Assessing the Relationship Between Chronotype & Cognitive Ability in the Morning

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Academic success is influenced by many different factors, including self-efficacy, socioeconomic status, parental support, peer influence, and more (Costa et al., 2024). These factors have been well-researched throughout the years in order to better support individuals in academic environments and increase their chances of success. One often overlooked variable is chronotype - an individual's preference for sleep and wake patterns, which dictates the time of day they feel most energized and perform the best (Roenneberg et al., 2003). It differentiates whether an individual is more active and alert in the morning (morning type) or evening (evening type), and any other in between types. Despite its importance, chronotype has received less attention within research compared to other factors, even though it has the potential to greatly affect a students academic success.

Morning types fall asleep and wake up early, exhibiting peak mental performance in the mornings. In contrast, evening types typically fall asleep later and sleep in, achieving peak mental performance in the afternoon (Taillard et al., 2004). Traditionally, academic schedules favour classes that start in the morning and finish in the late afternoon (Gariépy et al., 2017). Morning types have shown to achieve higher grades on learning evaluations than evening types (Wolfson & Carskadon, 2003). The reasoning behind this could be due to classes being held in the morning, and peak mental performance being in the afternoon for evening types. An important factor in learning and test-taking are an individual's cognitive abilities (Shi & Qu, 2022). Cognitive ability is characterized by the human brain's ability to store memory, process and extract information, attention, and logical reasoning (Shi & Qu, 2022). We hypothesize that evening types may have reduced cognitive abilities in the morning, leading to poorer scores on evaluations.

Determining if there is a relationship between chronotype and cognitive ability in the morning carries meaningful insights for developing better educational strategies to improve overall academic success. In this study, we aim to determine the potential relationship by assessing the participant's chronotype using the Morningness-Eveningness Questionnaire (MEQ), and by measuring cognitive ability in the morning with two different tasks. The first task is a Digit Span Test, which measures memory capacity and ability to maintain focus (Banken, 1985). The second task is a self-report questionnaire. A student's self-reports may provide a more reliable insight into their *overall* cognitive abilities in the morning when compared to the outcome of a single isolated test. However, incorporating both the self-report and the Digit Span Test will enhance the robustness and validity of our results (Twenge et al., 2022). We predict that the evening types (Moderate Evening and Definite Evening) will have a lower score on the Digit Span Test and a lower score on the self-report questionnaire when compared with the morning types (Moderate Morning and Definite Morning).

Methods

Participants

A total of fifty-two students, both male and female, from Thompson Rivers University participated in this study. Participants were recruited through social media platforms (e.g., instagram and facebook), word of mouth, and through professors sharing the study on their class Moodle pages. The inclusion criteria required participants to be students at Thompson Rivers University, have normal or corrected-to-normal vision, and be fluent in English. The exclusion criteria included any individuals who worked night shifts, since this is abnormal to natural chronotypes and thus would not contribute towards the results.

Materials

Morningness-Eveningness Questionnaire (QxMD, 2010)[1]

The Morningness-Eveningness Questionnaire assesses an individual's chronotype, which refers to their preferred timing of sleep and wakefulness. Developed by Horne and Östberg (1976), it consists of a series of questions designed to determine when an individual feels most alert, productive, and capable of performing physical and mental tasks. The MEQ categorizes individuals into different types based on their responses: Definite Morning (strong preference for early activities), Moderate Morning (moderate preference for mornings), Intermediate (no strong preference, adaptable to both), Moderate Evening (moderate preference for evenings), and Definite Evening (strong preference for later activities and waking times).

Digit Span Test (Denk, n.d)[2]

The Digit Span Test is a cognitive assessment tool used to measure working memory capacity. In this test, a series of digits are presented one at a time, and participants must recall the sequence in the correct order. As the test progresses the sequence increases in length, challenging

the participant's memory span. The test ends when the participant can no longer recall the sequence correctly (when they make an error).

Google Form[3]

The data was collected using an online survey made through Google Forms. The exact survey used is accessible through the link above. The survey included the purpose of the study, ethics statements, instructions on how to complete the Google Form along with the time commitment, links to the external tests, the contact information for each researcher, and eight response questions total.

