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Circadian Variations and Risky Decision Making

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CIRCADIAN VARIATIONS AND RISKY DECISION MAKING

by

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Abstract

Over the past decades, decision making under risk has garnered a great amount of attention both in the field of economics and psychology. Although state-dependent variabilities of risk taking are well-documented, little is known about the effects of a person's preferred time of day, or chronotype, in risky decision making. Under circumstances of circadian mismatch (e.g., when an "early bird" makes decisions in the evening), research suggests that decision making may reflect a greater reliance on heuristics, such as using stereotypes in social judgments. However, the effects of circadian mismatch on heuristics in risky decision making are relatively unexplored. This paper looks into the effects of circadian mismatch on the reflection effect: a behavioral bias in financial decision making, wherein individuals are risk averse when facing potential gains, and risk seeking when facing potential losses. Participants will be randomly assigned to their circadian matched or circadian mismatched conditions and will play a series of financial gambling tasks with real monetary incentives. This study predicts that the reflection effect will be exacerbated in circadian mismatched individuals as compared to matched participants. Exploring such an effect could have real-world implications on decision making under risk by providing critical knowledge about the effects of time of day on our susceptibility to behavioral biases. It could therefore point to the existence of a more optimal time of day to engage in such critical decision making.

Introduction

From betting on blackjack to investing in the stock market, economic decisions often involve risk. Defined as a scenario where a given prospect may yield different outcomes dependent upon different probabilities (Tobler & Weber, 2014), risky decision making has received extensive attention in the fields of psychology and economics. Exemplified by the influential Prospect Theory of Kahneman and Tversky (1979), descriptive models of preference formation point to the suboptimality, and often times irrationality, exhibited by individuals making decisions with uncertain outcomes. In hypothetical gambling scenarios involving loss and gain, Kahneman and Tversky identified a number of behavioral biases, including the so-called *reflection effect*: the observation that individuals tend to be more risk-averse when outcomes are in the gain domain, and conversely more risk-seeking when the same outcomes are in the loss domain (Kahneman & Tversky, 1979). This observed effect is thought to arise from an increased tendency to rely on mental shortcuts when faced with complex probabilistic outcomes. The reflection effect, therefore, stands in contrast to the Expected Utility Theory of neoclassical economics, which assumes absolute rationality in decision making.

Although the reflection effect has been observed in numerous studies over the last 39 years (Budescu & Weiss, 1987; Camerer, 1998), recent research suggests that this effect may be amplified by exogenous factors. For example, acute stress has been shown to enhance the reflection effect, presumably indicating an increase in reliance on behavioral biases during stressful situations (Porcelli & Delgado, 2009). On the other hand, total sleep deprivation has been found to increase risk-seeking for gains while blunting the negative response to losses (Venkatraman, Huettel, Chuah, Payne, & Chee, 2011). These disparate results suggest that rather than there being a purely innate risk attitude, the tendency towards risk aversion in gains and risk-seeking in losses can be influenced by factors related to one's current state.

In line with this idea, recent studies have identified time of day as a potential factor in cognitive function (Dickinson & McElroy, 2010; Dorrian, McLean, Banks, & Loetscher, 2017; May, Hasher, & Stoltzfus, 1993; May & Hasher 1998). Whereas some individuals consider themselves "early birds," functioning better in the morning, "night owls" show peak performance in the evening hours (Blake, 1967). Circadian rhythms, commonly referred to as the sleep/wake cycle, refer to an organism's internal body clock. Due to their cyclic nature, circadian rhythms tend to vary throughout the day, regulating body temperature, hormones, metabolism and sleep (Vitaterna, Takahashi, & Turek, 2001). This explains why we feel more awake during certain times of the day and sleepy during other times (Monk, 1991).

The Morningness-Eveningness Questionnaire (MEQ) devised by Horne and Östberg (1976) distinguishes three major categories, or *chronotypes*, of circadian functioning: extreme morning types, extreme evening types, and intermediate types falling between the two extremes. As the names suggest, extreme morning types not only prefer to wake and sleep earlier than extreme evening types, but also prefer to work significantly earlier in the day, as compared to evening types. Remarkably, studies have shown that self-reported chronotypes correlate with individual variations in circadian rhythm, measured by fluctuations in body temperature (Horne & Östberg, 1976). What determines an individual's chronotype is still unclear, with some research pointing to genetic variables (Vink, Groot, Kerkhod, & Boomsma, 2001) such as the CLOCK gene, which plays a role in generating circadian rhythms (King et al., 1997). Other research has shown the role of social factors, such as work or school schedules, in affecting preferred time of day (Ehlers, Frank, & Kupfer, 1988). Evidence also suggests that chronotypes vary with age (Samon, Crittenden, Mabulla, Mabulla, & Nunn, 2017), and are mediated by the role of different personality types (Walker, Kribs, Christopher, Shewach, & Weight, 2014). Therefore, any plausible psycho-biological explanation for the causes of variability in chronotype across individuals must consider the interaction between both genetic and environmental factors.

