Economic decision-making in morning/evening-type people as a function of time of day.

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Abstract

Decision-making is affected by psychological factors like emotional state or cognitive control, which may also vary with circadian rhythmicity. Here we tested the influence of circadian chronotype (32 morning-type vs. 32 evening-type) and time of day (9 am vs. 5 pm) on interpersonal decision-making as measured by the Ultimatum Game. Participants had to accept or reject different economic offers proposed by a virtual participant. Acceptance involved distribution of gains as proposed, whereas rejection resulted in no gain for either player. Results in the game showed a deviation from rational performance, as participants usually rejected the unfair offers. This behaviour was similar for both chronotype groups, and in both times of day. This result may reflect the robustness of decision-making strategies across standard circadian phases in ecological conditions. Furthermore, morning-types invested more time than evening-types to respond to high-uncertainty offers. This more cautious decision-making style of morning-types fits with our finding of higher proactive control as compared to evening-types when performing the AX-Continuous Performance Task. In line with personality traits literature, our results suggest that morning-types behave with more conscientiousness and less risk-taking than evening-type individuals.

Keywords: chronotype, time of day, economic decision-making, Ultimatum Game, AX-Continuous Performance Task, circadian rhythms, morningness, eveningness.

INTRODUCTION

Neurobehavioural functions fluctuate along the sleep-wake circadian cycle and are further influenced by individual differences in chronotype. Morning-type individuals prefer to sleep and wake at earlier times of day than evening-types (reviewed by Adan et al., 2012), which leads to a "synchrony effect" between chronotype and time of day at which a cognitive task is performed.

The synchrony effect implies superior performance for tasks completed at optimal (morning for morning-types and evening for evening-types) vs. suboptimal times of day. This has been observed in multiple cognitive domains including attention and memory (reviewed by Blatter & Cajochen, 2007; May & Hasher, 1998). However, research on the synchrony effect in decision-making is yet scarce and has provided divergent results. The current study tested whether people make better economic decisions at optimal times of day according to their chronotype.

Bodenhausen (1990) found that participants made more biased and stereotypic social judgments at suboptimal vs. optimal times of day. Similarly, suboptimal times of day have been associated with exacerbated unethical behaviour in moral decision tasks (Gunia, Barnes, & Sah, 2014). However, this synchrony effect was not fully replicated by a recent study using other tasks measuring ethical decision-making and risky decision-making (Ingram et al., 2016). These results altogether suggest that such tasks may tap different dimensions of decision-making, leading to differential modulations by chronotype and time of day.

Here we focused on a different task designed to study economic decision-making, the Ultimatum Game (Güth, Schmittberger, & Schwarze, 1982). It is an economic game in which two participants, a proposer and a responder, divide a specific amount of money (e.g. 10 Euros). The proposer offers a division of this amount (e.g. "3 / 7" meaning 3 Euros for responder and 7 Euros for proposer) and the responder either accepts (winning 3 Euros) or rejects the offer (and neither of them wins anything). This task is interesting because it emphasizes that human decision-making typically deviates from rational performance. In particular, the results show that responders tend not to accept unfair offers even though this rejecting decision means no gain for them (Camerer, 2003; Güth et al., 1982).

Neuroimaging research using the Ultimatum Game suggests that such irrational behaviour might be mediated by emotional and executive-control variables: acceptance of unfair (vs. fair) offers has been related to higher activity in the anterior insula and dorsolateral prefrontal cortex (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). Optimal decision-making (i.e., accepting all offers regardless of subjective fairness) may hence require regulatory control of negative emotions associated to the perception of unfair offers (see also Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006).

Given that both subjective affect and executive control are also influenced by circadian factors (Adan et al., 2012; Biss & Hasher, 2012; Díaz-Morales, Escribano, & Jankowski, 2015; Lara, Madrid, & Correa, 2014; Manly, Lewis, Robertson, Watson, & Datta, 2002; Natale, Alzani, & Cicogna, 2003), it makes sense to expect that their contribution to decision-making would be a function of circadian typology and time of day. If subjective affect is most positive, and regulatory control most efficient at optimal times of day, economic decision-making in the Ultimatum Game will be maximized. We tested this hypothesis by asking morning-type and evening-type participants to play the Ultimatum Game in morning and afternoon sessions. The roles of emotion and cognitive control in their decisions were respectively analysed by measuring subjective affect through a visual analogue scale (Monk, 1989) and by using a version of the Continuous Performance Test, the AX-CPT (Cohen, Braver, & O'Reilly, 1996), which can measure inhibitory control of inappropriate responses.

