

# Thoughtful days and valenced nights: How much will you think about the problem?

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## Abstract

Considerable research has pointed towards processing differences as a viable means for understanding the strength and likelihood of a framing effect. In the current study we explored how differences in processing may emerge through diurnal patterns in circadian rhythm, which varies across individuals. We predicted that during circadian off-times, participants would exhibit stronger framing effects whereas framing effects would be relatively weaker during on-times. Six-hundred and eighty five individuals took part in the study; the findings supported our hypothesis, revealing a diurnal pattern of risk responding that varies across the 24-hour circadian cycle.

Keywords: circadian rhythm, risk, dual-process, framing effect.

## 1 Introduction

The most studied examples of risk and decision making revolve around risky-choice framing (Levin, Schneider & Gaeth, 1998), which has its foundations in prospect theory (Kahneman & Tversky, 1979). According to prospect theory, the presentation of an outcome as either a loss or gain affects the amount of risk a person is willing to accept. This effect is due to differences in perceived subjective value and is captured by the S-shaped value function. This function is concave for gains, which leads to risk-averse preferences, and convex for losses, which leads to preference for risky alternatives.

In the most well known example of this framing effect, participants read of an Asian disease that will potentially kill 600 people (Tversky & Kahneman, 1981). The participant is then asked to choose between two alternatives for dealing with the disease. One alternative contains a certain outcome (e.g., 200 people saved for certain) and the other has a stated likelihood for an outcome (e.g., a 1/3 probability that all 600 people will be saved and a 2/3 probability that no one will be saved). The alternatives are presented either positively (people saved) or negatively (people die). Importantly, both of the alternatives contain exactly the same “expected outcome”, or numerical magnitude. People tend to choose the certain/risk free option when the problem is framed positively and the risky option when it is framed negatively.

While this framing effect has proved enduring, a num-

ber of studies have pointed toward processing differences as a determining factor for the strength of this framing effect. One of the most widely investigated personality factors in framing research is need-for-cognition (NFC) (Cacioppo & Petty, 1982). This personality trait reflects the extent to which people engage in effortful thought and how much they enjoy doing so. Thus, individuals with high levels of NFC should process tasks more effortfully whereas individuals low in this trait should use less effort. Research has shown that framing effects are lessened for individuals who are high in NFC (e.g., Chatterjee, Heath, Milberg & France, 2000; Curseu, 2006; Smith & Levin, 1996; Zhang & Buda, 1999). Similar results were found by Simon, Fagley and Halleran (2004) when high NFC was combined with math ability or depth of processing.

Related research has shown that merely requesting an elaboration or rationale (Miller & Fagley, 1991; Sieck & Yates, 1997) can influence the likelihood of framing effects. Other research has shown that presenting a task as either high or low in personal importance, which should lead to more or less effortful processing respectively, influences the likelihood of framing effects (e.g., Biswas, 2009; Igou & Bless, 2007; Leny-Meyers & Maheswaran, 2004; McElroy & Seta, 2003; McElroy & Mascari, 2007). Overall, the findings from these studies tend to show that, when more effort is involved in the task, this framing effect is attenuated, with one exception (Igou & Bless, 2007). In a somewhat similar approach, research from fuzzy-trace theory (Reyna & Brainerd, 1991) has shown that, when greater “gist like” memory retrieval is used, framing effects are robust whereas, when the more

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precise “verbatim” retrieval is relied on, framing effects are less evident. Recent investigations have shown support for fuzzy trace as a viable means for understanding framing effects (Kuhberger & Tanner, 2009).

One ability factor that has been identified is numeracy, which refers to the propensity to integrate complex numeric information. Research (Peters & Levin, 2008; Peters et al., 2006) has shown that low numerate individuals respond more superficially to non-numeric sources of information (i.e., frame) and consequently, they have been shown to demonstrate stronger framing effects (for review see Reyna, Nelson, Han & Dieckmann, 2009). In an investigation of another individual difference variable, Frederick (2005) used a Cognitive Reflection Test to show that risky-choice framing effects were attenuated for people relying on more conscious, deliberative processing and more robust for people using more automatic processing. Similar findings were reported by Oechssler, Roeder, & Schmitz (2009).

