# The effects of Chronotype and Social Jetlag on Measures of Executive Functioning

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Abstract

Sleep has an important effect on planning and decision-making abilities, which are integral to daily functioning and quality of life. Cronotype is the propensity to sleep at a particular time during a 24-hour period. Chronotype change across the lifespan, with adolescents and young adults preferring a delayed sleep period, which does not fit with societal norms and often results in social-jetlag. Social-jetlag might impact executive functioning and thus the ability for students to function adequately. As such, the aims of this study are to explore whether 1) there is an interaction effect of chronotype and social-jetlag on tests of executive functioning, and whether 2) there is a difference in executive functioning abilities between those with early and late chronotypes. Thirty-seven university students (mean age= 24.7) underwent an observational cross-sectional study. Measurements included, the Munich Chronotype Questionnaire, the Depression Anxiety Stress Scale, and the computerized tests of Planning (Tower of London) and Decision-making (Iowa Gambling Test). The results of two-way ANCOVAs showed a significant difference in planning, but *not* decision-making between early and low chronotype groups. The results of this study will have great implications for research, practice, and, policy regarding the alteration of college schedules based on students' biological clocks.

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# Introduction

This review will discuss the evidence on the impact of sleep on Executive Functioning (EF) among university students, as well as addressing the main gaps in the literature in relation to the impact of chronotype on EF, and the need for further research.

## Executive Functioning

EF is regarded as the control centre of the brain, which helps the purposeful regulation of one's thoughts and behaviour (Miyake & Friedman, 2012). The term Executive Functioning has been used arbitrary to refer to a broad range of mental processes, such as working-memory, attention, cognitive flexibility, goal-directed behaviour, decision-making, planning, and problem solving (Goldstein, Naglieri, Princiotta, & Otero, 2014). These complex processes are fulfilled by different regions of prefrontal cortex "PFC" (Braun et al., 2015). Since the introduction of the EF by Pribram (1973) at least 33 constructs have been added under the definition of this term, leading to difficulties with operationalization and measurement of EF (Goldstein et al., 2014). Researchers have generally agreed that EF include three basic components; working-memory, inhibition, and cognitive flexibility (Diamond, 2013; Friedman & Miyake, 2017). These components are interlinked, and their simultaneous functioning is at the core of higher-level EF such as, planning, and decision-making (Blair, 2016; Zelazo, 2015). Additionally, a conceptual distinction is made between "hot" and "cold" components of EF. Hot EF, such as decision-making refers to processes that activate the brain regions associated with regulating emotions, and reward system such as, limbic system, and orbito-frontal cortex (Sonuga-Barke, 2005). In contrast, cold EF, such as planning does not involve emotional salience, and activate the dorsolateral regions of PFC (Nejati, Salehinejad, & Nitsche, 2018). The possibility for the existence of separate pathways in the brain suggests the necessity for assessing the hot and cold EF separately (Nejati et al., 2018). Nevertheless, impairments in both hot and cold EF can have detrimental effects' on individuals' daily activities (Gustavson et al., 2017).

Due to critical role of EF in managing daily activities, previous studies have investigated factors that contribute to a decline and/or impairment of EF (Ha, Sohn, Kim, Sim, & Cheon, 2015; Hagen et al., 2016). Previous studies have found associations between impaired EF, and drug/alcohol addiction (Ellis et al., 2016; Yan et al., 2014). Additionally, mood disorders, such as depression and bipolar disorders have been shown to significantly impact components of EF, such as processing speed, and attention (MacQueen & Memedovich (2017). In a large study (N= 83,613) by Lugtenburg et al.(2017), major depression was found to be associated with worse EF in both young and old adults. Moreover, stress and anxiety disorders often co-morbid with major depression and, therefore, have also been found to be associated with impaired EF (Sommerfeldt et al., 2016). Further, Borderline Personality Disorder is shown to have a strong association with deficits in EF, such as planning, and decision-making (McClure, Hawes, and Dadds, 2016). While neuropsychological/neuroscientific studies provide useful insight in relation to factors that impact EF and/or are associated with poor EF, they only include clinical populations. Therefore, such studies do not explain the causes and correlates of impaired EF in non-clinical population.

**Executive Functioning and Sleep**

One factor that is extensively reported to be associated with EF is age. Albinet, Boucard, Bouquet, and Auiffren (2012) revealed significant differences between healthy young (18-32) and older adults (65-80) in their EF abilities, such as inhibition, and processing speed; the study concluded a detrimental effect of age on all measures of EF. In contrast, studies have provided evidence that shows the recruitment of compensatory mechanisms in healthy older adult; that is, a bilateral activation of PFC has been observed in older adults when completing tasks of EF, and no difference was shown in EF abilities between younger and older adults (Kirova, Bays, & Lagalwar, 2015). When investigating EF, it is generally recommended to consider the effect of age on EF; the age range used for studying EF in younger adults is 18-35 (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Springer et al., 2006). While, the findings on the association between age and EF are inconsistent, a factor that might explain this association is Poor sleep-quality (PSQ). Evidence suggests that PSQ maximizes the risk of EF deficits in older adults compared to younger adults (Landry, Best, & Liu-Ambrose, 2015). This is due to increased sleep disturbances which occur as the function of normal ageing (Crowley, 2011).

PSQ such as sleep disturbances, insufficient sleep duration, and irregular sleep time could possibly explain impaired EF in non-clinical population (Kuula et al., 2015). Generally, PSQ in non-clinical population refers to irregular sleep schedule, chronic sleep loss, sleep restriction, inadequate sleep duration, sleep deprivation, sleep disturbances e.g., snoring, and pain, non-refreshing sleep, and non-restorative sleep (Ohayon et al., 2017). There are theoretical frameworks that explain how sleep restriction and/or sleep deprivation can have detrimental effects on EF (Raven, Meerlo, Van der Zee, Abel, & Havekes, 2018). Based on the Frontal Lobe Hypothesis, PSQ directly impacts the frontal lobe by creating temporary structural and physiological alterations in Cerebral Metabolism i.e., inhibition of synaptic plasticity and changes in synaptic homeostasis; this ultimately leads to EF deficits (Gorgoni et al., 2013; Horne, 1993; Raven et al., 2018). Pasula et al. (2018) provided evidence for the Frontal Lobe Hypothesis through finding an association between sleep deprivation and decreased performance of the neuropsychological tasks involving PFC in healthy adults. Furthermore, a neuroimaging study by Ma, Dinges, Basner, and Rao (2015) provided evidence of a relationship between acute sleep loss and reduced activation of the PFC.

In contrast to the Frontal Lobe Hypotheis, Kusztor et al. (2019) showed that 24-hour sleep deprivation led to the decrement of sustained-attention, which subsequently led to a gradual breakdown of higher-level EF. The experiment by Kusztor et al (2019) provides evidence for the Vigilance Model of Attention which proposes that sleep loss initially causes deficits in attention, through which a deficit in higher-level EF occur (Doran et al., 2001). Mellor, Bucks, McGowan, and Waters (2018) tested both the Vigilance Model and the Frontal Lobe Hypothesis, and suggested that night-time sleep efficiency, and duration did not predict EF performance, instead daytime-sleepiness predicted attention deficits and subsequent EF deficit. However, the EF was assessed using self-reported measure rather than an objective neuropsychological assessment; self-reported measures of EF have been criticized as EF can be only measured directly through task performance (Buchanan, 2016). Furthermore, no explanation was given as to what led to daytime-sleepiness –if not short sleep duration– (Mellor et al., 2018).

**Sleep Quality in University Students**

Frequent sleep disruption and restriction are common issues for most individuals in modern society (Furtado, Bruno da Silva, Abranches, Abrantes, & Forner-Cordero, 2016). However, one specific population at high risk for PSQ is university students. University students sacrifice sleep to attend morning classes, balance college, work, social-life, and leisure-time (Owens, 2014). Lund, Reider, Whiting, and Prichard (2010) found that emotional and academic stress were significant predictors of PSQ in university students. Additionally, a meta-analysis involving N=112939 students found that 23.6% of students suffered from insomnia symptoms and 20.3% reported PSQ (Li et al., 2018). According to Carter, Chopak-foss, and Punungwe (2017), most students who experience PSQ, do not get the minimum amount of recommended sleep (only 8.1% reported sleeping 8.5 hours or more); additional findings showed a strong association between sleep duration and overall perceived sleep-quality in students. These findings are especially important, as the recommended sleep for university students (aged 18-35) is 8.5-9.5 hours per night; while, 7-9 hours for their non-student peers. This is to ensure an optimum level of functioning in students (Hirshkowitz et al., 2015). The adverse effects of PSQ on EF among university students are well recognized (Anderson, Strofer-Isser, Taylor, Rosen, & Redline, 2009). Evidence from randomized-control trials have shown that 24-hour sleep deprivation in students led to decrements in the accuracy and reaction-time of EF components, but not in those in non-experimental group (Couyoumdjian et al., 2010; Taheri & Arabameri, 2012). In contrast,Tucker et al. (2010) reported no difference in EF performance between experimental and control groups following 51-hour sleep deprivation. The first explanation for the inconsistency of these results is that experiments, such as the one by Tucker et al. (2010) have measured the components of EF individually through tasks of working-memory, attention, inhibition, and cognitive flexibility. These components are regarded as the low-level EF and can be preserved during sleep loss through neural compensatory response (Honn, Hinson, Whitney, & Van-Dongen. However, for higher-level Executive Functions to occur, the lower-level Executive Functions must work simultaneously which can lead to decreased working-memory capacity, and can ultimately decline higher-level EF, such as planning and decision-making (Frenda & Fenn, 2016). Normal EF is critical for managing college and personal activities in students; two particular aspects of EF for academic success and general well-being in university students are the ability to plan and make decisions (Robin, Fogel, & Nutter-Upham, 2011. In their study Robin et al. (2011) found that poor planning and decision-making were significant predictors of procrastination, and poor academic performance. Therefore this study focuses on the planning and decision-making abilities, as the two important aspects of EF in university students.

**Decision-making and Sleep quality**

Decision-making is the ability to select one option among many possible alternatives using attention, inhibition, working-memory, and judgement, and consideration of cost/benefit ratio (Buelow, Hupp, Proter, & Coleman). However, Ouerchefani et al. (2018) found no association between working-memory and decision-making. According to the Supervisory Attentional System proposed by Shallice et al. (2002), attention has an important role in decision-making. When encountering a novel situation, attention acts as a mediator to facilitate inhibition when making decisions in unfamiliar situations. Deficits in Supervisory Attentional System are associated with executive disorders, such as disinhibition (Shallice at al., 2002). Decision-making is commonly measured using Iowa Gambling Task developed by (Bechara, Damasio, Damasio, and, Anderson 1994). The initial trials are performed under the condition of uncertainty however, those without decision-making impairments learn to avoid punishment and gain long-term positive reward (Brevers, Bechara, Cleeremans, & Noel, 2013). In an experiment by Furthre, Killgore, Balkin, and Wesensten (2006) 49-hour sleep deprivation led to impaired decision-making and increased risk-taking behaviour. Similarly, Boyson and Kagan (2016) reported a significant relationship between PSQ and maladaptive career decision-making, after controlling for emotional-state, however the correlation was small. In contrast, Schaedler et al. (2018) found no effect of acute sleep restriction on decision-making among university students (aged 18-35). Despite the importance of decision-making in university students, studies on the effect of PSQ on decision-making in students are scarce, and more investigations are required.

**Planning and Sleep quality**

Planning is the achievement of a goal and solving problems through a sequence of predetermined and thoughtful steps which may or may not directly lead towards attaining that goal (Baker et al., 1996). Planning ability is commonly test using Tower of London test which requires the utilization of many interlinked mental skills, such as spatial processing, short-term memory, sustained-attention, recognizing and selecting goals, generating and implementing plans (Shallice, 1982; 2002). Generally, planning abilities are determined by the speed of planning (longer time indicates deliberative planning), and planning accuracy measured by total correct solutions (Deblak, Egle, Kostering, & Kaller, 2016). Planning abilities (measured by planning-time and planning-accuracy) were found to be significantly lower in university students with PSQ compared to those with satisfactory self-reported sleep-quality (Hakimi, Hosseini, & Naderi, 2017). Similarly, Chan (2017) reported an association between PSQ and planning abilities; however, this association was small. The evidence on the effect of PSQ on planning is inconsistent; Pace-Schott et al. (2009) failed to find deficits in planning/problem-solving following 24-hour sleep deprivation in university students, and suggested that only chronic sleep loss is associated with such deficits.

**Current Study**

While some studies show that PSQ leads to poor planning and decision making, other studies fail to do so; therefore, it still remains unclear as to what drives this association, even after controlling for stress, anxiety, and depression (Benitez & Gunstad, 2012). One potential candidate factor for explaining this association is chronotype. Chronotype is defined as one’s preferred timing for sleep and activity which is determined by biological/genetic factors, and are synchronized by zeitgebers (light) (Wittman, Dinich, Merrow, & Roennberg, 2006). There is a huge variation in individuals’ chronotype ranging from very early to very late

(Roenneberg, 2012). In university students, irregular and early class schedules lead to a disruption of chronotype, subsequent sleep-debt over the workdays, for which they compensate on free-days (McMahon et al., 2018). Particularly, students with late chronotype exhibit a huge circadian misalignment between their sleep timing on workdays compared to free-days, that is comparable to jetlag; therefore, the difference between social clock and biological clock is called social-jetlag (Silva et al., 2016; Wittman et al., 2006). Typical early morning college schedules are suitable for those with early chronotype; thus students with late chronotype suffer from poorer sleep quality and more day time sleepiness (Hershner & Chervin, 2014; Vitale, 2015; Wittmann et al., 2006). Although, there is an association between social-jetlag, and chronotype; social-jetlag is independent of chronotype (Silva et al., 2016). This indicates that an individual with late chronotype may not be socially-jetlagged, however, can still have poor EF; the explanation for this is that individuals with late chronotype are less exposed to sun (natural zeitgeber) compared to individuals with early chronotype as they wake up later (Roennberg, & Merrow, 2007). Exposure to day-time light has been found to be associated with improved EF and sustained-attention (Munch, Linhart, Borisuit, Jaeggi, & Scartezzini, 2012). Additionally, Roenneberg et al. (2007) suggest controlling for age when investigating chronotype; in their study Roennberg and colleagues found that chronotype is significantly dependent on age, reaching at the peak of “lateness” at age of 20, and gradually becoming earlier as age increases.

