How different aspects of Mind-Wandering Predict Intrusive thoughts across various cognitive tasks and whether these predictions differ between Gender

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INTRODUCTION

This project investigates how different aspects of mind-wandering (MW) predict intrusive thoughts (IT) across various cognitive tasks measured by an after imagining questionnaire and explores whether these predictions differ between men and women

DATA OVERVIEW
This study utilizes data from an open-access dataset titled "A test-retest resting and cognitive state EEG dataset during multiple subject-driven states", available on OpenNeuro. The dataset includes electroencephalogram (EEG) recordings collected across three sessions, each comprising five distinct conditions: two resting states (eyes open and eyes closed) and three subject-driven cognitive states (memory, music, and subtraction). In addition to EEG data, the dataset incorporates behavioral assessments evaluating demographic factors, sleep patterns, emotional states, mental health, and self-generated thoughts (mind wandering).

The dataset consists of 60 participants with an average age of 20.01 years (range: 18–28), and a median age of 20 years. The sample includes 32 females and 28 males.
To address our research question, we extracted relevant data from the Amsterdam Resting-State Questionnaire (ARSQ) 2.0, the Mini New York Cognition Questionnaire (Mini NYC-Q), and participant gender information.

Amsterdam Resting-State Questionnaire (ARSQ) 2.0: The ARSQ 2.0 measures mind-wandering across ten dimensions: Discontinuity of Mind, Theory of Mind, Self, Planning, Sleepiness, Comfort, Somatic Awareness, Health Concern, Visual Thought and Verbal Thought. We will refer to this questionnaire as MW. Participants rated 54 statements on a five-point Likert scale (1 = Completely Disagree, 5 = Completely Agree). The questionnaire was administered immediately after each resting-state EEG recording across all three sessions, with randomized item order.

Mini New York Cognition Questionnaire (Mini NYC-Q): The Mini NYC-Q is an adapted version of the New York Cognition Questionnaire, comprising 12 items. Participants rated each statement on an 11-point scale (0 = Completely did not describe my experience, 10 = Completely described my experience). We specifically extracted Item 12, which assesses intrusive thoughts (referred in this report as IT). The Mini NYC-Q was administered after each resting-state EEG and cognitive-state EEG recording at all three sessions, resulting in 15 total assessments per participant.

METHODS

All analysis and exploration methods in this project are structured for clarity and accessibility. The project is organized into separate directories: the `src` folder contains all core scripts and analysis modules, while the `test` folder includes testing scripts for

validation. Each of these folders contains a `tools` folder where all reusable modules relevant to data analysis and exploration are stored. Additionally, the `data` folder provides easy access to the dataset, ensuring seamless integration within the workflow.

To streamline execution, we use a `main.py` file, which imports all necessary modules and functions from the designated folders, consolidating the entire analysis into a single, concise script. Each function within the modules is documented in a `README.md` file, detailing the structure of the project, the functionality of each component, and its intended purpose. The `README.md` file also includes installation instructions, listing all required packages and dependencies. Configuration and package management are handled via the `pyproject.toml` file, ensuring a smooth and reproducible setup process.

Data cleaning and establishing a minimalistic and organized dataset for analysis included removing outliers from the data that could distort results. We then calculated the mean for each of the ten predictors from the ARSQ 2.0 MW questionnaire and the IT measurements from the Mini NYC-Q across all five cognitive tasks over the three sessions. Another critical step in managing the data was dividing it by gender, separating male and female participants before conducting all statistical analyses.

The strength of prediction was tested in the mixed-sex data, while the separated sex data was analyzed for significant differences in prediction between genders. The data was processed by encoding sex as a binary variable and creating interaction terms. Predictors were fitted using “sm.OLS” to estimate regression coefficients. All predictor p-values were visualized in bar plots, and only significant predictors were plotted in scatter plots with regression lines and correlation values for both overall and sex-stratified data.

The whole project was uploaded to GitHub as a public repository.