MATERIALS AND METHODS

Participants

Sixty-four Italian students from the University of Bologna (32 females; age range: 18-29 years, M = 21.6, SD = 2.3 years) participated voluntarily in the study, which was approved by the ethics committee of the University of Bologna. Participants were selected from a previous cross-sectional survey (Tonetti et al., 2016) according to their morningness-eveningness preference: half of them were morning-types (16 females and 16 males) and the remaining half comprised the evening-types group (16 females and 16 males). They were rewarded (18 Euros) for their collaboration.

Apparatus and stimuli

Reduced Morningness-Eveningness Questionnaire (rMEQ)

The Italian version (Natale, 1999) of the reduced Morningness-Eveningness Questionnaire (rMEQ; Adan & Almirall, 1991) was used in the original survey (Tonetti et al., 2016) to assess participants' chronotype. The rMEQ is composed of 5 items taken from the original MEQ developed by Horne and Östberg (1976). The rMEQ scores range between 4 (highest eveningness) to 25 (highest morningness), being our evening-types between 4 and 10 and morning-types above 18.

In the original survey, participants were also requested to reply to some questions about the frequency of drinking coffee (number of cups drank daily), smoking cigarettes (number of cigarettes smoked daily) and gambling (once a day, once a week, once a month or once a year).

Global Vigor-Affect Scale (GVA)
In the present study participants filled in the GVA (Monk, 1989) which is a 8-item visual analogue scale. Participants were requested to put a mark on a 10-cm line for each item to point out their feelings; on one side the extreme was "not at all" while on the other "very much". Four items (tenseness, happiness, sadness and calmness) assessed the perceived affect, while the other four items (sensation of vigor, tiredness, amount of effort required for everyday task and sleepiness) assessed participants' vigor ("activation"). Higher scores on affect and vigor corresponded to better mood and higher vigor, respectively.

Core body temperature was estimated by recording in the right armpit with a digital thermometer (Geratherm).

Behavioural tasks were delivered through E-prime software (Schneider, Eschman, & Zuccolotto, 2002) in desktop computers connected to 15-inch monitors located at about 60 cm from the participant.

Ultimatum Game
In our experiment participants played the role of the responder. To enhance ecological validity, participants were told that the research was part of a transcultural study, in which offers used in the experiment were made by participants in other experiments performed in Spain. They were instructed that the Spanish partners would receive a future payment according to the participants' decisions in the current experiment. To strengthen this cover story, at the end of the session they were invited to take the role of a proposer once and make an offer, that could be used in future experiments with a different sample. Instructions also stressed that participants' decisions did not influence the following offers in the game, as they were told they were playing with different proposers on each trial (Gaertig, Moser, Alguacil, & Ruz, 2012; Moser, Gaertig, & Ruz, 2014). In each of two sessions, 45 offers were presented; each one preceded by a picture of a different face of neutral expression selected from Karolinska and Nim Stim databases (Ekman & Friesen, 1978; Lundqvist, Flykt, & Öhman, 1998). A different set of pictures was used in each session, and they were presented in random order across participants. The gender of these faces was balanced across sessions (23 and 22 female pictures in Sets 1 and 2, respectively). There were five different offers, presented with the same frequency and randomly across trials, differing in the degree of fairness: 1/9 (most unfair), 2/8, 3/7, 4/6 and 5/5 (fair distribution of money). Half of the participants pressed the 'm' key to accept the offer and the 'z' to reject it (opposite mapping for the remaining half).

In every trial, a white fixation cross (0.4° of visual angle) was presented over a black background for 1500 ms at the centre of the screen. Next, the face

(18.92° on average) appeared for 2000 ms and was replaced by the fixation cross for 700 ms. The offer (0.95°) then appeared until the response.

Participants were instructed that the task involved real money, such that from all their responses (i.e., accepted and rejected) two of them would be randomly selected to compute the final gain. Therefore, rejection of offers increased the probability of no gains. Unknown to participants, they all received the same amount of money when pooled across the two sessions.

Continuous Performance Test (AX-CPT)

In this task (Cohen et al., 1996), two consecutive letters (cue and target) are presented. In every trial, a cue (letter A, B, D or E; 0.95°) is presented for 250 ms at the centre of the screen, followed by a blank interval of 1000 ms and then the target (B, D, E or X; 0.95°), until either participants' response or 2000 ms. In go trials, the cue-target sequence was AX and participants had to respond as quickly and accurately as possible by pressing the key '1'. In no-go trials the sequence was either AY, BX, BY. Participants were instructed not to respond to these sequences. The proportion of AX trials was .70, and .10 for each of the three remaining trial types (AY, BX, BY). A total of 240 trials were presented in random order, after a practice block of 30 trials at the beginning of each session. Feedback was delivered only in practice trials.

