rise to a distinctive pattern of sleep habits and preferred diurnal activity. We propose a synchrony effect and predict that people are creative when the external clock is aligned with their internal, biological clock. According to our model, positive mood and creative self-efficacy act as affective and cognitive mechanisms of this synchrony effect. We present three studies that test our theorizing: a quasi-experimental field study with 260 employees, a day-reconstruction study with 238 employees, and a one-day experience sampling study with 319 employees. Across the studies, we find that chronotype moderates the effect of time of day on creativity. Overall, late chronotypes were more creative in the late afternoon and early chronotypes tended to be more creative in the morning. The alignment between chronotype and time of day also gave rise to positive mood and creative self-efficacy; however, the studies provide only partial support for the hypothesis that positive mood acts as a mediating mechanism. We discuss the implications of these findings against the background of an embodied cognition perspective on creativity.

In 2017, Jeffrey C. Hall, Michael Rosbash, and Michael W. Young received the Nobel Prize in Physiology or Medicine for their discoveries of molecular mechanisms controlling the circadian rhythm (Nobel Media Outreach, 2017). These molecular mechanisms help to explain how the rhythm of a biological organism is synchronized with and adapted to different phases of the day. Biological clocks help to regulate sleep patterns, hormone release, blood pressure, and body temperature, and cause peaks and troughs in the functioning of an organism during the day (Borbély, 1982; Carrier & Monk, 2000; Czeisler & Gooley, 2007). These discoveries raise the question of whether the influence of biological clocks is limited to physiological processes or extends to complex cognitive phenomena such as the creativity people display in their everyday work lives.

Creativity—the development of novel and useful ideas or problem solutions (Amabile, 1996)—is recognized as "an important ingredient for effectiveness in all kinds of work" (George, 2007: 441). It enables individuals and groups to adapt to changing circumstances, to proactively deal with their environment, and to survive and prosper through social, technological, and medical innovations (Anderson, Potočnik, & Zhou, 2014; Bledow, Frese, Anderson, Erez, & Farr, 2009; Oldham & Cummings, 1996; West & Farr, 1990). As one of the most complex human capabilities that requires the integration of a variety of cognitive processes, creativity may be particularly

We thank Associate Editor Jill Perry-Smith and three anonymous reviewers for their support and guidance. We acknowledge the presentation of an earlier version of this manuscript at the 2018 Academy of Management annual conference in Chicago, Illinois. We are grateful to our students Alexandra Hofmann, Eva Christina Quednau, Laura Stark, Katharina Wagner, Katharina Wieser, and Janine Zimmermann for their help with collecting data, and to Michael M. Gielnik for helpful comments on an earlier version of this manuscript. This work was supported by the German Federal Ministry of Education and Research (SGP-PROG2 01DP14012) and Singapore's Ministry of Education (C207/MSS13B006 and C207/MSS18B011).

sensitive to the peaks and troughs people display as a result of how their biological clock is set. However, despite a large body of research on creativity in organizations, research has rarely considered the state of the human body as the carrier of cognitive and affective processes. Specifically, we do not know to what extent a person's biological clock causes within-person variability in creativity over the course of a workday.

An examination of whether creativity in organizations is grounded in the current state of the body does not necessarily require the isolation of specific physiological parameters—it can also be performed at the behavioral level. Individuals show naturally occurring variations in circadian parameters, known as their chronotype, that can be used to examine how creativity is influenced by a person's biological state. The particular chronotype of an individual results in pronounced differences in favorite periods of diurnal activity and sleep habits (Horne & Östberg, 1976; Roenneberg, Wirz-Justice, & Merrow, 2003): Some people (early chronotypes, or "morning people") tend to experience activity peaks in the morning, whereas others (late chronotypes, or "evening people") tend to experience peaks later during the day (Kerkhof, 1985; Schmidt, Collette, Cajochen, & Peigneux, 2007; Van Dongen & Dinges, 2000). While a few studies have compared the performance of early and late chronotypes in laboratory settings at different times of the day, research has not yet scrutinized the theoretical relevance of chronotype for real-world work settings and examined its explanatory potential for creativity.

Equally important to knowing whether biological clocks influence the time frames during which people can best access their creative potential is to explain the psychological processes through which this influence unfolds. An explanatory model needs to cross disciplinary boundaries by specifying the cognitive and affective processes that link biological mechanisms to work performance. We base our explanatory model on Borbély's two-process model of sleep-regulation that outlines the biological mechanisms underlying changes in human functioning over the course of a day (Borbély, 1982; Borbély, Daan, Wirz-Justice, & Deboer, 2016).

A critical component of the link between biological mechanism and creativity may be positive mood, which is a frequently studied affective antecedent of creativity that varies over the course of a day (e.g., Amabile, Barsade, Mueller, & Staw, 2005; To, Fisher, Ashkanasy, & Rowe, 2012). Previous research has located the source of positive mood primarily in the external environment and focused on the affective events people experience at work (Weiss & Cropanzano, 1996). We adopt an embodied cognition perspective and call attention to the internal, biological roots of positive mood and its influence on work performance (see also Rothbard & Wilk, 2011). Specifically, our model proposes that positive mood transmits the influence of a person's chronobiological clock on creativity.

A cognitive antecedent of creativity that has received considerable research attention and may transmit the influence of chronobiological processes is creative self-efficacy. Defined as the belief that one can produce creative outcomes (Tierney & Farmer, 2002), it has been found to mediate the influence of personal and contextual factors on creativity (Farmer & Tierney, 2017; Tierney & Farmer, 2011). However, the assumed causal role of this belief remains debatable as the available studies cannot rule out the alternative explanation that creative self-efficacy is a reflection of past creativity rather than a causal antecedent of creativity on its own (Richard, Diefendorff, & Martin, 2006; Sitzmann & Yeo, 2013). By studying creative self-efficacy as an embodied cognitive process that is linked to a person's chronobiological clock and varies over the course of a day, we offer a novel explanation of why creative self-efficacy arises and whether it operates as a causal factor underlying creativity.

In this article, we develop the outlined ideas and examine whether within-day fluctuations in creativity can be traced back to the alignment between chronotype and time of day—an effect we denote as the synchrony effect. Our research thereby contributes to the literature in the following ways. First, we inform the literature on creativity in organizations by demonstrating that within-person variation in creativity as well as its cognitive and affective antecedents are grounded in the current state of the body (Amabile et al., 2005; Nijstad, De Dreu, Rietzschel, & Baas, 2010; Shalley, Zhou, & Oldham, 2004). Our results suggest that theories of creativity need to account for the influence of the human body and pay more attention to the mind–body interface as suggested by an embodied cognition framework (Kiefer & Barsalou, 2013; Varela, Thompson, & Rosch, 1991). Second, we contribute to the growing body of research on how sleep and chronotype shape work behavior (see, e.g., Barnes, Lucianetti, Bhave, & Christian, 2015; Kühnel, Bledow, & Feuerhahn, 2016; Yam, Fehr, & Barnes, 2014). Specifically, we extend past research on the alignment between chronotype and time of day to the domain of creativity and offer an integrative explanation of the synchrony effect and its cognitive and affective mechanisms. We thereby contribute to the two-process model of sleep regulation (Borbély, 1982) and specify psychological processes that link biological mechanisms to work performance. Third, we add to research accounting for the dynamic nature of work performance by considering temporal factors (Dalal, Bhave, & Fiset, 2014). We show that employees' ability to be creative systematically varies not only across days, as previous studies have shown (e.g., Bledow, Rosing, & Frese, 2013), but also over the course of one day, and explain this variation through chronobiological processes. Moreover, our results are of practical relevance and inform employees on how to schedule work tasks to best make use of their creative potential and support leaders in establishing a creativity supportive context.

In the following, we first outline the theoretical foundation of our hypotheses, the two-process model of sleep regulation (Borbély, 1982). We then derive from this model that employees' creativity depends on the interplay between chronotype and the time of day. Finally, we introduce positive mood and creative self-efficacy as explanatory mechanisms through which the alignment between chronotype and time of day influences creativity. Our conceptual model is depicted in Figure 1.

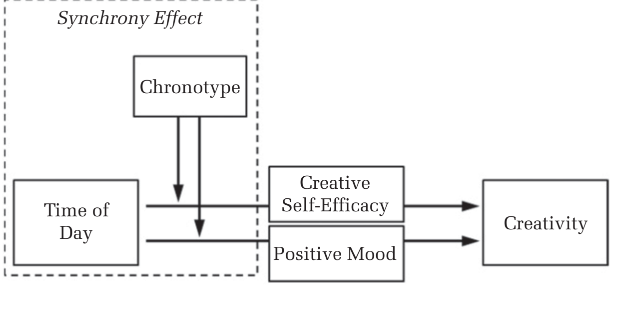
THEORY AND HYPOTHESES DEVELOPMENT

Peaks and Troughs in Cognitive Functioning during the Workday

According to the two-process model of sleep regulation, cognitive functioning changes over the course of the day because of complex interactions between two processes—the homeostatic "process S" and the circadian "process C" (Borbély, 1982; Borbély et al., 2016). The homeostatic, sleep-promoting process S continuously accumulates during time awake, concomitant with an increase in sleepiness and a decrease in cognitive performance and alertness. By contrast, process C represents a wake-promoting drive that balances the accumulating homeostatic drive for sleep during wakefulness (Dijk, Duffy, & Czeisler, 1992). Process C is generated by an endogenous circadian clock and oscillates with a period of about 24 hours, independent of whether the person is asleep or awake. Complex interactions between process S and process C result in an increase in alertness and cognitive functioning at the beginning of the waking day, consolidated cognitive functioning during the waking day, and a decrease in alertness and cognitive functioning at the end of the waking day.

Differences between people in the timing of process C result in individual differences when peaks and troughs in cognitive functioning occur during the day (Dijk & Lockley, 2002; Van Dongen & Dinges, 2000). Whether employees' peak period of cognitive functioning occurs earlier or later in the day is reflected in each individual's chronotype. In the population, the continuum of different chronotypes ranges from early chronotypes ("morning people"), who prefer to go to bed earlier at night and get up earlier in the morning, to late chronotypes ("evening people"), who prefer to go to bed later at night and get up later in the morning (Roenneberg et al., 2003). People in the middle of this continuum do not have clear preferences toward morning or evening and are called intermediate chronotypes. In their work on preferences for sleep–wake timing, Horne and Östberg (1976) referred to this continuum of different chronotypes as morningness–eveningness. Along with a person's standing on this continuum, the peak period of cognitive functioning occurs earlier or later in the day (Kerkhof, 1985; Kerkhof & Van Dongen, 1996; Schmidt et al., 2007).

FIGURE 1
Conceptual Model



The Alignment between Chronotype and Time of Day

We derive from the outlined two-process model of sleep regulation that creativity depends on the alignment between chronotype and time of day. When the time of day matches a person's chronotype, the person is in a cognitive-affective state that enables the person to display creativity. As this synchrony effect influences the whole organism, we expect it to broadly impact cognitive functioning at a high level rather than to promote low-level cognitive processes or specific behavioral responses. Specifically, we propose that the synchrony effect enhances executive functions (Gilbert & Burgess, 2008). Executive functions refer to high-level control processes that coordinate and integrate the activity of the variety of cognitive and affective subsystems and enable nonhabitual responses such as creativity and other complex behaviors (e.g., Cervone, Shadel, Smith, & Fiori, 2006; Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000).

The available evidence on time-of-day effects for different chronotypes supports our argument that the alignment between chronotype and time of day promotes executive functions. For example, in two experiments, Gunia, Barnes, and Sah (2014) found that people displayed more ethical behavior when chronotype and time of day were aligned. Early chronotypes displayed more ethical behavior in the morning, while late chronotypes displayed more ethical behavior in the evening. This finding was replicated for early chronotypes by Ingram et al. (2016), who identified individuals' chronotype based on their ribonucleic acid. Ethical behavior critically depends on executive functions that promote behaviors that are consistent with personal values and beliefs and dampen the influence of tempting alternatives (Gino, Schweitzer, Mead, & Ariely, 2011). By contrast, when there is a misalignment between chronotype and time of day, people have difficulties in ignoring distractions, in suppressing irrelevant information, in judging responses with regard to their appropriateness, and in restraining or preventing dominant responses that are inappropriate or unwanted (Hasher, Zacks, & May, 1999; Schmidt et al., 2007). People then tend to rely on stereotypes instead of engaging in effortful, systematic thought (Bodenhausen, 1990; Kruglanski & Pierro, 2008). In other words, when chronotype and time of day are misaligned, "strong responses [i.e. dominant, easily accessible, or automated responses] in both thought and action are more likely to be observed" (Hasher, Goldstein, & May, 2005: 213).

A closer look at studies on the alignment between chronotype and time of day for task performance provides further support for the argument that the synchrony effect promotes executive functions because it has been observed for tasks that depend on such functions but not for other tasks. The synchrony effect has been found for performance on a demanding driving simulator that required continuous attentional tracking and corrective action (Correa, Molina, & Sanabria, 2014) and for pianists' performance on a maximally challenging, nonroutine piano task (Van Vugt, Treutler, Altenmüller, & Jabusch, 2013). Moreover, the synchrony effect influences performance on tests of fluid intelligence that measure high-level cognitive functioning (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007). By contrast, the alignment between chronotype and time of day appears to matter less for routine tasks that require primarily low-level cognitive processes and routinized behavioral responses rather than executive functions (Hasher et al., 2005; Monk & Leng, 1986). Studies have not found a synchrony effect for standardized mathematical tests (Randler, Bechtold, & Vogel, 2016), for handwriting fluency (Jasper, Häußler, Marquardt, & Hermsdoerfer, 2009), for the efficiency of the orienting system that selects specific information from an array of potentially relevant stimuli (Matchock & Mordkoff, 2009), and for automatic retrieval processes (Goldstein et al., 2007; Puttaert, Adam, & Peigneux, 2019; Yang, Hasher, & Wilson, 2007). Taken together, research suggests that tasks that require executive functions and nonhabitual responses are most influenced by the synchrony effect. Performance on such tasks suffers when chronotype and time of day are misaligned.

The Synchrony Effect and Creativity

We assume that the alignment of chronotype and time of day enables creativity because executive functions are then best accessible. Creativity requires that a person can access executive functions that dampen dominant and habitual responses in favor of generating new and original responses. During the creative process, executive functions need to be available that coordinate and integrate a variety of cognitive processes (Beaty et al., 2018). A person needs to retrieve relevant goals, activate the knowledge repertoires that provide the raw material for ideas, and maintain representations of the context to determine what is useful (Baumann & Kuhl, 2002). Most importantly, however, the person needs to form remote associations and integrate different sources of information so that new and useful ideas can emerge (Tadmor, Galinsky, & Maddux, 2012). Schmidt et al. (2007) found that the executive functions that achieve such an integration are best accessible when chronotype and time of day are aligned (see also Blatter & Cajochen, 2007). Presumably, people can then switch between different categories or perspectives, integrate remotely associated information, and recombine elements in novel ways (De Dreu, Nijstad, & Baas, 2011; George, 2007).

Besides enabling the integration of the cognitive processes required for creativity, the synchrony effect also induces a motivational orientation toward exploration (Murray, Allen, & Trinder, 2002; Murray, Nicholas, Kleiman, Dwyer, Carrington, Allen, & Trinder, 2009). An orientation toward exploration lets people make use of their creative potential because they actively seek novel alternatives (Crowe & Higgins, 1997; Higgins, 1997). More specifically, people show a stronger inclination to generate many different alternatives instead of being repetitive (Crowe & Higgins, 1997). By contrast, during the time of day that misaligns with a person's chronotype, the person will more readily rely on habitual thought and easily accessible ideas and is less motivated to restrain dominant responses and recombine elements in novel ways (Hasher et al., 2005; Hasher et al., 1999; Schmidt et al., 2007). Taken together, we thus hypothesize that the ability to be creative depends on the alignment between chronotype and the time of day. People will be more creative when the time of day matches their chronotype.