RESULTS

The paper from which we took the dataset found results showing variability in mind-wandering (MW) both between and within participants. In our exploration we extracted the mean of the 3 sessions for each of the aspects of the MW questionnaires and calculated the differences between the max value to the min value. The plots (Figure 1) present a clear variety in these aspects which align with the researchers results.

Additionally, in the intrusive thoughts (IT), the paper showed that after resting state with closed eyes, participants reported significantly higher scores for IT compared to the subtraction task. From our explorations we found a similar trend as reported and can be seen in figure 1.

While the researchers in the paper did not analyze or investigate questions regarding differences between genders nor predictive relationship between different variables in the various questionnaires that were applied, we found significant predictive variables for item 12 (IT) in the MW aspects.

When we analyzed the data across all participants (without separating by gender), as shown in figure 4, the pairs of variables showing significant predictive relations ($p < 0.05$) were discontinuity of mind (1) with IT after closed eyes, discontinuity of mind (1) with IT after Music and verbal thoughts (10) with IT after Music.

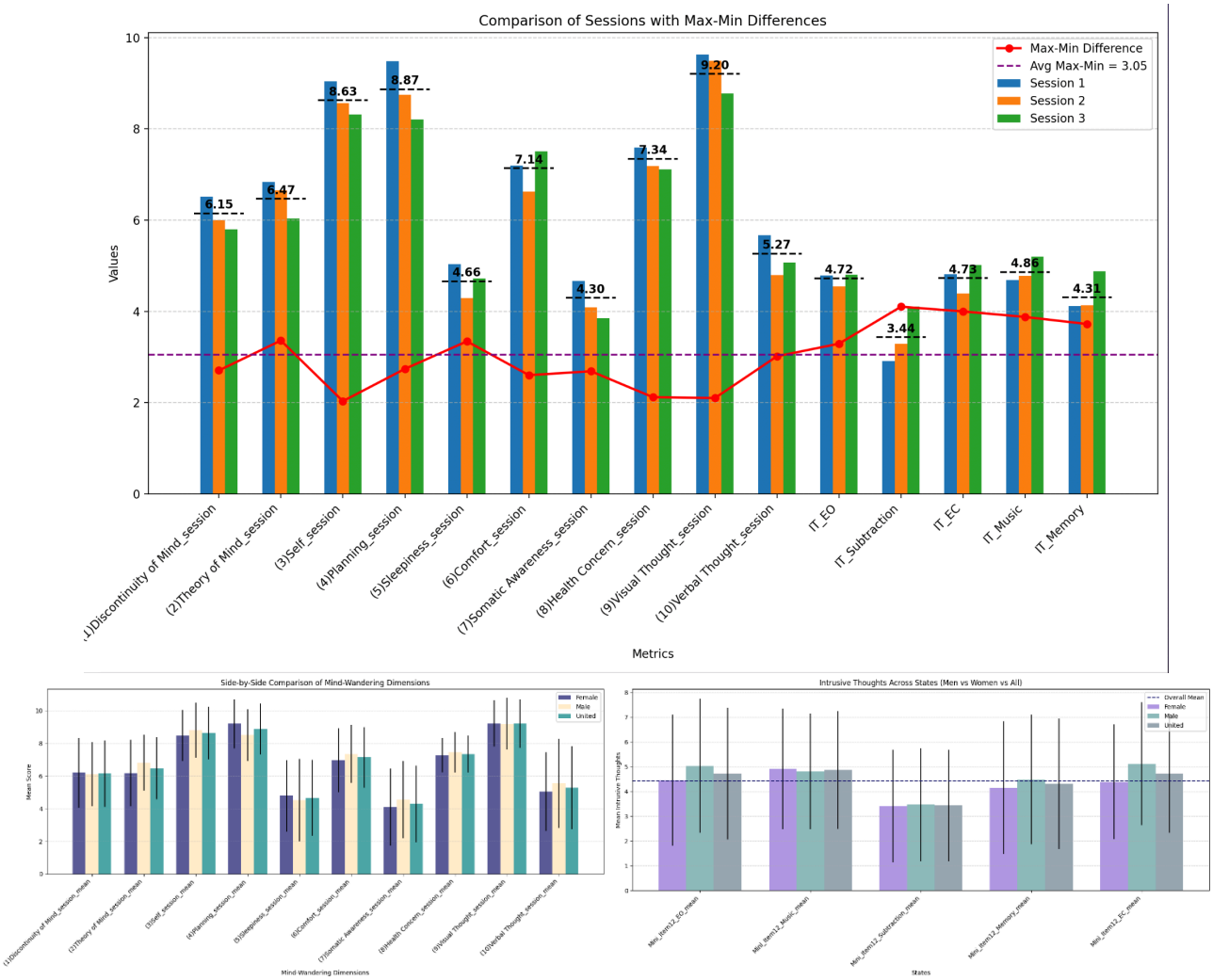
The one accounting for gender effects found ($p < 0.05$) Sleeping (5) with IT after Music, Visual thoughts(9) with IT after Music, and Visual thoughts (9) with IT after subtraction. as shown in figure 6. This suggests that in these paires the predictive power of MW dimensions differs significantly between the genders