Procedures

As mentioned above, a survey method was used to collect the data for this study. Once participants were acquired they were provided the Google Form link which led to the studies survey. Participants were instructed to complete the survey only between 8:00 am and 11:00 am to ensure cognitive ability was assessed during the morning hours. The ethics statement informed participants that the survey, including the external links, did not collect any identifying information (no email or name was required) and that by proceeding, participants were acknowledging their consent to participate in the study.

The survey consisted of three parts: two external links leading to the Digit Span Test and the Morningness-Eveningness Questionnaire, two internal questions that corresponded to the results of both the external tests, and an internal questionnaire with six additional questions. Participants were instructed to complete the Digit Span Test first and to enter the longest sequence they successfully recalled into the first question of the survey. Participants then completed the Morning-Eveningness Questionnaire and selected their assigned chronotype in question two of the survey (out of the five options). The final section of the survey included six

self-report questions on how students felt about their own cognitive ability in the morning. Two were based on attention and focus, two on memory and retention, and two on alertness and mental energy. Each had a response scale including five options ranging from strongly disagree to strongly agree. The questions were as follows: I can concentrate well during morning classes, I find my mind wandering frequently during morning lectures, I can easily remember what is taught in morning classes, I struggle to retain information from morning lectures, I feel alert and mentally sharp in morning classes, and I often feel mentally sluggish or fatigued in the mornings. Once participants completed each question and submitted the survey, their responses were stored anonymously in Google Forms.

Data Analysis

The data obtained from each participant via the Google Form was analyzed using RStudio (2022). The data was first exported from Google Forms into an Excel sheet, then imported into RStudio for analysis. The self-report questionnaire used a numerical scoring system, where each response rating was assigned a corresponding value (see Appendix A). These values were manually entered into Excel for data organization and the overall numerical scores for the questionnaire for each individual were calculated using R. ANOVA tests were conducted in RStudio to compare the Digit Span Test scores across chronotype groups and to compare the self-report questionnaire scores across chronotype groups. A regression analysis was conducted to compare the self-report questionnaire scores of the Moderate Morning chronotype with those of all other chronotypes. Similarly, a regression was performed to examine differences in the Digit Span Test scores between the Moderate Morning chronotype and all other chronotypes. Both regressions were used to make box plots to visualize the results.