**Aims and Hypotheses**

When investigating the association between EF and sleep, it is more appropriate to investigate the difference in EF between early and late chronotypes; rather than ignoring this well-recognized difference. Therefore, the rationale for the current study is to fill the existing gaps in the literature, as no previous study had looked at the effects of chronotype and social-jetlag on planning and decision-making. This study will investigate the following question "Do chronotype and social-jetlag have impact on EF?" To answer this question this study aims to investigate the effects of chronotype, and social-jetlag on planning and decision-making, after partialling out the effects of age and emotional-state (depression, anxiety, and stress). This study also aims to investigate the difference in EF between early and late chronotypes. The objective of this study is to investigate the interaction effects of chronotype and social-jetlag (using the Munich Chronotype Questionnaire) on scores of EF (using Tower of London, and Iowa Gambling Task), while controlling for age and emotional-state (using the Depression Anxiety Stress Scale) through conducting two-way ANCOVAs. These effects will be explored using a sample of healthy university students (aged 18-35) in Dublin over across 4 weeks of data-collection. Based on the existing theories and empirical evidence the following hypotheses are made:

$H_1$: There will be an interaction effect between chronotype and social-jetlag on overall positive decision-making, after controlling for age and emotional-state. Moreover, individuals with late chronotype will score lower on overall positive decision-making compared to those with early chronotype.

$H_2$: There will be an interaction effect between chronotype and social-jetlag on planning-accuracy, after controlling for age and emotional-state. Moreover, those with late chronotype will score lower on planning-accuracy compared to individuals with early chronotype.

$H_3$: There will be an interaction effect between chronotype and social-jetlag on planning-speed after controlling for age and emotional-state. Moreover, individuals with late chronotype will spend less time to plan compared to those early chronotype.

# Methods

## Participants

The desired sample size as indicated by a priori power analysis for ANCOVA (with two levels and two covariates), with an alpha of 0.05, a power of 0.80, and a medium effect size ($f$ = 0.25) was 179 (Faul, Erdfelder, Buchner, & Lang, 2019). Thirty-seven college/university students were recruited into the study through advertisement on social media and distribution of posters at National College of Ireland. Two participants were excluded from the analysis due to providing incomplete data, therefore, a total of ($N$ = 35) participants were included in the analysis. The sample included female (62.9%, $n$ = 22) and male (37.1%, $n$ = 13), and the age was ($M$ = 24.5, $SD$ = 4.4). Participants were recruited using a non-probabilistic convenience sampling. The criteria for inclusion in the study were as follows: college/university student (aged 18-35), and ability to speak/write fluently in English. The exclusion criteria were as follows: individuals with Clinical Sleep Disorders e.g., insomnias, narcolepsy, sleep apnea and so on; individuals with clinical depression, severe intellectual and learning disabilities, Attention-deficit/hyperactivity disorder, and brain injuries, individuals with physical illnesses that could interfere with sleep habits, such as Asthma, Kidney Disease, and Heart Failure (See Appendix A).

## Design

The research design of the current study was a 2x2 between subject, observational cross-sectional, as the variables of interest including chronotype, social-jetlag, positive decision-making, planning-accuracy, and planning-speed were measured naturally in a non-manipulative non-experimental manner, and at one point at time. Although the study investigated the difference between early chronotype, and late chronotype on measures of EF, the groups were not pre-determined, and were initially measured continuously. The independent variables (IVs) for the first, second, and third hypotheses included chronotype with two levels of early and late, and social-jetlag with two levels of low and high. The dependent variable (DV) for the first hypothesis was overall positive decision-making. The DV for the second hypothesis was planning-accuracy, and the DV for the third hypothesis was planning-speed. The two covariates for the first, second, and third hypotheses were emotional-state and age.

## Materials

### *Apparatus*

The apparatus required for this study included a printer for printing the posters, information/invitation sheet, informed-consent, and debriefing sheets, Munich Chronotype Questionnaire, Depression Anxiety Stress Scale, and demographic questionnaire. A laptop was used to present the two Executive Functioning tests of Tower of London and Iowa Gambling task using the Inquisit Lab (2016, Version 5.0.11). Additional material included pens, and a computer mouse. Additionally IBM SPSS (2017, Version 25.0) was used for all statistical analyses. Additionally a demographic questionnaire was used to record the participants age and gender (See Appendix B).

### *Iowa Gambling Task*

Iowa Gambling Task (IGT; Bechara et al., 1994) was used to assess decision-making. IGT is a gambling task in which participants are initially given a loan of $2,000 to start with and increase their profit by selecting cards from four decks (A, B, C, and D). Each card holds a win value of either $50 or $100; however, some cards also hold a loss value/penalty ranging from $5o to $1250. The current study used a computerized version of original IGT with 100 trials (Bechara et al., 1994) using Inquisit Lab (2016, Version 5.0.11). Decks A and B were considered as disadvantageous choices in long-term as they provide high immediate rewards but also high penalties. In contrast, Decks C and D were considered as advantageous cards in long-term as they provide low immediate rewards and low penalties. The data obtained from IGT included: Total Count Advantageous (total number of advantageous selection, Total Count Disadvantageous (total number of disadvantageous selection) and Positive Net (overall more positive decision-making = *Total Advantageous – Total Disadvantageous*). The current study used the Positive Net (overall more positive decision-making), as it has been commonly used in previous studies (Meshi, Elizarova, Bender, & Verdejo-Garcia, 2019). IGT has been shown to have adequate test-retest reliability in non-clinical population (Schmitz, Kunina-Habenich, Hildebrandt, Oberauer, & Wilhelm, 2018).

*Tower of London Test*

The computerized version of Tower of London (ToL; Shallice, 1982) was used to assess planning-accuracy and planning-speed. ToL is extensively used to test planning abilities in healthy population (D'Antuono et al., 2017; Zimmer et al., 2017). The computerized version of ToL (Inquisit Lab, 2016, Version 5.0.11) consisted of three pegs with different heights. There were 12 trials in ToL which incorporated a range of difficulty levels. The maximum possible score for ToL is 36. ToL produces many outcome measures including a total score, solution-time, execution-time, total correct trial, and total failed attempts. The first variable of interest in this study included the total score which measures the accuracy of planning (higher scores in ToL indicates efficient planning). The second variable of interest in this study was the time spent to plan before executing a move; therefore, the planning-speed was calculated by subtracting *mean execution time* from *mean solution time.* The ToL test has been shown to have adequate internal reliability ($\alpha$ = .69) and adequate split half reliability (r - .72) among healthy university students.

*The Munich Chronotype Questionnaire*

The Munich Chronotype Questionnaire (MCTQ; Roenneberg, 2015; Roenneberg et al., 2003) was used to measure chronotype and social-jetlag. As shown in Appendix C, the MCTQ consists of two separate sections for workdays and free-days. The “workdays” in the current study was modified to college days. Each section includes 7 questions related to sleep timing during past month. The variables measured by MCTQ include: Local bed time, local sleep preparation time, sleep latency, sleep end, alarm clock use, sleep inertia, and number of work and work-free days per week (in this case college, and college-free days). MCTQ has been shown to have excellent concurrent validity when compared against the Horne-Östberg's morningness-eveningness questionnaire in a large sample of university students (Zavada et al., 2005). Furthermore, a strong association has been reported between mid-point sleep as measured by MCTQ and mid-point sleep measured by wrist actigraphy ($r = 0.73$, $p < 0.001$); suggesting that MCTQ can be used as a reliable measure for calculating chronotype and social jetlag (Santisteban, Brown, & Gruber, 2018). The MCTQ is not a scale; therefore, its internal reliability cannot be examined (Di Milia, Adan, Natale, & Randler, 2013).

The computation of chronotype and social-jetlag involved a series of steps explained by (Roenneberg, 2015). In order to compute chronotype, the first step involved calculating, the sleep onset for workdays, sleep onset for free-days, sleep duration for workdays, sleep duration for free-days, and average weekly sleep duration were calculated; the formulas are as follows: ($\textit{Sleep Preparation}_{\text{weekdays}} + \textit{Sleep Latency}_{\text{weekdays}}$); ($\textit{Sleep preparation}_{\text{free-days}} + \textit{Sleep Latency}_{\textit{free-days}}$); ($\textit{Sleep End}_{\text{workdays}} - \textit{Sleep Onset}_{\text{weekdays}}$); ($\textit{Sleep End}_{\text{free-days}} - \textit{Sleep End}_{\text{free-days}}$); ($\textit{Sleep Duration}_{\text{workdays}} \times \textit{Number of workdays} + \textit{Sleep Duration}_{\text{free-days}} \times \textit{Number of Free-days}$)/7) respectively. Second, Mid-sleep for workdays and free-days were calculated based on the following formulas: ($\textit{Sleep Onset}_{\text{workdays}} + \textit{Sleep Duration}_{\text{workdays}}/2$);

(*Sleep Onset* $_{\text{free-days}}$ + *Sleep Duration* $_{\text{free-days}}$/2) respectively. Lastly, Chronotype was only computable if participants did not use Alarms to wake up on free-days; this was to ensure the natural Sleep End, the formula for calculating chronotype is as follows: (If *Sleep Duration* $_{\text{free-days}}$ ≤ *Sleep Duration* $_{\text{workdays}}$; then, *Chronotype = Mid sleep* $_{\text{free-days}}$); [(If *Sleep Duration* $_{\text{free-days}}$ > *Sleep Duration* $_{\text{workdays}}$; then, *Chronotype = Mid Sleep free-days* – (*Sleep Duration* $_{\text{free-days}}$ – *Average Weekly Sleep Duration*)/2 ]. Lastly, social-jetlag was calculated using the following formula |*Mid sleep* $_{\text{free-days}}$ – *Mid Sleep* $_{\text{workdays}}$ |.

*The Depression Anxiety and Stress Scale*

The short version of Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was used to assess anxiety, stress, and depressed mood – collectively referred to as emotional-state throughout the paper for easier reading– during past month. DASS-21 consists of three seven-item subscales that measure Stress, Depression, and Anxiety respectively (See Appendix D). Participants rated 21 items on a 4-point Likert scale ranging from 0 (*did not apply to me at all*) to 3 (*applied to me most of the time*), higher scores represented higher negative symptoms. The scores from stress, depression, and anxiety subscales were added to obtain the total emotional-state score ranging from 0 to 126. Based on the recommendation of Lovibond and Lovibond (1995), scores were multiplied by 2 to make them equivalent to the 42-item Depression, Anxiety, and Stress Scale. DASS-21 is a well-established measure of emotional-state in non-clinical population with excellent psychometric properties (Sinclair et al., 2012). In a sample of university students (aged 18-35) the internal consistency for the stress, depression, and anxiety were established as ($\alpha$ = .88; $\alpha$ = .85; $\alpha$ = .81), respectively (Osman et al., 2012). Furthermore, the internal consistency for total scale had been shown as $\alpha$ = .92 (Wang et al., 2016). The scale also has adequate test-retest reliability (Wang et al., 2016) good construct validity, as well as good convergent and discriminant-validity when compared with other measures of stress, anxiety, and depression in non-clinical population (Henry & Crawford, 2005). The internal reliability of total DASS-21 and subscales for the current sample were high as determined by Cronbach's alpha: (α = .89) for stress subscale, (α = .93) for depression subscale, (α = .87) for anxiety subscale, and (α = .93) for the total scale (emotional-state).

**Procedure**

The permission to conduct this study was obtained from National College of Ireland Ethics Committee. The data for the current study was collected over the course of 4 weeks. Advertisement flyers (Appendix E) were distributed at National College of Ireland with the researchers' contact detail. Invitation letter/information sheets (Appendix A) were sent to the individuals who expressed their interest in participating; time and place arrangements were then made based on the participants' availability. One participant at a time was brought to the Psychology Lab located at National College of Ireland in order to complete the study. The nature of the study was explained once again to the participants on the day of the study, and informed consents were then obtained (See Appendix F). Participants were advised to wear their contact lenses or glasses if they had visual impairment in order to easily perform the EF tests Participants were first asked to complete the demographic questionnaire, followed by MCTQ and DASS-21. Each questionnaire was adequately explained to participants and questions were answered. Upon completion of the questionnaires, participants were presented by ToL, and IGT respectively (See Appendices G & H for instructions). After completion of the study each participant was debriefed. Participants were informed about their right to withdraw their data before data analysis as their names and ID numbers were recorded in a separate excel sheet. Participants were once again ensured about the anonymity of their data. Each participant was given a debriefing sheet with a list of contact details (Samaritans, Aware, Niteline) in case they felt distressed as the result of the study (See Appendix I). The completion of all tasks, instructions, and debriefing took 25-30 minutes.