DISCUSSION

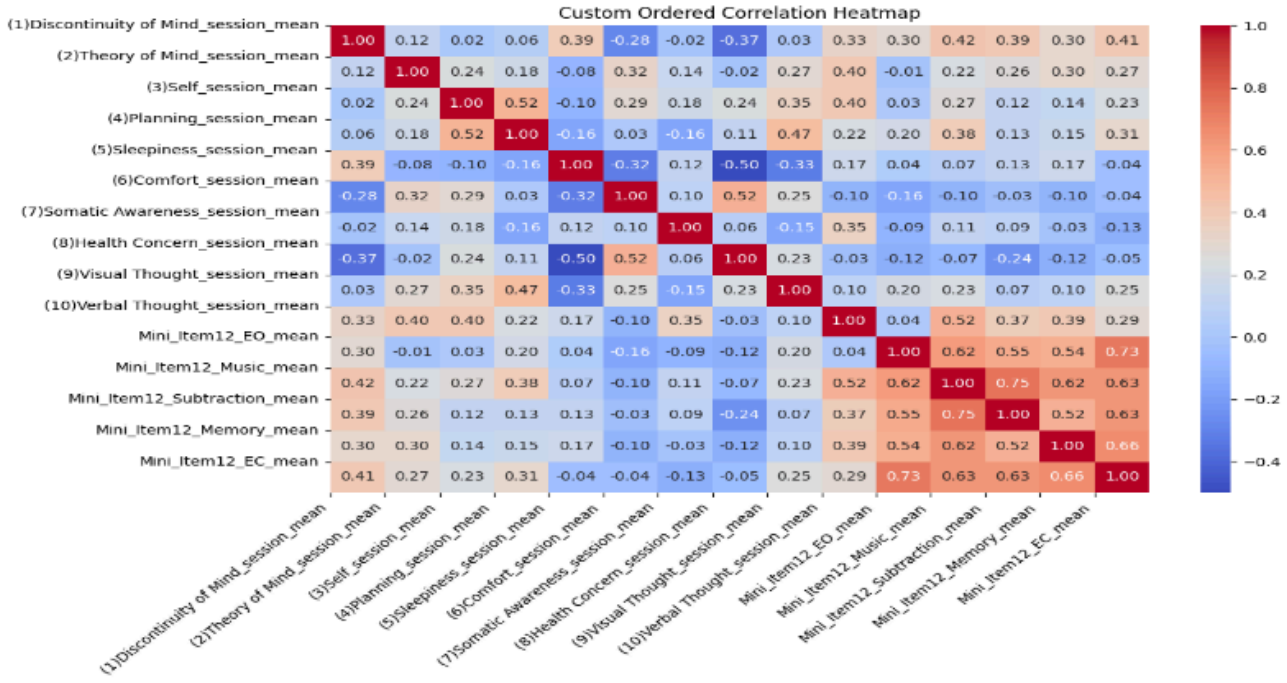
Our findings align with Wang et al. (2022), confirming variability in mind-wandering (MW) both within and between participants. The diversity observed across MW aspects suggests highly individualized experiences. Additionally, like the original study, our results did show the same differences in intrusive thoughts (IT) across cognitive states, contributing to the reliability of the original research results. Notably, we identified significant predictive dimensions for intrusive thoughts, including some whose predictive power differs significantly by gender. The identified dimensions are not identical, suggesting that when a predictor is strong, it holds relevance for both genders.