Hypothesis 1. Chronotype moderates the effect of time of day on creativity such that (a) earlier chronotypes are more creative in the morning compared to in the late afternoon, and (b) later chronotypes are more creative in the late afternoon compared to in the morning.

Positive Mood as an Affective Mechanism

We next argue that a person's affective state—specifically, the level of positive mood the person displays—operates as a mediating link between chronobiological processes and creativity. That is, the alignment between chronotype and time of day will be accompanied by elevated positive mood and thereby promote creativity. According to the two-process model of sleep regulation (Borbély et al., 2016), the circadian process C primes the organism toward activity and engagement during daytime (Watson, Wiese, Vaidya, & Tellegen, 1999). The experience of positive mood is part of the reward-oriented motivational system that is activated by humans' circadian rhythm (Murray et al., 2009). As a consequence, positive mood shows endogenous variation during the day that is coupled with humans' circadian rhythm (Clark, Watson, & Leeka, 1989; Thayer, Takahashi, & Pauli, 1988). More specifically, positive mood exhibits 24-hour temporal variations with a sinusoidal component of the same shape as the circadian temperature rhythm (see Murray et al., 2002). We therefore posit that people experience elevated positive mood when chronotype and time of day are aligned.

Hypothesis 2. Chronotype moderates the effect of time of day on positive mood such that (a) earlier chronotypes experience higher positive mood in the morning compared to in the late afternoon, and (b) later chronotypes experience higher positive mood in the late afternoon compared to in the morning.

We expect a state of elevated positive mood to be one mediating link through which the synchrony effect influences creativity because positive mood facilitates creativity-relevant cognitive processes (Ashby, Isen, & Turken, 1999; Kiefer, Schuch, Schenck, & Fiedler, 2006). For instance, Fredrickson's (2013) broaden-and-build theory holds that positive emotions stimulate global and holistic processing so that people see the "forest and not just the trees." A series of experiments by De Dreu, Baas, and Nijstad (2008) found that positive mood inductions led to enhanced cognitive flexibility, allowing people to develop many ideas that address a problem from multiple perspectives. Given our theorizing and the available evidence on the positive mood–creativity link (Amabile et al., 2005; Baas, De Dreu, & Nijstad, 2008), positive mood may therefore help to explain why employees' creativity is amplified when chronotype and time of day are aligned. Positive mood may thus be a mediator of the synchrony effect—that is, of the relationship between time of day and creativity that is moderated by chronotype.

Hypothesis 3. The relationship between time of day and creativity that is moderated by chronotype is mediated by positive mood. (a) Earlier chronotypes are more creative in the morning compared to in the late afternoon, because they experience higher positive mood in the morning. (b) Later chronotypes are more creative in the late afternoon compared to in the morning, because they experience higher positive mood in the late afternoon.

Creative Self-Efficacy as a Cognitive Mechanism

The alignment between chronotype and time of day may facilitate creativity not only by elevating positive mood but also by giving rise to the belief that one can access and use one's creative potential. Creative self-efficacy, in turn, will motivate people to apply their creative potential when performing work tasks (Tierney & Farmer, 2002). Research in organizational behavior has identified creative self-efficacy as a proximal predictor of creativity that mediates the effect of multiple personal and contextual factors (Farmer & Tierney, 2017). For instance, Gong, Huang, and Farh (2009) found that creative self-efficacy mediates the effect of transformational leadership and employees' learning orientation on creativity (see also Wang, Tsai, & Tsai, 2014). The relationship between creative self-efficacy and creativity is particularly strong in teams with high informational diversity and a shared understanding of who knows what in a team (Richter, Hirst, van Knippenberg, & Baer, 2012). Personal and contextual antecedents of creativity thus strengthen people's self-view that they have the ability to produce creative outcomes, which motivates them to be creative.

Our line of argument suggests that a person's biological clock may be a factor that gives rise to creative self-efficacy. When a person's biological clock and the time of day are aligned, creative self-efficacy may be amplified because the executive functions that enable creativity are currently accessible. According to this view, creative self-efficacy refers to people's awareness that they can access personal knowledge repertoires and generate new and useful ideas. In other words, people believe in their creative abilities because they are aware of the availability of the requisite executive functions. We thus assume that the alignment between chronotype and time of day lets people realize that they can be creative and that this realization will motivate them to enact their creative potential. In line with our argument that creative self-efficacy varies over time and may lead to fluctuations in creativity, previous studies have established a link between within-person variability in task-specific self-efficacy and task performance (Beck & Schmidt, 2012; Gielnik, Bledow, & Stark, 2020).

Hypothesis 4. Chronotype moderates the effect of time of day on creative self-efficacy such that (a) earlier chronotypes display higher creative self-efficacy in the morning, compared to in the late afternoon, and (b) later chronotypes experience higher creative self-efficacy in the late afternoon, compared to in the morning.

Hypothesis 5. The relationship between time of day and creativity that is moderated by chronotype is mediated by creative self-efficacy. (a) Earlier chronotypes are more creative in the morning, compared to in the late afternoon, because they display higher creative self-efficacy in the morning. (b) Later chronotypes are more creative in the late afternoon, compared to in the morning, because they display higher creative self-efficacy in the late afternoon.

Overview of the Three Studies

The goal of the first study was to establish internal validity of the proposed synchrony effect. The study used a quasi-experimental, repeated-measures design and compared creativity of employees in the morning and in the late afternoon. The second study used the day-reconstruction method to provide a continuous assessment of creativity over the course of a workday in a sample of employees doing creative work. The third study addressed methodological limitations of the previous studies and tested the entire conceptual model (see Figure 1). The study used a one-day experience sampling design with multiple occasions of measurement.

STUDY 1

Study 1 assessed performance on an objective creativity test. The alternative uses test (Guilford, 1967) examines participants overall ability to be creative at a specific point in time as a function of their ability to develop many new ideas (i.e., creative fluency), generate ideas that are original and uncommon (i.e., originality), and switch between domains and perspectives (i.e., cognitive flexibility) (Baas et al., 2008). We expect higher creative fluency, originality, cognitive flexibility, and overall creativity on the alternative uses test when chronotype and time of day are aligned because this alignment promotes executive functioning and thereby broadly enhances the ability to be creative.

Method

Sample and procedure. Study 1 was a repeated measures field study that was conducted in two parts with two groups of employees (combined sample size: $N = 260$; response rate: 57%). Data from the first group of employees ($N = 80$) were gathered at participants' respective workplaces; data from the second group ($N = 180$) were gathered via online questionnaires. Participants of both groups were nonshift workers from companies operating in diverse industries and were recruited by a group of students who approached their personal network and companies in the region as part of their theses. The first group of employees worked in mechanical engineering (47%), health care (19%), education (13%), electrical engineering (11%), social affairs (6%), and printing (4%). The second group of employees worked in public administration, defense and social insurance (9%), science and technology (8%), retail (6%), education (5%), finance and insurance (4%), health care (3%), and other industries (5%). Fifty-one percent of the participants were women, and average age was 35 years (SD = 13.0). Participants indicated to work, on average, 40 hours per week (SD = 9.1). Participants had, on average, seven years of professional experience in their current organization (SD = 9.9). Forty-four percent of the sample held a college or university degree, 25% had an intermediate or general secondary school leaving certificate, and 23% had a lower secondary school leaving certificate. To motivate companies and employees to voluntarily take part in the study, we offered feedback on the results of the study.

For the first group of employees (N = 80), participation consisted of attending two sessions on consecutive workdays at their workplace: one in the morning, between 8 a.m. and 10 a.m., and the other in the late afternoon, between 3:30 p.m. and 5:30 p.m. These two time points were chosen on the basis of previous research on the synchrony effect (e.g., Schmidt et al., 2007; Wieth & Zacks, 2011) and because testing needed to take place during work time. We randomly assigned participants to one of two conditions: attending the morning session first or attending the late-afternoon session first. Of the 83 participants who gave their consent to take part in the study, 81 attended both sessions. Of these, one participant had to be excluded because data on chronotype was missing. At the beginning of each session, participants' positive mood was measured. At the end of the first session, employees' chronotype and sociodemographic characteristics were assessed. In both sessions, previous night's sleep quality and sleep duration were assessed as control variables.

For the second group of employees, participation in the study consisted of answering two online questionnaires during work time; one of them had to be filled in between 9 a.m. and 10 a.m., and the other one had to be filled in between 5 p.m. and 6 p.m., on consecutive days. We randomly assigned participants to one of two conditions: filling in the morning session first or filling in the late-afternoon session first. Of the 372 participants who expressed their interest to take part in the study, 283 answered both questionnaires during the specified time frames. Of these, 14 participants were excluded because they provided incomplete data, 31 participants were excluded because their chronotype could not be calculated with the Munich chronotype questionnaire (MCTQ; see Measures), and 58 participants were excluded because they indicated that they were not working on the day of assessment. For both groups of employees, the same procedure and measures were used.

Measures: Chronotype. Chronotype was measured with the MCTQ (Roenneberg et al., 2003), which derives a person's chronotype from the person's sleep habits. The questionnaire asks a set of questions about *typical* sleep timing on workdays and work-free days. Based on these data, the midpoint between sleep onset and offset is calculated. Chronotype is defined as the midpoint of sleep on work-free days, corrected for 'oversleep' on work-free days (Roenneberg et al., 2003).[1] Lower values indicate an earlier midpoint of sleep and an earlier chronotype, while higher values indicate a later midpoint of sleep and a later chronotype. For example, a person whose sleep onset and sleep offset on work-free days are at 11:30 p.m. and at 8:30 a.m. has a midpoint of sleep at 4:00 a.m. and a chronotype of 4.0. Midpoint of sleep on work-free days shows high test–retest reliability (r = .88; Kühnle, 2006) and correlates strongly with wrist actimetry and sleep logs (r = .92; Kühnle, 2006) and melatonin levels (r = .89 with dim-light melatonin onset; Martin & Eastman, 2002). In the population, differences in chronotype can be as much as 12 hours (range from −1 to 11; Roenneberg, Pilz, Zerbini, & Winnebeck, 2019). People with values between 3 and 5 are labeled "intermediate chronotypes," people with values smaller than 3 are labeled "early chronotypes," and people with values greater than 5 are labeled "late chronotypes." In our sample, 19% were early chronotypes, 66% were intermediate chronotypes, and 15% were late chronotypes. Cut-offs and labels are provided to support the interpretation of different values; however, chronotype assessed with the MCTQ is a continuous, approximately normally distributed variable.

Measures: Positive mood. Participants' positive mood was assessed with the following six items of

[1] Most people's sleep is cut short on workdays, so they accumulate a sleep debt over the workweek. To compensate for this sleep debt, people sleep longer on work-free days (Roenneberg et al., 2003). The MCTQ corrects for sleeping longer on work-free days. For individuals who do not report *unrestricted* sleep times on work-free days, biologically preferred sleep–wake times (chronotype) cannot be calculated with the MCTQ. Exclusion criteria are when respondents use an alarm to wake up on work-free days, or when their naturally occurring sleep on work-free days is prematurely terminated because of small children or pets requiring attention.

the Positive and Negative Affect Schedule scales (PANAS; Watson, Clark, & Tellegen, 1988) used by Sonnentag, Binnewies, and Mojza (2008): active, interested, excited, strong, inspired, and alert. The scale referred to how the person felt *at the moment*. Items had to be answered on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). We excluded one item ("inspired") to improve Cronbach's alpha in Group 1. Cronbach's alphas were .72 (morning session) and .74 (late-afternoon session) in Group 1 and .83 (morning session) and .81 (late-afternoon session) in Group 2.

Measures: Creativity. Participants completed the extensively validated and widely used alternative uses test (Guilford, 1967) in both the morning and the late-afternoon sessions. Because we implemented a repeated-measures design, we assessed creativity with two versions of the alternative uses test and counterbalanced the two versions across sessions. The alternative uses test asks participants to come up with as many unusual uses for an everyday object (a brick, a newspaper) as possible within a time frame of five minutes. An advantage of this creativity test is that it provides not only an overall creativity score but also information about three interrelated facets of creativity that can be used as separate dependent variables (Baas et al., 2008): creative fluency, cognitive flexibility, and originality. Creative fluency refers to the number of unique ideas people generate. Cognitive flexibility refers to the breadth of generated ideas and indicates whether people can switch between different domains or consider different perspectives. Originality refers to the novelty and uncommonness of ideas and indicates whether people generate ideas that depart from routine and habitual thought.

Two independent raters, who were blind to condition, participants' chronotype, and the study hypotheses, rated participants' responses on the alternative uses test. For creative fluency, the raters counted the number of unique ideas a participant had generated. A higher number of unique ideas reflects greater creative fluency. For cognitive flexibility, each generated idea was assigned to one of seven a priori defined content categories (e.g., tool, weapon, decoration, sport; Nijstad et al., 2010). A higher number of content categories used by a participant reflects greater cognitive flexibility. For originality, the two raters assessed the originality of each participant's ideas on a scale from 1 (*not original at all*) to 7 (*very original*). A higher mean score on this scale reflects greater originality. Interrater reliability $ICC_{(2,2)}$ was above .80 for all measures. We aggregated the scores across the two raters for the object brick and for the object newspaper and *z*-standardized the scores to remove potential differences in the level of difficulty related to the specific object. For the composite measure of creativity, we averaged the three scores of creative fluency, cognitive flexibility, and originality.

Measures: Control variables. For sleep duration, participants reported the number of hours and minutes they had slept the previous night. We assessed previous night's sleep quality with the single item "How do you evaluate this night's sleep?", derived from the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989; Kühnel, Sonnentag, & Bledow, 2012). Participants rated their overall sleep quality on a 5-point Likert-type scale ranging from 1 (*very poor*) to 5 (*excellent*).

Results

Descriptive statistics. Table 1 shows the means, standard deviations, intercorrelations between variables, and intraclass correlations.

Analytic strategy. We used Mplus (version 8.2) to conduct multilevel analyses (Muthén & Muthén, 1998–2017). Multilevel analyses are suitable for any data set that has a hierarchical structure. This includes longitudinal analysis, in which an individuals' repeated measurements (morning and late-afternoon session; Level 1) are nested within the individuals being studied (Level 2). Mplus can fit models that explain variation in an outcome variable with predictors at Level 1 and Level 2. In the models in Table 2, we predicted creativity and positive mood with the explanatory variables *time of day* (0 = morning vs. 1 = late afternoon; Level 1), *chronotype* (Level 2), and the interaction between these variables (Time of day × Chronotype). In technical terms, chronotype is modeled as a predictor of the within-person effect of time of day on creativity and positive mood. To arrive at unbiased estimates, we followed the recommendations of Aguinis, Gottfredson, and Culpepper (2013) and grand-mean centered the cross-level moderator chronotype. We used a conditional indirect effect model to examine the proposed mediating effect of positive mood and tested the within-person indirect effect of time of day on creativity via positive mood for conditional values of the moderator chronotype (+ and −1 *SD*). To arrive at unbiased estimates for the indirect relationships, we followed the recommendations of Preacher and colleagues (Preacher, Zhang, & Zyphur, 2011; Preacher, Zyphur, & Zhang, 2010)

TABLE 1
Means, Standard Deviations, and Correlations between Variables of Study 1

Variable	*M*	*SD*	ICC[a]	1	2	3	4	5	6	7	8	9	10
1 Creativity: Composite measure of the AUT[b]	0.04	0.81	.52		.81***	.86***	.70***	.03	.04	−.02	.04		
2 Creativity: Creative fluency	0.04	1.01	.56	.86***		.62***	.31***	.03	−.03	−.03	.02		
3 Creativity: Cognitive flexibility	0.03	1.00	.39	.91***	.79***		.38***	.10*	.06	−.03	.05		
4 Creativity: Originality	0.06	0.96	.51	.72***	.32***	.48***		−.08	.06	.00	.04		
5 Positive mood	2.92	0.76	.39	.02	.08	−.01	−.03		.30***	.08	−.29***		
6 Sleep quality	3.65	0.89	.46	−.03	−.03	−.05	.01	.34***		.35***	−.09*		
7 Sleep duration (in hours)	6.65	1.12	.48	.04	−.01	.04	.06	−.08	.27***		−.09*		
8 Time of day (morning vs. late afternoon)[c]	0.50	0.50	.00	—	—	—	—	—	—	—			
9 Chronotype	3.91	1.10	—	.11	.05	.11	.11	−.12	−.16*	.08	—		
10 Age	34.76	13.03	—	−.04	−.02	−.05	−.03	.17**	.06	−.24***	—	−.41***	
11 Gender[d]	0.51	0.50	—	.13*	.09	.09	.13*	−.18**	.05	.13*	—	−.05	−.06

Note: N_{Level2} = 260 (persons) for between-person correlations below diagonal; N_{Level1} = 520 for within-person correlations above the diagonal.