Results

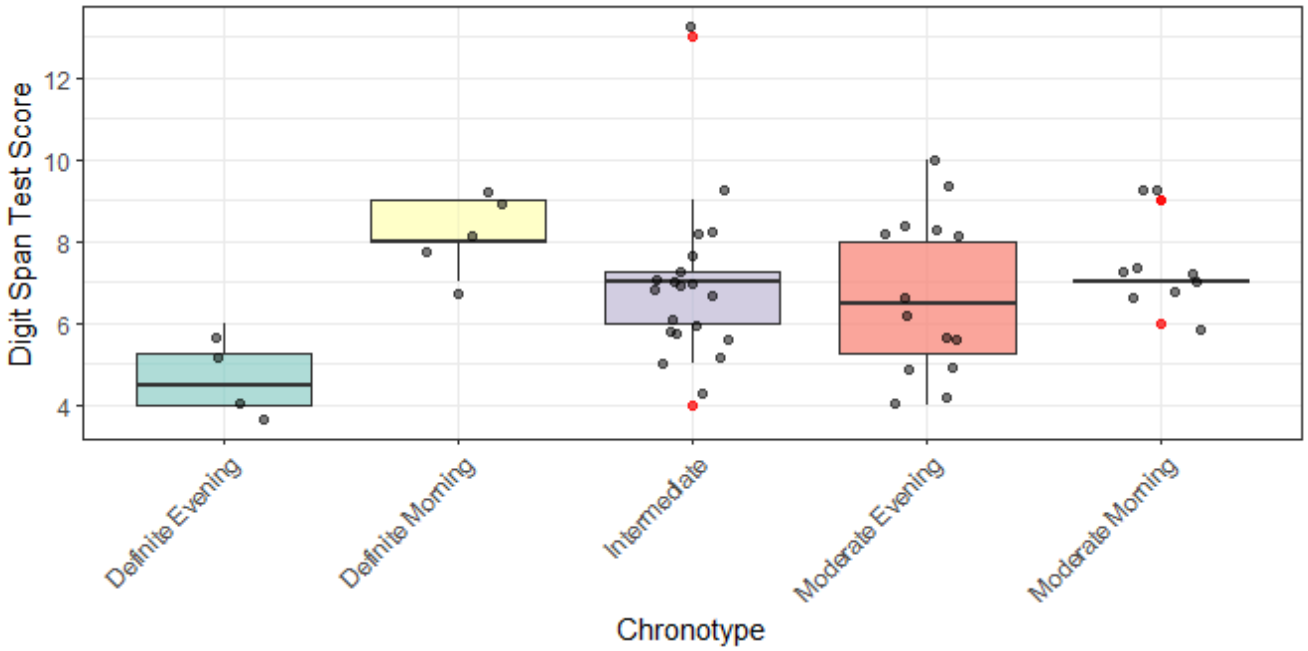

Figure 1. Effect of chronotype on the sequence length scored on the Digit Span Test.

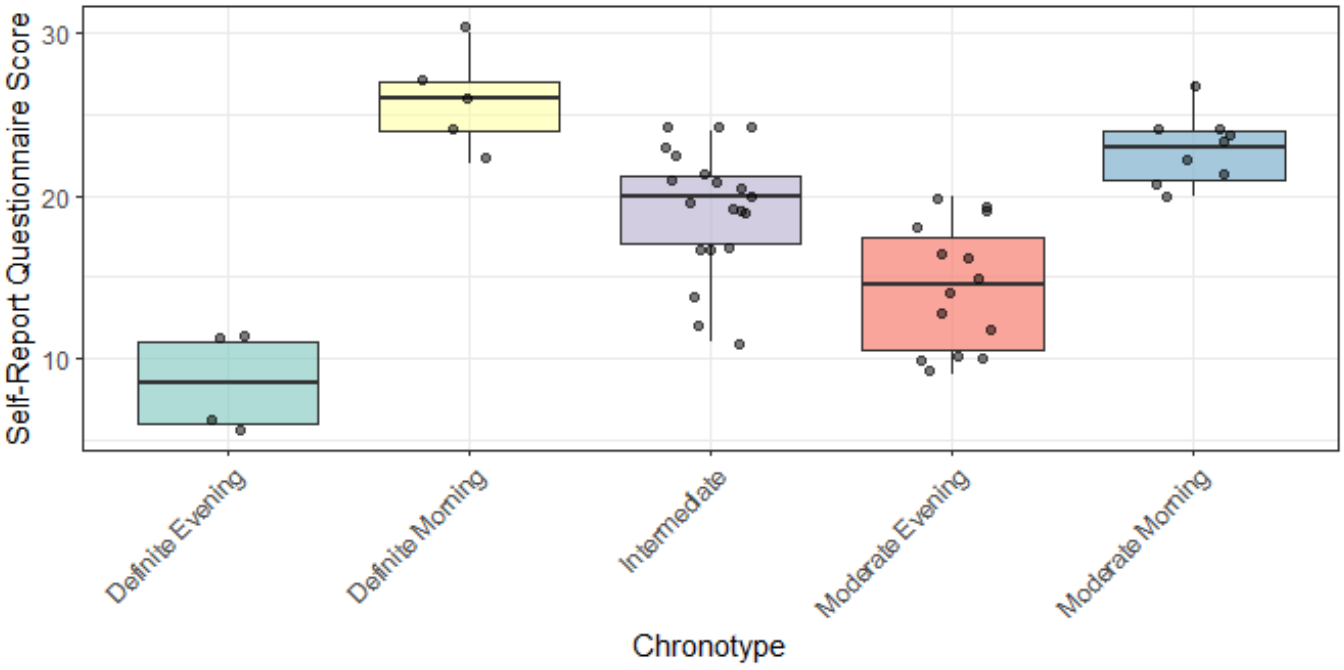

Figure 2. Effect of chronotype on self-report questionnaire responses, with a score of 0 representing poor cognitive ability in the morning and a score of 30 representing high cognitive ability in the morning.