Our findings emphasize the need to account for participants' cognitive states when designing experiments and analyzing raw EEG data. Different MW states and situational factors can influence intrusive thoughts (IT), potentially interfering with results, especially in studies measuring cognitive states like IT. IT can vary with different cognitive tasks and may be more pronounced in certain EEG tasks.

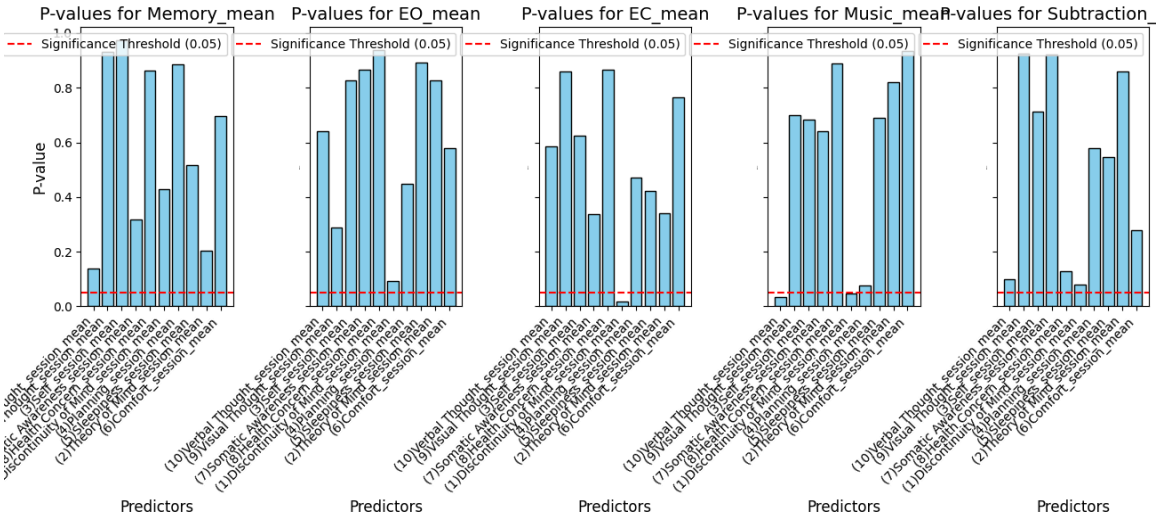
Additionally, our findings add nuance to the impact of gender, showing its influence is shaped by prior cognitive states. These factors should be considered in future research to improve generalizability. Future studies could further explore the neurophysiological basis of MW, IT, and other emotional states during EEG tasks, examine cultural influences on MW patterns, and investigate interventions to manage IT across different cognitive states.