[a] Intraclass correlation (ICC) = ratio of the between-person variance to the total variance; 1-ICC = ratio of the within-person variance to the total variance.

[b] AUT = alternative uses test.

[c] Time of day: 0 = morning, 1 = late afternoon.

[d] Gender: 1 = female, 0 = male.

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE 2
Results of Multilevel Analyses of Study 1 Predicting Creativity and Positive Mood

	Creativity: Composite measure[a]			Creative fluency			Cognitive flexibility		
	Est.	*SE*	*t*	Est.	*SE*	*t*	Est.	*SE*	*t*
Intercept	0.026	0.050	0.52	0.027	0.062	0.44	0.007	0.060	0.11
Level-1 predictor									
Time (morning vs. late afternoon)[b]	0.035	0.049	0.72	0.018	0.058	0.31	0.050	0.068	0.73
Level-2 predictor									
Chronotype	0.006	0.045	0.14	−0.027	0.056	−0.49	0.013	0.054	0.25
Cross-level interaction on time									
Chronotype	0.123	0.044	2.79**	0.129	0.053	2.45*	0.140	0.062	2.28*
−2 × Log likelihood (*df*)	1164.962 (7)			1382.534 (7)			1425.44 (7)		
Level-1 Intercept variance (*SE*)	0.300 (0.043)			0.415 (0.063)			0.535 (0.073)		
Level-2 Intercept variance (*SE*)	0.341 (0.045)			0.577 (0.072)			0.386 (0.066)		
Level-2 Slope variance (*SE*)	0.013 (0.068)			0.048 (0.104)			0.136 (0.113)		
Pseudo-R^2 Level 1	.077			.080			.087		
Pseudo-R^2 Level 2	.002			.002			.002		
Pseudo-R^2 Slope of time	.106			.074			.055		

Note: Est. = estimate.

[a] Composite measure of the three facets of the alternative uses test.

[b] Time of day: 0 = morning, 1 = late afternoon.

† $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE 2 (CONTINUED)
Results of Multilevel Analyses of Study 1 Predicting Creativity and Positive Mood

	Originality			Positive mood		
	Est.	***SE***	***t***	**Est.**	***SE***	***t***
Intercept	0.044	0.059	0.75	3.046	0.046	66.63***
Level-1 predictor						
Time (morning vs. late afternoon)[b]	0.037	0.058	0.63	−0.254	0.051	−4.98***
Level-2 predictor						
Chronotype	0.033	0.053	0.63	−0.124	0.042	−2.98**
Cross-level interaction on time						
Chronotype	0.099	0.053	1.88[+]	0.112	0.046	2.42*
−2 × Log likelihood (*df*)		1343.032 (7)			1126.58 (7)	
Level-1 Intercept variance (*SE*)		0.431 (0.058)			0.321 (0.043)	
Level-2 Intercept variance (*SE*)		0.463 (0.063)			0.221 (0.037)	
Level-2 Slope variance (*SE*)		0.019 (0.098)			0.035 (0.064)	
Pseudo-R^2 Level 1		.049			.103	
Pseudo-R^2 Level 2		.002			.044	
Pseudo-R^2 Slope of time		.066			.089	

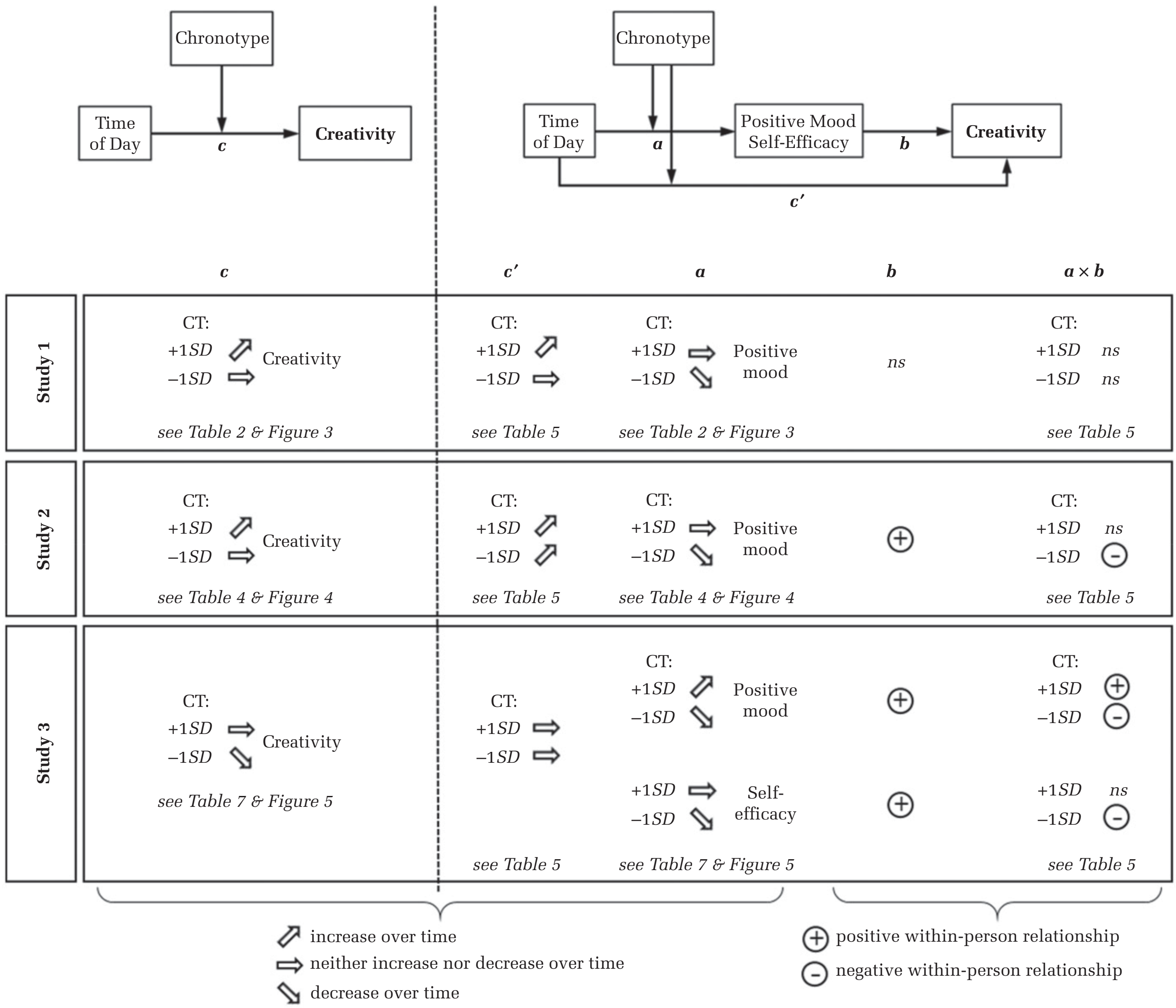
Note: Est. = estimate.
[a] Composite measure of the three facets of the alternative uses test.
[b] Time of day: 0 = morning, 1 = late afternoon.
[+] $p < .10$
* $p < .05$
** $p < .01$
*** $p < .001$

and modeled paths at the within-person level (Level 1) and at the between-person level (Level 2). We report conditional effects for + and −1 *SD* of the moderator chronotype. In addition, we report regions of significance for conditional effects that indicate at which values simple slopes become significant because −1 *SD* and +1 *SD* are sample specific (Hayes, 2018) and differ from the cut-off values for early and late chronotypes.

Test of Hypothesis 1. Table 2 and Figure 2 show that chronotype moderated the effect of time of day on the composite measure of creativity (estimate = 0.12, *SE* = 0.04, *t* = 2.79, *p* < .01, 95% CI [0.04, 0.21]). Figure 3a depicts the creativity of earlier (−1 *SD*) and later (+1 *SD*) chronotypes in the morning compared to the late-afternoon session. Analysis of conditional effects showed that later chronotypes (+1 *SD*, corresponding to a value of 5.0) displayed higher creativity in the late afternoon compared to in the morning (estimate = 0.17, *SE* = 0.07, *t* = 2.48, *p* < .05, 95% CI [0.04, 0.31]), supporting Hypothesis 1b. Earlier (−1 *SD*, corresponding to a value of 2.8) chronotypes' creativity did not significantly differ between morning and late afternoon (estimate = −0.10, *SE* = 0.07, *t* = −1.47, *p* = .142, 95% CI [−0.24, 0.03]), failing to support Hypothesis 1a. However, region of significance for the conditional effect showed that chronotypes earlier than 1.58 *SD* below the mean (corresponding to a value of 2.16) showed higher creativity in the morning compared to in the late afternoon (estimate = −0.18, *SE* = 0.09, *t* = −1.98, *p* < .05, 95% CI [−0.36, −0.002]).

We next examined the three facets of creativity as separate outcome variables (Table 2). For creative fluency, chronotype moderated the effect of time of day (estimate = 0.13, *SE* = 0.05, *t* = 2.45, *p* < .05, 95% CI [0.03, 0.23]). Conditional effects for + and −1 *SD* were not significant. Region of significance for the conditional effect showed that chronotypes later than +1.02 *SD* showed higher creative fluency in the late afternoon compared to in the morning (estimate = 0.16, *SE* = 0.08, *t* = 1.97, *p* < .05, 95% CI [0.001, 0.33]), and that chronotypes earlier than −1.80 *SD* showed higher creative fluency in the morning compared to in the late afternoon (estimate = −0.23, *SE* = 0.12, *t* = −1.96, *p* < .05, 95% CI [−0.45, −0.00]). For cognitive flexibility, chronotype moderated the effect of time of day (estimate = 0.14, *SE* = 0.06, *t* = 2.28, *p* < .05, 95% CI [0.02, 0.26]). Conditional effects showed that later chronotypes (+1 *SD*) showed higher cognitive flexibility in the late afternoon compared to in the morning (estimate = 0.21, *SE* = 0.10, *t* = 2.13, *p* < .05, 95% CI [0.02, 0.39]), and that earlier (−1 *SD*) chronotypes' cognitive flexibility did not differ between morning and late afternoon (estimate = −0.11, *SE* = 0.10,

FIGURE 2
Overview over Results across the Three Studies: Conditional Effects of Time of Day on Creativity for Earlier (−1 *SD*) and Later (+1 *SD*) Chronotypes

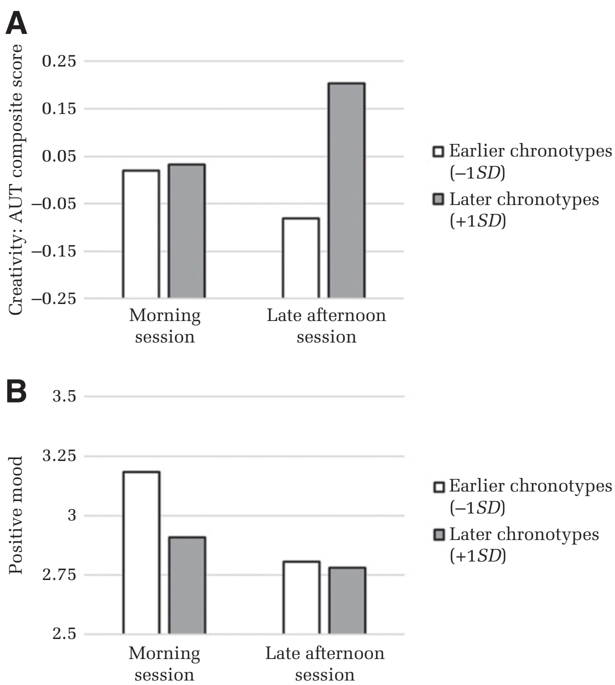


Notes: CT = chronotype. Self-efficacy = creative self-efficacy.

$t = -1.10$, $p = .273$, 95% CI [−0.30, 0.08]). For originality, chronotype moderated the effect of time of day only at a significance level with 10% error probability (estimate = 0.10, *SE* = 0.05, $t = 1.88$, $p = .060$, 95% CI [−0.004, 0.20]). Conditional effects for earlier (−1 *SD*) and later (+1 *SD*) chronotypes were not significant. Region of significance for the conditional effect found that chronotypes later than +2 *SD* showed higher originality in the late afternoon compared to in the morning (estimate = 0.26, *SE* = 0.13, $t = 1.97$, $p < .05$, 95% CI [0.00, 0.52]).

Test of Hypothesis 2. Table 2 shows that chronotype moderated the effect of time of day on positive mood (estimate = 0.11, *SE* = 0.05, $t = 2.42$, $p < .05$,

FIGURE 3
Study 1: The Moderating Effect of Chronotype on the Relationship between Time of Day and (a) Creativity: Alternative Uses Test Composite Score and (b) Positive Mood



Note: AUT = alternative uses test.

95% CI [0.02, 0.20]). Figure 3b depicts this moderation. Conditional effects revealed that later chronotypes' (+1 *SD*) positive mood did not significantly differ between morning and late afternoon (estimate = −0.13, *SE* = 0.07, $t = -1.80$, $p = .071$, 95% CI [−0.27, 0.01]), and that earlier (−1 *SD*) chronotypes experienced higher positive mood in the morning compared to in the late afternoon (estimate = −0.38, *SE* = 0.07, $t = -5.21$, $p < .001$, 95% CI [−0.52, −0.24]). Thus, Hypothesis 2a was supported, but Hypothesis 2b was not supported.

Test of Hypothesis 3. We tested the within-person indirect effect of time of day on creativity via positive mood for conditional values of the moderator chronotype (+ and −1 *SD*). Results for conditional indirect effects ($a \times b$) are depicted in Table 5 (below) and in Figure 2. Positive mood was not a significant predictor of creativity on the within-person level of analysis (*b* path; estimate = 0.02, *SE* = 0.06, $t = 0.27$, $p = .787$, 95% CI [−0.10, 0.13]). Consequently, conditional indirect effects ($a \times b$) were not significant and Hypothesis 3 was not supported.

Robustness tests and supplementary analyses. The pattern of results did not change when we included the control variables day-specific sleep quality and sleep duration. Neither sleep quality nor sleep duration were significant predictors of the composite score of creativity (Level 1: estimate = 0.05, *SE* = 0.06, $t = 0.90$, $p = .367$, Level 2: estimate = −0.06, *SE* = 0.10, $t = -0.62$, $p = .538$; and Level 1: estimate = −0.02, *SE* = 0.05, $t = -0.44$, $p = .663$, Level 2: estimate = 0.05, *SE* = 0.08, $t = 0.63$, $p = .527$, for sleep quality and sleep duration, respectively). Thus, we can rule out the alternative explanation that late chronotypes performed better in the late-afternoon session because they could sleep longer and better on this day compared to the day on which they had to attend the morning session of our study.