Other research has shown that ability differences may influence this framing effect. In one study, Stanovich and West (1998) found that individuals with relatively higher cognitive ability, as measured by SAT scores, were less likely to exhibit framing effects. Later research has shown that working memory also plays a role in framing effects (Cokely & Kelley, 2009; Corbin, McElroy & Black, 2010) but the exact nature of this role has not been completely defined. Recently, however, Stanovich and West (2008) have reexamined their original assumptions in a larger study and their findings seem to call their prior hypotheses for framing effects into question.

Taken together, these findings create a picture of how framing effects can differ across individuals and situations. Clearly the type of processing involved can have important and predictable influences on the choices people make. These findings suggest that framing effects will be less likely when a person is being more thoughtful, diligent, or involved in the decision task. A variety of factors may influence the effort and deliberative processing a person uses. One way that humans vary in this respect is diurnally, in a cyclic pattern known as circadian rhythm.

## 1.1 Circadian rhythms.

The circadian rhythm describes variations in our diurnal patterns that are relatively stable (e.g., Wever, 1992) and independent of both the sleep-wake cycle and body temperature (Folkard, Hume, Minors, Waterhouse, & Watson, 1985). A number of biological and psychological factors vary in accordance with the daily biological rhythm. The findings in this area show that during “on times” (e.g., 10:00 a.m.) people perform tasks with more cognitive effort relative to “off times” (e.g., 3:00 a.m.) (e.g., Martin & Marrington, 2005; Monk & Leng, 1986).

Research has also revealed a daily pattern in alertness that helps identify psychological components that vary across the circadian cycle.

For example, Akerstedt, Folkard and Portin (2004) presented an interactive computer model that addresses the question of alertness and performance in everyday life. According to this model, daily alertness levels are composed of three parameters: circadian rhythm, time from awakening and the wakeup process. The findings most pertinent for our investigation reveal that, for alertness levels, the daily circadian cycle appears to oscillate throughout the day, typically reaching a peak around 6 p.m. and decreasing steadily until around 6 a.m. at which point the pattern begins again.

Attesting to the effect of circadian rhythms on judgments, Bodenhausen (1990) measured the effects of circadian match on stereotype usage. Here, circadian match refers to performance at a more alert point during one’s circadian rhythm (the alternative being circadian mismatch). Bodenhausen hypothesized that circadian mismatch would constrain cognitive resources and thereby lead to greater reliance on judgmental heuristics (Bodenhausen, 1990). Across two studies, stereotype judgments had predictable diurnal patterns, with morning types relying more on heuristics for stereotype judgments during evening hours and evening types relying more on stereotype judgments during morning hours.

A domain of research related to circadian rhythm is that of sleep deprivation, which has been found to influence the quality of decision making (e.g., McKenna, Dickinson, & Drummond, 2007). In a review of the literature on this topic, Harrison and Horne (2000) found compelling evidence that sleep deprivation and fatigue impair decision making for some complex tasks. More recently, adverse sleep states have been shown to lead to less than optimal decision making in a higher-level decision task involving iterative reasoning (Dickinson & McElroy, 2010). However, other research suggests that sleep deprivation does not necessarily harm the quality of a Bayesian decision (Dickinson & Drummond, 2008). Thus, the effects of sleep deprivation, and therefore fatigue, may be domain specific.

## 1.2 Predictions

We have reviewed a number of studies that provide a general framework of factors that influence the likelihood of framing effects. These studies point toward a generalized notion that more thoughtful, effortful or deliberative processing will attenuate framing effects. This manner of processing is especially likely during circadian “on-times”. Conversely, less thoughtful, less effortful or more automatic processing will result in stronger framing effects. Participants should be most likely to process in

this manner when they are fatigued due to circadian “off-times”. In the current investigation we tested this hypothesis by manipulating the time-of-day when participants completed a framing task.

## 2 Method

### 2.1 Participants and design

Six-hundred and eighty five individuals, including 402 females and 282 males took part in the study; the average age of our participants was 23.3. Participants were students recruited via email for each 24-hour time slot. The design of our study was a 2 (off time, on time) x 2 (gain, loss) between subjects design. Participants’ level of reported risk preference was our dependent variable.