# Results

## Descriptive Statistics

Descriptive statistics including means and standard deviations for chronotype, social-jetlag, planning-accuracy, planning-speed, overall positive decision-making, combined depression, anxiety, and stress (emotional-state), and age are presented in Table 1. Preliminary Analysis indicated a few outliers; however, no extreme scores were detected. The distributions of data looked non-normal for emotional-state, and social-jetlag as evident through inspection of histograms and Shapiro-Wilk test of normality $p < 0.05$. However, due to the robustness of Analysis of Covariance (ANCOVA), the assumptions of normality were assumed satisfied as the skew levels were estimated less than i.e., skew < |2.0| and kurtosis levels were estimated less than i.e., kurtosis < |9.0| (Boneau, 1960, p.51; Posten, 1984; Schmider, Ziegler, Danay, Beyer, & Bühner, 2010).  Furthermore, the continuous scores of chronotype and social-jetlag (both computed in hh:mm) were first transformed to decimals time, and were then transformed into dichotomise scores by performing a median split in order to perform ANCOVAs. The frequency data for categorical chronotype, categorical social-jetlag, and gender are presented in Table 2.

Table 1

*Descriptive Statistics of all Continuous Variables*

| Variables | N | Mean (95% CI) | Std. Error Mean | Median | SD | Range | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| Chronotype | 35 | 4.96 (4.26-5.66) | .34 | 5.13 | 2.03 | .42-8.62 | -.29 | -.51 |
| Social-jetlag | 35 | 1.71 (1.32-2.09) | .19 | 1.5 | 1.11 | .25-4.75 | 1.04 | 1.36 |
| Planning-accuracy | 35 | 30.97 (29.72-32.23) | .62 | 31.00 | 3.65 | 21-36 | -.72 | .44 |
| Planning-speed | 35 | 15.14 (13.45-16.83) | .83 | 15.82 | 4.92 | 3.38-23.85 | -.701 | .32 |
| Positive D.M. | 35 | 3.03 (-15.12-21.18) | 8.93 | 6.00 | 52.84 | -90-88 | -.04 | -1.09 |
| Emotional-state | 35 | 55.54 (45.81-65.28) | 4.79 | 60.00 | 28.34 | 10-100 | -.12 | .39 |
| Age | 35 | 24.54 (23.03-26.06) | .75 | 24.00 | 4.41 | 18-35 | .66 | -.26 |

*Note.* CI= Confidence Interval; Std. = Standard; SD= Standard Deviation; Positive D.M. = Positive Decision-making

Table 2

*Information regarding all categorical variables*

| Variable | Frequency | Valid Percentage (%) |
|---|---|---|
| **Gender** | | |
| Male | 13 | 37.1 |
| Female | 22 | 62.9 |
| **Categorical Chronotype** | | |
| Early Chronotype | 18 | 51.4 |
| Late Chronotype | 17 | 48.6 |
| **Categorical Social Jetlag** | | |
| Low Social Jetlag | 18 | 51.4 |
| High Social Jetlag | 17 | 48.6 |

**Inferential Statistics**

Three separate two-way ANCOVA were performed to test the three main hypotheses. The assumption of multicollinearity of covariates was assessed by a Pearson's product-moment correlation, and was assumed satisfied as there was no statistically significant correlation between age and emotional-state, and the strength of relationship was weak, $r(33) = -.27$, $p = .118$. Furthermore, a Bonferroni correction was made to adjust for the interaction effects within three ANCOVAs ($p = 0.017$). Additionally, a Bonferroni Type Adjustment was applied in SPSS, to adjust for multiple comparisons of the main effects within the dataset; therefore the *p*-value for main effects will remain at 0.05.

*Two-way ANCOVA for the overall positive decision-making*

A two-way ANCOVA was performed to examine the effects of chronotype and social-jetlag on overall positive decision-making, after controlling for age and emotional-state. The linearity assumption was assessed by visual inspection of a scatterplot between emotional state and overall positive decision-making for every combination of the two independent variables. As shown in Figure, the scatterplot looked non-linear for the late chronotype with low social-jetlag group, and early chronotype with high social-jetlag group; however, this was due to the presence of very small numbers of data point (five scores) in these two groups. Furthermore, the linearity assumption between age and overall positive decision-making for every combination of the two independent variables was assumed satisfied, as assessed by visual inspection of a scatterplot (see Figure 2). There was homogeneity of regression slopes between emotional-state and independent variables, and age and independent variables as determined by two separate comparisons between the two-way ANCOVA model with and without the interaction terms, $F_{emotional\ state}(3, 23) = .465$, $p = .710$; $F_{age}(3,23) = .619$, $p = .610$. There was homoscedasticity within groups, as assessed by visual inspection of the studentized residuals plotted against the predicted values for each group (see Figure 3). There was also homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p = .488$). There were no outliers in the data, as assessed by no cases with studentized residuals greater than ±3 standard deviations. Furthermore, there were no leverage, and no influential points, as assessed by Leverage Values, and Cook's distance respectively. Finally, studentized residuals were assessed by Shapiro-Wilk test, and were normally distributed ($p > 0.05$), with the exception of late chronotype with high social jetlag group ($p = .018$); however, due to the robustness of ANCOVA the normality distribution was satisfactory as skewness and kurtosis were less than |2.0| and |9.0| respectively (Laerd Statistics, 2018; Schmider et al., 2010).

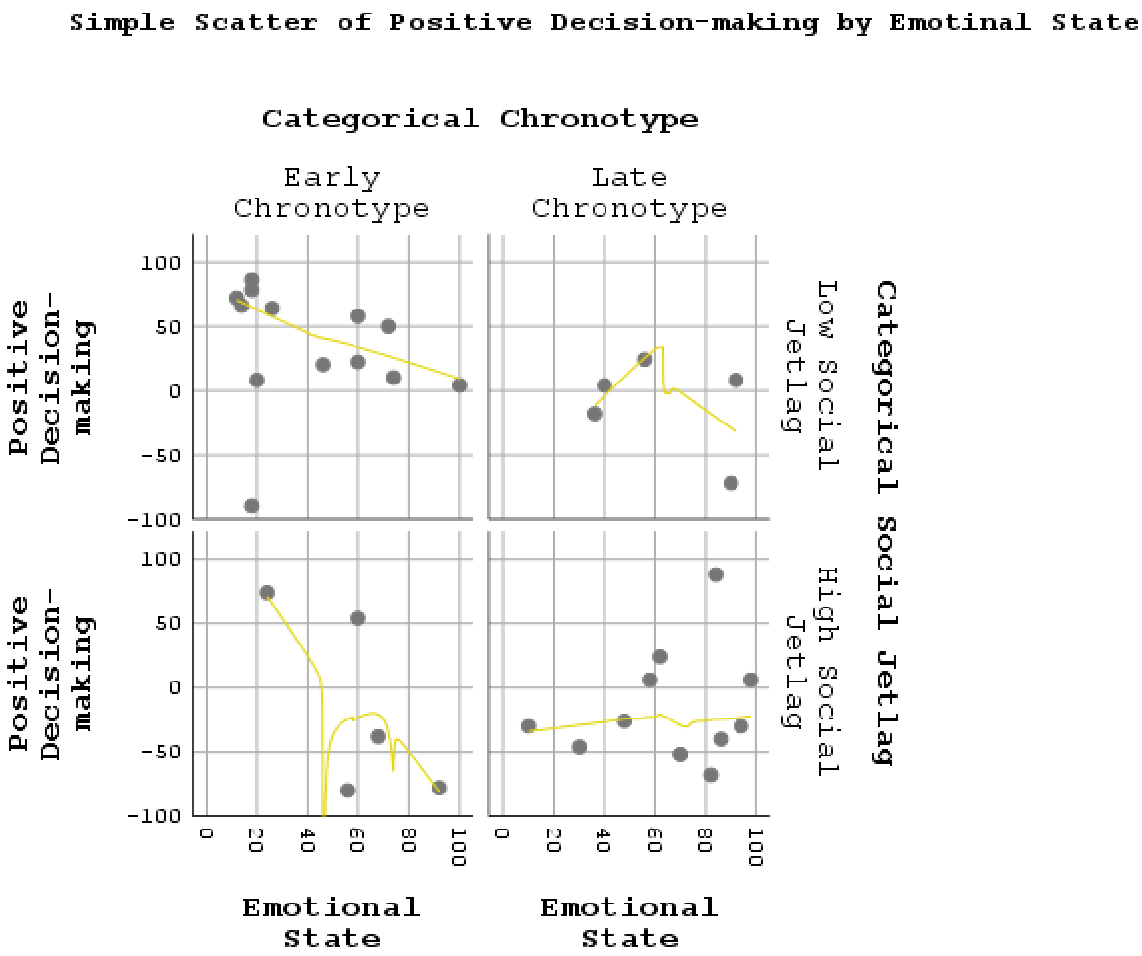


*Figure 1.* The relationship between emotional-state, and overall positive decision-making for each combination of the groups of chronotype and social-jetlag

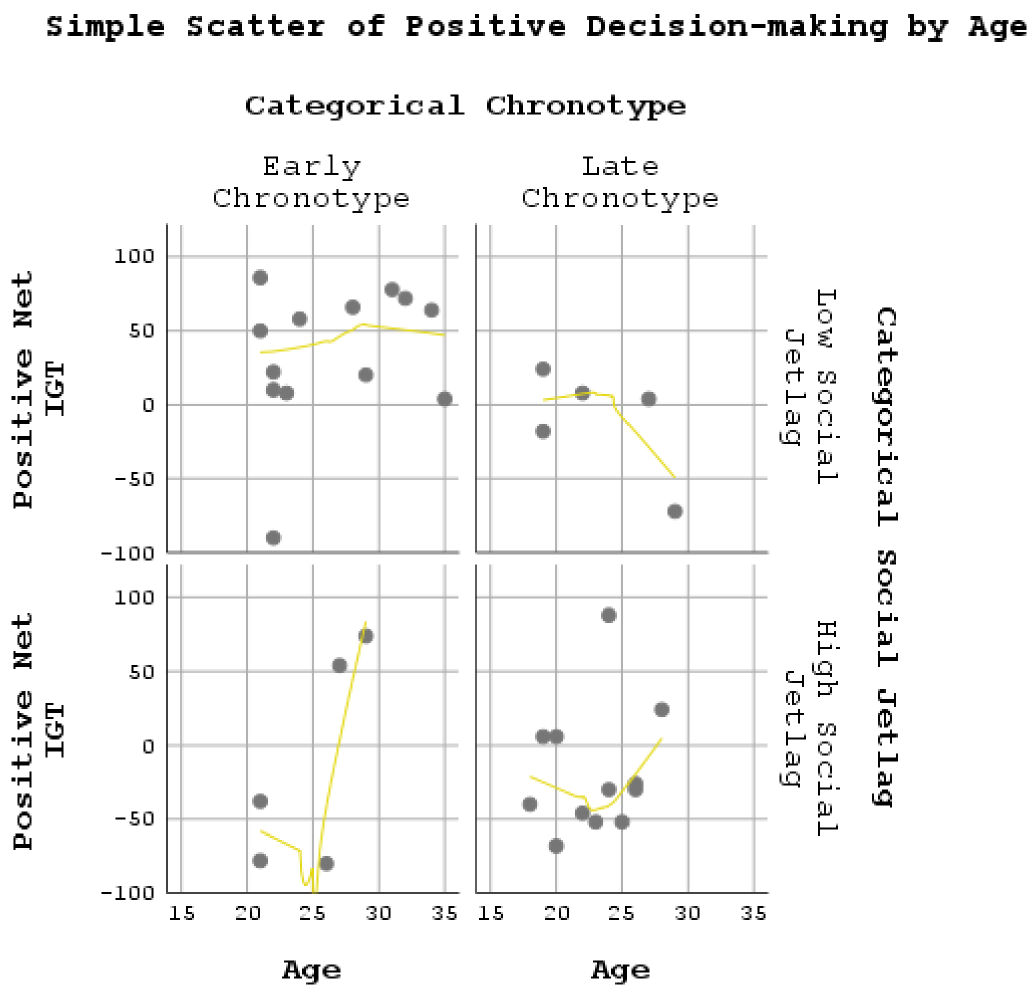


*Figure 2.* The relationship between age, and overall positive decision-making for each combination of the groups of chronotype and social-jetlag