The sequence length of the Digit Span Test does differ between chronotypes, but the relationship is relatively weak ($F_{4,47} = 2.778$, $p = 0.0375$), with chronotype explaining 19.1% of the variation in Digit Span sequence length. The sequence length of **Moderate Morning** chronotypes did not differ from Moderate Evening chronotypes ($p = 0.899$), Intermediate chronotypes ($p = 0.976$), or Definite Evening chronotypes ($p = 0.0768$). Sequence lengths of **Moderate Evening** chronotypes did not differ from Intermediate chronotypes ($p = 0.993$) or Definite Morning chronotypes ($p = 0.408$). Sequence lengths of **Intermediate** chronotypes did not differ from Definite Evening chronotypes ($p = 0.223$) or Definite Morning chronotypes ($p = 0.540$). Finally, the **Definite Evening** chronotype had Digit Span sequences 3.450 digits (CI: 0.367 - 6.533, $p = 0.021$) longer than Definite Morning chronotypes.

The sequence length of the Digit Span Test are the same in Moderate Morning chronotypes and Moderate Evening chronotypes ($t_{47} = -0.894$, $p = 0.375$). Moderate Morning and Intermediate chronotypes scored the same sequence length on average ($t_{47} = -0.589$, $p = 0.558$). The sequence length of the Digit Span Test was 2.583±0.974 shorter in Moderate Morning chronotypes than Definite Evening chronotypes ($t_{47} = -2.654$, $p = 0.011$). Moderate Morning and Definite Morning chronotypes scored the same sequence length on the Digit Span Test on average ($t_{47} = 0.959$, $p = 0.342$). Chronotype explains 19.1% of the variation in the Digit Span sequence length. These results are visualized in **Figure 1**.

The results of the self-report questionnaire (SRQ) do differ between chronotypes ($F_{4,47} = 23.31$, $p < 0.0001$), with chronotype explaining 66.5% of the variation in the results of the self-report questionnaire. **Moderate Morning** chronotypes had SRQ scores 8.532 points (CI: -12.676 - -4.387, $p < 0.0001$) lower than Moderate Evening chronotypes, 3.639 points (CI: -7.532 - 0.255, $p = 0.0772$) lower than Intermediate chronotypes, and 14.3889 points (CI:

-20.218 - -8.560, $p < -.0001$) lower than Definite Evening chronotypes. **Moderate Evening** chronotypes had SRQ scores 4.893 points (CI: -1.513 - 8.273, $p = 0.0001$) higher than Intermediate chronotypes, and 5.857 points (CI: -11.357 - -0.3577, $p = 0.032$) lower than Definite Morning chronotypes. **Intermediate** chronotypes had SRQ scores 10.750 points (CI: -16.063 - -5.437, $p < 0.001$) lower than Definite Evening chronotypes, and 6.550 points (CI: 1.700 - 11.400, $p = 0.003$) higher than Definite Morning chronotypes. Finally, the **Definite Evening** chronotype had SRQ scores 17.300 points (CI: 10.793 - 23.807, $p = 0$) higher than Definite Morning chronotypes.

The scores on the self-report questionnaire (SRQ) are 8.532±1.461 points lower in Moderate Morning chronotypes than Moderate Evening chronotypes ($t_{47} = -5.839$, $p < 0.0001$). SRQ scores are 3.639±1.373 points lower in Moderate Morning chronotypes than intermediate chronotypes ($t_{47} = -2.651$, $p = 0.0109$). SRQ scores are 14.389±2.055 points lower in Moderate Morning chronotypes than Definite Evening chronotypes ($t_{47} = -7.002$, $p < 0.0001$). Moderate Morning and Definite Morning chronotypes scored the same on the SRQ ($t_{47} = 1.526$, $p = 0.1337$). Chronotype explains 66.5% of the variation in the SRQ scores. These results are visualized in **Figure 2**.