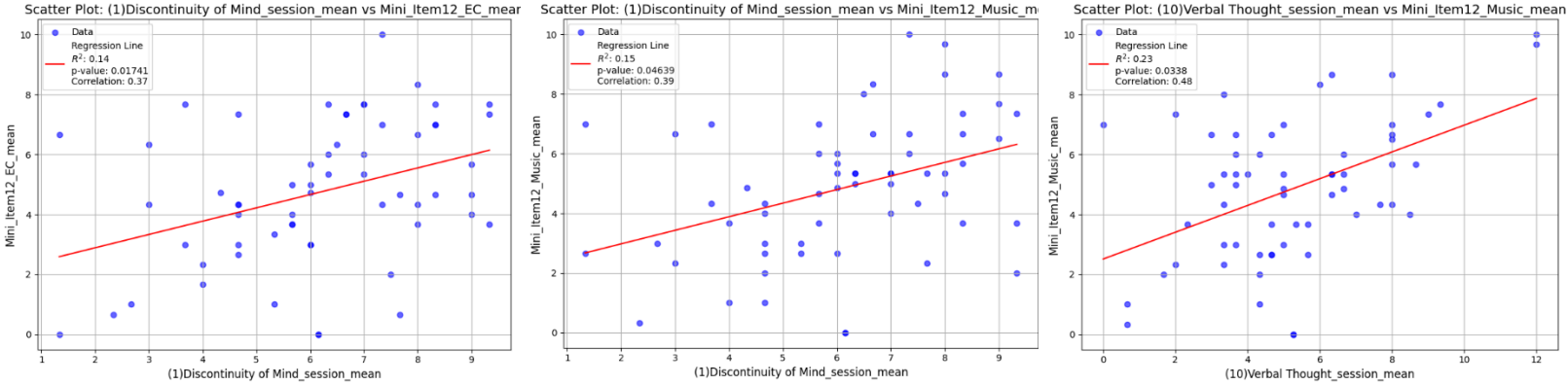
*In this **figure (1)** we can see clearly the diversity of the mind-wandering questionnaires regarding the variety and distributions of the mean and the Max-Min differences.*
The plot below shows separately the distributions of the mean data for each cognitive state scores for IT and each MW aspect.



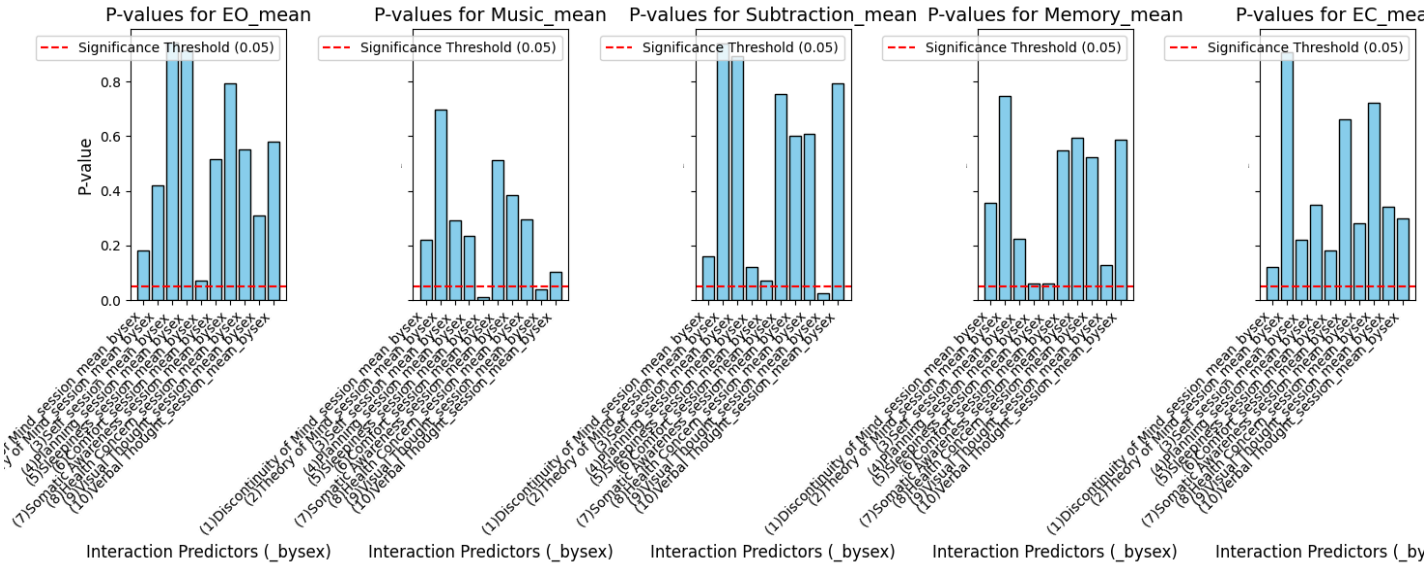
*In this **figure (2)** a heatmap showing all the variables used in this project showing them in one correlations plot with all combination's possibilities, to easily visualize strong correlations and differences between pairs of variables easily*



