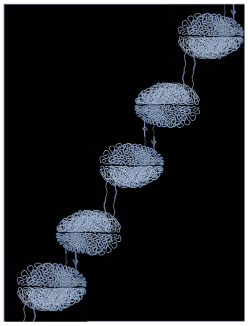
International Journal of PSYCHOLOGICAL RESEARCH

RESEARCH ARTICLE



Vol 16, N° 2
https://revistas.usb.edu.co/index.php/IJPR
ISSN 2011-2084
E-ISSN 2011-7922

Chronotype and Time of Day Effects on a Famous Face Recognition Task with Dynamic Stimuli

Efectos del cronotipo y la hora del día en una tarea de reconocimiento de rostros famosos con estímulos dinámicos

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OPEN ACCESS

Manuscript received: 29-09-2022
Revised: 06-07-2023
Accepted: 25-07-2023

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Declaration of data availability: All relevant data are within the article, as well as the information support files.

Conflict of interests: The authors have declared that there is no conflict of interest.

How to Cite:
Bem-Haja, P., Silva, A., Rosa, C., Queiroz, D. F., Barroso, T., Cerri, L., Alves, M. F., Silva, C. F., & Santos, I. M. (2023). Chronotype and Time of Day Effects on a Famous Face Recognition Task with Dynamic Stimuli. *International Journal of Psichologycal Research*, *16*(2), 51–61. https://doi.org/10.21500/20112084.6583

Abstract.
Chronotype and Time of Day (ToD) can modulate several aspects of cognitive performance. However, there is limited evidence about the effect of these variables on face recognition performance, so the aim of the present study is to investigate this influence. For this, 274 participants (82.5% females; age 18-49 years old, mean = 27.2, SD = 1.82) were shown 20 short videoclips, each gradually morphing from a general identity unfamiliar face to a famous face. Participants should press the spacebar to stop each video as soon as they could identify the famous face, and then provide the name or an unequivocal description of the person. Analysis of response times (RT) showed that evening-types recognised the faces faster than morning-types. Considering different ToD windows, the effect of chronotype was only significant in the 13h-17h and in the 21h-6h time-windows. Altogether, results suggest an advantage of evening-types on famous face recognition using dynamic stimuli with morning-types, being particularly slower during their non-optimal period.

Resumen.
El cronotipo y la hora del día pueden modular varios aspectos del rendimiento cognitivo. Sin embargo, existen pocas pruebas sobre el efecto de estas variables en el rendimiento en el reconocimiento de caras, por lo que el objetivo del presente estudio es investigar esta influencia. Para ello, se mostraron a 274 participantes (82.5% mujeres; edad 18-49 años, media = 27.2, DE = 1.82) 20 videoclips cortos, cada uno de los cuales pasaba gradualmente de una cara desconocida de identidad general a una cara famosa. Los participantes debían pulsar la barra espaciadora para detener cada vídeo en cuanto pudieran identificar la cara famosa y, a continuación, proporcionar el nombre o una descripción inequívoca de la persona. El análisis de los tiempos de respuesta (TR) mostró que los participantes vespertinos reconocían las caras más rápidamente que los matutinos. Considerando diferentes ventanas de hora del día, el efecto del cronotipo solo fue significativo en las ventanas temporales de 13h-17h y de 21h-6h. En conjunto, los resultados sugieren una ventaja de los tipos vespertinos en el reconocimiento de caras famosas al utilizar estímulos dinámicos, siendo los tipos matutinos particularmente más lentos durante su periodo no óptimo.

Keywords.
Sleep; Chronotype; Time of Day; Familiarity; Face Recognition; Memory.
Palabras Clave.
Sueño, cronotipo, hora del día, familiaridad, reconocimiento de caras, memoria.