We tested whether results differed across the two groups of employees that were combined for Study 1 by taking into account the dummy-coded control variable group (1 = Group 1, 0 = Group 2). Group was neither a significant predictor of creativity nor of positive mood. We also tested whether the within-person relationships of interest were the same across the two groups. These tests revealed that group was a significant cross-level moderator of the within-person relationship between positive mood and creativity (*b* path). However, simple slope tests for Group 1 and Group 2 showed that positive mood was no significant within-person predictor of creativity in Group 1 and in Group 2 (estimate = −0.10, *SD* = 0.10, $p = .274$, 95% CI [−0.31, 0.08], and estimate = 0.14, *SD* = 0.08, $p = .110$, 95% CI [−0.03, 0.26], respectively). Results for conditional indirect effects for Group 1 and Group 2 did not differ from results for the combined sample.

In the second group of employees, who participated in the online surveys, we measured work-related creativity as an additional outcome variable (see Appendix A for details). In support of Hypothesis 1, chronotype moderated the effect of time of day on work-related creativity (Appendix A, Figure A1). Results of the conditional indirect effects model showed, as predicted by Hypothesis 3a, a negative indirect effect ($a \times b$) of time of day on creativity via positive mood for earlier chronotypes (−1 *SD*). The indirect effect ($a \times b$) was not significant for later chronotypes (+1 *SD*), failing to support Hypothesis 3b. Results also showed a positive direct effect (c') of time of day on creativity for all chronotypes when the indirect effect via positive mood was controlled for.

Discussion

Study 1 found support for the idea that creativity exhibits circadian variation. The effect of time of day on creativity significantly varied as a function of chronotype. The earlier someone's chronotype, the less positive was the effect of time of day and the later someone's chronotype, the more positive was the effect of time of day. A closer look at the three facets of creativity showed that the effect of the alignment between chronotype and time of day was strongest for creative fluency and cognitive flexibility. Positive mood also exhibited circadian variation for early chronotypes but did not increase from morning to late afternoon for later chronotypes; they may, however, have displayed an increase in positive mood during off-job time after our second measurement occasion.

While positive mood exhibited circadian variation, we found only weak support for the hypothesis that positive mood functioned as a mediating mechanism. Specifically, positive mood partially mediated the relationship between time of day and work-related creativity but not the relationship between time of day and performance on the alternative uses test. The alternative uses test may capture cognitive components of creativity that are less influenced by the affective-motivational processes related to positive mood that let participants initiate creativity in a work setting. Indeed, previous studies also found only a small effect of positive mood on performance on the alternative uses test (Baas et al., 2008) even though experimental mood inductions were used that likely have a stronger effect than naturally occurring fluctuations in positive mood. In contrast to what is implied by our model, Study 1 showed that the pattern of change in positive mood did not occur in parallel to the pattern of change in work-related creativity. Specifically, for later chronotypes, there was an increase in creativity during the day without a concurrent increase in positive mood. This suggests that positive mood is only a partial mediator, and that other mediating processes are also at play.

STUDY 2

After having established internal validity of the synchrony effect, we next examined whether the alignment between chronotype and time of day influences creativity in jobs for which creativity is particularly important and extended the time frame that was studied.

Method

Sample and procedure. Participants of this day-reconstruction study were 238 full-time employees doing creative work (e.g., architects, designers, artists, creative directors) in various companies. Participants were recruited by three students as part of their theses. To motivate employees to voluntarily take part in the study, we offered feedback on the study results. Fifty-five percent of the participants were women, average age was 44 years ($SD = 14.6$). On average, participants worked 42 hours per week ($SD = 11.5$) and had worked for six years for their organization ($SD = 9.3$). Sixty-one percent held a college or university degree, 14% had an intermediate or general secondary school leaving certificate, and 22% had a lower secondary school leaving certificate.

Participation in the study consisted of answering several online questionnaires. First, employees' chronotype and sociodemographic characteristics were assessed. Then, over the course of one work week, participants received an individually scheduled e-mail with the link to an online questionnaire at the end of each workday. We employed the day-reconstruction method and asked participants to reconstruct the activities and experiences of their workday (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004). At the beginning of each daily questionnaire, participants had to select all performance episodes of the workday during which they had worked (available performance episodes were 6 a.m.–9 a.m., 9 a.m.–noon, noon–3 p.m., 3 p.m.–6 p.m., and 6 p.m.–9 p.m.). They next wrote down what they did during each performance episode and indicated their level of positive mood and creativity during the respective performance episode. Of the 345 participants who gave their consent to take part in the study, 238 provided sufficient data to be included in the study (response rate of 69%), resulting in 849 days and 2,716 performance episodes ($M = 3.2$ performance episodes per day).

Measures: Chronotype. As in Study 1, participants' chronotype was assessed as a continuous variable with the MCTQ (Roenneberg et al., 2003). In this sample, 24% were early chronotypes, 65% were intermediate chronotypes, and 11% were late chronotypes.

Measures: Positive mood. Participants' positive mood was assessed with the same items as in Study 1. The items referred to how the person felt during a specific performance episode. Cronbach's alphas ranged between .83 and .90 across performance episodes.

Measures: Creativity. We measured work-related creativity with the five-item version (Bledow et al., 2013) of the scale of Tierney, Farmer, and Graen (1999). Items had to be answered on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Example items were “Between *xx* a.m./p.m. and *xx* a.m./p.m. [time frame of the respective performance episode], I generated novel but operable work-related ideas” and “Between *xx* a.m./p.m. and *xx* a.m./p.m. [time frame of the respective performance episode], I served as a good role model for creativity.” Cronbach’s alphas ranged between .86 and .90 across performance episodes.

Measures: Control variables. As in Study 1, we assessed previous night’s sleep duration and sleep quality in each daily questionnaire. In addition, we assessed day-specific time pressure and day-specific job control with items developed by Semmer, Zapf, and Dunckel (1999). Items had to be answered on a 5-point Likert-type scale ranging from 1 (*never or very rarely*) to 5 (*frequently*) and from 1 (*very little*) to 5 (*very much*), respectively. Time pressure was assessed with three items (e.g., “How often were you pressed for time today?”). Cronbach’s alphas ranged between .83 and .92 over the days. Job control was assessed with three items (e.g., “Today, to what extent could you influence the way in which you accomplished your tasks?”). Cronbach’s alphas ranged between .80 and .88 over the days.

Results

Descriptive statistics. Table 3 shows the means, standard deviations, intercorrelations between variables, and intraclass correlations.

Analytic strategy. We used the same multilevel analysis in Mplus 8.2 as in Study 1 and predicted creativity during a performance episode with the explanatory variables time of day and chronotype. The variable *time of day* refers to the performance episodes that were coded 0 (*6 a.m.–9 a.m.*), 1 (*9 a.m.–noon*), 2 (*noon–3 p.m.*), 3 (*3 p.m.–6 p.m.*), and 4 (*6 p.m.–9 p.m.*).

Test of Hypothesis 1. Table 4 shows that chronotype moderated the effect of time of day on creativity (estimate = 0.07, SE = 0.03, t = 2.70, $p < .01$, 95% CI [0.02, 0.12]). Figure 4a illustrates this moderation. In support of Hypothesis 1b, conditional effects revealed an increase in creativity over the course of the workday for later chronotypes (+1 *SD,* corresponding to a value of 4.8; estimate = 0.12, SE = 0.04, t = 3.13, $p < .01$, 95% CI [0.05, 0.20]). Earlier chronotypes’ (−1 *SD*, corresponding to a value of 2.8) creativity remained stable across the workday (estimate = −0.02, SE = 0.04, t = −0.64, p = .525, 95% CI [−0.09, 0.05]). Region-of-significance tests for the conditional effect showed that creativity would significantly decrease for chronotypes with values earlier than 0.9. However, the earliest chronotypes in our sample had a value of 1.8. Consequently, Hypothesis 1a was not supported.

Test of Hypothesis 2. Table 4 shows that chronotype moderated the effect of time of day on positive mood (estimate = 0.05, SE = 0.01, t = 3.28, $p < .01$, 95% CI [0.02, 0.08]). Figure 4b illustrates this moderation. In support of Hypothesis 2a, conditional effects revealed a decrease in positive mood for earlier chronotypes (−1 *SD*; estimate = −0.08, SE = 0.02, t = −3.79, $p < .001$, 95% CI [−0.12, −0.04]). Positive mood remained stable over the course of the workday for later chronotypes (+1 *SD*; estimate = 0.02, SE = 0.02, t = 0.96, p = .336, 95% CI [−0.02, 0.06]). Note that the value tested for later chronotypes (+1 *SD*) corresponds to a value of 4.8 and thus lies within the range of values for *intermediate* chronotypes (3–5). Region-of-significance tests for the conditional effect showed that chronotypes later than +1.87 *SD* (corresponding to a value of 5.7) showed an increase in positive mood over the course of the day. Consequently, Hypothesis 2b received partial support.

Test of Hypothesis 3. We tested the within-person indirect effect of time of day on creativity via positive mood for conditional values of the moderator chronotype. Results for conditional indirect effects are summarized in Table 5 and depicted in Figure 2. Positive mood predicted creativity on the within-person level (b path; estimate = 1.11, SE = 0.03, t = 33.92, $p < .001$, 95% CI [1.05, 1.18]). The direct effect (c') of time of day on creativity was positive for all chronotypes when the indirect effect via positive mood was controlled for (estimate = 0.08, SE = 0.02, t = 4.03, $p < .001$, 95% CI [0.04, 0.12]). In support of Hypothesis 3a, analysis of conditional indirect effects ($a \times b$) found a negative, indirect effect of time of day on creativity via positive mood for earlier chronotypes (−1 *SD*). However, the conditional indirect effect ($a \times b$) was not significant for later chronotypes (+1 *SD*) because the relationship between time of day and positive mood (a path) was not significant for later chronotypes. Note that the value tested for later chronotypes (+1 *SD*) corresponds to a value of 4.8 and thus lies within the range of values for *intermediate* chronotypes (3–5).

TABLE 3
Means, Standard Deviations, and Correlations between Variables of Study 2

	Variable	*M*	*SD*	ICC[a]	1	2	3	4	5	6	7	8	9
1	Creativity	3.97	1.48	.41		.56***	.05**	.09***	.03	.18***	.11***		
2	Positive mood	3.23	0.77	.44	.49***		−.05**	.19***	.06**	.12***	.08***		
3	Time of day (performance episode)[b]	1.77	1.15	.06	.04	−.05		−.01	.01	.01	−.00		
4	Day-specific sleep quality	3.50	1.01	.52	.10	.22**	−.09		.18***	.14***	−.03		
5	Day-specific sleep duration	6.96	1.34	.49	−.00	−.09	.20**	.08		.08***	−.00		
6	Day-specific time pressure	2.58	1.11	.67	.26***	.27***	.04	.10	.07		−.08***		
7	Day-specific job control	4.05	0.83	.55	.10	−.01	−.10	−.02	−.13*	−.28***			
8	Chronotype	3.78	1.04	—	.05	−.17*	.31***	−.17**	.14*	.13*	−.07		
9	Age	44.30	14.59	—	.02	.17**	.18**	.05	−.07	.07	−.16*	−.23***	
10	Gender[c]	0.56	0.50	—	−.08	−.08	.07	−.04	.12	−.00	−.05	.06	−.02

Note: $N_{\text{Level2}} = 238$ (persons) for between-person correlations below diagonal; $N_{\text{Level1}} = 2{,}716$ (performance episodes) for within-person correlations above the diagonal.
[a] Intraclass correlation (ICC) = ratio of the between-person variance to the total variance, 1-ICC = ratio of the within-person variance to the total variance.
[b] Time of day (performance episode): 0 = 6 a.m.–9 a.m., 1 = 9 a.m.–noon, 2 = noon–3 p.m., 3 = 3 p.m.–6 p.m., 4 = 6 p.m.–9 p.m.
[c] Gender: 1 = female, 0 = male.
* $p < .05$
** $p < .01$
*** $p < .001$

Region of significance for the conditional indirect effect ($a \times b$) showed a significant, positive indirect effect of time of day on creativity via positive mood for chronotypes later than +1.89 *SD* (corresponding to a value of 5.7). Consequently, Hypothesis 3b received partial support.

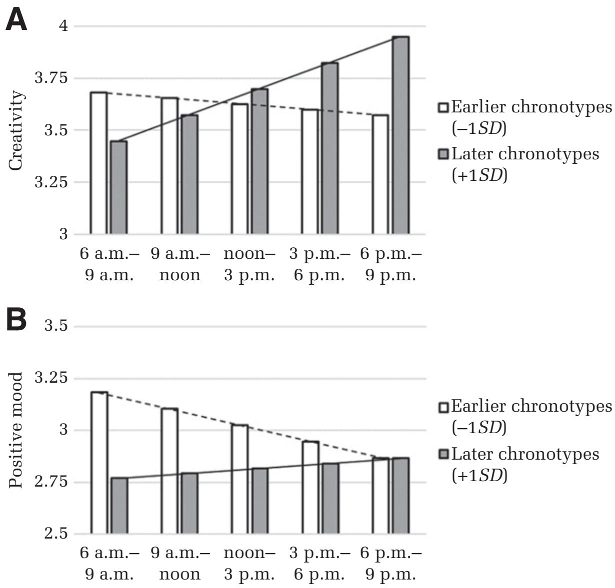
Robustness tests. The pattern of results did not change when we controlled for previous night's sleep quality and sleep duration, day-specific time pressure, and day-specific job control. Neither sleep quality nor sleep duration were significant predictors of creativity (Level 1: estimate = −0.04, *SE* =

TABLE 4
Results of Multilevel Analyses of Study 2 Predicting Creativity and Positive Mood

	Creativity			Positive mood		
	Est.	*SE*	*t*	Est.	*SE*	*t*
Intercept	3.564	0.764	4.66***	2.977	0.404	7.37***
Level-1 predictor						
Time (performance episode)[a]	0.049	0.026	1.85	−0.028	0.015	−1.91
Level-2 predictors						
Time (performance episode)[a]	0.175	0.430	0.41	0.158	0.227	0.70
Chronotype	−0.106	0.092	−1.15	−0.188	0.050	−3.74***
Cross-level interaction on time						
Chronotype	0.069	0.026	2.70**	0.047	0.014	3.28**
−2 × Log likelihood (*df*)	17280.872 (9)			13575.532 (9)		
Level-1 Intercept variance (*SE*)	1.216 (0.036)			0.303 (0.009)		
Level-2 Intercept variance (*SE*)	0.950 (0.130)			0.306 (0.039)		
Level-2 Slope variance (*SE*)	0.060 (0.015)			0.024 (0.005)		
Pseudo-R^2 Level 1	.066			.092		
Pseudo-R^2 Level 2	.013			.026		
Pseudo-R^2 Slope of time	.034			.043		

Note: Est. = estimate.
[a] Time of day (performance episode): 0 = 6 a.m.–9 a.m., 1 = 9 a.m.–noon, 2 = noon–3 p.m., 3 = 3 p.m.–6 p.m., 4 = 6 p.m.–9 p.m.
** $p < .01$
*** $p < .001$

FIGURE 4
Study 2: The Moderating Effect of Chronotype on the Relationship between Time of Day and (a) Creativity and (b) Positive Mood



0.03, $t = -1.36$, $p = .173$, Level 2: estimate $= -0.01$, $SE = 0.08$, $t = -0.11$, $p = .912$; and Level 1: estimate $= -0.01$, $SE = 0.02$, $t = -0.55$, $p = .579$, Level 2: estimate $= 0.03$, $SE = 0.08$, $t = 0.35$, $p = .726$, for sleep quality and sleep duration, respectively). Job control and time pressure were significant positive predictors of creativity on both the within- and between-level of analysis (Level 1: estimate $= 0.25$, $SE = 0.03$, $t = 7.40$, $p < .001$, Level 2: estimate $= 0.28$, $SE = 0.10$, $t = 2.71$, $p < .01$; and Level 1: estimate $= 0.13$, $SE = 0.03$, $t = 4.32$, $p < .001$, Level 2: estimate $= 0.20$, $SE = 0.07$, $t = 2.95$, $p < .01$, for job control and time pressure, respectively).