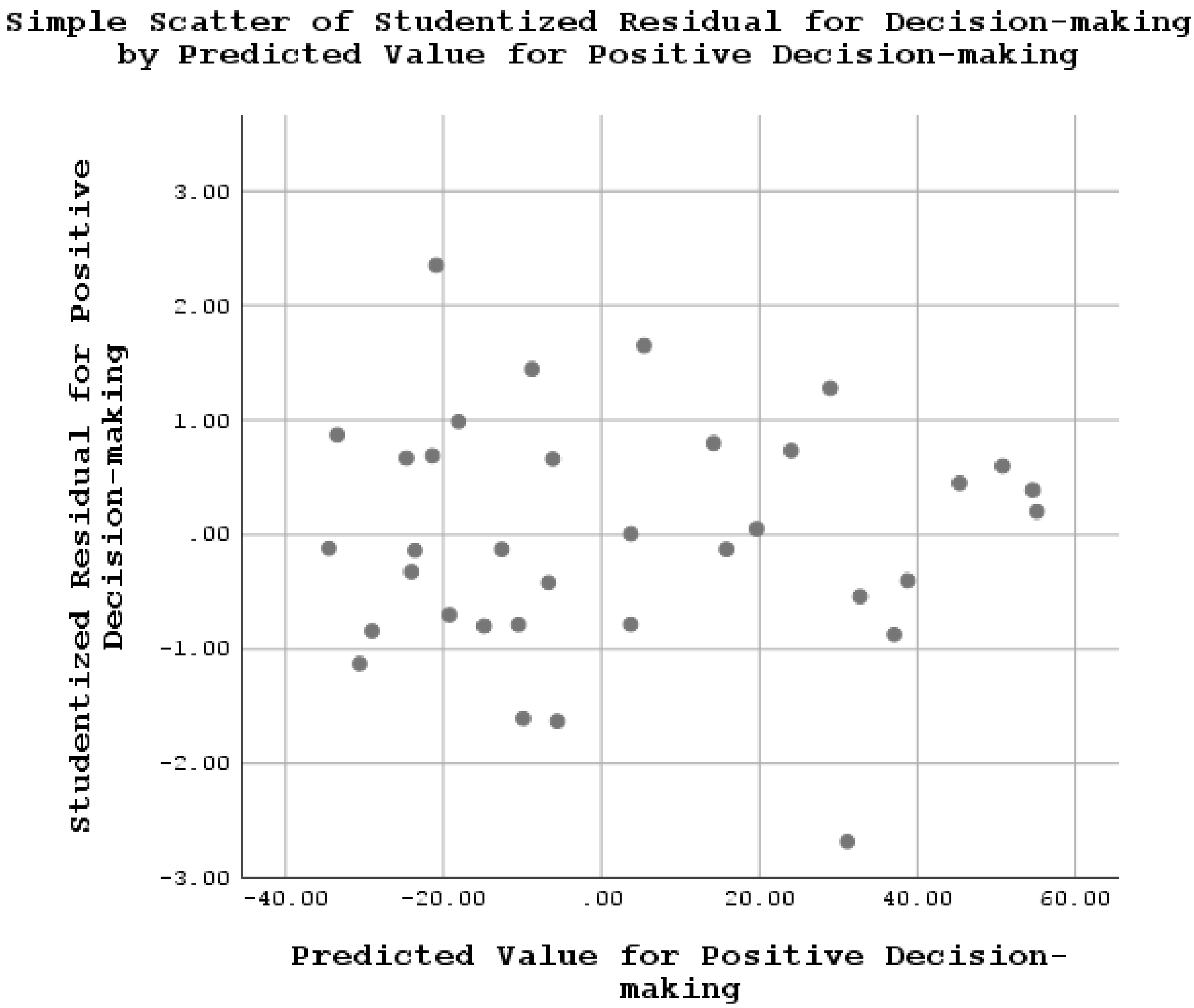


*Figure 3.* The simple scatterplot for overall positive decision-making, indicating no trend in the studentized residuals, and suggesting a random scatter of data points with the same breadth

Means, adjusted means, standard deviations, and standard errors for overall positive decision-making are presented in Table 3. There was not a statically significant two-way interaction between chronotype and social-jetlag on overall positive decision-making, whilst controlling for emotional-state, and age, $F$ (1, 29) = .813, $p$ = .375, partial $\eta^2$ = .027. Therefore, an analysis of the main effects for chronotype, and social-jetlag was performed. The main effect of chronotype did not show a statistically significant difference in the adjusted marginal mean positive decision-making for individuals with early chronotype (6.732) versus individuals with late chronotype (-8.908), 15.641 (95% CI, -23.965 to 55.246), $p$ = .426. There was also not a statistically significant main effect of social-jetlag in the adjusted marginal mean positive decision-making for individuals with low social-jetlag (10.260) compared to individuals with high social-jetlag (-12.435), 22.695 (95% CI, -15.488 to 60.878) $p$ = .234.

*Two-way ANCOVA for the planning-accuracy*

A second two-way ANCOVA was conducted to examine the effects of chronotype and social-jetlag on planning-accuracy, whilst controlling for emotional-state and age. There was a linear relationship between emotional-state and planning-accuracy for every combination of the two independent variables, as assessed by visual inspection of a scatter plot; with the exception of early chronotype with high social-jetlag group, which was due to a small number of data points (See Figure 4). Similarly, there was a linear relationship between age and planning-accuracy for every combination of the two independent variables, as assessed by a scatter plot; except the early chronotype with high social-jetlag, and late chronotype with low social-jetlag groups due to a limited number of data points (See Figure 5). There was homogeneity of regression slopes between emotional-state and independent variables, and age and independent variables as determined by two separate comparisons between the two-way ANCOVA model with and without the interaction terms, $F_{emotional\ state}$ (3, 23) = .521, $p$ = .672; $F_{age}$ (3, 23) = 1.305, $p$ = .297. There was homoscedasticity within groups, as assessed by visual inspection of the studentized residuals plotted against the predicted values for each group (see Figure 6). There was also homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p$ = .523). There were no outliers in the data, as assessed by no cases with studentized residuals greater than ±3 standard deviations. Furthermore, there were no leverage, as assessed by leverage values, and no influential points, as assessed by Cook's distance. Finally, studentized residuals were normally distributed, as assessed by Shapiro-Wilk test ($p > 0.05$).

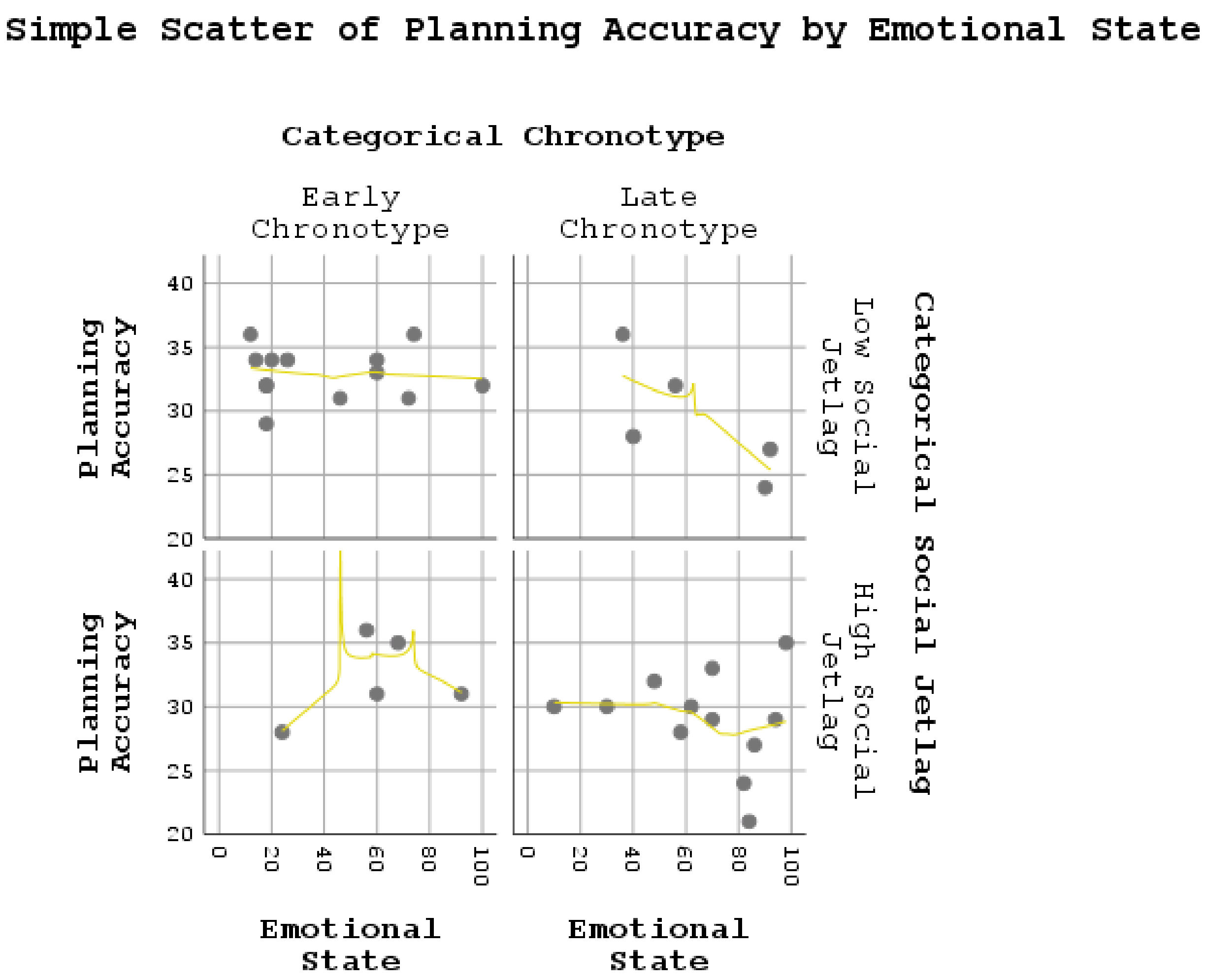


*Figure 4.* The relationship between emotional-state, and planning-accuracy for each combination of the groups of chronotype and social-jetlag

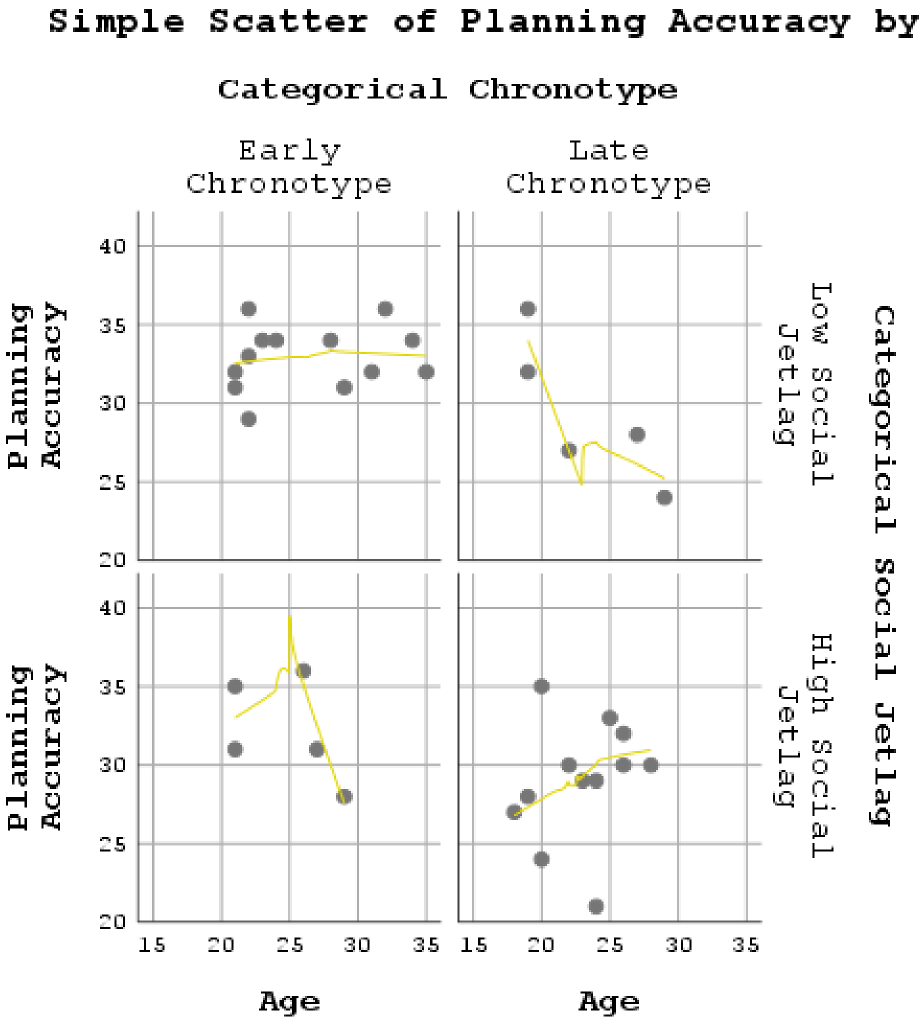


*Figure 5.* The relationship between age, and planning-accuracy for each combination of the groups of chronotype and social-jetlag