1. Introduction

Humans, as well as most other animals, synchronise their internal circadian clock to their daily rhythms, which leads to the concept of chronotype (e.g., Adan et al., 2012). People can vary along a continuum between extreme morningness and extreme eveningness. According to this, several chronotypes may exist (see Levandovski et al., 2013), but most of the literature differentiates three main chronotypes: evening-types (ET), morning-types (MT), and intermediate-types (IT) (Horne & Ostberg, 1976). These are sometimes referred to, respectively, as owls, larks, and doves. ET feel at their best later in the day whereas MT prefer doing demanding activities in the morning. IT can either oscillate between having characteristics similar to morning-types and to evening-types or having neither (see Schmidt et al., 2007). Given this daily fluctuation in preference or in performance, the chronotype emerges in the literature often related to the Time of Day (ToD) (Lunn & Chen, 2022), which concerns the period of day (e.g., morning), in which someone performs a certain task (e.g., Facer-Childs et al., 2018). Studying ToD as a variable implies the recording of performance in two or more times during the day, in individuals living in their normal environment (Monteiro et al., 2022). When analysed together, these two variables lead to the concept of synchrony. Most of the literature shows an effect of synchrony on a variety of cognitive processes (e.g., Correa et al., 2014; Evansová et al., 2022; Schmidt et al., 2007) where the participants perform better at their optimal times compared to their non-optimal times (synchrony effect), i.e., MT express improved performance throughout the morning and inferior performance in the evening, while ET show an inverse pattern. However, mixed results exist. For example, Fabbri and colleagues (2013) found a ToD effect in their semantic classification task but not a synchrony effect —regardless of chronotype, and also found unreliable effects for both ToD and synchrony for a number-matching task. Additionally, and more extreme, asynchrony effects were also found in the literature, where individuals exhibit an improved performance at a non-optimal ToD, i.e., MT with better performance at night and ET with better performance in the morning (e.g., Carciofo et al., 2014; May et al., 2005; Simor & Polner, 2017).

Despite the inconsistent results, the biopsychological framework behind the synchrony effect is more robust than the rational for asynchrony. Indeed, literature shows that the rhythms of some cognitive variables such as attention and memory have a high correlation with core temperature (Valdez, 2019), with the highest temperature points (acrophase) occurring earlier in the day for MT and later in the day for ET (Kerkhof & Van Dongen, 1996). The same pattern is found for melatonin (the endogenous decoder of photoperiod), which peaks earlier in the day for MT than for ET (Lack & Bailey, 1994). In addition to core temperature and melatonin, which have an objective and endogenous nature, self-response variables such as sleepiness and alertness also help to explain the synchrony effect. For example, a study carried out by Lack et al. (2009) showed that MT have a maximum peak of sleepiness 5 hours and a half before ET and a maximum alertness peak 9 hours before ET.

Memory is one of the cognitive dimensions where the effects of chronotype, ToD, and their interaction have been most studied (Puttaert et al., 2019). However, once again the results are not consistent regarding the effect of synchrony. In fact, if on the one hand most studies with declarative memory showed a synchrony effect (e.g., Yang et al., 2007), several studies with implicit memory have shown asynchrony effects (e.g., Rothen & Meier, 2016). Despite the existence of many studies that have tested the effect of synchrony on memory performance, most have not focused specifically on face memory (Yaremenko et al., 2021a). As faces are stimuli of particular relevance to our species, it is important to develop studies that explore how chronobiological variables impact face perception. In fact, humans derive a wealth of information from faces, such as age (e.g., Liao et al., 2020), health (e.g., Axelsson et al., 2018), personality traits (e.g., Kachur et al., 2020), and identity (e.g., Boutet & Meinhardt-Injac, 2021). In our literature search, we were only able to find two articles that explored the effect of synchrony in memory for faces (Yaremenko et al., 2021a, 2021b). However, despite the authors expecting a synchrony effect, the results failed to demonstrate one. The authors point out several reasons for this, including: a difficult task was used which led to obtaining a floor effect; the encoding and the recall were in the same session, confounding the chronobiological effects on encoding and recall; the studies were carried out in an eyewitness framework.

Therefore, in the present study we decided to test the existence of a synchrony effect for face recognition performance in a neutral context (avoiding the emotional arousal of an eyewitness framework) and using a dynamic recognition paradigm with famous faces to avoid encoding and recall in the same session. In addition, we also explored the role of sleep and fatigue. Some studies have shown that there are sleep variables such as sleep onset, sleep length, and quality of sleep that may interfere with task performance by themselves or in their interaction with other variables for all chronotypes (e.g., Venkat et al., 2020). In the same line, Bernstein and colleagues (2019) showed that greater sleep quality, measured by actigraphy, and longer sleep onset latencies were overall associated with better performance on measures related to cognition. Additionally, fatigue, often resulting from sleep loss issues, is linked to a variety of cognitive and behavioural impairments (Frings, 2015). When we consider recognition memory for faces in specific, there is also evidence that sleep restriction negatively affects memory performance (e.g., Mograss et al., 2006; Santos et al., 2022). Thus, in the present study, we controlled the influence of those variables that the literature points out as potentially confounding, namely, sleep quality and duration and mental and physical fatigue.