Discussion

Study 2 replicated the moderating effect of chronotype and showed that creativity exhibited circadian variation in a sample of employees with creative jobs. Contrary to our expectations, the expected decrease in creativity during the day for earlier chronotypes was not significant. This was presumably due to the fact that creativity showed an overall positive trend over the course of the day and the underrepresentation of extreme chronotypes in our sample (the standard deviation of chronotype was 1.04 hours in our sample of working adults in contrast to 2 hours in the general population; Fischer, Lombardi, Marucci-Wellman, & Roenneberg, 2017; Roenneberg, Pilz, Zerbini, & Winnebeck, 2019). Results of Study 2 further support the idea that positive mood exhibits circadian variation and that this variation influences creativity. Notably, and in line with Study 1 and previous findings (Clark et al., 1989), we observed overall higher positive mood for earlier chronotypes. They started the day with a higher level of positive mood than later chronotypes. Over the course of the day, the levels of positive mood of earlier and later chronotypes converged. Due to these differences in positive mood, the pattern of the observed synchrony effect deviates from a symmetric crossover pattern (see Figure 4b). Moreover, as in Study 1, fluctuations in positive mood were not entirely parallel to fluctuations in creativity and did not fully explain the effect of time of day on creativity. For later chronotypes, an increase in creativity occurred without an equally strong concurrent increase in positive mood such that positive mood cannot have acted as the mediating mechanism. Thus, for later chronotypes, the executive functions that enable creativity were available in the late afternoon, but their availability was not accompanied by positive mood. This again indicates that other, presumably cognitive mechanisms also contribute to the joint effect of time of day and chronotype on creativity. A general limitation of Study 2 is that it may have been subject to a recollection bias. Earlier and later chronotypes may differently recollect their creativity and positive mood at the end of the day. To address this limitation, Study 3 uses multiple measurement occasions and measures creativity with a time lag of one hour after the mediators.

STUDY 3

Study 3 provides a test of the complete conceptual model and examines positive mood and creative self-efficacy as parallel mediators of the proposed synchrony effect.

Method

Sample and procedure. Participants of this one-day experience sampling study were 319 full-time employees recruited via Amazon's Mechanical Turk. Forty-nine percent were women, and average age was 40 years ($SD = 10.3$). On average, participants worked 42 hours per week ($SD = 4.2$) and had worked for eight years in their current organization

($SD = 6.6$). Twenty-one percent held a graduate or professional degree, 54% had a college degree, and 25% had a high school diploma or GED diploma.

Participation in the study consisted of answering five online questionnaires. First, employees' chronotype and sociodemographic characteristics were assessed. Over the course of the next workday, participants received invitations to answer four online questionnaires; the first at 8 a.m. (T1a), the second at 9 a.m. (T1b), the third at 4 p.m. (T2a), and the last at 5 p.m. (T2b). For improved causal inferences, we separated the measurement of the mediators from the measurement of the dependent variable. We assessed positive mood and creative self-efficacy in the first (T1a) and the third (T2a) questionnaire, and creativity in the second (T1b) and the fourth (T2b) questionnaire, and explicitly referred to creativity in the last hour. Of the 562 participants who answered the general questionnaire and were invited to fill in the four questionnaires on the next day, 339 participants provided data on all measurement occasions (completion rate of 60%). Participants received 1.25 USD for completing the entry questionnaire, 0.30 USD for completing each of the four short questionnaires, and a bonus of 3 USD for full completion. At the beginning of each of the five questionnaires, we used reCAPTCHA (version 2) to screen for valid users. After a manual quality screening of the data, we excluded 20 participants with very short survey answering times (the lowest 2.5%), resulting in a final sample of 319 participants.

Measures: Chronotype. In addition to the MCTQ that was used in Study 1 and Study 2 to measure chronotype, we assessed chronotype with the short scale (rMEQ; Adan & Almirall, 1991) of the morningness–eveningness questionnaire (MEQ; Horne & Östberg, 1976), a widely used self-assessment questionnaire to determine circadian preference. Compared to the MCTQ, the rMEQ has the advantage that no exclusion criteria exist and that we did not need to exclude 49 participants (15% of the sample) whose chronotype could not be calculated with the MCTQ because they reported restricted sleep times on work-free days. We therefore used participants' scores on the rMEQ for the analyses.[2] The rMEQ consists of five questions; for example, "Approximately what time would you get up if you were entirely free to plan your day?", with response options being 1 (*5:00–6:30 a.m.*), 2 (*6:30–7:45 a.m.*), 3 (*7:45–9:45 a.m.*), 4 (*9:45–11:00 a.m.*), and 5 (*11:00–noon*); and "One hears about 'morning types' and 'evening types' of people. Which one of these types do you consider yourself to be?', with response options being 0 (*definitely a morning type*), 2 (*rather more a morning type than an evening type*), 4 (*rather more an evening type than a morning type*), and 6 (*definitely an evening type*). Response options were coded in such a way that a higher sum score indicates a later chronotype. Cronbach's alpha was .75. The rMEQ measures a continuous dimension with values ranging from 4 to 25. According to the cut-off scores defined by Adan and Almirall (1991), 33% of participants were early (values < 12), 50% were intermediate (12–17), and 17% were late chronotypes (values > 17).

Measures: Positive mood. We assessed participants' positive mood with the same items as in Study 1 and Study 2 (Watson et al., 1988). Respondents indicated how they felt "right now." Cronbach's alphas were .91 and .89 for the T1a and T2a questionnaires, respectively.

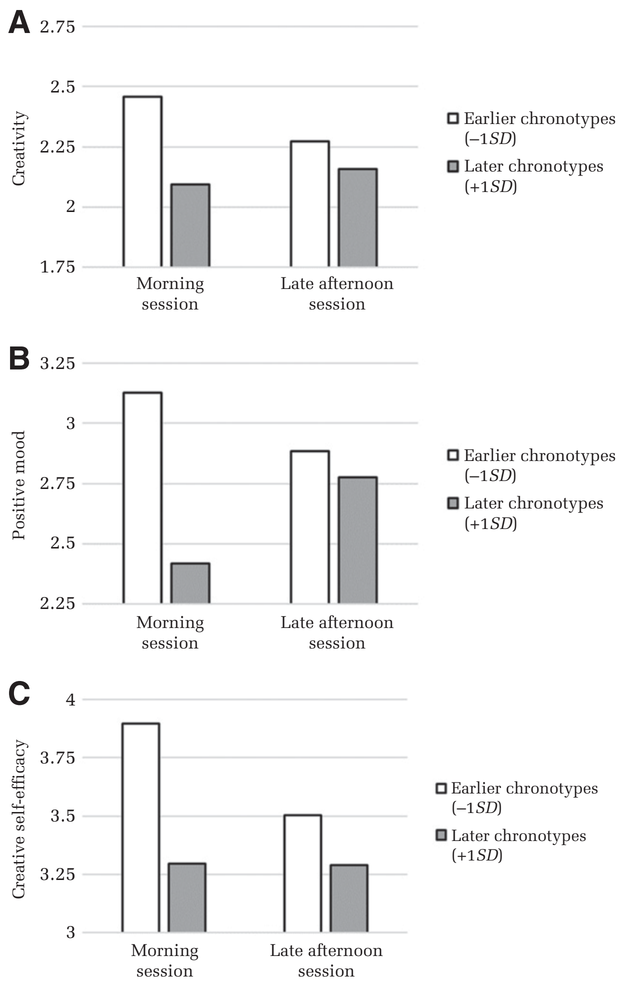
Measures: Creative self-efficacy. We assessed creative self-efficacy with the three items of Tierney and Farmer (2002) that were adapted to capture within-person variation. An example item is "Right now, I have confidence in my ability to solve problems creatively." Respondents indicated their agreement on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's alphas were .91 and .92 for the T1a and T2a questionnaires, respectively.

Measures: Creativity. The same measure as in Study 1 and Study 2 was used to measure work-related creativity. Items referred to the last hour and were answered on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's alpha was .91 on both occasions.

Measures: Control variables. As in Study 1 and 2, we assessed previous night's sleep duration and sleep quality. In addition, we assessed workload in the T1b and the T2b questionnaire with the item "During the last hour, I had too much work to do in too little time," taken from Amabile, Conti, Coon, Lazenby, and Herron (1996). Respondents indicated their agreement on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

[2] The correlation between the scores of the MCTQ and the rMEQ was high, $r = .711$, $p < .001$. The pattern of results for the conditional indirect effects model was the same when using the scores of the MCTQ.

FIGURE 5
Study 3: The Moderating Effect of Chronotype on the Relationship between Time of Day and (a) Creativity, (b) Positive Mood, and (c) Creative Self-Efficacy



Results

Descriptive statistics. Table 6 shows the means, standard deviations, intercorrelations between variables, and intraclass correlations.

Analytic strategy. We used Mplus 8.2 to conduct multilevel analyses and examined chronotype as a moderator of the effect of time of day on creativity, positive mood, and creative self-efficacy. The variable *time of day* refers to the four measurement occasions that were coded 0 (*morning;* mediators measured at T1a and creativity measured at T1b) and 1 (*late afternoon;* mediators measured at T2a and creativity measured at T2b). We followed the same analytical procedures as in Study 1 and 2 (Preacher et al., 2011; Preacher et al., 2010) to examine the mediating role of positive mood and creative self-efficacy.

Test of Hypothesis 1. Table 7 shows that chronotype moderated the effect of time of day on creativity (estimate = 0.03, SE = 0.01, t = 2.53, $p < .05$, 95% CI [0.01, 0.06]). Figure 5a depicts this moderation. In support of Hypothesis 1a, conditional effects showed that earlier (−1 SD, corresponding to a value of 9.8) chronotypes' creativity was higher in the morning compared to in the afternoon (estimate = −0.18, SE = 0.07, t = −2.65, $p < .01$, 95% CI [−0.32, −0.05]). Later chronotypes' (+1 SD, corresponding to a value of 17.5) creativity did not significantly differ between morning and late afternoon (estimate = 0.07, SE = 0.07, t = 0.93, p = .350, 95% CI [−0.07, 0.20]). According to region-of-significance tests for the conditional effect, chronotypes with values greater than 24 would show higher creativity in the late afternoon compared to in the morning. However, the latest chronotypes in the sample had a value of 23. Hypothesis 1b was thus not supported.

Test of Hypothesis 2. As presented in Table 7, chronotype moderated the effect of time of day on positive mood (estimate = 0.08, SE = 0.01, t = 6.84, $p < .001$, 95% CI [0.06, 0.10]). Figure 5b illustrates this moderation. In support of Hypothesis 2b, for later chronotypes' (+1 SD) positive mood was higher in the late afternoon compared to in the morning (estimate = 0.36, SE = 0.06, t = 5.79, $p < .001$, 95% CI [0.24, 0.48]). In support of Hypothesis 2a, earlier chronotypes (−1 SD) showed higher positive mood in the morning compared to in the late afternoon (estimate = −0.24, SE = 0.06, t = −3.90, $p < .001$, 95% CI [−0.36, −0.12].

Test of Hypothesis 4. As shown in Table 7, chronotype moderated the effect of time of day on creative self-efficacy (estimate = 0.05, SE = 0.02, t = 3.39, $p < .01$, 95% CI [0.02, 0.08]). Figure 5c displays this moderation. Earlier chronotypes (−1 SD) showed higher creative self-efficacy in the morning compared to in the late afternoon (estimate = −0.40, SE = 0.08, t = −4.89, $p < .001$, 95% CI [−0.55, −0.24]). Later chronotypes' (+1 SD) creative self-efficacy did not differ between morning and late afternoon (estimate = −0.01, SE = 0.08, t = −0.09, p = .932, 95% CI [−0.17, 0.15]). Hypothesis 4a was thus supported, whereas Hypothesis 4b was not supported.

Test of Hypotheses 3 and 5. We used a conditional indirect effects model to simultaneously test if positive mood and creative self-efficacy operated as mediators. More specifically, we tested the within-

TABLE 5
Conditional Indirect Effects ($a \times b$) and Conditional Direct Effects (c') for Study 1, Study 2, and Study 3

	Conditional indirect effects ($a \times b$)					Conditional direct effects (c')	
	Estimate	*SE*	*t*	*p*	95% CI [LL, UL][a]	Estimate	*SE*
Study 1							
Time of day[b] on creativity (AUT)[c] via positive mood							
For later chronotypes (+1 *SD*)	−0.002	0.008	−0.267	.789	−0.018, 0.013	0.173*	0.069
For earlier chronotypes (−1 *SD*)	−0.006	0.023	−0.270	.788	−0.050, 0.038	−0.095	0.072
Study 2							
Time of day[d] on creativity via positive mood							
For later chronotypes (+1 *SD*)	0.023	0.024	0.957	.338	−0.024, 0.069	0.100**	0.029
For earlier chronotypes (−1 *SD*)	−0.085***	0.023	−3.767	.000	−0.130, −0.041	0.062*	0.028
Study 3							
Time of day[b] on creativity via positive mood							
For later chronotypes (+1 *SD*)	0.064*	0.026	2.423	.015	0.012, 0.116	−0.038	0.049
For earlier chronotypes (−1 *SD*)	−0.043*	0.020	−2.201	.028	−0.082, −0.005	−0.038	0.049
Time of day[b] on creativity via creative self-efficacy							
For later chronotypes (+1 *SD*)	−0.001	0.013	−0.085	.932	−0.026, 0.024	−0.038	0.049
For earlier chronotypes (−1 *SD*)	−0.063*	0.025	−2.517	.012	−0.111, −0.014	−0.038	0.049

[a] 95% confidence interval [lower limit, upper limit].
[b] Time of day: 0 = morning, 1 = late afternoon.
[c] AUT = alternative uses test.
[d] Time of day (performance episode): 0 = 6 a.m.–9 a.m., 1 = 9 a.m.–noon, 2 = noon–3 p.m., 3 = 3 p.m.–6 p.m., 4 = 6 p.m.–9 p.m.
* $p < .05$
** $p < .01$
*** $p < .001$

person indirect effects of time of day on creativity via positive mood and of time of day on creativity via creative self-efficacy for conditional values of the moderator chronotype. Results for conditional indirect effects are summarized in Table 5 and depicted in Figure 2. Positive mood predicted creativity on the within-person level of analysis (b_{mood} path; estimate = 0.18, SE = 0.07, t = 2.67, $p < .01$,

TABLE 6
Means, Standard Deviations, and Correlations between Variables of Study 3

	Variable	*M*	*SD*	ICC[a]	1	2	3	4	5	6	7	8	9
1	Creativity	2.25	1.01	.62		.26***	.28***	.19***	−.07				
2	Positive mood	2.80	0.97	.63	.53***		.52***	.06	.07				
3	Creative self-efficacy	3.50	1.05	.50	.54***	.64***		−.00	−.19***				
4	Workload	2.38	1.28	.42	.19**	−.03	−.04		.15***				
5	Time of day[b]	0.50	0.50	.00	—	—	—	—					
6	Day-specific sleep quality	3.72	1.05	—	.17**	.37***	.37***	−.08	—				
7	Day-specific sleep duration	6.64	1.13	—	.05	.13*	.20***	−.15**	—	.54***			
8	Chronotype (MEQ score)	13.64	3.86	—	−.13*	−.23***	−.23***	.12*	—	−.18**	−.16**		
9	Age	39.60	10.32	—	.06	.29***	.16**	.00	—	.15**	−.00	−.18**	
10	Gender[c]	0.51	0.50	—	.07	.09	.12*	.01	—	−.08	.02	.01	−.15**