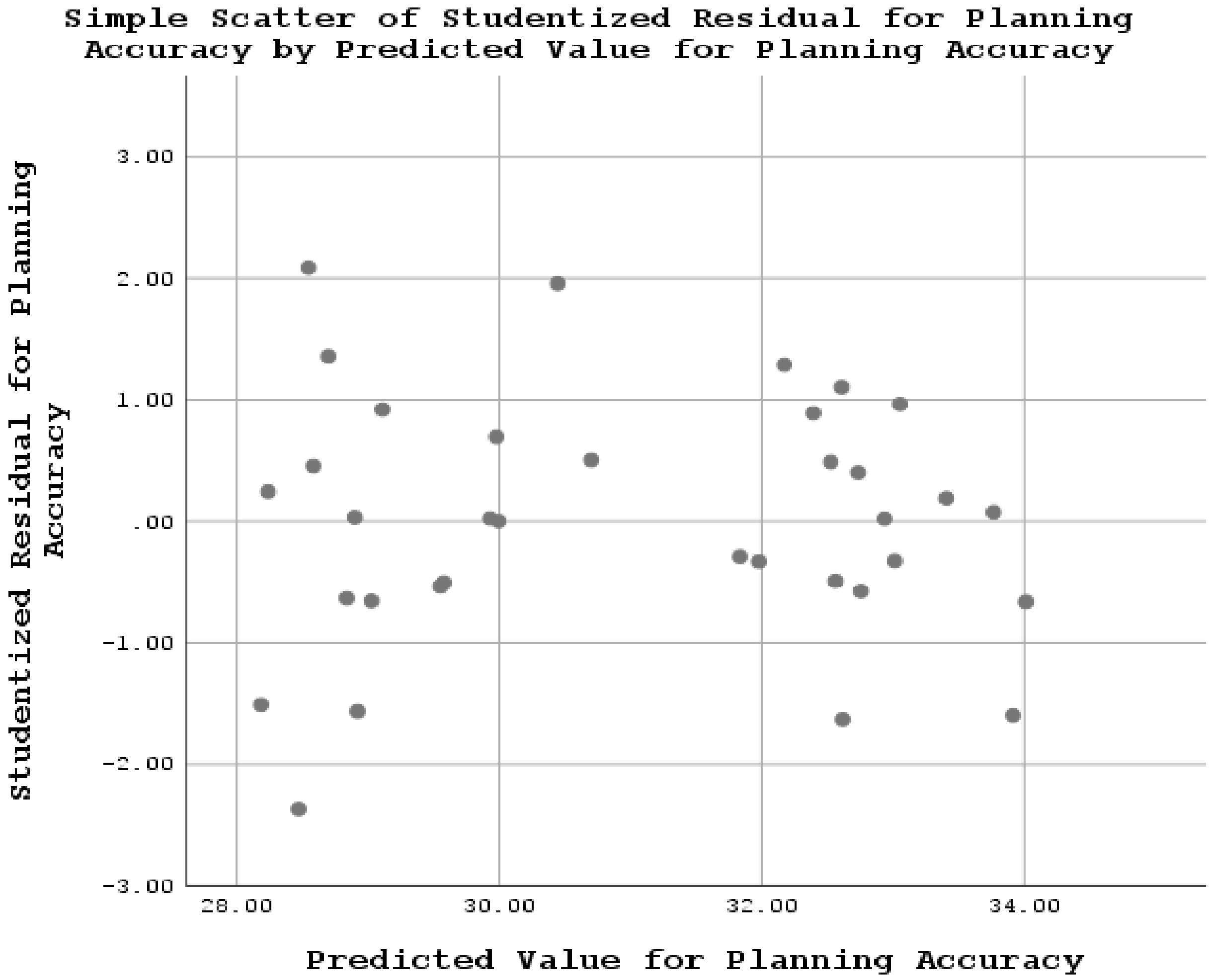


*Figure 6.* The simple scatterplot for planning-accuracy indicating no trend in the studentized residuals, and suggesting a random scatter of data points with the same breadth

Means, adjusted means, standard deviations, and standard errors for planning-accuracy are presented in Table 3. The analysis showed a non-statically significant two-way interaction between chronotype and social jetlag on planning-accuracy, after controlling for emotional state, and age, $F$ (1, 29) = .002, $p$ = .968, partial $\eta^2 <$ 0.001. Therefore, an analysis of the main effects for chronotype, and social-jetlag was performed. The main effect of chronotype showed a statistically significant difference in the adjusted marginal mean planning-accuracy for those with early chronotype (32.557) in comparison to those with late chronotype (29.258), 3.300 (95% CI, .601 to 5.999), $p$ = .018. Figure 7 shows the magnitude of difference in planning-accuracy between high and low chronotype groups. However, there was not a statistically significant main effect of social-jetlag in the adjusted marginal mean planning-accuracy for individuals with low social-jetlag (31.110) compared to individuals with high social-jetlag (30.705), .405 (95% CI, -2.197 to 3.007) *p* = .753.

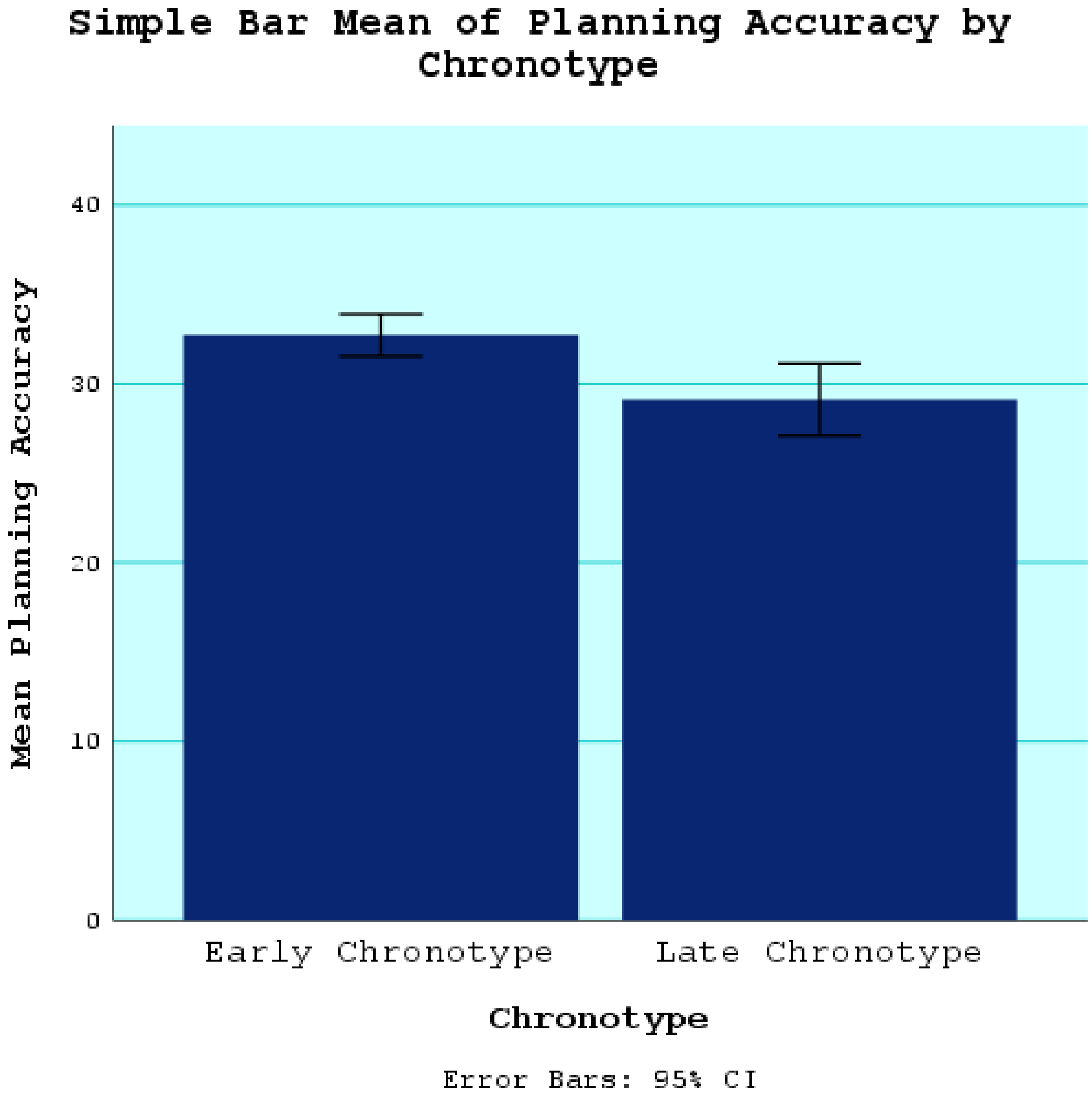


*Figure 7.* Comparison of mean planning-accuracy between early and late chronotype; error bars displaying 95% confidence interval

*Two-way ANCOVA for the planning-speed*

Lastly, a third two-way ANCOVA was conducted to examine the effects of chronotype and social-jetlag on planning-speed, whilst controlling for emotional-state and age. There was a linear relationship between emotional-state and planning-speed for every combination of the two independent variables, as well as a linear relationship between age and planning-speed for every combination of the two independent variables, as assessed by separate scatter plots; however, relationship looked non-linear for the early chronotype with high social-jetlag group, due to a limited number of data points (See Figure 8 & 9 respectively). There was homogeneity of regression slopes between emotional-state and independent variables, and age and independent variables as determined by two separate comparisons between the two-way ANCOVA model with and without the interaction terms, $F_{emotional\ state}$ (3, 23) = .422, $p$ = .739; $F_{age}$ (3, 23) = 1.154, $p$ = .349. There was homoscedasticity within groups, as assessed by visual inspection of the studentized residuals plotted against the predicted values for each group (see Figure 10). There was also homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p$ = .608). There were no outliers in the data, as assessed by no cases with studentized residuals greater than ±3 standard deviations. Furthermore, there were no leverage, as assessed by leverage values, and no influential points, as assessed by Cook's distance. Finally, studentized residuals were normally distributed, as assessed by Shapiro-Wilk test ($p$ > 0.05).

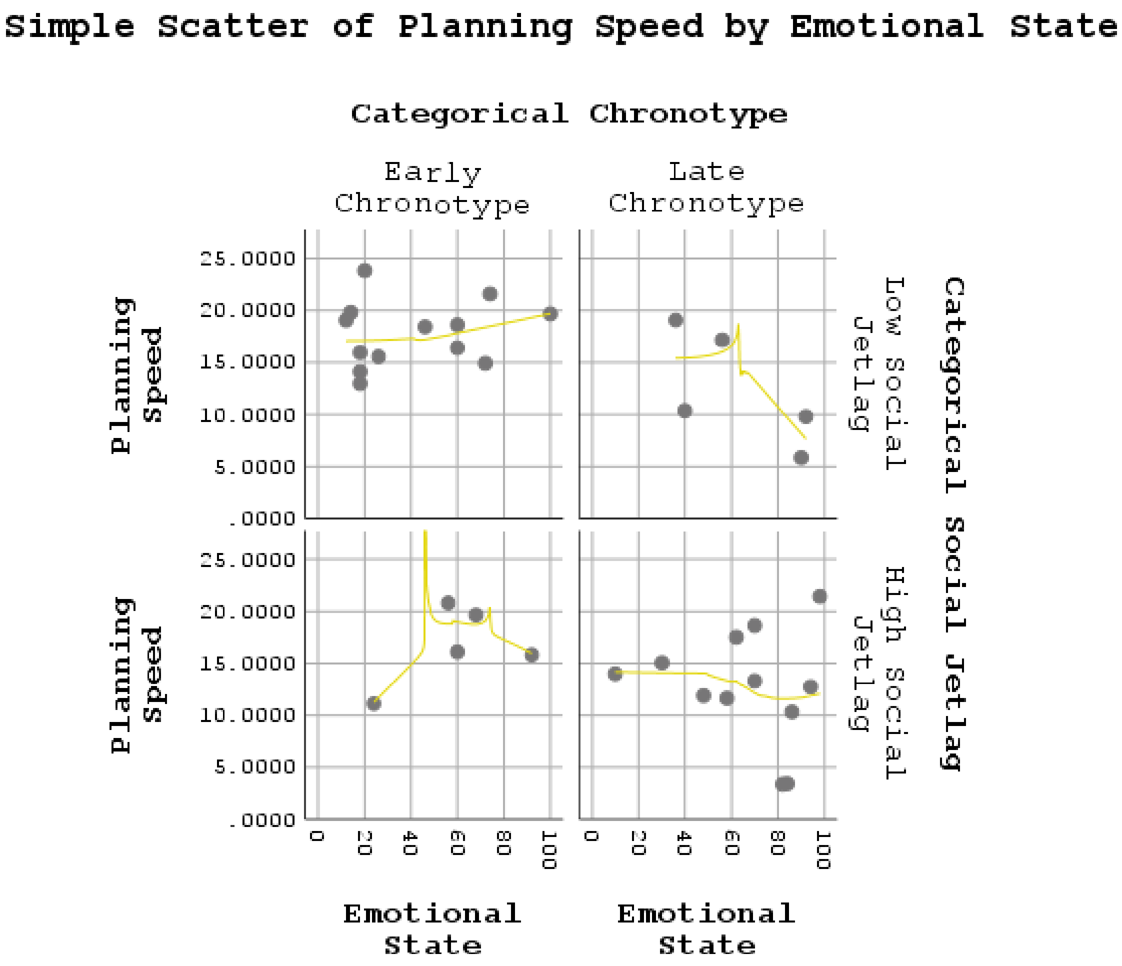


*Figure 8.* The relationship between emotional-state, and planning-speed (measured by seconds and milliseconds) for each combination of the groups of chronotype and social-jetlag