2. Method

2.1 Participants

Participants were recruited through sharing the experiment's poster on social media, by word of mouth, and by e-mail through the university's institutional e-mailing lists. The shared link led to a questionnaire implemented in LimeSurvey (LimeSurvey Project Team, 2012), where participants were asked to answer sociodemographic questions and other self-report measures described below. At the end of the questionnaire, they were asked to follow one of two links —the only difference being task order counterbalancing. Our study comprised two experimental tasks, of which only one is of interest to the present work. These links led to the online experiment, which was built in PsychoPy for Windows (Version 2021.1.4, Peirce et al., 2019), and uploaded to Pavlovia —https://pavlovia.org/— (Bridges et al., 2020) for online data collection.

Although 914 participants accessed the initial LimeSurvey link, only 274 participants (roughly 30%) completed all the questionnaires and the Famous Faces Recognition Task reported in this paper. The 274 participants (82.5% females) were aged between 18 and 49 years old and had a mean age of 27.2 (SD = 1.82). Before carrying out the investigation protocol, the participants completed an informed consent online. This study was approved by the Ethics and Deontology Committee of the University of Aveiro (N°40-CED/2019, approved on January the 22nd, 2020).

2.2 Materials

2.2.1 Chronotype and sleep assessment

The reduced version of the Morningness-Eveningness Questionnaire (rMEQ: Adan & Almirall, 1991; European Portuguese adaptation by Loureiro & Garcia-Marques, 2015) was used to assess participants' chronotype. The questionnaire consists of five items and shows good reliability and validity across several languages of which European Portuguese is no exception (Loureiro & Garcia-Marques, 2015). Scores in the questionnaire range from 4 to 25 and have cut-off points which classify individuals into evening-types (scores between 4 and 11), morning-types (scores of 18-25), and intermediate-types (scores in between these two). However, the total score on the rMEQ in this study was considered in the statistical analyses, placing participants along a continuum, between extreme eveningness and extreme morningness, instead of classifying individuals in one of the three chronotypes. Cronbach's alfa for this questionnaire in the present study was .73, indicating acceptable reliability.

The Basic Scale on Insomnia symptoms and Quality of Sleep (BaSIQS: Allen Gomes et al., 2015) was used as measure of sleep quality. It aims at gathering information on night-time sleep quality and insomnia, intentionally avoiding assessing daytime disfunction and other sleep aspects such as sleep duration, schedules, and disturbances other than insomnia aspects. This instrument consists of eight items and participants are required to select one of five possible answers for each item, considering the previous month, and keeping in mind a typical work week. Scores can be interpreted in terms of normative percentiles, classifying participants into having four sleep quality levels (very good to good, good to average, average to poor, and poor to very poor), but a higher overall score can be considered as corresponding to poorer sleep quality. Cronbach's alfa for this questionnaire in the present study was .81, indicating good reliability.

Additionally, participants provided information about the wake-up time on the day of data collection and the bedtime the night before, so that we could calculate sleep duration.

2.2.2 Other self-report measures

Besides typical questions asked in a sociodemographic questionnaire —such as age, gender, education, country of residence, and whether the participant was a student or not—, we also asked participants to report both mental and physical fatigue on a 10-point Likert-type Visual Analog Scale (VAS), ranging from 1 (*nothing at all*) to 10 (*extremely*).

2.2.3 Face recognition task

The faces used in the study were selected from a database of famous faces created in our lab, which contains faces with various degrees of familiarity, assessed by a Portuguese sample (Monteiro et al., 2023), and images of unfamiliar faces matched for sex, approximate age, race, and global features (e.g., hairstyle, presence of facial hair, expression, etc.) with each famous face. For this study, 24 faces of celebrities (12 male and 12 female) whose validation studies showed high recognition rates (range 71-100% recognition, mean = 84%, SD = 0.08) were chosen. These celebrities were mostly Hollywood actors (e.g., Anne Hathaway, Eddie Redmayne) or widely known TV personalities or politicians (e.g., Ellen DeGeneres, Donald Trump) and singers (e.g., Justin Bieber, Britney Spears). The 12 male and 12 female match faces were used to create a male and female unfamiliar average face, respectively, to be used as an unfamiliar face starting point in the dynamic stimuli (videoclips), which was common to all the stimuli, described as follows. In this way, we aimed to avoid any differences in task performance that could be due to how closely each match face resembled the paired famous face. The average faces were created using Psychomorph (v. 6; Tiddeman & Perrett, 2002).