Discussion

The findings provide partial support for our hypothesis that morning chronotypes would exhibit peak cognitive ability in the morning, while evening chronotypes would perform better in the afternoon. Based on the Digit Span Test, which was conducted in the morning, Definite Morning and Moderate Morning chronotypes did not perform better than the other chronotypes as we hypothesized. In fact, individuals with a Definite Evening chronotype demonstrated a better cognitive ability in the morning compared to those with a Definite Morning chronotype. This result suggests that Definite Morning chronotypes may not hit their cognitive peak in the morning, which could be partially due to sleep inertia or differences in sleep quality (Santhi et al., 2013). Moderate and Intermediate chronotypes showed no differences in cognitive ability between one another or between other chronotypes, further emphasizing that the relationship between chronotype and cognitive ability is most likely influenced by other variables.

Another study by Roberts and Kylloen (1999) explored the relationship between chronotype and cognitive ability. They provided individuals with standardized cognitive tests administered at different times of the day. Their findings reported that individuals who were high in Eveningness did better on tests of memory and other cognitive abilities, even when those tests were performed in the morning. This aligns with our findings, where Definite Evening chronotypes outperformed all other groups on the Digit Span Test. The researchers suggested that Definite Evening types may have psychological traits, such as greater cognitive adaptability, which enable them to perform well outside of their usual peak hours.

The results from the self-report cognitive questions contrasted the results of the Digit Span Test. Definite Morning chronotypes perceived their cognitive functioning to be optimal in the morning, whereas Definite Evening chronotypes reported less favourable perceptions of their cognitive functioning during the morning. The difference between objective performance and subjective self-assessment highlights a discrepancy between how individuals feel about their cognitive abilities and their actual performance. It may reflect an overestimation of abilities by morning chronotypes, or an underestimation by evening chronotypes. In a study completed by Herreen & Zajac (2018), researchers found that participant's personality traits, rather than actual cognitive ability, strongly influenced their self-report scores. Individuals with high extraversioness overestimated their cognitive abilities, while individuals who were high in neuroticism underestimated them. This could be an explanation as to why the results showed a discrepancy between objective performance and subjective self-assessment.

Together, these findings suggest that while chronotype can influence cognitive ability in the morning, its influence may not align with our hypothesized "peak times". Future studies could assess performance at different times of day to fully explore how chronotype aligns with cognitive ability and whether the observed discrepancies are present across varied testing times.

This study also faced several limitations. Only fifty-two participants were included, all of whom were students from Thompson Rivers University. This limited and homogenous sample size may not generalize to larger populations or individuals in other academic settings. Self-report measures are subject to biases, including interpretation discrepancies or personality-driven variations, as highlighted earlier in the discussion (Twenge et al., 2022). To increase the reliability of future research, it would be beneficial to prioritize objective measurements of cognitive ability over self-report measurements. Additionally, this study

focused only on one objective aspect of cognitive ability: working memory. However, cognitive ability encompasses many different aspects (Shi & Qu, 2022). Future research should include a wider array of objective tests assessing different aspects of cognitive ability to gain a better understanding of its relationship with chronotype.

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Appendix A

The following includes the scoring guide for how we calculated the self-report questionnaire numerical score.

Scoring Guide:

Positive statements are scored as:

Strongly Disagree = 1

Disagree = 2

Neutral = 3

Agree = 4

Strongly Agree = 5

Reverse-scored statements are scored as*:*

Strongly Disagree = 5

Disagree = 4

Neutral = 3

Agree = 2

Strongly Agree = 1

Interpreting the Total Score:

Range: The total score will range from 6 to 30.

High Scores (24-30): Indicate strong self-perceived cognitive abilities during morning classes.

Moderate Scores (15-23): Indicate average cognitive abilities.

Low Scores (6-14): Suggest poor cognitive abilities in morning classes.

Appendix B

The following includes the R outputs used for all conducted tests and written results.