Psychological interest in the effects of circadian variations has focused on determining the potential negative impact on cognitive functioning during suboptimal times of day, also known as *circadian mismatching*. For example, a morning chronotype working in the evening would be circadian mismatched, as would an evening chronotype functioning in the morning. In contrast, a morning chronotype functioning during the morning is theorized to be at their most optimal time, known as circadian matching. Sometimes referred to as the *synchrony effect*, this phenomenon highlights the costs and benefits of circadian variations and performance (May, 1999).

Circadian mismatching has been found to negatively affect a number of cognitive domains, including memory (May, Hasher & Stoltzfus, 1993), strategic reasoning (Dickinson & McElroy, 2010), attention (Dorrian et al., 2017), and thought inhibition (May & Hasher, 1998). Based on a previous literature suggesting a causal relationship between circadian variations and mental performance (Blake, 1967; Rutenfranz & Colquhoun, 1979; Dongen & Dinges, 2000), these diverse effects on cognition have been theorized to arise from the tendency to rely more on heuristics when making decisions or judgements during circadian mismatched times (Bodenhausen, 1990). Heuristics are mental shortcuts, or rules of thumb, in decision making; they are more intuitive and less effortful, thereby demanding little to no in-depth information processing (Tversky & Kahneman, 1974). Because heuristics tend to be automatic in nature, they are understood as low-level information processing.

Bodenhausen (1990) examined the effects of circadian variations on cognition by looking at whether individuals relied more heavily on social judgment heuristics, such as stereotyping, during their suboptimal times as compared to their optimal times. The study compared the rate of stereotyping in participants who were circadian matched versus mismatched and found that participants did in fact rely more heavily on heuristics during their circadian mismatched times. Conversely, he found that people processed information more thoroughly during optimal times, thereby exhibiting fewer stereotypes. He hypothesized that this effect was caused by a temporary reduction in cognitive and motivational resources due to lowered levels of arousal during suboptimal times. These states of lowered arousal subsequently increase reliance on lower-level information processing, such as heuristics. Similar effects have been observed for other types of social judgment heuristics as well (e.g., Kruglanski & Pierro, 2007).

To further clarify the precipitating factors behind these effects, Martin and Martin (2013) tested the influence of circadian mismatching on depth of information processing during attitude change. They utilized the Elaboration Likelihood Model (Petty & Cacioppo, 1986) to measure persuasion and the extent of resilient attitude change. According to the Elaboration Likelihood Model, there are two routes to persuasion: the first is the central route wherein an individual is persuaded due to thorough information processing of the content provided. This route forms very stable and resilient attitude change. In contrast the second route to persuasion, known as the peripheral route, is when an individual attends to superficial information in the content and relies on lower-level information processing, which leads to weak attitude formation. The results of their study clarified that the cognitive changes observed in circadian mismatching are in fact due to a greater reliance on more automatic processing of available information. During circadian mismatch, resilient attitude formation was decreased without a subsequent change in persuasion levels, reflecting a decreased level of scrutiny of the provided information. The data was therefore indicative of the increased tendency of circadian mismatched individuals to rely on the peripheral route of persuasion (i.e., more automatic and less effortful), which is functionally similar to the workings of heuristics.

Despite substantial evidence for increased reliance on heuristics in circadian mismatch, less study has been devoted to the behavioral biases associated with risky decision making in Prospect Theory (Kahneman & Tversky, 1979). In one of the few experimental manipulations to test risky decision making under circadian mismatch, Castillo, Dickinson, and Petrie (2017) explored risky asset allocation. They found that circadian mismatched individuals were less risk averse when allocating assets between two financial bundles, independent of rational choice behavior measured through the Generalized Axiom of Revealed Preferences (GARP). The authors interpreted the observed changes in risk preferences to be caused by the time of day manipulation, and not because of an increase in noise for circadian mismatched participants.