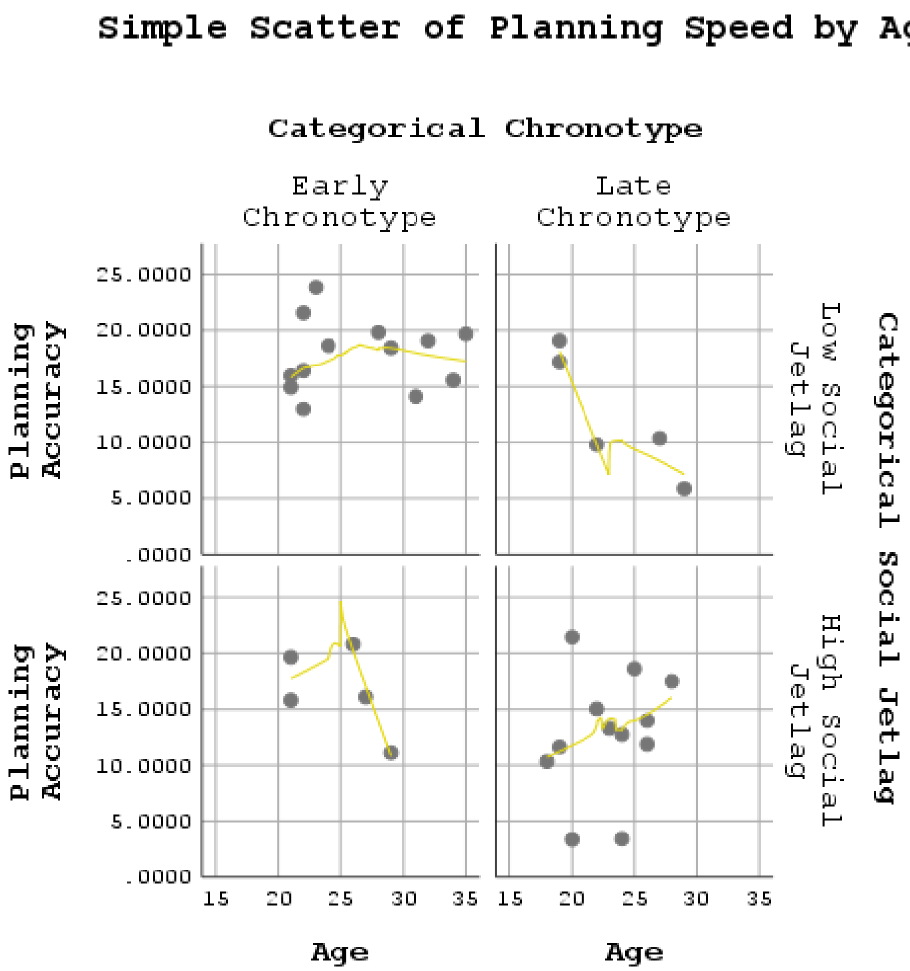


*Figure 9.* The relationship between age, and planning-speed (measured by seconds and milliseconds) for each combination of the groups of chronotype and social-jetlag

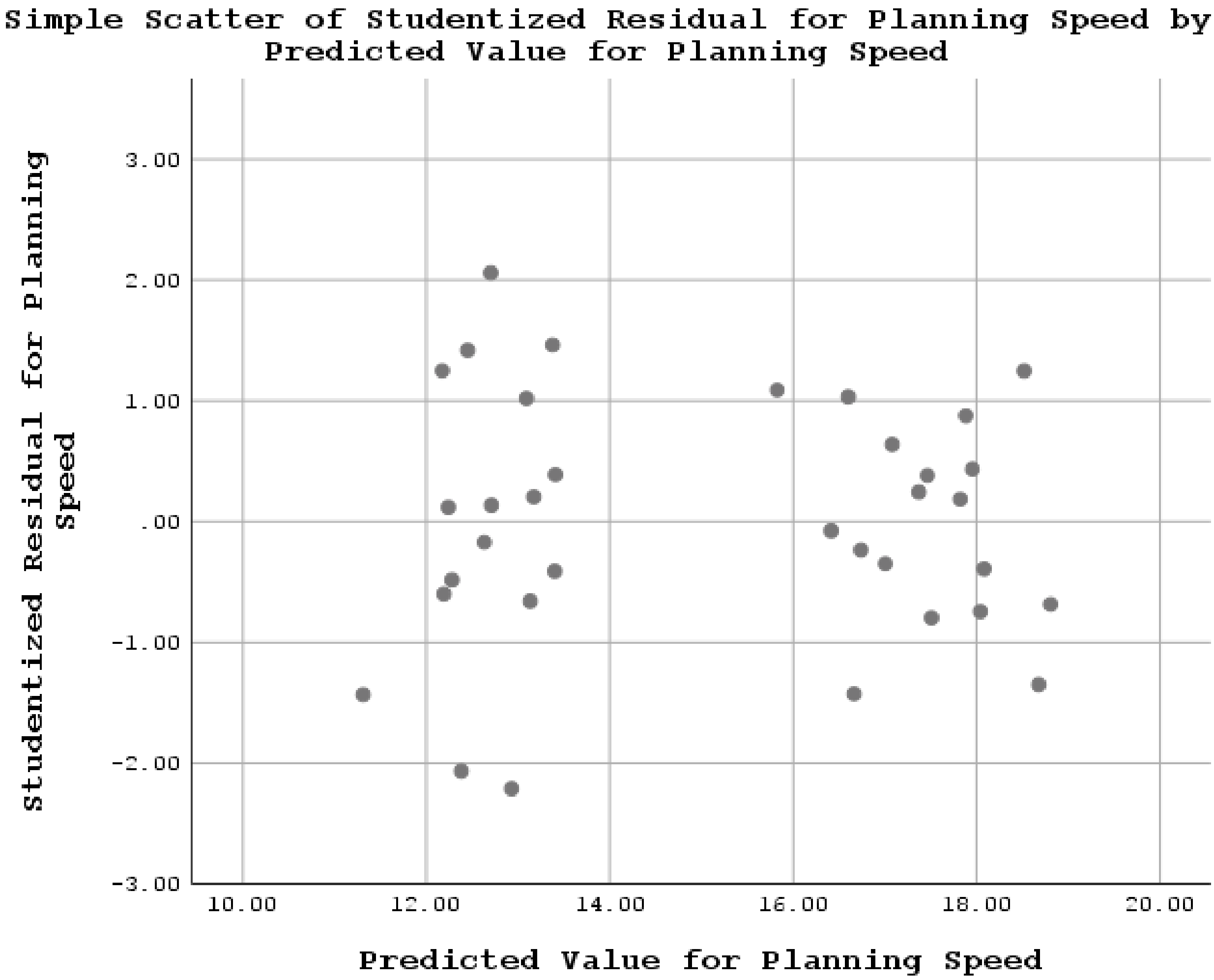


*Figure 10.* The simple scatterplot for planning-speed indicating no trend in the studentized residuals, and suggesting a random scatter of data points with the same breadth

Means, adjusted means, standard deviations, and standard errors for planning-speed are presented in Table 3. The analysis did not show a statically significant two-way interaction between chronotype and social-jetlag on planning-speed, after controlling for emotional-state, and age, $F$ (1, 29) = .153, $p$ = .698, partial $\eta^2$ = 0.005. Therefore, an analysis of the main effects for chronotype, and social-jetlag was performed. The main effect of chronotype showed a statistically significant difference in the adjusted marginal mean planning-speed for those with early chronotype (17.305) compared to those with late chronotype (12.547), 4.758 (95% CI,  1.052 to -8.464), $p$ = .014.  Figure 11 shows the magnitude of difference in planning-speed between early and late chronotype groups.

However, there was not a statistically significant main effect of social-jetlag in the adjusted marginal mean planning-speed for individuals with low social-jetlag (15.097) compared to individuals with high social-jetlag (14.756), .341 (95% CI, -3.231 to 3.914) *p* = .847.

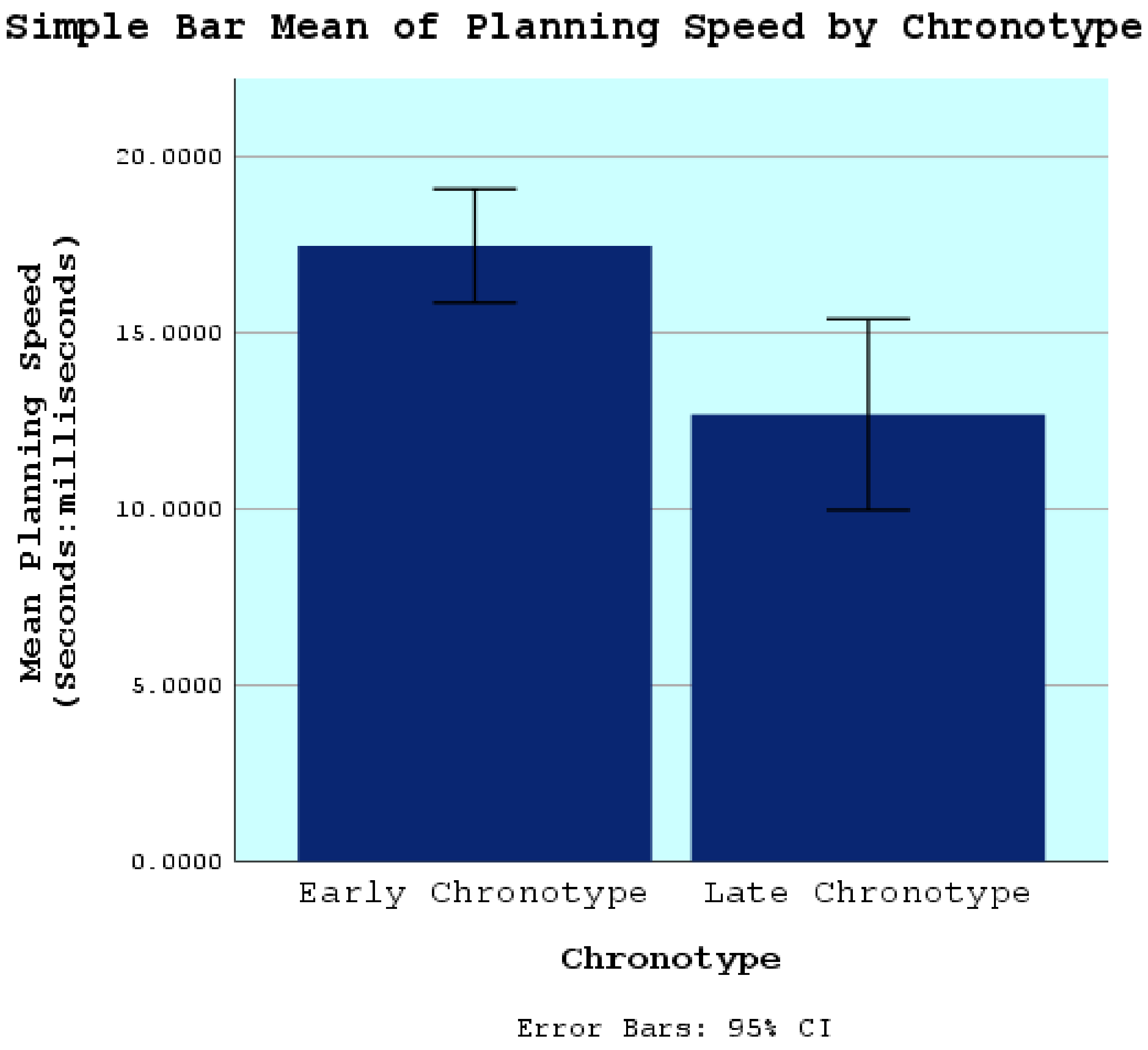


*Figure 11.* Comparison of mean planning-speed between early and late chronotype; error bars displaying 95% confidence interval

Table 3.

*Means, Adjusted Means, Standard Deviations, and Standard Errors for all Dependent Variables for every Combination of the Independent Variables*

| | Early Chronotype | | Late Chronotype | |
|---|---|---|---|---|
| Positive-D.M. | Low Social-jetlag | High Social-jetlag | Low Social-jetlag | High Social-jetlag |
| *M* | 34.46 | -13.60 | -10.80 | -18.33 |
| *(SD)* | (47.175) | (73.135) | (37.352) | (43.257) |
| $M_{adj}$ | 26.41 | -12.94 | -5.89 | -11.93 |
| *(SE)* | (14.659) | (21.900) | (22.097) | (14.770) |
| Planning-accuracy | Low Social-jetlag | High Social-jetlag | Low Social-jetlag | High Social-jetlag |
| *M* | 32.92 | 32.20 | 29.40 | 29.00 |
| *(SD)* | (2.019) | (3.271) | (4.669) | (3.790) |
| $M_{adj}$ | 32.78 | 32.33 | 29.43 | 29.08 |
| *(SE)* | (.999) | (1.492) | (1.506) | (1.007) |
| Planning-speed | Low Social-jetlag | High Social-jetlag | Low Social-jetlag | High Social-jetlag |
| *M* | 17.76 | 16.67 | 12.45 | 12.78 |
| *(SD)* | (3.119) | (3.803) | (5.498) | (5.412) |
| $M_{adj}$ | 17.81 | 16.79 | 12.38 | 12.71 |
| *(SE)* | (1.372) | (2.049) | (2.067) | (1.382) |

*Note.* Positive D.M. = Positive Decision-making

*Summary of the main results*

From the above analyses it can be concluded that the difference between early chronotype and late chronotype groups on their decision-making, efficient planning, and speed of planning did not depend on whether or not individuals had low or high social-jetlag; suggesting that chronotype and social-jetlag are independent of each other. Moreover, on average individuals with early chronotype were able to plan more efficiently/accurately compared to individuals with late chronotype, and individuals with early chronotype on average took longer to plan compared to those with late chronotype. However, there was no difference in overall positive decision-making whether the individuals had early or late chronotypes. Overall, all three measures of Executive Functions remained the same in both low and high social-jetlag groups.

## Discussion

The current study was the first study to investigate the effects of chronotype and social-jetlag on measures of EF, while controlling for the effects of age and emotional-state. The results failed to support the first hypothesis regarding an interaction effect of chronotype and social jet-lag on positive decision-making; furthermore, results failed to find a difference in positive decision-making between individuals with early and late chronotypes. The current results failed to support previous findings by Furthre et al. (2016). However, current findings supported the findings by Schaedler et al. (2018) in that sleep restriction in university students did not affect decision-making. However, the results of this study partially supported the second hypothesis. Although this study did not find an interaction effect of chronotype, and social-jetlag on planning-accuracy; the results supported the hypothesis that individuals with late chronotype display lower scores on planning-accuracy compared to individuals with early chronotype.