Procedure

Selected participants came twice to the Laboratory of Applied Chronopsychology at the Department of Psychology of the University of Bologna within a 24-h interval, at 9 am and 5 pm. The order of these sessions was counterbalanced across morning-type and evening-type participants. They first reported subjective activation and affect (GVA), and their temperature was measured. Then they performed the Ultimatum game and AX-CPT, presented in counterbalanced order across participants.

Design and data analysis

We used a mixed factorial design with chronotype (morning-type, evening-type) manipulated between groups and time of day (9 am, 5 pm) manipulated within participants. Separate Analyses of Variance (ANOVA) were conducted on body temperature, subjective activation and affect.

The Ultimatum Game further included offer (1/9, 2/8, 3/7, 4/6 and 5/5) as within-participant factor, with acceptance rate and decision time as dependent variables. The analysis of decision time did not include responses below 100 ms or above two standard deviations of the overall average.

The AX-CPT included trial type (AX, AY, BX and BY) as within-participant factor, with accuracy as dependent variable. Low accuracy in AY trials indicated high proactive control (i.e., the 'A' cue induced anticipation of an 'X' target, which impaired response inhibition of the actual 'Y' target), whereas BX trials measured reactive control.

The Greenhouse-Geisser correction was applied, and corrected probability values and degrees of freedom are reported, when sphericity was violated (Jennings & Wood, 1976).

RESULTS

Subjective and physiological data

The mean rMEQ score of morning-types was 19.78 (SD=.97), while that of evening types was 7.78 (SD=1.52). The groups were balanced in age (morning-types: M=21.91, SD=2.07; evening-types: M=21.28, SD=2.56), t_{62}=1.08; p = .25.
The distribution of morning and evening types across the categories of those who usually drink coffee (morning types=62.50%, n=20; evening-types=53.13%, n=17) or not (morning-types=37.50%, n=12; evening-types=46.88%; n=15) was not significantly different (χ^2_1=.58; p=.45). Nevertheless, among those who regularly drank coffee, evening-types reported to drink a higher mean number of cups of coffee per day (2.91$\pm$0.97) than morning-types (1.70$\pm$0.75), t_{35}=4.28; p < .001.

Extreme chronotypes were differently distributed (χ^2_1=5.74; p<.05) among the categories of smokers (evening types=46.88%, n=15; morning-types=18.75%, n=6) and no smokers (evening-types=53.13%, n=17; morning-types=81.25%, n=26). However, focusing only on smokers, evening-types (8.73$\pm$4.41) did not differ from morning-types (7$\pm$4.56) in the mean number of cigarettes smoked on a daily basis (t_{19}=0.81; p=.43).

Evening-types (12.50%, n=4) were over-represented in the category of gamblers in relation to morning-types (0%, n=0) (χ^2_1=4.27; p<.05). From these 4 gamblers, one reported a frequency of gambling once a year, while the other three a frequency of once a week.

The time of day x chronotype ANOVA on body temperature showed a significant effect of time of day, F(1, 62)= 16.5, p < .01, ηp^2 = .21, being lower in the morning than in the afternoon (M = 36.34, SD = .51 vs. M = 36.58, SD = .57). The time of day x chronotype interaction was not significant (F < 1).

The time of day x chronotype ANOVA on subjective activation (vigor) showed a main effect of chronotype, F(1, 62)= 9.48, p < .01, ηp^2 = . 13, which was better qualified by a significant interaction between time of day and chronotype, F(1, 62)= 20.69, p < .01, ηp^2 = . 25. Planned comparisons replicated the typical synchrony effect, with morning-types reporting higher activation in the morning than in the afternoon (M = 79.56, SD = 14.70 vs. M = 66.53, SD = 14.67), F(1, 62)= 10.52, p < .01. In contrast, evening-types reported higher activation in the afternoon than in the morning (M = 69.18, SD = 18.72 vs. M = 56.36, SD = 21.17), F(1, 62)= 10.18, p < .01.

The time of day x chronotype ANOVA on subjective affect showed no significant effects (all *ps* > .18)

Ultimatum game performance

The time of day x chronotype x offer (1/9, 2/8, 3/7, 4/6, 5/5) ANOVA on acceptance rate only showed a main effect of offer, $F(2.23, 138.36) = 139.54$, $p < .01$, $\eta p^2 = .69$, with increasing acceptance as offers became more fair (Figure 1). This pattern did not differ between chronotypes or times of day (all *ps* > .22).