However, the more basic association of decision biases and circadian mismatch has not been explored to date. This paper therefore investigates whether circadian mismatching enhances the reflection effect: the tendency to be risk-averse for gains but risk-seeking for losses. Seen in an estimated 72% of the population (Baucells & Villasís, 2010), the reflection effect is exemplified by the following choice scenarios from Kahneman and Tversky (1979). Given a choice between two possible gains, a 90% chance of obtaining $3,000 versus a 45% chance of obtaining $6,000, 86% of individuals chose the former. However, when the same prospects were reflected at zero and provided in terms of losses (90% chance of *losing* $3,000 versus 45% chance of losing $6,000), a surprising 92% of individuals chose the second option. Contrary to the traditional economic Expected Utility Theory, which treats risk in the gain and loss domains equivalently, the reflection effect demonstrates that when making decisions individuals value losses and gains separately, rather than the total outcome. Therefore, when given the choice between gaining two probabilistic outcomes we tend to prefer the sure gain, or the less risky option. On the other hand, when given the choice between losing two probabilistic outcomes, we tend to avoid the prospect of sure loss by taking the chance of a potentially more severe loss, thereby acting in more risk-seeking ways. This behavioral inconsistency has been proposed to reflect increased reliance on relatively simple heuristics in the face of complex probabilistic outcomes (Gillovich, Griffin, & Kahneman, 2002).

If the reflection effect arises from more automatic or heuristic processing, it follows that this bias should be enhanced by circadian mismatch. However, one potential concern is that previous experimental studies of the reflection effect have reported difficulties in replication. Laury and Holt (2005) administered a series of gambling tasks with “real-world” risks, as opposed to the hypothetical scenarios of Kahneman and Tversky (1979), and found that only 39% of participants were jointly risk averse in gains and risk seeking in losses. More recently, however, Baucells and Villasís (2010) demonstrated that applying a stochastic model to control for errors in decision making dramatically increased the estimated number of participants making choices in line with the reflection effect to 72%. The remaining 28% of participants were found to be risk averse on the whole, exhibiting risk aversion on both the loss and gain domain, thereby attenuating the overall effect. A similar number (68%) has been reported more recently using an optimized testing paradigm that dynamically adjusts gamble amounts while adjusting for potential errors (Chapman, Snowberg, Wang, & Camerer, 2018). Support for the reflection effect has also come from a paradigm in which each gamble set was repeated 20 times, providing a measure of control for choice errors (Porcelli & Delgado, 2009).

Of particular interest, Porcelli and Delgado (2009) additionally reported that this effect was exacerbated when individuals were under acute stress. Similar to the observed effects of circadian mismatch, acute stress had previously been shown to interfere with deliberative and rational processing, prompting individuals to fall back on more automatic heuristics (Kahneman & Frederick, 2002). Porcelli and Delgado (2009) interpreted the enhancement of the reflection effect in their study as arising from an increased reliance on heuristics due to the exposure to an external source of stress.

Therefore, I set out a proposed experiment to replicate the Porcelli & Delgado (2009) study under circadian mismatch. If circadian mismatch increases reliance on automatic decision heuristics under risk, we should therefore see a similar enhancement of the reflection effect in individuals who are circadian mismatched. Specifically, we predict that mismatched participants will exhibit a greater behavioral bias to gambles by being more risk averse when outcomes are in gains, and less risk averse when outcomes are in losses, as compared to circadian matched participants. This effect, if found, would suggest a greater susceptibility to biases during circadian mismatched times. Such a finding would have implications not only for professions that deal regularly with high-risk situations, such as financial traders or emergency first responders, but could also improve daily decision-making across the population by taking chronotype information into account.

Proposed Method

Participants

Based on the average sample size across previous studies measuring the effects of circadian mismatch (Bodenhausen, 1990; Dickinson et al., 2012; Kruglanski et al., 2008; May et al., 1998), an expected 90 participants will be required for the experimental session. As in previous studies, we intend to test circadian mismatching solely within extreme morning and extreme evening types. Given that approximately half of the population falls in-between extreme chronotypes (BaHammam, Almestehi, Albatli, & AlShaya, 2011), we plan to initially recruit double the target sample size. Additionally, Baucells and Villasís (2009) found that 28% of individuals within their sample were risk averse in both the gain and loss domain, suggesting that an additional recruitment of roughly 30% of the target sample should be performed to avoid attenuating the reflection effect. In light of these concerns, we aim to initially recruit 180 participants, so that the experimental session includes approximately 45 participants within each condition. Participants are required to be above the age of 18 years, and will be predominantly recruited from an undergraduate and postgraduate student population within the local college community. Recruitment of participants will be directed through the Psychology department as extra credit for those students enrolled in Psychology courses. Moreover, emails will be sent to the entire student body across the university, and flyers will be posted in popular locations both on campus and in surrounding towns. Compensation will be a fixed amount of $5 U.S. dollars, or course credit in the case of psychology undergraduate students. Since participants will be asked to play a series of financial gambles with real monetary incentives, all participants will be endowed with an additional amount of $36 dollars for gambling purpose. Based on performance, participants may earn additional money beyond the endowed amount of $36, or they may lose all or a part of the endowed amount. One randomly selected trial from the three experimental blocks will be fulfilled. The maximum amount a participants can lose is the entirety of the endowed amount, and not more.