The stimuli used in the face recognition task were videoclips of faces in which a general identity face (the male or female average face previously described) gradually morphed into a photograph of the face of one famous individual. Each videoclip's duration was 18 seconds: the time it took for each face to completely change from the general identity face (0% famous face) to a famous face (100% famous face). Intermediate images between the same sex average face and each famous face were created in Psychomorph, with 1% increments (v. 6; Tiddeman & Perrett, 2002), which yielded 101 images to be used in each video. As videos needed to run at 30 frames per second, a further 80 images were obtained, identical to the ones shown at the middle of the interval between the average face and the famous face. Each individual image was presented for .1s before being followed by the next one. These videos were created using a custom Python (Version 3.9) script which employed FFmpeg (Version 4.3.2, see https://ffmpeg.org/) in a WSL Ubuntu environment run on Windows 10.

When participants followed one of the links at the end of the questionnaires, they were directed to the experimental tasks implemented in Pavlovia. There, they were presented with one of two tasks: the famous face recognition task described in this article, or an emotion recognition task, which is outside the scope of this work. Upon completion of the first task, the second one immediately followed, preceded by the respective task instructions. The link participants chose to click at the end of the previous questionnaire determined task order. During the famous face recognition task, each trial initiated with a fixation cross presented for 1 second, after which the videoclip started. Participants were asked to press the spacebar as soon as they were able to determine which famous person was depicted. If they did not press the spacebar, the videoclip would run until the end (18 seconds). Regardless, in both cases a new screen was then presented where participants were asked to type the name of the famous person being shown. They were instructed that if they did not remember the name of the famous person, they could provide other pieces of information that allowed to individualise the person beyond doubt, i.e., they could describe their profession and films they were featured on, etc., so that we would know which person they were referring to. Vague descriptions were considered wrong answers (e.g., simply typing "actor" for Brad Pitt would not be enough to be considered a correct answer, but typing main actress from "Lost in Translation" for Scarlett Johansson would be accepted). Upon giving their answer and clicking with the left mouse button on the confirmation button, a new trial was presented. The task consisted of four training stimuli (two males and two females), so that participants could get used to the task and the type of stimuli, and 20 test stimuli (10 males and 10 females), which were always presented in random order.

2.3 Data Analysis

The dependent variable considered in data analysis was always the response times (RTs), i.e., the time elapsed between the onset of the stimuli and participants' spacebar keypress, for correct responses. RTs were considered to be the variable that better indexed the participants' face recognition ability, as a faster RT on a correctly scored response (assessed by the information provided afterwards) indicated that less visual information was required to correctly identify the person.

Due to technical issues, we have discarded 1.03% of trials. These corresponded to instances where RTs, as recorded in Pavlovia's data file, exceeded the total duration of the stimuli (18 seconds). Furthermore, we have applied a filter to our data, so that trials whose RTs were lower than two standard deviations from the mean were also discarded. This further eliminated 9.20% of trials. The upper limits were those corresponding to stimuli duration, as participants could watch the videoclip stimuli until they disappeared from the screen (18s after onset).

Regarding Time of Day (ToD), we have created time windows to allow a better understanding of this variable. These time windows refer to when participants completed the task, and correspond to the cut-points already established by the Portuguese version of the full-version of the MEQ (Silva et al., 2002), namely: "9h-13h" (38 participants), "13h-17h" (71 participants), "17h-21h" (125 participants), "21h-6h" (38 participants). We have not included the remaining window in the analyses –6h to 9h– because only one participant (.3%) completed the task during this period.

Statistical analyses were conducted in SPSS (Version 28; IBM Corp., 2021) and Jamovi (Version 2.2.5.0; The jamovi project, 2021). A general linear model (GLM) fitted with ordinary least-squares (OLS) with the rMEQ score as covariate, the ToD windows as a factor, and the time until the identification of the famous person (RT) as a dependent variable, was performed. In addition, and considering the influence of sleep quality and duration, and physical and mental fatigue on cognitive performance and on chronotype expression, these variables were added to the previous model in isolation. Thus, a model was computed for each of the four variables that could be a significant covariate: quality of sleep (BaSIQS), sleep duration (minutes), and self-reported mental and physical fatigue. Each of the models produced can be expressed using Equation 1 shown below, where each of the possible confounders appears in the expression as "Conf".

$$\begin{aligned} RT = 1 + ToD + rMEQ + Conf + ToD : rMEQ + \\ ToD : Conf + rMEQ : Conf + ToD : rMEQ : Conf \end{aligned} \tag{1}$$