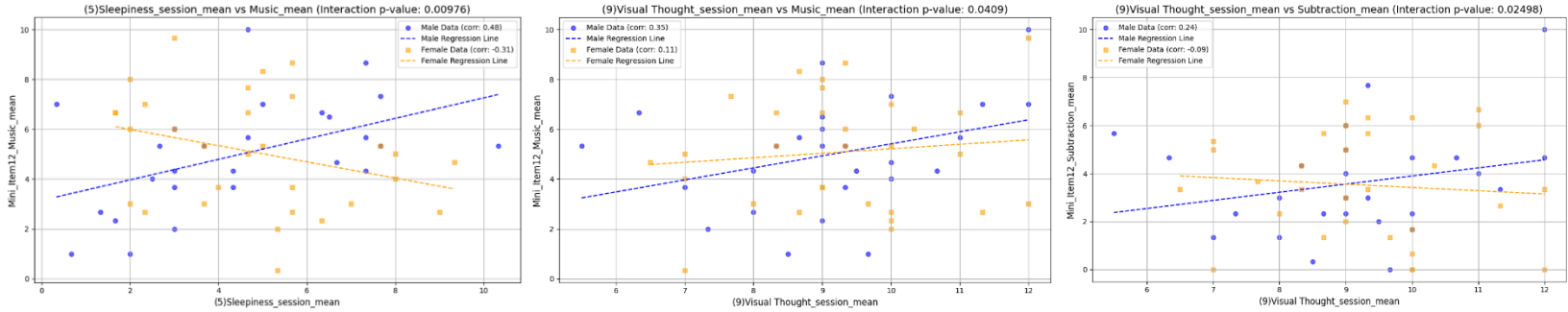
*This **figure (3)** shows in one histogram plot each state (in mixed gender), the p-value for each of the 10 of the MW aspect in the linear regression analysis. Histograms that are beneath the red line showed p<0.05 and are identified as strong predictors for intrusive thoughts*



(Figure 4) *These plots show the correlation (mixed genders) for significant predictors.correlation between the first aspect of MW correlate with Mini item 12 after the Eyes closed session (left) correlation between the same MW aspect with Mini item 12 after the music session (middle), and Music correlate also with aspect 10 of MW (right).*



*This **figure (5)** shows in one histogram plot of differences between gender for each state, the p-value to each of the 10 of the MW aspect in the linear regression analysis, histograms that are beneath the red line showed p<0.05 and are identified as strong predictors for intrusive thoughts*



*in this **figure (6)** we showed plots for a significant result of the differences between gender as we calculated the interaction of question 5 from the MW questionnaires to the after-music paradigm Item12 questionnaire (left), question 9 of MW to Music (middle), and question 9 of MW to subtraction (right).*

Link to our Project proposal:
https://docs.google.com/document/d/1UivLB8QXj9JdQKjBjBoU3abGYvDbTCck/edit

Link to the OpenNeuro dataset:
https://openneuro.org/datasets/ds004148/versions/1.0.1/file-display/participants.tsv

Link to the project's repository in GitHub:
https://github.com/mayac1600/project_gadol

APA to the paper:
Wang, Y., Duan, W., Dong, D., Ding, L., & Lei, X. (2022). A test-retest resting, and cognitive state EEG dataset during multiple subject-driven states. Scientific data, 9(1), 566