Materials

The Reduced Morningness-Eveningness Questionnaire. Chronotype will be assessed using a reduced version of the Morningness-Eveningness Questionnaire (MEQr; Adan & Almirall, 1991). The MEQr contains 5 self-report questions which evaluate sleep habits, feelings of subjective alertness, and the participant's own understanding of what chronotype they may be. A sample question from the MEQr is: “At what time of the day do you think you reach your 'feeling best' peak?"(see Appendix A for the full scale). The scoring ranges from 4-7 for extreme evening types, and 22-25 for extreme morning types. The Spearman correlation coefficient for the MEQr and the original MEQ is highly significant (r=0.898, p <0.00001), supporting the idea that the MEQr efficiently measures chronotypes.

Risky Decision Making Task. The reflection effect will be measured using a gambling task that has been modelled after Porcelli and Delgado (2009). This computerized gambling task serves as a straightforward and robust measure of the reflection effect. This design consists of two sets of gambles, presented in either a loss or gain domain: a 80% chance to lose/gain $0.75, or a 20% chance to lose/gain $3.00. The second set of gambles is a 60% chance to lose/gain $1.00, or a 40% chance to lose/gain $1.50. All prospects within each gamble are with respect to gaining or losing $0, and the two gambles in each set are equal in expected value. There are two experimental blocks, one for the gain domain and one for the loss domain, therefore each domain contains two sets of gambles. The timing of the presentation of stimuli is shown in Figure 1. Prospects associated with a lower probability are considered the risky option, whereas prospects with a higher probability are considered the conservative option. There are a total of 80 trials in this design, 40 are within each block domain, therefore each set within a specific domain is repeated 20 times. The repetition of each gamble set within a specific domain is likely to reduce noise and therefore may effectively capture a preference, whilst reducing potential errors. On the other hand, the repetition may lead to concerns regarding practice effects. Since feedback of the gamble is provided to participants almost immediately, and the study includes real monetary incentives, we predict practice effects will be diminished.

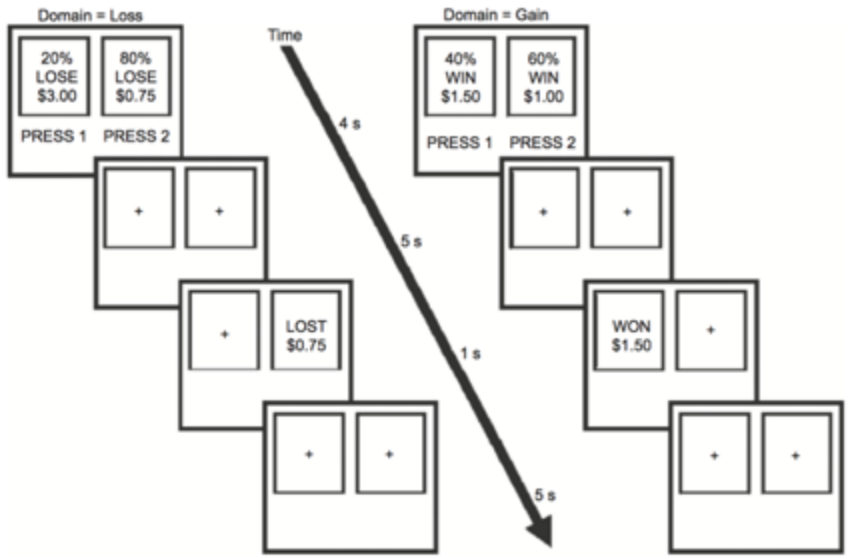

Figure 1. Illustration of the Financial Decision Making Task. Reprinted from Porcelli & Delgado (2009),

Data of both sets within a single domain are to be collapsed for the purpose of analysis; the occurrence of two separate sets within a domain is to increase the variety of choice. This computer task will be executed on a Microsoft Desktop that will be stationed inside the laboratory, all sensory-motor aspects of the task and the laboratory will be controlled for across all domains and conditions.