Note: N_{Level2} = 319 (persons) for between-person correlations below diagonal; N_{Level1} = 638 matched measurement occasions (t1a with t1b, and t2a with t2b) for within-person correlations above the diagonal.
[a] Intraclass correlation (ICC) = ratio of the between-person variance to the total variance; 1-ICC = ratio of the within-person variance to the total variance.
[b] Time of day: 0 = morning, 1 = late afternoon.
[c] Gender: 1 = male, 0 = female.
* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 7
Results of Multilevel Analyses of Study 3 Predicting Creativity, Positive Mood, and Creative Self-Efficacy

	Creativity			Positive mood			Creative self-efficacy		
	Est.	***SE***	***t***	**Est.**	***SE***	***t***	**Est.**	***SE***	***t***
Intercept	2.276	0.056	40.73***	2.772	0.052	53.55***	3.597	0.056	63.74***
Level-1 predictor									
Time (morning vs. late afternoon)[a]	−0.060	0.049	−1.21	0.059	0.044	1.34	−0.201	0.057	−3.52***
Level-2 predictor									
Chronotype	−0.047	0.015	−3.27**	−0.092	0.013	−6.85***	−0.078	0.015	−5.34***
Cross-level interaction on time									
Chronotype	0.032	0.013	2.53*	0.078	0.011	6.84***	0.050	0.015	3.39**
−2 × Log likelihood (*df*)	1622.498 (7)			1549.156 (7)			1740.472 (7)		
Level-1 Intercept variance (*SE*)	0.372 (0.051)			0.286 (0.043)			0.503 (0.064)		
Level-2 Intercept variance (*SE*)	0.625 (0.067)			0.569 (0.059)			0.513 (0.065)		
Level-2 Slope variance (*SE*)	0.027 (0.090)			0.041 (0.075)			0.033 (0.100)		
Pseudo-R^2 Level 1	.052			.112			.089		
Pseudo-R^2 Level 2	.024			.096			.077		
Pseudo-R^2 Slope of time	.084			.422			.121		

Note: Est. = estimate.
[a] Time of day: 0 = morning, 1 = late afternoon.
* $p < .05$
** $p < .01$
*** $p < .001$

95% CI [0.05, 0.31]). Results of conditional indirect effects ($a_{\text{mood}} \times b_{\text{mood}}$) showed a positive indirect effect of time of day on creativity via positive mood for later chronotypes (+1 *SD*), and a negative indirect effect of time of day on creativity via positive mood for earlier chronotypes (−1 *SD*), supporting Hypotheses 3a and 3b. Creative self-efficacy predicted creativity on the within-person level of analysis ($b_{\text{self-efficacy}}$ path; estimate = 0.16, $SE = 0.05$, $t = 2.94$, $p < .01$, 95% CI [0.05, 0.27]). Results of conditional indirect effects ($a_{\text{self-efficacy}} \times b_{\text{self-efficacy}}$) showed a negative indirect effect of time of day on creativity via creative self-efficacy for earlier (−1 *SD*) but not for later chronotypes (+1 *SD*). Thus, Hypothesis 5a was supported. Hypothesis 5b could not be supported because the relationship between time of day and creative self-efficacy ($a_{\text{self-efficacy}}$ path) was nonsignificant for later chronotypes. The direct effect (c') of time of day on creativity was nonsignificant after taking into account the indirect effects via positive mood and creative self-efficacy. The overall effect of the alignment between chronotype and time of day is a function of the direct effect (c') and both indirect effects ($a_{\text{mood}} \times b_{\text{mood}}$ and $a_{\text{self-efficacy}} \times b_{\text{self-efficacy}}$). Earlier chronotypes' creativity was higher in the morning compared to in the afternoon because their positive mood and their creative self-efficacy were also higher. Contrary to expectations, later chronotypes' creativity was not significantly higher in the afternoon compared to in the morning although their positive mood was higher in the afternoon.

Robustness tests. The pattern of results did not change when the control variables previous night's sleep quality and sleep duration as well as workload during the last hour were taken into account. Because Study 3 was a *one-day* experience sampling study, previous night's sleep quality and sleep duration are person-level (Level 2) variables. To rule out the alternative explanation that previous night's sleep is a third variable that drives the relationships between chronotype and within-day changes in positive mood and creative self-efficacy, we ran a model that included sleep quality and sleep duration as cross-level moderators of the effects of time of day on positive mood and creative self-efficacy. Results showed that chronotype remained a significant cross-level moderator of the effects of time of day on positive mood and creative self-efficacy. Sleep quality explained differences in positive mood and creative self-efficacy in the morning compared to in the late afternoon over and above chronotype. The pattern of results suggested that people who slept worse started the day with low levels of positive mood and self-efficacy and showed small increases in positive mood until the late afternoon. People who slept better started the day with high levels of positive mood and self-efficacy and displayed a slight decline until the late afternoon. Day-specific sleep duration did not explain differences in positive mood and creative self-efficacy in the morning compared to in the late afternoon. There was a significant positive relationship between workload and creativity (Level 1: estimate = 0.12, $SE = 0.03$, $t = 3.60$, $p < .001$, Level 2: estimate = 0.22, $SE = 0.07$, $t = 3.20$, $p < .01$).

Discussion

Study 3 replicated and extended our previous studies and showed that creativity, positive mood, and creative self-efficacy exhibit circadian variation. The earlier someone's chronotype, the less positive, and the later someone's chronotype, the more positive was the effect of time of day on these variables. In partial support of our mediation hypotheses, creative self-efficacy and positive mood decreased during the day among earlier chronotypes, which resulted in a decrease in creativity. Consistent with the previous studies, Study 3 found that intraday changes in creativity are coupled less to concurrent positive mood for later than for earlier chronotypes. For later chronotypes, simple slope tests found only an increase in positive mood but no significant increase in creative self-efficacy and creativity. In Study 3, a significant increase in creativity for later chronotypes presumably occurred *after* the afternoon time frame we studied. Work-related creativity was assessed in the afternoon at 4 to 5 p.m. in Study 3, as compared to 5 to 6 p.m. in Study 1 (Study 2 examined work-related creativity until 9 p.m.). From the perspective of the biological clock, measurements in Study 3 captured even earlier time frames, because Study 3 took place during daylight saving time. During daylight saving time, social clocks (clock time) are advanced by one hour. Biological clocks, however, are not advanced as they are coupled to the sun clock (Roenneberg, Kumar, & Merrow, 2007; Roenneberg, Winnebeck, & Klerman, 2019). Thus, in biological clock time, work-related creativity was assessed in the afternoon at 3 to 4 p.m. in Study 3, as compared to 5 to 6 p.m. in Study 1. Capturing an effect for late chronotypes was also hindered by the underrepresentation of late relative to early chronotypes in Study 3 compared to Study 1, which both took two "snapshots" of creativity during a day.

GENERAL DISCUSSION

Across three studies, we found that chronotype moderated the effect of time of day on creativity. What mattered for creativity was the *alignment* between chronotype and the time of day—a phenomenon we term the synchrony effect. This synchrony effect appeared most consistently for late chronotypes. Across the three studies, the synchrony effect also gave rise to positive mood, but positive mood mediated the effect of the alignment between chronotype and time of day on creativity only in Studies 2 and 3. In support of the assumption that a state of synchrony promotes the executive functions that enable creativity, Study 3 found that the alignment between chronotype and time of day also gave rise to creative self-efficacy and thereby influenced creativity. Our studies suggest, however, that the interplay between variables is more complex than implied by our mediation model—in particular for late chronotypes.

As extreme chronotypes were underrepresented in our samples, our studies provide a conservative test of the impact of chronobiological processes. Unlike most research on the synchrony effect that has preselected extreme chronotypes and compared their performance in laboratory settings (e.g., Goldstein et al., 2007; Gunia et al., 2014; Ingram et al., 2016), we took the full spectrum of chronotypes into account and scrutinized its real-world relevance. Underrepresentation of extreme chronotypes was due to the start-of-work and end-of-work times we needed to set as participation requirements. Presumably, many early and late chronotypes did not meet these requirements when their jobs allowed for earlier end times or later start times, respectively. However, the working hours of our study samples correspond to typical office hours and are thus relevant for the majority of employees (Bui, 2014).

Although we consistently found that within-day changes in creativity, positive mood, and creative self-efficacy are coupled to humans' endogenous biological clock, the pattern of the synchrony effect did not always correspond to a symmetric crossover pattern and varied across the three variables. Specifically, the daily oscillations in positive mood, creative self-efficacy, and creativity were not entirely parallel and appeared to reach their peak amplitude at slightly different points during the day. This pattern of findings is not surprising and can be explained by a phenomenon termed masking. In field settings, the endogenous circadian component of any variable is *masked* to some extent by exogenous influences (Kerkhof, 1985). Masking occurs because field settings do not allow the control of the environment in the same way as constant routine protocols that aim to capture the endogenous circadian component of physiological and behavioral variables (Dijk et al., 1992). In constant routine protocols, some or all of the exogenous influences, such as light exposure, ambient temperature, humidity, posture, physical activity, mealtimes, and caloric intake, are held constant, while participants are kept awake and sedentary (Murray et al., 2002). Because masking differently affects variables that are influenced by the synchrony effect, fully parallel and symmetric crossover patterns are rarely observed under normal day–night conditions. Our results illustrate the challenge to observe synchrony effects across diverse and "noisy" field settings, and that a focus on typical office hours captures only a part of the sinusoidal fluctuation that occurs over the 24-hour day-and-night cycle (see also Carrier & Monk, 2000).

Notably, within-day changes in creativity and positive mood were more closely coupled for earlier than for later chronotypes. Specifically, the creativity of later chronotypes depended less on positive mood so that our conceptual model specifies primarily the affective-motivational processes underlying the creativity of early chronotypes. The implicit assumption of the model that the same processes drive the creativity of early and late chronotypes thus needs revision. Research has found that late chronotypes engage in different thinking and decision-making styles compared to early chronotypes that may enable creativity independent of the experience of positive mood (Tonetti, Fabbri, Boreggiani, Guastella, Martoni, Ruiz Herrera, & Natale, 2016). Late chronotypes adopt a more spontaneous decision-making style and tend to process information in a more intuitive, Gestalt-type, and visual-motor way that has been associated with the right cerebral hemisphere (Fabbri, Antonietti, Giorgetti, Tonetti, & Natale, 2007). An increase in the accessibility of these executive functions over the course of the day may facilitate creativity among later chronotypes irrespective of their positive mood. Considering that the regulation of unpleasant emotions has also been associated with the right cerebral hemisphere (Kuhl, 2000; Tomarken & Keener, 1998), it is even possible that the creativity of later chronotypes depends less on positive mood because it serves the function to cope with negative emotions and to restore positive mood. Future research is needed to test this hypothesis and to examine differences in the interplay between executive functions and affective processes among early and late chronotypes.

Theoretical Implications

We think that an embodied cognition perspective and the findings we report advance theories of creativity and offer avenues for future research. We contribute to research on the mood–creativity link (e.g., Baas et al., 2008; Forgas & George, 2001; George & Zhou, 2002) by showing that positive mood is subject to diurnal variation and thereby contributes to intraday variation in creativity. Positive mood is thus not only the result of the affective events a person encounters (Weiss & Cropanzano, 1996) but is also influenced by a person's biological clock. Naturally occurring variations in positive mood are part of the reward-oriented motivational system that is coupled with humans' circadian rhythm (Murray et al., 2009). Affective events at a given time of day meet a person's endogenously activated reward system and may have different consequences depending on how activated this system already is. An important question for further research is to examine whether affective events encountered at work as well as experimental mood inductions are differentially related to creativity depending on whether they boost or counteract endogenous peaks and troughs (see Cavanaugh, Cutright, Luce, & Bettman, 2011).

Our theoretical model holds that the alignment between chronotype and time of day promotes executive functions and thereby enhances positive mood and creativity. The findings of our three studies suggest that—at least for late chronotypes—the accessibility of the executive functions that enable creativity does not necessarily give rise to positive mood. Potential dissociations between executive functions and positive mood can help to explain findings that are inconsistent with the positive mood–creativity link. Low creativity can be expected when positive mood is high but the requisite executive functions are not accessible. This may happen, for example, if positive mood is accompanied by very high activation so that executive functions are negatively affected and dominant responses elicited (Baer & Oldham, 2006; Gable & Harmon-Jones, 2008). To the extent that people can access executive functions, they may even be able to show high creativity when negative mood is experienced (Bledow et al., 2013). A critical task for future research following this theorizing is to disentangle and directly measure the relevant executive functions.

Our study contributes to the literature on creative self-efficacy (Farmer & Tierney, 2017; Tierney & Farmer, 2011) by showing that the belief that one can produce creative outcomes is grounded in chronobiological processes. The metaphor of an iceberg can help to illustrate our view that creative self-efficacy indicates a person's awareness of their actual creative abilities (Bledow, 2013). We propose that the cognitive representation of one's creative ability is the visible tip of the iceberg that is based on creativity enhancing executive functions that reside below the surface. Research is needed to specify and disentangle the creativity-relevant processes that are summarized when a person indicates their creative self-efficacy (Farmer & Tierney, 2017). Thereby the criticism could be addressed that self-efficacy beliefs are descriptive but do not provide a precise theoretical explanation of how their positive consequences unfold and that misleading practical implications can be inferred from correlational studies on self-efficacy (Vancouver, More, & Yoder, 2008). Moreover, there may be boundary conditions for whether it is effective for leaders to directly strengthen creative self-efficacy, for instance through verbal persuasion (e.g., Latham & Budworth, 2006). Increasing creative self-efficacy may remove the barriers that prevent the person from being creative when a person can be creative but does not trust their creative abilities. However, when low creative self-efficacy indicates that a person actually lacks creative abilities, boosting creative self-efficacy may have no benefits and even lead to frustration.

Besides contributing to the creativity literature, our study informs research on the two-process model of sleep regulation. Borbély et al.'s (2016) model was originally developed to predict the onset and intensity of sleep, and has been used to explain performance on cognitive tasks at different times of day (Schmidt et al., 2007). We expand the scope of application of this model by linking it to creativity in a high-stakes context and by specifying affective and cognitive mechanisms. Notably, the influence of chronotype on creativity was distinct from the influence of sleep quality and sleep duration. We thus inform research on sleep that chronobiological drivers explain within-day fluctuations in work performance over and above day-specific sleep characteristics. The two-process model of sleep regulation offers the potential to theoretically integrate and investigate the joint impact of the synchrony effect and sleep. Growing evidence on the two-process model suggests that process S and process C interact. The circadian amplitude (process C) tends to be lower when the need for sleep (process S) is high (see Borbély et al., 2016). Employees who skip one night of sleep due to excessive workload may thus not benefit from the synchrony effect the following day, which opens interesting avenues for future research on boundary conditions of the synchrony effect.

Limitations

We demonstrated the synchrony effect across two different operationalizations of creativity: employees' performance on the alternative uses test (Guilford, 1967; Plucker & Makel, 2010) and employees' self-rated creativity. While the alternative uses test is an objective measure, the self-report measure may have limitations for the inferences that can be drawn from our studies: the usefulness of self-reports of creativity rests on the assumptions that people are aware of what is being asked and that they are willing to provide accurate reports (Kaufman, 2019; Reiter-Palmon, Robinson-Morral, Kaufman, & Santo, 2012). Moreover, some people may report overall higher creativity because they see their creativity in a more positive light and respond more socially desirably than others. They may also report higher positive mood and higher creative self-efficacy, and, thus, social desirability may create spurious relationships between the variables of interest on the between-person level. However, such response tendencies should consistently influence self-reported creativity throughout the day and can therefore not explain the intraday changes in creativity that were the focus of our studies (see Gabriel, Podsakoff, Beal, Scott, Sonnentag, Trougakos, & Butts, 2019).