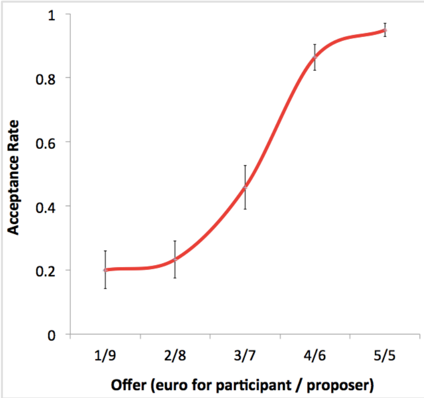

Fig. 1. *Mean acceptance rate in the Ultimatum Game as a function of offer ("1/9" was the most unfair offer, with 1 Euro for the participant and 9 Euros for the proposer).*

The time of day x chronotype x offer ANOVA on decision time revealed a main effect of offer, $F(2.79, 172.70) = 15.64$, $p < .01$, $\eta p^2 = .20$, which was better qualified by the interaction between chronotype and offer, $F(2.79, 172.70) = 2.74$, $p = .049$, $\eta p^2 = .04$. Figure 2 suggests that morning-types invested more time than evening-types to decide on offers that were not clearly fair or unfair; that is, on the 2/8 offer, $F(1, 62) = 4.66$, $p = .035$ (the effect of chronotype did not reach significance for the 3/7 offer, $F(1, 62) = 2.20$, $p = .14$).

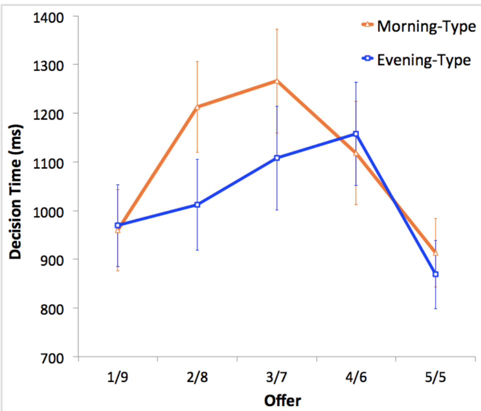

Fig. 2. *Decision time in the Ultimatum Game as a function of offer and chronotype (morning-type in triangle-shape marker, evening-type in squared marker).*

AX-CPT performance

The time of day x chronotype x trial type (AX, AY, BX, BY) ANOVA on accuracy showed main effects of chronotype, $F(1, 62) = 6.30$, $p = .015$, $\eta p^2 = .09$, and trial type, $F(1, 62) = 85.66$, $p < .001$, $\eta p^2 = .58$, which were better qualified by a significant interaction between chronotype and trial type, $F(1, 62) = 5.20$, $p = .002$, $\eta p^2 = .08$ (Figure 3). In AY trials, morning-types produced lower inhibition rates as compared to evening-types, $F(1, 62) = 6.03$, $p = .012$. No significant differences were found for the remaining trial types (all *ps* > .25).

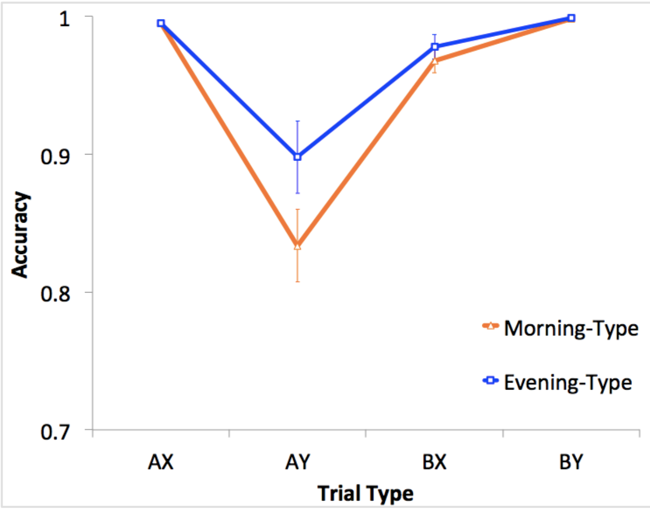

***Fig. 3**. Accuracy in the AX-CPT as a function of trial type and chronotype (morning-type in triangle-shape marker, evening-type in squared marker).*

DISCUSSION

The aim of the current research was to study, for the first time, the influence of circadian typology and time of day on economic decision-making as measured by the Ultimatum Game. It was further tested whether performance in this game was related to subjective affect and executive-control skills (proactive and reactive control) as measured by the affect dimension of the GVA and AX-CPT, respectively. We expected interpersonal decision-making in the Ultimatum Game to be enhanced at optimal times of day for each chronotype. If so, the maximization of gains in this game could rely on the ability to control for distracting information (e.g., negative emotions related to unfair offers), which would be reflected in enhanced performance of the AX-CPT at optimal times of day. Furthermore, high positive affect at optimal times of day could enhance performance in the Ultimatum Game.