ANOVA output comparing the relationship between chronotype and Digit Span Test scores

```
            Df Sum Sq Mean Sq F value Pr(>F)
CHRONOTYPE   4  29.16   7.291   2.778 0.0375 *
Residuals   47 123.36   2.625
---
```

```
$CHRONOTYPE
                                          diff        lwr       upr     p adj
Moderate Evening-Moderate Morning -0.6190476 -2.5823754 1.3442802 0.8975650
Intermediate-Moderate Morning     -0.3833333 -2.2278259 1.4611593 0.9760046
Definite Evening-Moderate Morning -2.5833333 -5.3447669 0.1781002 0.0768281
Definite Morning-Moderate Morning  0.8666667 -1.6964710 3.4298043 0.8718595
Intermediate-Moderate Evening      0.2357143 -1.3655928 1.8370213 0.9934226
Definite Evening-Moderate Evening -1.9642857 -4.5695777 0.6410063 0.2213303
Definite Morning-Moderate Evening  1.4857143 -0.9083839 3.8798124 0.4084053
Definite Evening-Intermediate     -2.2000000 -4.7169512 0.3169512 0.1128292
Definite Morning-Intermediate      1.2500000 -1.0476516 3.5476516 0.5404186
Definite Morning-Definite Evening  3.4500000  0.3673769 6.5326231 0.0212273
```

Regression output comparing the relationship between chronotype and Digit Span Test scores

```
Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                 7.3333     0.5400  13.580   <2e-16 ***
CHRONOTYPEModerate Evening -0.6190     0.6922  -0.894   0.3757
CHRONOTYPEIntermediate     -0.3833     0.6503  -0.589   0.5584
CHRONOTYPEDefinite Evening -2.5833     0.9735  -2.654   0.0108 *
CHRONOTYPEDefinite Morning  0.8667     0.9036   0.959   0.3424
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.62 on 47 degrees of freedom
Multiple R-squared:  0.1912,    Adjusted R-squared:  0.1224
F-statistic: 2.778 on 4 and 47 DF,  p-value: 0.0375
```

ANOVA output comparing the relationship between chronotype and self-report questionnaire results

```
            Df Sum Sq Mean Sq F value   Pr(>F)
CHRONOTYPE   4 1090.4  272.60   23.31 1.16e-10 ***
Residuals   47  549.7   11.69
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
$CHRONOTYPE
                                          diff        lwr        upr     p adj
Moderate Evening-Moderate Morning  -8.531746 -12.676083 -4.3874093 0.0000046
Intermediate-Moderate Morning      -3.638889  -7.532380  0.2546018 0.0772738
Definite Evening-Moderate Morning -14.388889 -20.217926 -8.5598518 0.0000001
Definite Morning-Moderate Morning   2.911111  -2.499348  8.3215706 0.5511038
Intermediate-Moderate Evening       4.892857   1.512700  8.2730138 0.0014369
Definite Evening-Moderate Evening  -5.857143 -11.356585 -0.3577008 0.0316260
Definite Morning-Moderate Evening  11.442857   6.389219 16.4964956 0.0000006
Definite Evening-Intermediate     -10.750000 -16.062966 -5.4370342 0.0000065
Definite Morning-Intermediate       6.550000   1.699948 11.4000520 0.0033213
Definite Morning-Definite Evening  17.300000  10.792972 23.8070276 0.0000000
```

Regression output comparing the relationship between chronotype and self-report questionnaire results

```
Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                 22.889      1.140  20.079  < 2e-16 ***
CHRONOTYPEModerate Evening  -8.532      1.461  -5.839 4.71e-07 ***
CHRONOTYPEIntermediate      -3.639      1.373  -2.651   0.0109 *
CHRONOTYPEDefinite Evening -14.389      2.055  -7.002 8.12e-09 ***
CHRONOTYPEDefinite Morning   2.911      1.907   1.526   0.1337
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.42 on 47 degrees of freedom
Multiple R-squared:  0.6649,    Adjusted R-squared:  0.6363
F-statistic: 23.31 on 4 and 47 DF,  p-value: 1.158e-10
```