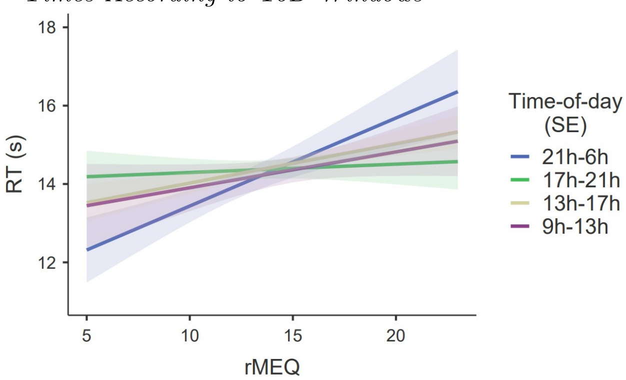
3. Results

The results showed an effect of chronotype, $F(1,256) = 6.90$, $p = .009$, $\eta_p^2 = .031$, with a positive relationship between the time taken to identify the famous faces and the score in the chronotype questionnaire, that is, a higher level of morningness (higher rMEQ score) was related to a slowness in identifying the famous faces. On the other hand, there was no main effect of ToD, $F(3,256) = 1.03$, $p = .382$, $\eta_p^2 = .006$, nor a ToD*rMEQ interaction, $F(3,256) = .92$, $p = .432$, $\eta_p^2 = .011$.

Despite the absence of a significant interaction, considering the exploratory nature of the study and the pattern that can be observed in Figure 1, simple main effects of rMEQ were performed with ToD as a moderator. In fact, the results showed effects of rMEQ in the time windows 13h-17h, $F(1,248) = 4.60$, $p = .033$, $\eta_p^2 = .018$, and 21h-6h, $F(1,248) = 5.08$, $p = .025$, $\eta_p^2 = .020$, but not in the time windows 9h-13h, $F(1,248) = .80$, $p = .373$, $\eta_p^2 = .003$, and 17h-21h, $F(1,248) = .09$, $p = .766$, $\eta_p^2 < .001$. However, these results must be regarded with caution, due to the possibility of the presence of a type I error due to top-down violation.

Figure 1

Simple Main Effects of Chronotype on Response Times According to ToD Windows



Considering the influence of sleep quality and duration, and physical and mental fatigue on cognitive performance and on chronotype expression, these variables were added to the previous model in isolation.

3.1 Sleep quality (BaSIQS score)

Results showed a trend for an effect of sleep quality, $F(1,256) = 3.32$, $p = .070$, $\eta_p^2 = .004$, where subjects with higher BaSIQS scores exhibited slower responses. Despite this, the main effect of chronotype was maintained, $F(1,256) = 4.67$, $p = .032$, $\eta_p^2 = .032$, as well as the simple effects in the time windows 13h-17h, $F(1,240) = 3.88$, $p = .05$, $\eta_p^2 = .016$, and 21h-6h, $F(1,240) = 4.65$, $p = .032$, $\eta_p^2 = .019$. No other main effects or interactions were found.

3.2 Sleep duration

As for sleep duration, results showed that the effect of chronotype was maintained, $F(1,256) = 4.66$, $p = .032$, $\eta_p^2 = .032$. However, only the simple effect for the 13h-17h time window remained significant, $F(1,240) = 4.56$, $p = .033$, $\eta_p^2 = .015$. To explore the dropped effect in the 21h-6h time window, simple effects of chronotype on RT were performed with ToD as moderator and sleep duration as a breaking variable (Mean±1SD). Results showed an effect chronotype on RT in the 21h-6h time window only for shorter sleep durations (Mean-1SD), $F(1,240) = 4.54$, $p = .034$, $\eta_p^2 = .015$. The model results did not show other main effects or interactions.