### 2.2 Procedure and materials

A large student email list of various majors was obtained and used to invite participants to take part in a 10-minute study, which they could access via hyperlink. The study had to be completed during a specified and randomly assigned one-hour time slot indicated in the email invitation. Random assignment to a gain/loss framing condition was also done *ex ante*. Participants were offered entry into a drawing for a cash prize of \$100 (9 a.m. to 11p.m. time slots) or \$300 (midnight to 8 a.m. time slots) in return for their participation. Our sample was derived only from those who responded to our invitation. The survey software program recorded start and completion times for each participant. This same recruitment took place across two semesters, with prize drawings at the end of each semester.

Upon accessing the online survey, participants were first presented with informed consent, followed by several demographic questions. Next, they were presented with our measure of circadian rhythm, the reduced Horne and Östberg inventory (rH&D). The rH&D is a shortened version of the Horne and Östberg (1976) inventory and has been shown to have good validity (Adan & Almirall, 1991). The rH&D was followed by questions assessing recent sleep levels and caffeine consumption. Next, participants were presented with the Asian disease problem (Tversky & Kahneman, 1981) followed by a risk-free and risky alternative; both alternatives were framed either positively or negatively. Participants were then asked to rate their preference toward the alternatives on a 7-point scale from “Definitely would recommend Program A” to “Definitely would recommend Program B”. The use of a scale rather than dichotomous choice has been shown to be a valid measure of risk preference (Levin, Gaeth, Schreiber, & Lauriola, 2002). The midpoint on our scale

Table 1: Average risk response as a function of time-of-day and frame for the Asian disease problem.

Time of day	Gains		Losses	
	N	Risk response	N	Risk response
1 a.m.	19	3.3	15	4.0
2 a.m.	15	3.1	12	4.7
3 a.m.	15	2.9	11	4.4
4 a.m.	15	3.3	10	4.5
5 a.m.	2	3.5	13	4.5
6 a.m.	8	4.5	11	4.6
7 a.m.	13	3.6	10	4.3
8 a.m.	18	3.1	12	4.8
9 a.m.	10	3.8	12	3.8
10 a.m.	20	3.6	17	4.1
11 a.m.	17	3.2	17	3.7
12 p.m.	15	2.9	8	5.1
1 p.m.	16	3.2	1	4.4
2 p.m.	22	3.7	1	5.3
3 p.m.	17	3.7	17	4.7
4 p.m.	16	3.1	20	5.1
5 p.m.	16	2.8	21	4.3
6 p.m.	12	4.8	11	4.6
7 p.m.	21	3.4	11	3.9
8 p.m.	8	3.8	11	3.5
9 p.m.	12	4.3	13	4.4
10 p.m.	10	2.9	6	5.5
11 p.m.	14	4.3	17	4.1
12 a.m.	19	3.1	11	4.3

was “4” which is indicative of neutrality; numeric ratings above this point indicate greater preference for the risky alternative whereas ratings below indicate preference for the risk-averse alternative. After making their choice, participants were asked several remaining questions and then thanked for participating.

## 3 Results

In our initial examination, we tested for evidence of this framing effect for all participants across the 24-hour assigned times. This analysis revealed the typical framing effect  $F(1,668) = 47, p < .001$  and the data are presented in Table 1. However, it is evident that cell sizes are un-

Table 2: Average risk response as a function of time-of-day and frame for the Asian disease problem.

Time of day	Gains		Losses	
	N	Risk response	N	Risk response
1 a.m.–3 a.m.	49	3.1	38	4.3
4 a.m.–6 a.m.	25	3.7	34	4.5
7 a.m.–9 a.m.	41	3.4	34	4.3
10 a.m.–12 p.m.	52	3.3	42	4.1
1 p.m.–3 p.m.	55	3.5	51	4.8
4 p.m.–6 p.m.	44	3.4	52	4.7
7 p.m.–9 p.m.	41	3.8	35	3.9
10 p.m.–12 a.m.	43	3.4	34	4.4

equal in many of the off-time hours, to gain a better perspective we combined the data into 3-hour increments, presented in Table 2. Because of the temporal variability in the presentation of our data, we next observed participants circadian typology. Consistent with the literature examining young adult samples (Chelminski, Petros, Plaud & Ferraro, 2000), we found the percentage of morning types in our sample to be very low, with less than 1 percent of our sample meeting the “moderate” or “definite” morning type criteria. Given the low percentage, we excluded morning types from further analysis and focused on the majority of our university sample.