The findings also partially supported the third hypothesis. Although the findings did not show an interaction effect of chronotype, and social-jetlag on planning-speed; the results supported the hypothesis that individuals with late chronotype spend less time plan compared to those with early chronotype. The results for the second and third hypotheses collectively suggest that social-jetlag and chronotype are independent of each other as was previously noted by (Silva et al., 2016). Additionally, the insignificant interaction between chronotype and social-jetlag supports previous findings suggesting that exposure to day-time light impacts performance of EF (Munch et al., 2012). These findings also indicates that individuals with late-chronotype tend to have poorer sleep quality (Hershner & Chervin, 2014; Vitale, 2015) which can have negative impact on the abilities to take time in order to plan beforehand, which leads to an inaccurate and inefficient planning, as was previously found by (Chan, 2017; Hakimi et al., 2017).

The current findings provide support for the Frontal Lobe Hypothesis (Gorgoni et al., 2013; Horne, 1993; Raven et al., 2018), suggesting a direct impact of PSQ on EF (Pasula et al., 2018). In contrast, the current findings failed to support the Vigilance Model of Attention which suggests that PSQ and sleep restriction initially lead to the decrement of sustained-attention, which subsequently leads to a gradual breakdown of higher-EF, such as planning and decision-making (Doran et al., 2001; Kusztor, 2019). This is conclusion can be drawn due to two factors: 1) According to the Supervisory Attentional System proposed by Shallice et al. (2002), attention has an important role in decision-making; especially, when an individual encounters a novel an ambiguous situation, such as IGT (where no detailed information is given to the participants as to what to expect). In these situations attention acts as a mediator to facilitated rationale decision-making. If poor sleep quality which exists in individuals with late chronotype did affect attention, there would be a significant difference in decision-making between the two groups. 2) There is an extensive body of research that suggests the existence of two separate pathways for hot and cold EF. While hot EF (decision-making) is associated with orbito-frontal cortex and limbic system, the cold EF (planning) is associated with dorsolateral regions of PFC (Nejati et al., 2018). Therefore, it is possible that sleep chronotype may impact the brain areas associated with planning, without affecting the areas associated with decision-making.

**Implications, Limitations and Strengths**

Current findings have valuable research, practical, and policy implications. The current study provided evidence regarding the differences in planning abilities (accuracy and speed) between individuals with early and late chronotypes. Therefore, policy makers should consider allowing university students to schedule their own classes based on their biological natural clock. Furthermore, current findings contribute to the existing literature by providing useful information for research and practice. Future studies can expand on these findings by replicating the current study as well as investigating other aspects of EF in relation to chronotype and social-jetlag.

While this study provides important and useful findings, the limitations of this study should be acknowledged. First, the current sample was far from the desired sample size recommended by power analysis; increasing the chances of Type II error in relation to the interaction effects between chronotype and social-jetlag on EF, as well as the difference in overall positive decision-making between early and late chronotypes. Second, it is not possible to infer causality from the current study; therefore, it is unclear whether having late chronotype causes poor planning ability, or poor planning ability causes a change in chronotype (chronotype is dynamic and changes by increased age). Third, the current sample was based on convenience sampling, therefore, the current findings lack external validity and cannot be generalizable to all student population. Fourth, dichotomizing the scores of chronotype and social-jelag may ignore the variation that exists in chronotype and social-jetlag.

The current study also has several strengths that should be discussed: First, current study used objective measures of planning and decision-making, which is considered very important for the accurate measurement of EF performance (Buchanan, 2016). Second, more valid and objective measure of chronotype and social-jetlag was used as opposed to questionnaires such as, morningness-eveningness questionnaire (Horne & Östberg) that is based on subjective preferences of individuals. Third, the current study investigated both hot and cold components of EF, making it possible to draw more valid and meaningful conclusions. This also avoided the generalizability of one aspect of EF to other aspects of EF (e.g., if there was a difference in planning between late and early chronotypes, there should also be a difference in decision-making between these groups). Fourth, the current study statically controlled for the effects of age and emotional-state that could potentially impact current findings and act as extraneous variables. Fifth, the current study ensured the exclusion of individuals with clinical sleep disorders, clinical depression, traumatic brain injuries, severe intellectual and learning disabilities, and physical illnesses such as, asthma and so on that could negatively impact sleep and/or EF.

**Future Directions and Conclusion**

Future studies are advised to replicate the current study using a larger sample in order to decrease the chances of type II error; that is, accepting the false null hypothesis regarding the no interaction effects between chronotype and social-jetlag. Similarly, a larger sample size is required to avoid accepting the false null hypothesis regarding the no difference in decision-making between early and late chronotypes. Additionally, future studies may choose more representative sample of university students in order to make generalizable findings. Furthermore, future studies are suggested to use real-life decision-making scenarios (e.g., choosing between different Master’s programme) in order to better capture the hot component of EF. Similarly, studies can replicate these findings using real-life planning tasks, such as planning to study for an exam.

To conclude, the current study was the first study to investigate the effects of chronotype, and social-jetlag on EF abilities (overall positive decision-making, planning-accuracy, and planning-speed), while controlling for potential confounding variables of age and emotional-state. The current findings suggest the possibility that having late chronotype may impact planning abilities, without affecting decision-making abilities in university students. Further studies are required to expand on current findings and provide policy makers with useful information in relation to whether or not students should be given the choice to alter their class schedules based on their biological clock.

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## Appendices

**Appendix A.** Information Sheet

**Project Title:** The association between Chronotype and Executive Functions abilities: Evidence from tests of Planning and Decision-making.

**Invitation:**

I would like to thank you for reading this information sheet about my final year undergraduate thesis. My name is Marzia Mohseni, and I am a final year student at National College of Ireland. You are kindly invited to participate in a psychological study concerned with the relationship between your Chronotype and abilities on planning and decision-making. Chronotype refers to your natural preference for a particular time to go to sleep and to do other activities. The research will be take place within the National College of Ireland. The permission for conducting this study has been granted by the National College of Ireland Psychology Research Ethics Committee. Additionally, this study will be supervised by Dr. April Hargreaves a lecturer in Psychology. Please note that in order to participate in this study, you will be required to meet the below criteria:

1. You must be a College student
2. You must be between the ages of 18 and 35
3. You must be able to speak and write in fluently in English.
4. You must not be have any Clinical Sleep Disorders e.g.,, insomnias, narcolepsy, sleep apnea.
5. You must not suffer from clinical depression, severe intellectual and learning disabilities, or Brain Injury

6. You must be physically healthy and do not suffer from any Physical illness that can interfere with your sleep habits such as Asthma, Kidney Disease, Heart Failure.

**What will happen?**

On the day of the study you will be required to come in to the National College of Ireland, where you will be brought to a quiet room. Your participation in the study will involve the completion of a short questionnaire about your gender and age. You will then be asked to complete a fun task on the computer "Tower of London Task" which requires you to concentrate, pay attention, plan ahead and use flexibly from your choices. This task will take approx. 7 minutes to complete. Next you will be asked to complete a computer task "Iowa Gambling Task" which measures your ability of decision making. This task will take 3-4 minutes to complete. After the completion of these tasks you will be given two questionnaires to complete which will measure the difference in your sleep-habits during the college/work days and free days and the second questionnaire will measure your anxiety, stress, and depression levels. Both questionnaires will take around 8-10minutues to complete. Please note if you have visual impairments, please make sure to wear your glasses/lens in order to complete the tasks easily and be comfortable.

**Time Commitment**

The completion of all the tasks should take between 20-25 minutes on average.

**Participant's rights**

As a participant your participation in this study is completely voluntary and you have the right to be respected for your decision to leave the research study any time without explanation. You have the right to ask that any data you have provided to that point be withdrawn or destroyed without any penalty and explanation. You also have the right to be debriefed after you complete the assessments (or in case you want to discontinue being a part of the study) and will be given the right to withdraw the all the data you provided. After you complete the research study and then decide that you longer want your data to be a part of the study, you can contact the researcher by the email provided and ask for your data to be withdrawn and destroyed.

However, please note that the data about you will be completely anonymous; this is only possible if you have written your name in the Consent sheet (your name written on the Consent Sheet is kept in a excel sheet along with your Identification number that will be given to you before you begin the study in case you want to withdraw from the study). Additionally you have the right to refuse to answer or respond to any questions that are asked of you or not complete the tasks without any penalty. You have the right to have your questions about the procedures to be answered. If you have any questions after as the result of reading this information sheet, you should contact the researcher before the study begins.

**Benefits and Risks**

This research study is very straightforward and will be consisted of all the procedures outlined above; therefore, there will not be no misleading information, deception or any physical or psychological problems. The researcher is responsible for the research to be conducted according to the Codes of Ethics and you will be treated with respect and integrity. Although there are no potential physical and psychological risks that could happen during or after the study, you will be debriefed after the completion of the study. This means that once again you will be told about the aims of the study and will be given the chance to ask any questions. Also, it is also for me to ensure you are not feeling stressed or uncomfortable as the result of the study and if you do, you will be directed to the appropriate resources to contact.

The assessment of Subjective anxiety, stress and depression may make you feel uncomfortable; if this is the case please inform the researcher if you want to stop participating in the study. The assessments of Executive Functions (Tower of London and Iowa Gambling Task) may make you feel stressed or aware of your difficulties, and this should be considered as a benefit rather than a risk, as the participant may come to a realization for further improvements that may not have been aware of prior to the study. The data provided by you will contribute to the academic research and might have some implications for further research for College Students.

Please **NOTE** that the researcher is not qualified to make any diagnosis based on individual results, therefore it is important to be aware of this to avoid disappointment and unwillingness to participate in the study.

**Cost, Reimbursement, and compensation**

Your participation in this study is voluntary, and no incentives are given.

**Confidentiality/ Anonymity**

The researcher will guarantee confidentiality. The date will not be revealed to an unauthorised person, or be used for any other purposes. After the data collection is complete, no one including the researcher, will be able to link the data you provided to you in anyway as it will not contain your personal information (unless you want to withdraw your data after data collection). Your name will be kept in a separate excel sheet along with your Identification number, this is done only if you change your mind and want to withdraw the data you provided otherwise you are not obliged to provide your name. The information collected from you anonymized and added with the information received by other people and will be reported in “statistics” form to the National College of Ireland and will be presented at National College of Ireland research conference. Additionally according tothe Freedome of information legislation it will be accessible to the public [via NCI's website under section of Thesis Institutional Repository (TRAP)], and will be destroyed after 5 years

**Further Information**

If you have any questions at any time, the researcher will be glad to answer them by email provided below.

**E-mail:marziastudy@gmail.com**

Alternatively, if you would like to speak with the supervisor of this research study, you may contact Dr April Hargreaves at **april.hargreaves@ncirl.ie**

**Appendix B.** Demographic Questionnaire

Are you a college student? Yes No

What is your gender? Male Females Others

Please state your age in years? -------------------------------------

**Appendix C.** Munich Chronotype Questionnaire

## Munich ChronoType Questionnaire (MCTQ)

In this questionnaire, you report on your typical sleep behaviour over the past 4 weeks. We ask about work days and work-free days separately. Please respond to the questions according to your perception of a standard week that includes your usual work days and work-free days.

I have a regular work schedule (this includes being, for example, a housewife or househusband):
Yes ☐ I work on 1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ days per week.
No ☐
Is your answer "*Yes, on 7 days*" or "*No*", please consider if your sleep times may nonetheless differ between regular 'workdays' and 'weekend days' and fill out the MCTQ in this respect.


**Please use 24-hour time scale (e.g. 23:00 instead of 11:00 pm)!**

**Workdays**

Image 1: I go to bed at ________ o'clock.
Image 2: Note that some people stay awake for some time when in bed!
Image 3: I actually get ready to fall asleep at ________ o'clock.
Image 4: I need ________ minutes to fall asleep.
Image 5: I wake up at ________ o'clock.
Image 6: After ________ minutes I get up.
I use an alarm clock on workdays: Yes ☐ No ☐
If "Yes": I regularly wake up BEFORE the alarm rings: Yes ☐ No ☐

**Free Days**

Image 1: I go to bed at ________ o'clock.
Image 2: Note that some people stay awake for some time when in bed!
Image 3: I actually get ready to fall asleep at ________ o'clock.
Image 4: I need ________ minutes to fall asleep.
Image 5: I wake up at ________ o'clock.
Image 6: After ________ minutes I get up.
My wake-up time (Image 5) is due to the use of an alarm clock: Yes ☐ No ☐
There are particular reasons why I cannot freely choose my sleep times on free days:
Yes ☐ If "Yes": Child(ren)/pet(s) ☐ Hobbies ☐ Others ☐, for example:________________
No ☐

**Appendix D.** The Depression, Anxiety, and Stress Scale (DASS-21)

**Depression Anxiety Stress Scale-21 (DASS-21)**

Participant ID number ( )

**INSTRUCTION:**The following scale asks youabout your usual state of mood, feelings and thought during the past month ONLY. Your answers should indicate the most accurate response for the majority of the times in the past month. Please answer all questions by circling the most accurate option for each.