3.3 Mental fatigue (VAS)

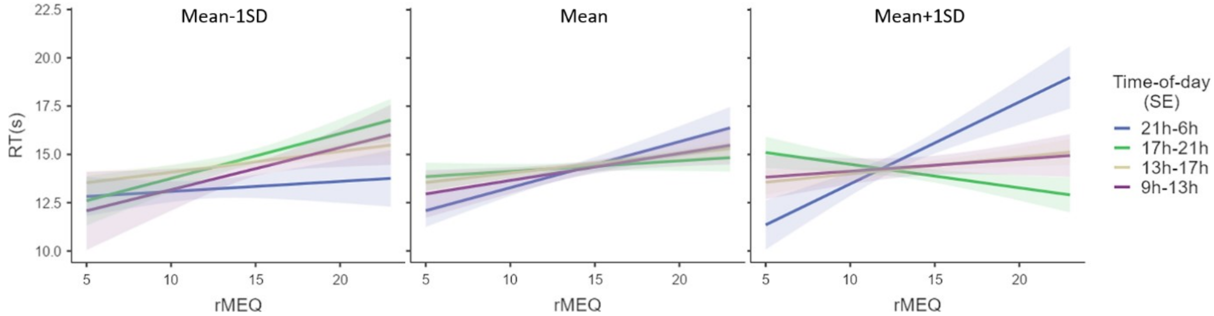
Once again, results showed that the main effect of chronotype was maintained, $F(1,256) = 8.88$, $p = .003$, $\eta_p^2 = .033$, as well as the simple effects in both 13h-17h time window, $F(1,240) = 4.37$, $p = .038$, $\eta_p^2 = .018$, and 21h-6h time window, $F(1,240) = 5.66$, $p = .018$, $\eta_p^2 = .023$. Interestingly, an interaction between ToD and mental fatigue, $F(3,256) = 3.14$, $p = .026$, $\eta_p^2 = .031$, and a triple interaction between ToD, rMEQ and mental fatigue, $F(3,256) = 2.95$, $p = .033$, $\eta_p^2 = .036$, were also obtained. The existence of an interaction between ToD and mental fatigue can be explained by the fact that effects of fatigue on RTs were only obtained for the 21h-6h time window, $F(1,240) = 6.72$, $p = .010$, $\eta_p^2 = .027$, with longer response times for individuals with higher perceived mental fatigue.

To better explore the triple interaction, simple effects of chronotype on RT were performed with ToD as moderator and mental fatigue as a breaking variable (Mean±1SD). The descriptive results of this analysis can be seen in Figure 2.

Visual data analysis of Figure 2 indicates that the relationship between ToD and chronotype on RTs seems to depend on the level of mental fatigue. Results of the simple main effects showed that when mental fatigue is low (Mean-1SD) there were no rMEQ effects on RT in any of the time windows. On the other hand, when mental fatigue was average (Mean), response behaviour was very similar to the one found for the initial model (without sleep covariates), with effects of rMEQ in the 13h-17h, $F(1,240) = 5.66$, $p = .018$, $\eta_p^2 = .023$, and 21h-6h time windows, $F(1,240) = 4.37$, $p = .038$, $\eta_p^2 = .018$. When mental fatigue was high (Mean+1SD), results showed rMEQ effects only for the 21h-6h time window, $F(1,240) = 7.74$, $p = .006$, $\eta_p^2 = .031$. Interestingly, if we look at the effect of rMEQ in the 21h-6h time window across fatigue levels, we can see that the effect size increased with the increase of mental fatigue (Mean-1SD: $\eta_p^2 = .001$; Mean: $\eta_p^2 = .023$; Mean+1SD: $\eta_p^2 = .031$), that is, the greater the mental fatigue, the greater the positive relationship between the rMEQ and the RT on this time window.

Figure 2

Simple Effects of Chronotype on Response Times with ToD Windows as Moderator and Mental Fatigue as Breaking Variable (Mean±1SD)



3.4 Physical fatigue (VAS)

Results for physical fatigue also showed that the chronotype effect was maintained, $F(1, 256) = 5.57$, $p = .019$, $\eta_p^2 = .032$. However, similarly to what was observed for sleep duration, only the simple effect for the 13h-17h time window remained significant, $F(1, 240) = 5.97$, $p = .015$, $\eta_p^2 = .024$. To further explore the absence of an effect of chronotype in the 21h-6h time window, simple effects of chronotype on RT with ToD as moderator and physical fatigue as a breaking variable (Mean±1SD) were performed. Results showed a chronotype effect on RT in the 21h-6h time window only for high physical fatigue (Mean+1SD), $F(1, 240) = 7.69$, $p = .006$, $\eta_p^2 = .031$. The model results did not show other main effects or interactions.

4. Discussion

The effect of chronobiological variables on cognitive performance is well established in the literature. However, if for a long time the synchrony effect on cognition was the reality announced by the chronobiological literature (see Schmidt et al., 2007), in more recent years many studies suggesting a superior performance of individuals in a non-optimal time-asynchrony have emerged (e.g., Rothen & Meier, 2016). This dichotomy was also applied to memory performance, with studies showing synchrony in explicit memory tasks and asynchrony in implicit memory tasks (Puttaert et al., 2019). However, studies exploring these effects with a specific focus on memory for faces are scarce (Yaremenko et al., 2021a). Given the major importance of faces in personal, social, and professional contexts, it is relevant to understand how chronobiological variables modulate their processing, especially face recognition. The present study aimed to explore the existence of a possible synchrony effect on famous face recognition performance, controlling the effect of sleep and fatigue variables that may interact with this process, and could confound the results.