To examine our primary circadian-match hypothesis, we first needed to divide the 24-hour cycle into “on” and “off” times for our population. To accomplish this we relied on previous research (e.g., Díaz-Morales & Sánchez-López, 2005; Smith, et al., 2002). This research shows the following on-times for evening types (9:00 a.m. to 1:59 p.m., 5:00 p.m. to 1:59 a.m.), daily off-times (2:00 a.m. to 8:59 a.m.), and “siesta” off-time hours (2:00 p.m. to 4:59 p.m.).

Based upon the on- and off-time sorting, the average risk response across frame and circadian match/mismatch for participants is reported in Table 3. We next performed an ANOVA on all of our participants with frame and circadian match/mismatch as our independent variables and risk response as our dependent variable. This analysis revealed a significant main effect for framing  $F(1, 666) = 47.1, p < .001$ , a main effect that approached significance for circadian match/mismatch  $F(1, 666) = 3.2, p < .08$  as well as the predicted circadian match by frame interaction  $F(1, 666) = 4.7, p < .04^1$ .

<sup>1</sup>We also performed an analysis using only participants who were classified as “moderate” or “strong” evening types. This analysis revealed a similar pattern of data with a main effect for circadian match

Table 3: Average risk response as a function of circadian times-of-day and frame for the Asian disease problem.

Circadian times-of-day	Gains		Losses	
	N	Risk response	N	Risk response
Off times	141	3.4	133	4.7
On times	209	3.5	187	4.2

To further examine our data we performed contrast analyses which revealed framing effects in both the circadian off-times  $F(1, 666) = 36.7, p < .001$  as well as on-times  $F(1, 666) = 15.1, p < .001$ , testifying to the robustness of framing effects while also depicting the effects of time-of-day. Post-hoc comparisons revealed that the variability present in our interaction was due almost exclusively to the losses condition which revealed a highly significant difference between circadian on and off times  $F(1, 666) = 7.52, p < .001$ . In sharp contrast, there was no difference between circadian on and off times for the gains framing condition  $F(1, 666) = .08, p > .7$ .

## 4 Discussion

Our findings provide support for the overall robustness of framing effects across the 24-hour day and also reveal a diurnal pattern of risk responding that depicts a predictable pattern for strength in framing effects across the daily cycle. Our predictions are derived from two sources of literature. First, research on framing effects has shown that more effortful and deliberative processing will attenuate framing effects, whereas less effort and more automatic processing will enhance this framing effect. Research on circadian rhythms has shown that individuals are more fatigued and tend to use less cognitive effort during circadian “off times” than “on times”. Based on these two areas of research, we predicted that framing effects would be stronger during circadian “off times” and relatively weaker during “on times”. The results from our study support this hypothesis.

Our findings provide evidence for daily variations in the strength of this framing effect, a variable that should be of interest to those investigating risk and decision mak-

$F(1, 312) = 4.1, p < .05$ , frame  $F(1, 312) = 24.7, p < .001$  and a frame by circadian match interaction that approached significance  $F(1, 312) = 3.3, p < .08$ . In light of the findings of our primary analysis, we performed a post-hoc analysis to test whether the gains and losses conditions differed across the circadian match conditions. This analysis revealed that the losses condition differed across the circadian match conditions  $F(1, 161) = 7.5, p < .007$  but the gains condition did not  $F(1, 151) = .01, p > .9$ .

ing. Identifying new variables, especially those common to all humans, that constrain or enhance biases in decision-making is especially important. As prior theoretical work has shown, we are constrained in our decision making abilities (e.g., Payne, Bettman, & Johnson, 1993; Simon 1990), the current study identifies how this constraint may vary diurnally.