The results on the differences between chronotypes in the behaviour of drinking coffee, smoking cigarettes and gambling are overall in line with those previously reported (e.g., Adan et al., 2012), thus highlighting the good representativeness of the investigated sample. Furthermore, the accurate selection of participants according to their chronotype is supported by the interaction between chronotype and time of day on the vigor dimension of the GVA, in line with previous studies (e.g., Natale et al., 2003).

Our results in the Ultimatum Game confirmed the extant literature (Camerer, 2003), as participants deviated from rational performance by decreasing acceptance rates as offers became more unfair. This behaviour may be a punishing response to the proposer, driven by a negative emotion in the participants produced by unfair offers (Nowak, Page, & Sigmund, 2000). Most relevant, we found that this decision-making pattern did not differ between chronotypes or times of day.

This finding is in line with a recent report of absent synchrony effects in ethical decision-making (the matrix task) and risky decision-making (balloon analog risk task) for chronotypes measured by the morningness-eveningness questionnaire (Ingram et al., 2016). Remarkably, the Ingram et al.'s study found a significant synchrony effect in ethical decision-making when chronotype grouping was based on phase differences in the expression of circadian clock genes (Per3, Nr1d2). However, this interesting result ought to be replicated with a larger sample (the evening-type group only included 8 participants) and further discussed in relation to research supporting a relationship between subjective and biological measures of chronotype (e.g., Katzenberg et al., 1998).

On the other hand, the results on the lack of differences across chronotypes and time of day can be interpreted as reflecting the robustness of decision-making strategies across standard circadian phases in ecological conditions (i.e., without sleep deprivation; Anderson & Dickinson, 2010; Killgore, 2007; Killgore, Balkin, & Wesensten, 2006). Indeed, our circadian manipulation effectively altered temperature and subjective activation as expected, but not decision-making performance. This dissociation between circadian effects at physiological, subjective and behavioural levels might hold an adaptive value. In other words, adapting to the environment could be compromised if decisions were excessively labile across times of day. This argument is in line with literature proposing an automatic nature of many everyday decisions (Evans, 2003). Indeed, automatic processing is usually more resistant than controlled processing to the synchrony circadian effect (Lara et al., 2014; May & Hasher, 1998).

In relation to individual differences in circadian typology, we observed dissociable behaviours between extreme chronotypes. First, morning-types invested more time than evening-types to reach a decision in offers most uncertain in terms of fairness. Decision time has been related to acceptance rates of 5/5, 4/6 and 1/9 offers, but, in line with our results, longer decision times to 2/8 and 3/7 offers were not associated with reliable changes in the decision taken (Ferguson, Maltby, Bibby, & Lawrence, 2014), as shown in our data by a similar pattern of rejections in morning- and evening-type participants. Second, morning-types applied higher proactive control than evening-types in the AX-

CPT. The increased anticipation of AX trials in morning-types was reflected as a lower inhibition rate in AY trials. The possibility of poorer inhibitory control in morning-types can be ruled out as we observed that both chronotypes showed similarly high performance in both BX and BY conditions, in which responses also had to be withheld. Thus, the lower performance of morning-types in AY trials was indicative of higher proactive control.

These results altogether suggest a cautious decision-making style associated with morningness, in line with previous research. Specifically, conscientiousness (i.e., being thorough with the aim of performing a task well), a marker of self-regulation in proactive mode, has been identified within the Big Five Personality Model (Costa & McRae, 1992) as the best factor discriminating between chronotypes (Tonetti, Fabbri, & Natale, 2009; Tsaousis, 2010), being higher in morning- than evening-types. It is thus possible that personality features of morning-types modulate their performance in the Ultimatum Game (decision time) and AX-CPT.

Overall, the current findings are important because they add to the evidence based on subjective self-report measures by further providing objective evidence on differential cognitive styles between chronotypes when they perform behavioural tasks. Although in our research such individual differences were not reflected in economic decision-making, novel approaches to the measurement of human chronotype could provide a richer answer to the main question addressed here.

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Declaration of Interest

The authors report no conflicts of interest.

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