Dynamically Optimized Sequential Experimentation (DOSE). Because previous research suggests that approximately one-third of individuals are risk averse in both gain and loss domains, a further experimental test is necessary to provide an independent criterion for excluding purely risk-averse participants. The DOSE will be used to estimate each individual's risk aversion parameter (denoted by ρ), separately for the loss and gain domains. The DOSE is fast, less noisy and at least twice as accurate as any other measure of risk aversion (Chapman, et al. 2018). It estimates a ρ parameter by selecting and providing participants with personalized and optimal choice sequences using a Bayesian updating procedure. The rapid computation of the Bayesian update continually adjusts the participant's preference parameter, and subsequently provides the next question that is best suited to each participant, maximizing the information collected. The DOSE also takes into consideration that participants make occasional errors, as well as identifies individuals who are not actively paying attention to the tasks. To adequately estimate ρ for the gain and loss domains separately, the DOSE utilizes a variant of the original utility function of the prospect theory by Kahneman & Tversky (1979, shown in Equation 1).

$$u(x, \rho_i^+, \rho_i^-, \lambda_i) = \begin{cases} u(x) = x^{\rho_i^+} & \text{for } x \geq 0 \\ u(x) = -\lambda_i(-x)^{\rho_i^-} & \text{for } x \leq 0 \end{cases} \quad (1)$$

The DOSE can therefore provide estimates of ρ in a loss domain (ρ^-) and gain domain (ρ^+) separately, even without the existence of a separate loss domain. Whereas the estimates of ρ in the gain domain are by far the most accurate, with a Spearman correlation of 0.73 with the true risk parameter, estimates of ρ in the loss domain yield noisier results, exhibiting a Spearman correlation of 0.51. Though this number is relatively small, the DOSE still stands to be the most accurate estimation of ρ parameters thus far. Therefore, the 20 personalize questions selected by the DOSE will constitute the third block of this experimental study. The questions are conjointly sampled from Sokkol- Hessner et al. (2009) and Frydman, Camerer, Bossaerts, and Rangel (2011). Each gamble is a choice between a sure amount or a gamble with 50/50 probability. For example, participants may select a gamble with a 50% chance to win $9.00 or a 50% chance to lose $8.25, or instead accept a sure amount of $0 (see Appendix B for sample screenshot of gamble). Feedback on gambles will be provided immediately after a choice is selected, and one random trial will be selected and fulfilled from this block. Based on the participants response, DOSE dynamically updates the parameter and selects the next question to thereby maximize information collected on an individual level.

Basic Sleep Survey. In order to control for confounding variables such as total sleep deprivation (TSD), a basic paper and pencil sleep survey will be administered following the DOSE. This survey includes 5 mixed format questions regarding sleep habits, such as “How many hours of sleep did you receive last night?” (see Appendix B for complete survey). The purpose of this survey is to identify participants that have received non-sufficient sleep the night before the experiment, as well as to identify sleep medication use that may confound results. Both behavioral and neural evidence has shown that individuals who are sleep-deprived exhibit a greater expectation of gains, and a simultaneous diminished response to losses (Venkatraman et al., 2007). Additionally, information regarding the current use of sleep medications that impact circadian rhythms is collected so that those individuals who are currently prescribed or have taken a sleep medication may be excluded from analysis due to the effects on circadian rhythms.

Procedure

The experiment will employ a 2 x 2 mixed design, with circadian matching (matched/mismatched) as a between-subjects factor and domain (loss/gain) as a within-subjects factor. In the Match group, extreme morning (evening) participants will be recruited and asked to participate in the laboratory session at 9 am (8 pm), whereas participants in the Mismatch group will be asked to come in at the opposite time. The measurement of interest will be the degree to which Mismatched participants show greater risk-averse choice behavior in the gain domain and risk-seeking in the loss domain, relative to the Matched group.

At the time of recruitment, participants will be asked to fill out an electronic version of the MEQr; they will be informed that their results on this questionnaire will determine whether they are eligible to participate in the experimental session of this study. This version of the MEQr will be created using ‘Survey Monkey’, and will simply be the digitized replication of the questionnaire. Participants will be asked to complete it and await further instructions. After determining extreme morning and evening types, and randomly assigning participants into either a morning or evening condition, those eligible individuals will be informed accordingly. They will be contacted and asked to come into the laboratory during a fixed session time. The morning session will be scheduled for 9 a.m., whereas the evening session will be held at 8 p.m.. Participants will be advised to get a minimum of 6 hours of sleep the night prior to the experiment. Upon reaching the laboratory, participants will be asked to complete the consent form, following which instructions for the computer gambling tasks will be given. Participants will be endowed with an additional $36 U.S. dollars and informed that they may use this money to gamble. They will be instructed to treat each gamble as if it’s the only one, and that at the end of the experiment one trial from each of the three blocks will be randomly selected and fulfilled. Therefore, the $36 may be increased or decreased depending on their performance on any of those random gambles. Upon completing the gambling tasks, participants will be requested to fill out the basic sleep survey, and then will be debriefed and thanked.