It is curious that circadian effects seem exclusive to the losses condition, leaving the gains condition seemingly unaffected. At first glance, this gain/loss discrepancy seems contradictory to previous research by Watson, Wiese, Vaidya and Tellegen (1999).<sup>2</sup> In their studies, Watson focused on how positive and negative affect may be related to circadian rhythm. In their model, they propose positive and negative activation as biologically based systems that vary in accordance with bodily states. The premise most related to our current study focuses on how positive and negative mood activation varies across the day. Their findings suggest that negative mood is relatively stable across the awakening hours. Positive mood, however, shows vicissitude, being very low after awakening (e.g., 6 a.m.) and increasing steadily to plateau and then dropping off again in the evening hours (e.g., 7 p.m.).

While the Watson et al. findings seem contradictory, they may actually provide an explanation for the gain/loss discrepancy in our study and a nexus to related research. First, it is important to point out that we focused on how risky decision making was influenced by positively or negatively valenced information, whereas the Watson studies focused on internal mood states. A closely related line of research by Isen and colleagues (e.g., Isen & Geva, 1987; Isen & Patrick, 1983; Isen, Nygren, & Ashby, 1988) also looks at how mood may influence risky choice. These studies show that individuals in a positive mood are more sensitive to losses, showing more negative subjective utility, whereas sensitivity to gains is relatively unchanged as a function of positive mood. However, for individuals in a negative mood, there appears to be no difference in sensitivity to either gains or losses.

The contrast of findings from the Watson et al. studies and the Isen et al. studies presents a picture of mood states and valence sensitivity that can describe our data well. Specifically, research by Watson shows that only positive mood seems to vary across the diurnal circadian cycle. The research from Isen and colleagues shows that, as levels of positive mood vary, so too does a person's sensitivity to losses information but not gains. Therefore it is reasonable that we should observe diurnal circadian effects for the losses condition and not for gains. While this reasoning is *post-hoc*, it suggests that further investigation of the interaction between mood states and prob-

lem valence is important for future research.

Another variable that may warrant future consideration for circadian effects on gain loss sensitivity is the social context within which the problem is presented. For example, Wang, Simons and Brédart (2001) found that social context can determine whether the framing effect is driven by the gains or losses condition. We did not examine social context as a variable, so this is a possible subject for future research.

Future research should also examine variables that may interact with daily variations in circadian rhythm. For example, examining whether variables that can elicit high levels of arousal (Cheng & Chiou, 2008; Fagley & Miller, 1997; McElroy & Seta, 2006; Miller & Fagley, 1991; Wang, Simons, & Brédart, 2001; Wang, 2006) will attenuate or override circadian rhythm effects seems warranted (Akerstedt, Folkard, & Portin, 2004).

Similarly, increased motivation may influence the effects of circadian rhythm. For example, consider a study by Horne (1988) which involved a vigilance task wherein higher levels of motivation were induced (via monetary reward). This study found that participant's maintained performance levels similar to controls up until about thirty six hours of sleep deprivation. This finding suggests that some of the physiological effects of sleep deprivation on higher mental functions can be overcome with proper incentive. Similar conclusions can be drawn from a study by Baranski et al. (2007) which compared the motivational factor of being part of a team to working alone. They found that the motivation attributed to teamwork can overcome some effects of sleep deprivation. Future research should address whether additional incentives can overcome the circadian mismatch deficits we have reported.

Another important question involves the physiological effects that can occur from circadian rhythm match and how they may influence decision making. Addressing this question, Horne (1988, 1993) proposed a pre-frontal cortex (PFC) vulnerability hypothesis, which states that under conditions of sleep deprivation the prefrontal regions of the brain are impaired. Research investigating this question has shown that, in tasks requiring high levels of mental functioning, which is associated with frontal lobe activity, performance deteriorates with sleep deprivation (Harrison & Horne, 1999). However, there is reason to believe that the deficit in prefrontal activity levels may vary depending on the type of decision task involved (Drummond, Brown, Stricker, Buxton, Wong, & Gillin, 1999). Future research may benefit from examining whether PFC deficits are responsible for the types of circadian effects we have reported.

In conclusion, our findings, although preliminary, provide new insight into how diurnal variations influence valence processing and risky choice. We have also at-

<sup>2</sup>We thank Irwin Levin for his thoughtful insights which led us to develop this point.

tempted to highlight the future potential for research elucidating how factors associated with circadian variation interact with the decision task. We are confident that many other important factors related to circadian rhythm remain to be discovered and these will no doubt further our understanding of human decision processing.

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