We assumed peaks and troughs in executive functions across the workday but did not continuously monitor the temporal dynamics of creativity in Study 1 and Study 3. Instead, we took a snapshot approach and investigated creativity in the morning and in the late afternoon. To address this limitation, Study 2 employed the day reconstruction method to capture employees' creativity across the entire workday. To go one step further, we encourage future studies to capture the temporal dynamics of creativity across the entire workday without relying on the recollection of employees. There are, however, limits in how often employees' creativity can be assessed with creativity tests during work time, and obtaining indicators of work-related creativity such as contributions to an organization's employee suggestion program or supervisor ratings of creativity (see, e.g., Oldham & Cummings, 1996) multiple times a day may often not be feasible. Whether intraday variability in creativity is also observable for others such as colleagues and supervisors remains an open question and a challenge for future research (see, e.g., Moneta, Amabile, Schatzel, & Kramer, 2010).

Our focus on creativity as an embodied cognitive process came at the cost of neglecting the complex social environment in which employees are creative (Perry-Smith, 2006; Perry-Smith & Shalley, 2003). People are embedded in social networks that influence their creativity, and they may rely on their social network to be creative when they experience a misalignment of time of day and their chronotype. Interpersonal interactions may foster creativity-relevant cognitive processes and provide relevant knowledge and may thereby contribute to an individual's creativity. Thus, future studies may want to explore how creativity at a certain time of day is not only a function of a person's bodily state, but how embodied processes interact with the social context (see also Volk, Pearsall, Christian, & Becker, 2017).

The times of measurement in Study 1 and Study 3 were chosen on the basis of previous research (e.g., Schmidt et al., 2007; Wieth & Zacks, 2011) and because testing needed to take place during work time to assess work-related creativity. A study by Puttaert et al. (2019) showed that people self-select the time of day to show maximum performance between 8 a.m. and 6 p.m. (median 3 p.m.). Thus, working very early in the morning or very late at night may be only beneficial for people who are extremely early or late chronotypes. However, given the increased flexibility of work hours, an examination of how chronotype influences creativity at earlier and later times is a critical endeavor for future research. Extending measurement occasions to later points during the day could reveal an advantage of later chronotypes in the late evening that counterbalances the advantage earlier chronotypes have in the morning (see Caminada & De Bruijn, 1992; Gunia et al., 2014).

Practical Implications

The most important implication from our findings is that employees' chronotype should be considered when organizations aspire to stimulate employee creativity. Managers should be aware that employees' ability to be creative is not a time-invariant trait but changes over the course of the day and that there are individual differences in whether someone is more creative in the morning or later in the day. Studies estimate that about 50% of the variability in chronotype in adults is due to genetic factors (e.g., Koskenvuo, Hublin, Partinen, Heikkilä, & Kaprio, 2007). Diurnal preferences are thus a biological constraint that cannot be easily controlled, changed, or overridden by acts of self-control (Kühnel, Syrek, & Dreher, 2018).

We therefore recommend providing employees with the freedom to schedule tasks according to their chronotypes so that they can work on tasks that require creative ideas and problem solutions when they are in a state of synchrony. This can entail, for example, dedicating this time of day to important tasks only, and shielding this time from less important commitments and meeting requests. Routine tasks that require less flexible thinking and highly automated responses can be scheduled for other times because they suffer less from troughs in cognitive functioning. Besides having the autonomy to schedule work tasks, employees need to be aware of their chronobiological preferences to make "wise" scheduling decisions. Scheduling tasks according to one's chronotype may be particularly useful for people who are unambiguously early or late chronotypes. For intermediate chronotypes, scheduling tasks that require creativity to certain times of day may not be necessary. However, as managers and team members, they may benefit from understanding that others' creativity is more strongly subject to diurnal variation than their own, which can prevent them from having unrealistic expectations and misattributing others' lack of creativity.

REFERENCES

Adan, A., & Almirall, H. 1991. Horne & Östberg morningness–eveningness questionnaire: A reduced scale. ***Personality and Individual Differences***, 12: 241–253.

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: 1490–1528.

Amabile, T. M. 1996. ***Creativity in context: Update to the social psychology of creativity***. Boulder, CO: Westview Press.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. 1996. Assessing the work environment for creativity. ***Academy of Management Journal***, 39: 1154–1184.

Amabile, T. M., Barsade, S. G., Mueller, J. S., & Staw, B. M. 2005. Affect and creativity at work. ***Administrative Science Quarterly***, 50: 367–403.

Anderson, N., Potočnik, K., & Zhou, J. 2014. Innovation and creativity in organizations: A state-of-the-science review, prospective commentary, and guiding framework. ***Journal of Management***, 40: 1297–1333.

Ashby, F. G., Isen, A. M., & Turken, A. U. 1999. A neuropsychological theory of positive affect and its influence on cognition. ***Psychological Review***, 106: 529–550.

Baas, M., De Dreu, C. K., & Nijstad, B. A. 2008. A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? ***Psychological Bulletin***, 134: 779–806.

Baer, M., & Oldham, G. R. 2006. The curvilinear relation between experienced creative time pressure and creativity: Moderating effects of openness to experience and support for creativity. ***Journal of Applied Psychology***, 91: 963–970.

Barnes, C. M., Lucianetti, L., Bhave, D., & Christian, M. 2015. "You wouldn't like me when I'm sleepy": Leaders' sleep, daily abusive supervision, and work unit engagement. ***Academy of Management Journal***, 58: 1419–1437.

Baumann, N., & Kuhl, J. 2002. Intuition, affect, and personality: Unconscious coherence judgments and self-regulation of negative affect. ***Journal of Personality and Social Psychology***, 83: 1213–1223.

Beaty, R. E., Kenett, Y. N., Christensen, A. P., Rosenberg, M. D., Benedek, M., Chen, Q., Fink, A., Qiu, J., Kwapil, T. R., Kane, M. J., & Silvia, P. J. 2018. Robust prediction of individual creative ability from brain functional connectivity. ***Proceedings of the National Academy of Sciences of the United States of America***, 115: 1087–1092.

Beck, J. W., & Schmidt, A. M. 2012. Taken out of context? Cross-level effects of between-person self-efficacy and difficulty on the within-person relationship of self-efficacy with resource allocation and performance. ***Organizational Behavior and Human Decision Processes***, 119: 195–208.

Blatter, K., & Cajochen, C. 2007. Circadian rhythms in cognitive performance: Methodological constraints, protocols, theoretical underpinnings. ***Physiology & Behavior***, 90: 196–208.

Bledow, R. 2013. Demand-perception and self-motivation as opponent processes: A response to Bandura and Vancouver. ***Journal of Management***, 39: 14–26.

Bledow, R., Frese, M., Anderson, N., Erez, M., & Farr, J. 2009. A dialectic perspective on innovation: Conflicting demands, multiple pathways, and ambidexterity. ***Industrial and Organizational Psychology: Perspectives on Science and Practice***, 2: 305–337.

Bledow, R., Rosing, K., & Frese, M. 2013. A dynamic perspective on affect and creativity. ***Academy of Management Journal***, 56: 432–450.

Bodenhausen, G. V. 1990. Stereotypes as judgmental heuristics: Evidence of circadian variations in discrimination. ***Psychological Science***, 1: 319–322.

Borbély, A. A. 1982. A two-process model of sleep regulation. ***Human Neurobiology***, 1: 195–204.

Borbély, A. A., Daan, S., Wirz-Justice, A., & Deboer, T. 2016. The two-process model of sleep regulation: A reappraisal. ***Journal of Sleep Research***, 25: 131–143.

Bui, Q. 2014, August 27. Who's in the office? The American workday in one graph. Retrieved from https://www.npr.org/sections/money/2014/08/27/343415569/whos-in-the-office-the-american-workday-in-one-graph?t=1602175153408

Buysse, D. J., Reynolds, 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.

Caminada, H., & De Bruijn, F. 1992. Diurnal variation, morningness–eveningness, and momentary affect. ***European Journal of Personality***, 6: 43–69.

Carrier, J., & Monk, T. H. 2000. Circadian rhythms of performance: New trends. ***Chronobiology International***, 17: 719–732.

Cavanaugh, L. A., Cutright, K. M., Luce, M. F., & Bettman, J. R. 2011. Hope, pride, and processing during optimal and nonoptimal times of day. ***Emotion***, 11: 38–46.

Cervone, D., Shadel, W. G., Smith, R. E., & Fiori, M. 2006. Self-regulation: Reminders and suggestions from personality science. ***Applied Psychology***, 55: 333–385.

Clark, L. A., Watson, D., & Leeka, J. 1989. Diurnal variation in the positive affects. ***Motivation and Emotion***, 13: 205–234.

Correa, Á., Molina, E., & Sanabria, D. 2014. Effects of chronotype and time of day on the vigilance decrement during simulated driving. ***Accident; Analysis and Prevention***, 67: 113–118.

Crowe, E., & Higgins, E. T. 1997. Regulatory focus and strategic inclinations: Promotion and prevention in decision-making. ***Organizational Behavior and Human Decision Processes***, 69: 117–132.

Czeisler, C. A., & Gooley, J. J. 2007. Sleep and circadian rhythms in humans. ***Cold Spring Harbor Symposia on Quantitative Biology***, 72: 579–597.

Dalal, R. S., Bhave, D. P., & Fiset, J. 2014. Within-person variability in job performance: A theoretical review and research agenda. ***Journal of Management***, 40: 1396–1436.

De Dreu, C. K., Baas, M., & Nijstad, B. A. 2008. Hedonic tone and activation level in the mood–creativity link: Toward a dual pathway to creativity model. ***Journal of Personality and Social Psychology***, 94: 739–756.

De Dreu, C. K., Nijstad, B. A., & Baas, M. 2011. Behavioral activation links to creativity because of increased cognitive flexibility. ***Social Psychological & Personality Science***, 2: 72–80.

Dijk, D.-J., Duffy, J. F., & Czeisler, C. A. 1992. Circadian and sleep/wake dependent aspects of subjective alertness and cognitive performance. ***Journal of Sleep Research***, 1: 112–117.

Dijk, D.-J., & Lockley, S. W. 2002. Integration of human sleep–wake regulation and circadian rhythmicity. ***Journal of Applied Physiology***, 92: 852–862.

Fabbri, M., Antonietti, A., Giorgetti, M., Tonetti, L., & Natale, V. 2007. Circadian typology and style of thinking differences. ***Learning and Individual Differences***, 17: 175–180.

Farmer, S. M., & Tierney, P. 2017. Considering creative self-efficacy: Its current state and ideas for future inquiry. In M. Karwowski & J. C. Kaufman (Eds.), ***The creative self***: 23–47. London, U.K.: Elsevier.

Fischer, D., Lombardi, D. A., Marucci-Wellman, H., & Roenneberg, T. 2017. Chronotypes in the US: Influence of age and sex. ***PLoS One***, 12: e0178782.

Forgas, J. P., & George, J. M. 2001. Affective influences on judgments and behavior in organizations: An information processing perspective. ***Organizational Behavior and Human Decision Processes***, 86: 3–34.

Fredrickson, B. L. 2013. Positive emotions broaden and build. In P. Devine & A. Plant (Eds.), ***Advances in experimental social psychology***, vol. 47: 1–53. New York, NY: Academic Press.

Gable, P. A., & Harmon-Jones, E. 2008. Approach-motivated positive affect reduces breadth of attention. ***Psychological Science***, 19: 476–482.

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: 969–1006.

George, J. M. 2007. Creativity in organizations. ***Academy of Management Annals***, 1: 439–477.

George, J. M., & Zhou, J. 2002. Understanding when bad moods foster creativity and good ones don't: The role of context and clarity of feelings. ***Journal of Applied Psychology***, 87: 687–697.

Gielnik, M. M., Bledow, R., & Stark, M. S. 2020. A dynamic account of self-efficacy in entrepreneurship. ***Journal of Applied Psychology***, 105: 487–505.

Gilbert, S. J., & Burgess, P. W. 2008. Executive function. ***Current Biology***, 18: R110–R114.

Gino, F., Schweitzer, M. E., Mead, N. L., & Ariely, D. 2011. Unable to resist temptation: How self-control depletion promotes unethical behavior. ***Organizational Behavior and Human Decision Processes***, 115: 191–203.

Goldstein, D., Hahn, C. S., Hasher, L., Wiprzycka, U. J., & Zelazo, P. D. 2007. Time of day, intellectual performance, and behavioral problems in morning versus evening type adolescents: Is there a synchrony effect? ***Personality and Individual Differences***, 42: 431–440.

Gong, Y., Huang, J.-C., & Farh, J.-L. 2009. Employee learning orientation, transformational leadership, and employee creativity: The mediating role of employee creative self-efficacy. ***Academy of Management Journal***, 52: 765–778.

Guilford, J. P. 1967. ***The nature of human intelligence***. New York, NY: McGraw-Hill.

Gunia, B. C., Barnes, C. M., & Sah, S. 2014. The morality of larks and owls' unethical behavior depends on chronotype as well as time of day. ***Psychological Science***, 25: 2272–2274.

Hasher, L., Goldstein, D., & May, C. P. 2005. It's about time: Circadian rhythms, memory, and aging. In C. Izawa & N. Ohta (Eds.), ***Human learning and memory: Advances in theory and applications: The 4th Tsukuba international conference on memory***: 199–217. Mahwah, NJ: Lawrence Erlbaum Associates.

Hasher, L., Zacks, R. T., & May, C. P. 1999. Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), ***Attention and performance XVII: Cognitive regulation of performance—interaction of theory and application***: 653–675. Cambridge, MA: MIT Press.

Hayes, A. F. 2018. ***Introduction to mediation, moderation, and conditional process analysis: A regression-based approach***. New York, NY: Guilford Press.

Higgins, E. T. 1997. Beyond pleasure and pain. ***American Psychologist***, 52: 1280–1300.

Horne, J. A., & Östberg, O. 1976. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. ***International Journal of Chronobiology***, 4: 97–110.

Ingram, K. K., Ay, A., Kwon, S. B., Woods, K., Escobar, S., Gordon, M., Smith, I. H., Bearden, N., Filipowicz, A., & Jain, K. 2016. Molecular insights into chronotype and time-of-day effects on decision-making. ***Scientific Reports***, 6. doi: 10.1038/srep29392

Jasper, I., Häußler, A., Marquardt, C., & Hermsdoerfer, J. 2009. Circadian rhythm in handwriting. ***Journal of Sleep Research***, 18: 264–271.

Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. 2004. A survey method for characterizing daily life experience: The day reconstruction method. ***Science***, 306: 1776–1780.

Kaufman, J. C. 2019. Self-assessments of creativity: Not ideal, but better than you think. ***Psychology of Aesthetics, Creativity, and the Arts***, 13: 187–192.

Kerkhof, G. A. 1985. Inter-individual differences in the human circadian system: A review. ***Biological Psychology***, 20: 83–112.

Kerkhof, G. A., & Van Dongen, H. P. A. 1996. Morning-type and evening-type individuals differ in the phase position of their endogenous circadian oscillator. ***Neuroscience Letters***, 218: 153–156.

Kiefer, M., & Barsalou, L. W. 2013. Grounding the human conceptual system in perception, action, and internal states. In W. Prinz, M. Beisert, & A. Herwig (Eds.), ***Action science: Foundations of an emerging discipline***: 381–407. Cambridge: MIT Press.

Kiefer, M., Schuch, S., Schenck, W., & Fiedler, K. 2006. Mood states modulate activity in semantic brain areas during emotional word encoding. ***Cerebral Cortex***, 17: 1516–1530.

Koskenvuo, M., Hublin, C., Partinen, M., Heikkilä, K., & Kaprio, J. 2007. Heritability of diurnal type: A nationwide study of 8,753 adult twin pairs. ***Journal of Sleep Research***, 16: 156–162.

Kruglanski, A. W., & Pierro, A. 2008. Night and day, you are the one: On circadian mismatches and the transference effect in social perception. ***Psychological Science***, 19: 296–301.