Ethics

This study tests risky decision making on a series of financial gambles, the results of which involve the prospect of gaining or losing money on an endowed amount of $36 dollars. All participants, however, will be equally compensated with a fixed sum of $5 dollars, or course credit, awarded at the time of completion regardless of their performance on the gambles. The participants are all to be above the age of consent and will be informed in detail about what the experiment entails prior to providing their consent to participant. Participants will be allowed to opt out and discontinue their participation in the experiment at any time, and most importantly they will be informed of that fact before the start of the computer gambling task. All data will be anonymous, distinct subject codes will be anonymized and kept secured in a separate location. Because this study involves no form of deception, collects no sensitive information and does not involve a protected group of participants, we conclude that this study is below the level of minimal risk. The benefits of this study on the other hand, far outweigh the minimal risk involved. If the results are found to be significant, this study would provide critical insight into the realm of decision making by providing strong markers to suggest an optimal time to engage in risky decision making. The benefits of this would go above and beyond the scientific knowledge of such a relationship, as it could positively impact the society at large if implemented into daily decision making. The results could educate individuals, and thereby, potentially prevent them from making suboptimal and biased decisions, especially in matters entailing risks.

Predicted Results

The targeted sample size for data collection will be 90 participants, corresponding to approximately 45 participants per group. Additional criteria for exclusion include sleep deprivation (< 6 hours of sleep), use of sleep medication, and purely risk-averse decision making, as these factors have previously been shown to influence circadian rhythms and/or risky choices (Baucells et al., 2010; Dinges et al., 1997; Harrison & Horne, 2000; Venkatraman et al., 2007). A majority of participants should have received a minimum of 6 hours of sleep the night prior to the experiment. Participants currently taking sleep medication will be excluded from analysis due to the known effects of these medications on circadian rhythms (Sack, Lewy, & Hughes, 2009). To identify individuals who are purely risk-averse, I will rely on the ρ parameters provided by the DOSE estimation. An individual who is risk averse across both domains will have a gain domain risk aversion parameter (ρ^+) that is higher than their loss domain risk aversion parameter (ρ^-). Therefore, all participants that exhibit:

$\rho^+ - \rho^- > 0$, will be considered purely risk-averse and will be excluded from the analysis.

The dependent variable in this experiment is the decision strategy chosen, whether that is “risky” in the case of risk-seeking choices, or “conservative” in the case of risk-averse choices. To distinguish “risky” versus “conservative” decision strategies, the percentage of risky decisions in each domain will be calculated. The two sets of gambles within each domain will be collapsed for statistical analysis. There are two predictor variables in this study, both of which are categorical variables with two levels: domain (gain versus loss) and circadian matching (matched versus mismatched). A mixed-design

ANCOVA will be administered to determine whether there exists an interaction of circadian matching and gamble domain on the decision strategy chosen. For this analysis, gamble domain serves as a within-subject factor, and circadian matching is a between-subject factor. The number of hours of sleep, collected through the basic sleep survey, will be included as a covariate in the analysis. In line with the reflection effect, the results should show a main effect of domain type on decision strategy, such that there is a significant decrease in the percentage of risky decisions in the gain domain, as compared to the loss domain which should show a significant increase in percentage of risky decisions. Furthermore, in agreement with my hypothesis, I predict the results will show a significant interaction between circadian matching and gamble domain on decision strategy chosen, such that circadian mismatched participants in the gain domain will show a significantly decreased percentage of risky choices selected as compared to circadian matched. Moreover, circadian mismatched participants in the loss domain will show a significantly increased percentage of risky gambles chosen as compared to circadian matched participants (Figure 2).