4.1 Effect of Chronotype

Unlike what was expected, the most noticeable result of the present study was the presence of a robust effect of chronotype. In fact, the effect of chronotype remained unblemished even after statistical control of sleep quality, sleep duration and mental and physical fatigue. Descriptively, this effect shows that individuals with a stronger eveningness preference (lower rMEQ score) were faster at recognizing famous faces than those with more morningness characteristics (higher rMEQ score). Although this effect was not expected, it is not "startling", as several studies have shown an advantage of evening-types (ETs) in general cognitive performance, measured either objectively or by self-report (Mecacci & Righi, 2006; Nowack & Van Der Meer, 2014; Preckel et al., 2011). One of the possible explanations advanced in the literature for this superiority is called the "training effects hypothesis", which postulates that because ETs are more exposed to discrepancies between internal and social timing, they have to adapt and train to overcome any difficulties (Preckel et al., 2011). Bearing in mind that face recognition is also a cognitive task, the "training effects hypothesis" may help to explain our result. On the other hand, considering the existence of plentiful correlates between chronotype and other individual differences (e.g., Adan et al., 2012), it is possible that this result was dragged by one of these associations or interactions. For example, there is an association between eveningness and depressive symptoms (see Au & Reece, 2017), and people with depressive symptoms devote significantly more hours in a day to watching TV or using a computer (e.g., Madhav et al., 2017). This increased time in contact with digital media might make the ETs more exposed to the faces of celebrities, increasing the memory trait for face details, which might translate into being able to recognize their identity earlier and with less available information.

4.2 Time windows analysis

Although no significant interaction between chronotype and ToD was observed, we attempted to explore this relationship further. When looking at the different time windows, a significant main effect of chronotype was found only for the 13h-17h and 21h-6h time windows.

Both cases confirm that those with higher eveningness preferences (i.e., lower scores on the rMEQ) were definitely faster at identifying the famous faces. The results obtained for these time windows seem to be dragging the main effect obtained and discussed above. Conceptually, the result obtained for the 21h-6h time window seems to mimic a partial synchrony effect. It is not surprising that this time window is difficult for individuals with stronger morningness preference, as this is their non-optimal time window (Correa et al., 2014). In this line, there is evidence that morning-types (MTs) accumulate the homeostatic sleep drive faster during wakefulness, becoming sleepier earlier (Schmidt et al., 2009). In fact, this homeostatic sleep pressure is accompanied by a decrease in cognitive performance and in subjective alertness (e.g., Blatter & Cajochen, 2007), which explains the slowness in individuals with higher morningness preferences in this time window.

Regarding the time window 13h-17h, the results are not related to the synchrony effect as they fall into a suboptimal time-window. Nevertheless, these results may show the greatest "post-lunch dip" effect for individuals with more morningness characteristics. Indeed, the chronobiological literature shows that the "post-lunch dip effect" on cognitive performance was evident for MT, but not for ET (e.g., Horne et al., 1980).

On the other hand, and considering that the descriptive data show a moderate slope (see Figure 1), there is still a methodological-analytical explanation for the significant results in this time window (13h-17h). In fact, this time window, probably because it is intermediate in the day, had the highest proportion of responses (45.6%), so that the result obtained can be explained by the higher statistical power when compared with the other time windows, particularly with the window 21h-6h with 13.9% of the answers (38 participants).

The absence of results in the time window 9h-13h can be explained bilaterally, that is, it is neither an optimal time window for MT, nor is it entirely non-optimal for ET. Even so, as we are facing morning responses, we expected an increase in RT (interpreted as lower face recognition ability) accompanied by an increase in eveningness, which did not happen. This result can be conceptually framed in studies that show that the cognitive performance of ET is more stable throughout the day, while morning types have a decline in performance throughout the day (Maierova et al., 2016; Matchock & Mordkoff, 2009). Despite that, this stability seems to be at the expense of the sleep deficit accumulation during weekdays due to social jetlag, which is commonly recovered over the weekend (Vitale et al., 2015). Furthermore, the absence of responses in the early hours (6h-9h) meant that the ET were not tested at their non-optimal time and therefore we had no chance to rigorously test a synchrony effect for this chronotype.