0= Did not apply to me at all

1= Applied to me to some degree, or some of the time

2= Applied to me to a considerable degree, or a good part of time

3= Applied to me very much, or most of the time

***Stress Scale***

During the past month…

| | | | | | |
|---|---|---|---|---|---|
| (1) | I was intolerant of anything that kept me... | 0 | 1 | 2 | 3 |
| ….from getting on with what I was doing | | | | | |
| (2) | I felt I was rather touchy | 0 | 1 | 2 | 3 |
| (3) | I found it difficult to relax | 0 | 1 | 2 | 3 |
| (4) | I found myself getting agitated | 0 | 1 | 2 | 3 |
| (5) | I felt that I was using a lot of nervous energy | 0 | 1 | 2 | 3 |
| (6) | I found it hard to wind down | 0 | 1 | 2 | 3 |
| (7) | I tended to over-react to situations | 0 | 1 | 2 | 3 |

***Depression Scale***

During the past month…

| | | | | | |
|---|---|---|---|---|---|
| (8) | I felt that life was meaningless | 0 | 1 | 2 | 3 |
| (9) | I felt that I had nothing to look forward to | 0 | 1 | 2 | 3 |

(10) I couldn't seem to experience any positive… 0 1 2 3

…feeling at all

(11) I was unable to become enthusiastic about… 0 1 2 3

… anything

(12) I felt that I wasn't worth much as a person 0 1 2 3

(13) I felt down-hearted and blue 0 1 2 3

(14) I found it difficult to work up the initiative… 0 1 2 3

… to do things

---

***Anxiety Scale***

(15) I was aware of the action of my heart in the absence of physical exertion(e.g, sense of heart rate increase, heart missing a beat) ` 0 1 2 3

(16) I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion) 0 1 2 3

(17) I experienced trembling (e.g., in the hands) 0 1 2 3

(18) I felt I was close to panic 0 1 2 3

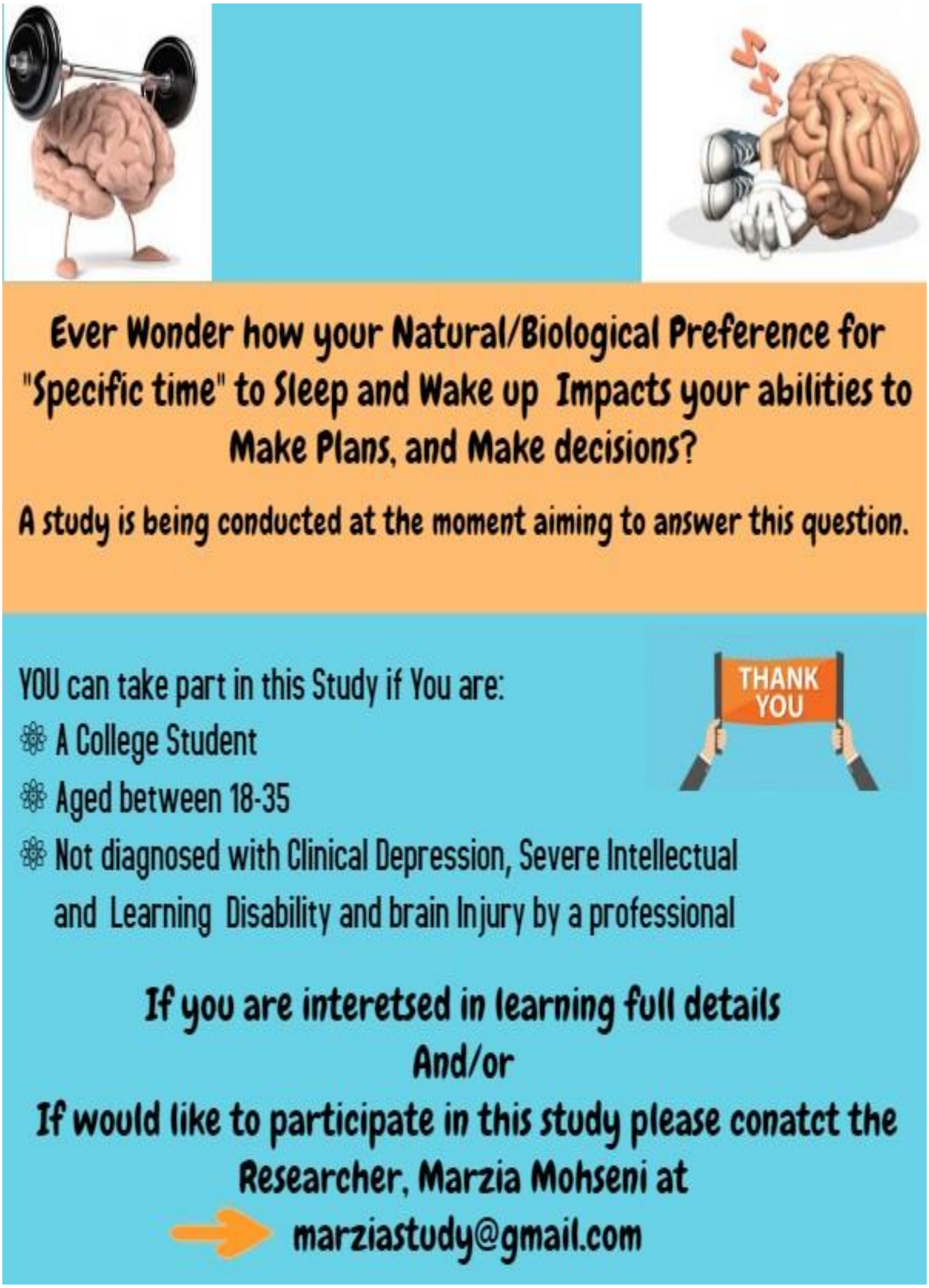
(19) I felt scared without any good reason ` 0 1 2 3

(20) I was worried about situations in which…

…I might panic and make a fool of myself ` 0 1 2 3

(21) I was aware of dryness of my mouth ` 0 1 2 3

**Appendix E.** Advertisement Poster



**Appendix F.** Informed Consent

**Research Title**: The association between Chronotype and Executive Functions abilities: Evidence from tests of Planning and Decision-making.

By signing below, you are agreeing that (1) You have been informed about the nature of the research study, (2) your questions about your participation have been answered satisfactorily (3) you understand that your participation in this study is voluntary and you have the right to withdraw consent any time from the study without any explanation and adverse consequences, (4) you understand that no information about you will be identifiable and data will remain anonymous, (5) you understand that this study is conducted for academic purposes and the researcher is not qualified in making any diagnoses.

___________________________________

Participants' Name (printed)

__________________________________ ____________________________

Participant's Signature Date

**Researcher's Statement:**

I have explained the nature and the aim of the current research study, the procedures and any risks involved undertaking the study. I have answered each question asked by the participant fully. I believe that the above participant understands the nature of the study and has been given informed consent.

Researcher's signature Date

**Appendix G.** Instruction for Tower of London Test

"You will be presented with a starting pattern; your task is to arrange the three coloured balls to match the goal pattern. You can only move on ball at a time, and you cannot place them anywhere else other than the three pegs. You can only place 3 balls on the left peg, 2 on the middle and 1 on the right, only within a specific number of moves displayed on the screen".

**Appendix H.** Instruction for Iowa Gambling Task

"You will be asked to select a card from the four decks for hundred trials by clicking the mouse. You should aim at increasing your profit, and try to choose profitable cards, you will figure out how which cards are more profitable after a few trials".

**Appendix I.** Debriefing Form

**Project Title:** The association between Chronotype and Executive Functions abilities: Evidence from tests of Planning and Decision-making.

Thank you for participating in this study! The general aim of this research was to explore whether Sleep Chronotype was linked with abilities of planning and decision-making. As you might know at this stage, you have the right to withdraw the data you provided. However, please remember that the data about you will be completely anonymous. If you want to withdraw your data after this point please email me and I will omit and destroy the data you have provided before I start data analysis. However, I will not be able to withdraw your data once the process of data analyses taken place as by that time it has been anonymously added with data provided by others.

The researcher does not know anything about any information you provided on the questionnaires of demographics, Chronotype, and Depression Stress Anxiety scale. The data you provided on the tasks of Tower of London and Iowa Gamling taskwill remain confidential and will not be discussed with any third party. The results from this study will help the researcher to investigate the relationship between sleep Chronotype and executive functions. Please note that the data collected by you and other participants will be anonymously reported to National College of Ireland and will be presented at National College of Ireland research conference in an unidentifiable form. Additionally according tothe Freedome of information legislation it will be accessible to the public [via NCI's website under section of Thesis Institutional Repository (TRAP)], and will be destroyed after 5 years.

Please note that the researcher will not be able to provide you with your individual score on any components of the study as the tests will not be used for any diagnosis and will only be used for academic research. If you feel especially concerned about your performance or feel distressed after completion of the tasks, please consider contacting the below services:

**Samaritans:**(Free 24 hours helpline) Tel: (01) 116 123; Email: jo@samaritans.ie

**NiteLine: (**Student Support, Every Night of Term, Lines open 9pm- 2:30am Tel: 1800793793

**Pieta House**: Free 24 hours helpline National Suicide Helpline Tel: 1800247247

**Aware:** everyday 10am to 10pm Tel: 1800804848; Email: supportmail@aware.ie

**Additional Resources:** If you are concerned about your sleep or need some tips for sleeping better you may want to have a look at the followings:

https://www.psychologytoday.com/us/blog/think-act-be/201609/helping-college-students-manage-sleep-issues

https://www.youtube.com/watch?v=G0Zj_InJ4BQ

https://www2.hse.ie/wellbeing/mental-health/problems-sleeping.html

https://spunout.ie/health/article/10-great-ways-to-improve-your-sleep https://www.youtube.com/watch?v=9KaMufF0rAY

https://www.youtube.com/watch?v=A5dE25ANU0k

**Appendix J.** Evidence of Data

9 : ID 1031 Visible: 58 of 58 Variab

| | ID | Gender | Age | Chronotype | Social_jet lag | Positive_Net | TOL_total | Planning_time | Stress1 | Stress2 | Stress3 | Stress4 | Stress5 | Stress6 | Stress |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1029 | 1 | 35 | 0:25 | 0:40 | 4 | 32 | 19.671012308 | 3 | 3 | 3 | 3 | 3 | 3 | |
| 2 | 1025 | 0 | 34 | 2:12 | 1:07 | 64 | 34 | 15.558923077 | 1 | 2 | 2 | 2 | 1 | 1 | |
| 3 | 1032 | 0 | 32 | 1:04 | 0:15 | 72 | 36 | 19.064538462 | 1 | 1 | 1 | 0 | 0 | 1 | |
| 4 | 1027 | 1 | 31 | 3:19 | 1:00 | 78 | 32 | 14.108416667 | 0 | 0 | 1 | 1 | 0 | 0 | |
| 5 | 1026 | 0 | 29 | 2:15 | 1:00 | 20 | 31 | 18.433857143 | 2 | 2 | 2 | 1 | 1 | 1 | |
| 6 | 1008 | 0 | 29 | 4:41 | 2:37 | 74 | 28 | 11.119937500 | 1 | 0 | 2 | 1 | 1 | 2 | |
| 7 | 1022 | 1 | 29 | 7:09 | 0:52 | -72 | 24 | 5.856769230 | 1 | 2 | 2 | 1 | 2 | 2 | |
| 8 | 1021 | 1 | 28 | 3:02 | 0:52 | 66 | 34 | 19.822923077 | 0 | 0 | 1 | 1 | 0 | 0 | |
| 9 | 1031 | 1 | 28 | 7:56 | 2:55 | 24 | 30 | 17.499250000 | 2 | 1 | 2 | 3 | 2 | 2 | |
| 10 | 1037 | 1 | 27 | 4:03 | 2:07 | 54 | 31 | 16.103200000 | 1 | 2 | 3 | 3 | 2 | 2 | |
| 11 | 1005 | 0 | 27 | 5:37 | 1:22 | 4 | 28 | 10.358500000 | 1 | 0 | 1 | 0 | 0 | 1 | |
| 12 | 1030 | 0 | 26 | 3:45 | 2:00 | -80 | 36 | 20.812384620 | 1 | 0 | 3 | 2 | 2 | 2 | |
| 13 | 1006 | 1 | 26 | 7:42 | 4:45 | -30 | 30 | 13.994750000 | 1 | 0 | 1 | 1 | 0 | 1 | |
| 14 | 1007 | 0 | 26 | 5:58 | 2:45 | -26 | 32 | 11.893000000 | 2 | 1 | 2 | 1 | 2 | 2 | |
| 15 | 1035 | 1 | 25 | 7:06 | 4:45 | -52 | 33 | 18.623333333 | 2 | 2 | 2 | 2 | 3 | 2 | |
| 16 | 1024 | 0 | 24 | 4:00 | 0:27 | 58 | 34 | 18.623384615 | 3 | 2 | 1 | 2 | 1 | 2 | |
| 17 | 1003 | 0 | 24 | 7:30 | 2:20 | 88 | 21 | 3.434312500 | 1 | 0 | 2 | 1 | 2 | 1 | |
| 18 | 1034 | 0 | 24 | 6:11 | 2:30 | -30 | 29 | 12.747272727 | 2 | 2 | 1 | 3 | 2 | 2 | |
| 19 | 1004 | 1 | 23 | 3:35 | 1:30 | 8 | 34 | 23.848714290 | 0 | 2 | 1 | 2 | 1 | 0 | |
| 20 | 1001 | 1 | 23 | 6:20 | 2:22 | -52 | 29 | 13.302736842 | 2 | 2 | 3 | 3 | 2 | 2 | |
| 21 | 1012 | 1 | 22 | 3:37 | 0:15 | -90 | 29 | 12.974538460 | 2 | 0 | 1 | 0 | 0 | 0 | |
| 22 | 1017 | 1 | 22 | 5:08 | 1:30 | 10 | 36 | 21.579153850 | 1 | 3 | 3 | 2 | 2 | 1 | |

Data View Variable View