Kuhl, J. 2000. A functional-design approach to motivation and self-regulation: The dynamics of personality systems interactions. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), ***Handbook of self-regulation***: 111–169. San Diego, CA: Elsevier Academic Press.

Kühnel, J., Bledow, R., & Feuerhahn, N. 2016. When do you procrastinate? Sleep quality and social sleep lag jointly predict self-regulatory failure at work. ***Journal of Organizational Behavior***, 37: 983–1002.

Kühnel, J., Sonnentag, S., & Bledow, R. 2012. Resources and time pressure as day-level antecedents of work engagement. ***Journal of Occupational and Organizational Psychology***, 85: 181–198.

Kühnel, J., Syrek, C. J., & Dreher, A. 2018. Why don't you go to bed on time? A daily diary study on the relationships between chronotype, self-control resources and the phenomenon of bedtime procrastination. ***Frontiers in Psychology***, 9: 77. doi: 10.3389/fpsyg.2018.00077

Kühnle, T. 2006. ***Quantitative analysis of human chronotype*** (Unpublished doctoral thesis). Ludwig-Maximilian-University, Munich, Germany.

Latham, G. P., & Budworth, M. H. 2006. The effect of training in verbal self-guidance on the self-efficacy and performance of Native North Americans in the selection interview. ***Journal of Vocational Behavior***, 68: 516–523.

Martin, S. K., & Eastman, C. I. 2002. Sleep logs of young adults with self-selected sleep times predict the dim light melatonin onset. ***Chronobiology International***, 19: 695–707.

Matchock, R. L., & Mordkoff, J. T. 2009. Chronotype and time-of-day influences on the alerting, orienting, and executive components of attention. ***Experimental Brain Research***, 192: 189–198.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. 2000. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. ***Cognitive Psychology***, 41: 49–100.

Moneta, G. B., Amabile, T. M., Schatzel, E. A., & Kramer, S. J. 2010. Multirater assessment of creative contributions to team projects in organizations. ***European Journal of Work and Organizational Psychology***, 19: 150–176.

Monk, T. H., & Leng, V. C. 1986. Interactions between inter-individual and inter-task differences in the diurnal variation of human performance. ***Chronobiology International***, 3: 171–177.

Murray, G., Allen, N. B., & Trinder, J. 2002. Mood and the circadian system: Investigation of a circadian component in positive affect. ***Chronobiology International***, 19: 1151–1169.

Murray, G., Nicholas, C. L., Kleiman, J., Dwyer, R., Carrington, M. J., Allen, N. B., & Trinder, J. 2009. Nature's clocks and human mood: The circadian system modulates reward motivation. ***Emotion***, 9: 705–716.

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

Nijstad, B. A., De Dreu, C. K., Rietzschel, E. F., & Baas, M. 2010. The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence. ***European Review of Social Psychology***, 21: 34–77.

Nobel Prize Outreach. 2017. The Nobel Prize in Physiology or Medicine 2017 [Press release]. Retrieved from http://www.nobelprize.org/nobel_prizes/medicine/laureates/2017/press.html

Oldham, G. R., & Cummings, A. 1996. Employee creativity: Personal and contextual factors at work. ***Academy of Management Journal***, 39: 607–634.

Perry-Smith, J. E. 2006. Social yet creative: The role of social relationships in facilitating individual creativity. ***Academy of Management Journal***, 49: 85–101.

Perry-Smith, J. E., & Shalley, C. E. 2003. The social side of creativity: A static and dynamic social network perspective. ***Academy of Management Review***, 28: 89–106.

Plucker, J. A., & Makel, M. C. 2010. Assessment of creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), ***The Cambridge handbook of creativity***: 48–73. Cambridge, U.K.: Cambridge University Press.

Preacher, K. J., Zhang, Z., & Zyphur, M. J. 2011. Alternative methods for assessing mediation in multilevel data: The advantages of multilevel SEM. ***Structural Equation Modeling***, 18: 161–182.

Preacher, K. J., Zyphur, M. J., & Zhang, Z. 2010. A general multilevel SEM framework for assessing multilevel mediation. ***Psychological Methods***, 15: 209–233.

Puttaert, D., Adam, S., & Peigneux, P. 2019. Subjectively defined optimal/non-optimal time of day modulates controlled but not automatic retrieval processes in verbal memory. ***Journal of Sleep Research***, 28: e12798. doi: 10.1111/jsr.12798

Randler, C., Bechtold, K., & Vogel, M. 2016. Chronotype and time of day do not influence mathematical achievement in standardised tests, but impact on affect: Results from a field experiment. ***International Online Journal of Educational Sciences***, 8: 54–61.

Reiter-Palmon, R., Robinson-Morral, E. J., Kaufman, J. C., & Santo, J. B. 2012. Evaluation of self-perceptions of creativity: Is it a useful criterion? ***Creativity Research Journal***, 24: 107–114.

Richard, E. M., Diefendorff, J. M., & Martin, J. H. 2006. Revisiting the within-person self-efficacy and performance relation. ***Human Performance***, 19: 67–87.

Richter, A. W., Hirst, G., van Knippenberg, D., & Baer, M. 2012. Creative self-efficacy and individual creativity in team contexts: Cross-level interactions with team informational resources. ***Journal of Applied Psychology***, 97: 1282–1290.

Roenneberg, T., Kumar, C. J., & Merrow, M. 2007. The human circadian clock entrains to sun time. ***Current Biology***, 17: R44–R45.

Roenneberg, T., Pilz, L. K., Zerbini, G., & Winnebeck, E. C. 2019. Chronotype and social jetlag: A (self-) critical review. ***Biology***, 8: 54. doi: 10.3390/biology8030054

Roenneberg, T., Winnebeck, E. C., & Klerman, E. B. 2019. Daylight saving time and artificial time zones: A battle between biological and social times. ***Frontiers in Physiology***, 10: 944. doi: 10.3389/fphys.2019.00944

Roenneberg, T., Wirz-Justice, A., & Merrow, M. 2003. Life between clocks: Daily temporal patterns of human chronotypes. ***Journal of Biological Rhythms***, 18: 80–90.

Rothbard, N. P., & Wilk, S. L. 2011. Waking up on the right or wrong side of the bed: Start-of-workday mood, work events, employee affect, and performance. ***Academy of Management Journal***, 54: 959–980.

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. 2007. A time to think: Circadian rhythms in human cognition. ***Cognitive Neuropsychology***, 24: 755–789.

Semmer, N. K., Zapf, D., & Dunckel, H. 1999. Instrument zur Stressbezogenen Tätigkeitsanalyse ISTA [Instrument for stress-related job analysis]. In H. Dunckel (Ed.), ***Handbuch psychologischer Arbeitsanalyseverfahren***: 179–204. Zürich, Switzerland: vdf Hochschulverlag.

Shalley, C. E., Zhou, J., & Oldham, G. R. 2004. The effects of personal and contextual characteristics on creativity: Where should we go from here? ***Journal of Management***, 30: 933–958.

Sitzmann, T., & Yeo, G. 2013. A meta-analytic investigation of the within-person self-efficacy domain: Is self-efficacy a product of past performance or a driver of future performance? ***Personnel Psychology***, 66: 531–568.

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: 674–684.

Tadmor, C. T., Galinsky, A. D., & Maddux, W. W. 2012. Getting the most out of living abroad: Biculturalism and integrative complexity as key drivers of creative and professional success. ***Journal of Personality and Social Psychology***, 103: 520–542.

Thayer, R. E., Takahashi, P. J., & Pauli, J. A. 1988. Multidimensional arousal states, diurnal rhythms, cognitive and social processes, and extraversion. ***Personality and Individual Differences***, 9: 15–24.

Tierney, P., & Farmer, S. M. 2002. Creative self-efficacy: Its potential antecedents and relationship to creative performance. ***Academy of Management Journal***, 45: 1137–1148.

Tierney, P., & Farmer, S. M. 2011. Creative self-efficacy development and creative performance over time. ***Journal of Applied Psychology***, 96: 277–293.

Tierney, P., Farmer, S. M., & Graen, G. B. 1999. An examination of leadership and employee creativity: The relevance of traits and relationships. ***Personnel Psychology***, 52: 591–620.

To, M. L., Fisher, C. D., Ashkanasy, N. M., & Rowe, P. A. 2012. Within-person relationships between mood and creativity. ***Journal of Applied Psychology***, 97: 599–612.

Tomarken, A. J., & Keener, A. D. 1998. Frontal brain asymmetry and depression: A self-regulatory perspective. ***Cognition and Emotion***, 12: 387–420.

Tonetti, L., Fabbri, M., Boreggiani, M., Guastella, P., Martoni, M., Ruiz Herrera, N., & Natale, V. 2016. Circadian preference and decision-making styles. ***Biological Rhythm Research***, 47: 573–581.

Van Dongen, H. P. A., & Dinges, D. F. 2000. Circadian rhythms in fatigue, alertness, and performance. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), ***Principles and practice of sleep medicine*** (3rd ed.): 391–399. Philadelphia, Pennsylvania: W. B. Saunders.

Van Vugt, F. T., Treutler, K., Altenmüller, E., & Jabusch, H.-C. 2013. The influence of chronotype on making music: Circadian fluctuations in pianists’ fine motor skills. ***Frontiers in Human Neuroscience***, 7: 347. doi: 10.3389/fnhum.2013.00347

Vancouver, J. B., More, K. M., & Yoder, R. J. 2008. Self-efficacy and resource allocation: Support for a nonmonotonic, discontinuous model. ***Journal of Applied Psychology***, 93: 35–47.

Varela, F. J., Thompson, E. T., & Rosch, E. 1991. ***The embodied mind: Cognitive science and human experience***. Cambridge: MIT Press.

Volk, S., Pearsall, M. J., Christian, M. S., & Becker, W. J. 2017. Chronotype diversity in teams: Toward a theory of team energetic asynchrony. ***Academy of Management Review***, 42: 683–702.

Wang, C.-J., Tsai, H.-T., & Tsai, M.-T. 2014. Linking transformational leadership and employee creativity in the hospitality industry: The influences of creative role identity, creative self-efficacy, and job complexity. ***Tourism Management***, 40: 79–89.

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: 1063–1070.

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. 1999. The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. ***Journal of Personality and Social Psychology***, 76: 820–838.

Weiss, H. M., & Cropanzano, R. 1996. Affective events theory: A theoretical discussion of the structure, causes and consequences of affective experiences at work. In B. M. Staw & L. L. Cummings (Eds.), ***Research in organizational behavior: An annual series of analytical essays and critical reviews***, vol. 18: 1–74. Greenwich, CT: Elsevier Science/JAI Press.

West, M. A., & Farr, J. L. (Eds.). 1990. ***Innovation and creativity at work: Psychological and organizational strategies***. Chichester, U.K.: Wiley.

Wieth, M. B., & Zacks, R. T. 2011. Time of day effects on problem solving: When the non-optimal is optimal. ***Thinking & Reasoning***, 17: 387–401.

Yam, K. C., Fehr, R., & Barnes, C. M. 2014. Morning employees are perceived as better employees: Employees' start times influence supervisor performance ratings. ***Journal of Applied Psychology***, 99: 1288–1299.

Yang, L., Hasher, L., & Wilson, D. E. 2007. Synchrony effects in automatic and controlled retrieval. ***Psychonomic Bulletin & Review***, 14: 51–56.

Jana Kühnel (jana.kuehnel@univie.ac.at) is an assistant professor of psychology with a focus on changes in work, society, and economy at University of Vienna, Austria. Jana received her PhD from University of Konstanz in Germany and worked as strategy consultant at Boston Consulting Group. Her research focuses on the role of sleep and chronotype for effective functioning at work, on recovery from work-related stress, and on creativity and innovation.

Ronald Bledow (rbledow@smu.edu.sg) is an associate professor of organizational behavior and human resources management at Singapore Management University's Lee Kong Chian School of Business. Ronald obtained his PhD from University of Giessen in Germany. His research explores the dynamics of motivation and the microfoundations of innovation in organizations.

Markus Kiefer (markus.kiefer@uni-ulm.de) is an associate professor of psychology and neuroscience. He directs the Section for Cognitive Electrophysiology at the Clinic of Psychiatry and Psychotherapy III of Ulm University and teaches cognitive psychology and cognitive neuroscience at Ulm University's Institute of Psychology and Education. Markus's research covers memory, language, emotion, and consciousness. He received his PhD from the University of Heidelberg.

APPENDIX A

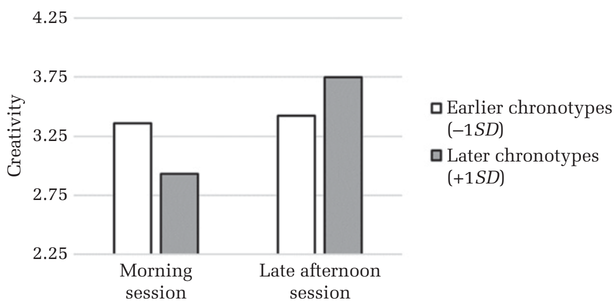
ADDITIONAL ANALYSES OF STUDY 1

In the second group of employees, who participated in the online surveys, we additionally measured self-rated creativity with the five-item version (Bledow et al., 2013) of the scale of Tierney et al. (1999) that refers to a specific time frame. Example items were "Within the last two hours at work, I generated novel but operable work-related ideas" and "Within the last two hours at work, I served as a good role model for creativity." Items had to be answered on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Cronbach's alphas were .88 and .86 at the morning and at the late-afternoon sessions, respectively.

Test of Hypothesis 1

Chronotype moderated the effect of time of day on work-related creativity (estimate = 0.34, $SE = 0.13$, $t = 2.62$, $p < .01$, 95% CI [0.09, 0.60]; pseudo-R^2 slope of time = .29). The pattern of this two-way interaction is depicted in Figure A1, showing earlier (−1 *SD*) and later (+1 *SD*) chronotypes' work-related creativity in the morning compared to the

FIGURE A1
Study 1: The Moderating Effect of Chronotype on the Relationship between Time of Day and Work-Related Creativity



late-afternoon session. Conditional effects showed that later chronotypes (+1 *SD*) showed higher creativity in the late afternoon compared to in the morning (estimate = 0.83, SE = 0.20, t = 4.21, $p < .001$, 95% CI [0.44, 1.21]), and that earlier (−1 *SD*) chronotypes' creativity did not differ between morning and late afternoon (estimate = 0.06, SE = 0.19, t = 0.32, p = .745, 95% CI [−0.32, 0.45]). Thus, Hypothesis 1a was not supported, but Hypothesis 1b was supported.

Test of Hypothesis 3

We tested the within-person indirect effect of time of day on creativity via positive mood for conditional values of the moderator chronotype (+ and −1*SD*). Positive mood was a significant predictor of work-related creativity on the within-person level of analysis (b path; estimate = 0.80, SE = 0.16, t = 5.11, $p <$ .001, 95% CI [0.50, 1.11]). The direct effect (c') of time of day on creativity was positive for all chronotypes when the indirect effect via positive mood was controlled for (estimate = 0.41, SE = 0.20, t = 2.08, $p < .05$, 95% CI [0.02, 0.80], and estimate = 1.01, SE = 0.18, t = 5.51, $p < .001$, 95% CI [0.65, 1.38], for earlier [−1 *SD*] and later [+1 *SD*] chronotypes, respectively). In support of Hypothesis 3a, for earlier chronotypes (−1 *SD*), results of conditional indirect effects showed a negative indirect effect of time of day on creativity via positive mood ($a \times b$; estimate = −0.30, SE = 0.08, t = −3.65, $p < .001$, 95% CI [−0.47, −0.14]). For later chronotypes (+1 *SD*), the conditional indirect effect was not significant ($a \times b$; estimate = −0.10, SE = 0.06, t = −1.70, p = .089, 95% CI [−0.22, 0.02]) because the relationship between time of day and positive mood (a path) was not significant for later chronotypes. Consequently, Hypothesis 3b was not supported.