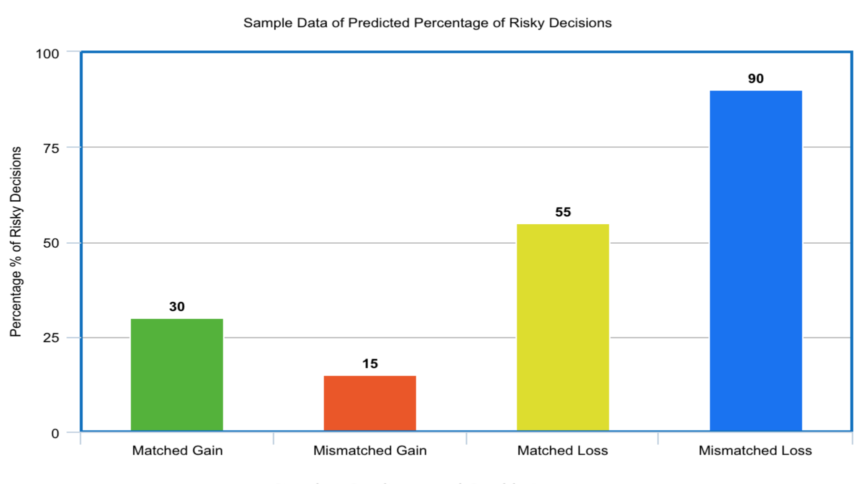

Figure 2: Predicted proportion of participants' risky and conservative strategy choices as a function of domain (loss or gain domain) and condition (circadian matched vs. circadian mismatched). Although analyses were conducted only on risky choices, data on both risky and conservative choices are presented for completeness.

Conclusion

Because risk is a common component of real-world choices, it is important to understand how behavioral biases can produce suboptimal decision making in risky scenarios. Although deviations from “rational” choice under risk have been observed for over 30 years, there is growing awareness that risky decision making can be influenced by state-dependent changes such as sleep deprivation (Venkatraman et al., 2007) and acute stress (Porcelli & Delgado, 2009). The proposed study would further add to our understanding of these dynamics by fleshing out the relationship between decision making and time of day. Specifically, we predict that circadian mismatching will be associated with increases in the reflection effect, driving participants to become more risk-averse in the gain domain while seeking risk under losses. Supporting this basic idea, previous research has reported that participants show riskier asset allocations under circadian mismatching, which is not simply due to greater noise in the decision process (Castillo et al., 2017).

However, it is important to note several limitations of the current study. First of all, the basic replicability of the reflection effect has itself been a topic of debate in the economic literature (Laury & Holt, 2005). To alleviate these difficulties, we recommend the incorporation of loss only gambles in the DOSE. The efficiency and accuracy of the DOSE may be able to finally resolve previous difficulties in finding the reflection effect due to the high number of errors associated with such gambling tasks (Baucells et al., 2010). It is also imperative to further explore the effects of circadian mismatch on a wide number of other behavioral biases, such as the representativeness heuristic (Kahneman &

Tverksy, 1972), availability heuristic (Gilovich et al., 2002), and the framing effect (Kahneman and Tversky, 1979). In particular, examining the effects of circadian mismatching on the framing effect is critical as it may inform individuals to be more cognizant of advertisement and political strategies that play on word choice to increase sales or voter traction.

There also exists a need in the literature to address all types of chronotypes. Experimental studies examining circadian mismatch have overwhelmingly focused only on extreme morning and extreme evening chronotypes. Yet approximately half of the population is estimated to be of intermediate chronotype, raising the question of whether this study, along with the larger body of work on circadian mismatching is truly generalizable. The proposed results of this paper may also raise questions regarding the association between chronotypes and social constructs of time. For example, evening chronotypes may exhibit better proficiency at cognitive tasks during their suboptimal time due to the normal structure of a working day, or a school day, that is designed to run during the morning and afternoon times. Therefore, these individuals may be better at functioning during those times because they have adapted to social norms and structures. Alternatively, social constructs underlying the working day may reflect unexplored cognitive advantages associated with adopting a morning chronotype schedule, irrespective of actual chronotype. Consistent with this idea, a recent study found that earlier timing of sleep and wakefulness, rather than total sleep time or morning tendency, correlated with higher academic performance in college students (Eliasson, Lettieri, & Eliasson, 2010). Therefore, the proposed results may provide a stepping stone towards discovering the nuances of circadian variation and how they may affect each unique individual's functioning.

Lastly, the results of this study are not limited to monetary decision making. If this effect is found to be true it can be predictive of risky decision making across numerous domains. Research shows that financial risky decision making is not necessarily constricted to matters of money but can actually determine how we make decisions when it comes to matters of survival such as food and water (Levy & Glimcher, 2011). It can therefore be generalized to other decisions entailing risks. Thus, this paper could shed light on whether there exists a more optimal time of day wherein individuals should make decisions for important aspects in their life, and avoid or delay making decisions during other suboptimal times to reduce susceptibility to behavioral biases.