Still, regarding the analysis of time-windows, when the sleep quality, sleep duration and mental and physical fatigue were statistically controlled, the effects for the time window 13h-17h remained intact. However, the effects for the time window 21h-6h disappeared when controlling for sleep duration and physical fatigue. Indeed, results showed an effect of chronotype on face recognition in the 21h-6h time window only for shorter sleep durations and for high physical fatigue. If the literature shows that morning people accumulate the homeostatic sleep drive faster during wakefulness, they also dissipate it better during sleep (Schmidt et al., 2009; Taillard et al., 2003). Thus, it seems that if the MTs sleep well, they can be as proficient as the ETs, even in non-optimal time windows. Additionally, the existence of MT with low or medium physical fatigue in the time window 21h-6h is not expectable (see Lack et al., 2009), and biological rhythms may have been dragged by the intense social rhythms of contemporary society (e.g., Van Tienoven et al., 2014).

4.3 Interaction chronotype, ToD and mental fatigue

Interestingly, when we tested the interaction between Chronotype and ToD, controlling for mental fatigue, we got a triple interaction. In exploring this interaction, the results showed that the relationship between ToD and chronotype on face recognition depends on the level of mental fatigue. When mental fatigue is low there were no effects of chronotype on RT in any of the time windows. This result shows the great influence of mental fatigue on RT, which, when nearly absent, makes the effect of the individual difference —chronotype— not apparent. In fact, this effect is supported by a wealth of literature, with authors claiming that mental fatigue is a powerful predictor of slow response times (Fan et al., 2015; Langner et al., 2010).

On the other hand, when mental fatigue was average, the effect of chronotype was observed in the 13h-17h and 21h-6h time windows, and when mental fatigue was high the results showed an effect of chronotype only for the 21h-6h time window. This result can be explained similarly to those found for physical fatigue and sleep duration, showing a potential protective role of nocturnal dissipation of sleep pressure (Schmidt et al., 2009; Taillard et al., 2003). In addition, some of the morning people may already be adjusted to social rhythms (Van Tienoven et al., 2014), going to bed later, and so not feeling mentally fatigued in the typically extreme window for their chronotype.

4.4 Limitations and future research

A few limitations need to be addressed: the fact that participants could complete the task at any ToD led to having a large number of participants doing so during the middle part of the day, in comparison to more extreme ToD. In addition, because we rely on participants' knowledge of the famous individuals depicted, some participants showed a low percentage of correct responses. However, as mentioned above, we have only used RTs from correct responses, so that this effect was diluted. Another problem is that we did not use a within subjects' manipulation in this study, where morning-type participants and evening-type participants could be tested at their optimal and non-optimal times, in a counterbalanced manner. Also, online research suffers from lack of control, albeit providing convenience. Therefore, future research should replicate the present findings, as well as adapt the procedure to a more controlled laboratory setting, preferably using a within-subjects design.

5. Conclusion

This study showed a robust effect of chronotype on face recognition, where individuals with a stronger eveningness preference showed better performance on a famous face recognition task with dynamic stimuli. This effect may be due to the "training effects hypothesis", which postulates that the ET's advantage in the cognitive dimensions may be related to the fact that they have to adapt and train harder to overcome the larger discrepancies between internal and social timing that they experience. However, when we look specifically at the different time windows throughout the day, the effect of chronotype is only verified for the time window 13h-17h, apparently showing a "post-lunch dip effect" associated with stronger morningness, and for the time window 21h-6h, showing an apparent partial synchronization effect. While the effect of chronotype on the time window 13h-17h was maintained even after statistically controlling for sleep quality, sleep duration and mental and physical fatigue, the effect for time window 21h-6h disappeared when controlling for sleep duration and physical fatigue. Still, an effect of chronotype was obtained in the 21h-6h time window for shorter sleep durations and for high physical and mental fatigue. This result may show that when MT sleep well, they dissipate more proficiently the homeostatic sleep pressure and are able to perform at the same level as ET. On the other hand, MTs with low mental and physical fatigue in the 21h-6h time window are likely to have their biological rhythm dragged along by the intense social rhythms existing nowadays. More studies are needed to validate the present results, as well as specifically controlled laboratory studies using a within-subjects manipulation, allowing MT and ET to be tested at their optimal and non-optimal times.

6. Funding

This study was supported by national funds through FCT - Fundação para a Ciência e a Tecnologia, I.P., with the project PTDC/PSI-GER/31082/2017; and by FCT - Fundação para a Ciência e a Tecnologia, I.P., within the William James Center for Research (reference UIDB/04810/2020).

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