Determining whether the time of day can have an effect on how we make risky decisions is of great importance due to the consequences that may result from these cognitive biases. In the financial world, traders and analysts tend to work long hours, often operating into the early hours of the morning or the late hours at night. If these individuals are operating during their circadian mismatched times, they may be behaving more conservatively when given the choice between two positive assets, thereby foregoing a potentially higher return. On the other hand, when dealing with a perceived loss scenario, they may make riskier decisions that entail substantially greater losses. This brings to mind the infamous "London Whale" trader who accrued a loss of $6.2 billion for J.P. Morgan, due to his unprecedented risk seeking attitude in the faces of losses (Hurtado, 2016). Paramedics, policemen, and firefighters are also constantly confronted with high-risk situations that may entail a trade-off between losses. Often times these decisions are made during odd times due to the nature of shift work. Results from this study would suggest that these individuals during their suboptimal time are significantly more susceptible to taking risks, with potentially life-or-death consequences.

Of course, most of us face risky decisions in one domain or another throughout our daily lives. Therefore, all of society will potentially benefit from any basic knowledge that we can apply to maximize our abilities, while keeping in mind our natural limitations. If this study points to the existence of a time of day where we are most susceptible to suboptimal decision making, we can use this information to subsequently work around our mismatched times, so we may function in the most optimal and efficient manner.

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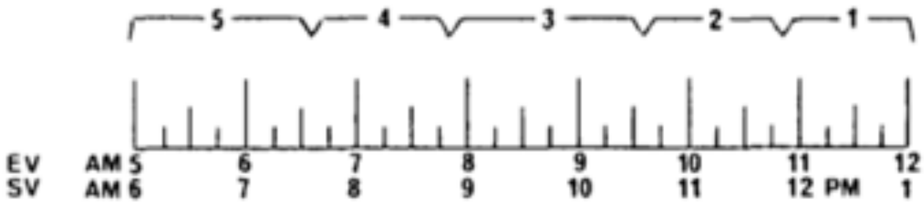
Appendix A: Reduced Morningness, Eveningness Questionnaire (Adan & Almirall,1991)

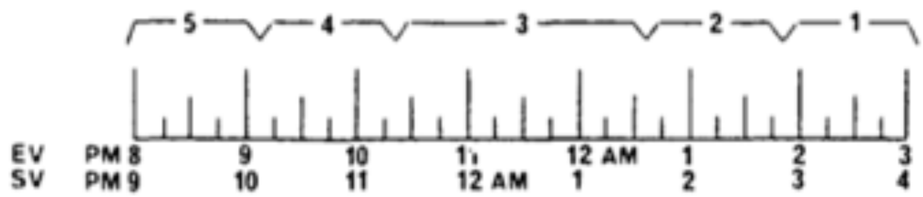
1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?



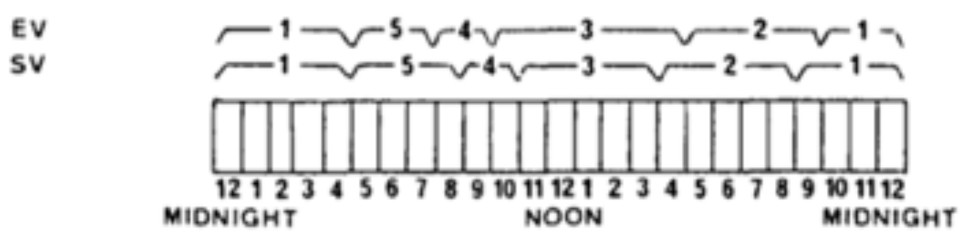
2. During the first half-hour after having woken in the morning, how tired do you feel?

- Very tired........ ☐ 1
- Fairly tired........ ☐ 2
- Fairly refreshed..... ☐ 3
- Very refreshed....... ☐ 4

3. At what time in the evening do you feel tired and as a result in need of sleep?



4. At what time of the day do you think that you reach your "feeling best" peak?



5. One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

- Definitely a "morning" type.............. ☐ 6
- Rather more a "morning" than an "evening" type.... ☐ 4
- Rather more a "evening" than a "morning" type.... ☐ 2
- Definitely a "evening" type.............. ☐ 0

Scheme 1

Appendix B

Basic Sleep Survey

Date: ____________ ID: ____

Time: ______________

Please Tick the Appropriate Box

(1) Are you currently taking any medication?

Yes	No

(2) If Yes to the question above, does your current medication have an effect on your sleep habits?

Yes	No

(3) If you have answered Yes to both the question above, please list the name of the medication(s) below:

____

(4) How many hours of Sleep did you receive last night?

____

(5) Do you have any other comments that you would like to share regarding your sleeping habits?

____

____

____

Appendix C: A sample screenshot of one of the gambles from the financial decision making task. (Sokol-Hessner et al., 2008)