The Impact of Different Exercise Intensities on Memory Game Performance

Group 20 - Elena Flauto, Sofia Jain, Dave Le, Ryo Sato, Liandong Zou

Introduction

The exploration of physical exercise's role in enhancing cognitive functions, particularly memory, is at the forefront of our research interests due to the increasing prevalence of sedentary lifestyles and the potential benefits of active behaviors. This project investigates how different types of exercise—light jogging, swimming, and stretching—affect memory recall speed as measured by a memory game. These activities, representing a range of physical exertions, provide a unique lens through which we can assess their immediate cognitive impacts.

The primary motivation for this study stems from a desire to better understand which exercises might bolster cognitive health, aiming to inform recommendations for daily activities that could improve mental agility and memory retention. Given the virtual setting of The Islands, this study utilizes a controlled environment to mimic real-world conditions without the ethical and logistical complications often associated with human subject research.

Our expectation is that the type and intensity of exercise will significantly influence memory game performance, with the hypothesis that milder, less physically demanding activities like stretching could potentially enhance cognitive performance more effectively than more strenuous activities. The plan involves employing a replicated 3x3 Latin square design to systematically evaluate the effects of exercise while controlling for potential confounding factors such as age and geographical variations. This method will allow us to isolate the impact of exercise on memory speed accurately and provide clear, actionable insights into the cognitive benefits of different physical activities.

Design of the Experiment

To address the investigative question of how different levels of exercise affect memory speed, we employed a replicated 3x3 Latin Square design with the model equation: $Y_{ijkl} = \mu + \alpha_i + + \tau_j + \beta_k + \rho_l + \epsilon_{ijkl.}$ Where Y_{ijkl} = difference of speeds for the ith row, kth col for jth treatment and lth replicate. μ = overall mean, α_i = ith row (age) effect, τ_j = jth treatment (exercise) effect, β_k = kth column (location) effect, ρ_l = lth replicate effect and ϵ_{ijkl} = random error.

This design was chosen because it allows us to control for two nuisance variables (age and location) while systematically varying the exercise treatments across all participants. Each participant received all treatments in a balanced sequence, minimizing the potential confounding effects that could arise from environmental and individual differences. The specific designs for the three replicates were randomly formulated as follows.

```
##      [,1] [,2] [,3]
## [1,] "A"  "B"  "C"
## [2,] "B"  "C"  "A"
## [3,] "C"  "A"  "B"
```

```
##      [,1] [,2] [,3]
## [1,] "A"  "C"  "B"
## [2,] "B"  "A"  "C"
## [3,] "C"  "B"  "A"
```

```
##      [,1] [,2] [,3]
## [1,] "B"  "C"  "A"
## [2,] "C"  "A"  "B"
## [3,] "A"  "B"  "C"
```

The Latin Square design is particularly beneficial in experiments where resources are limited and there is a need to control for more than one extraneous variable. In our case, we are able to adjust for variations across three age groups and three distinct locations on the virtual islands, thereby enhancing the reliability of our findings by reducing variability not attributed to the exercise treatments.

Description of the Sample

The sample for this experiment was composed of virtual subjects from The Islands platform, selected to ensure a broad demographic representation. We randomly selected one town from each of the three islands, and from each town, we randomly chose participants such that each age group (18-29, 30-65, over 65) was represented. This stratified random sampling approach helped in achieving a balanced representation of age and location, which are critical factors in studying cognitive functions.

To determine the adequate sample size for this study, we conducted power calculations using the assumptions about the expected effect sizes based on preliminary data and the variance observed in previous studies. Power calculations were performed using the software G*Power, specifying an effect size, alpha level of 0.05 (for a 95% confidence level), and a power of 0.80 (80% chance of detecting a true effect if it exists). Based on these parameters, the recommended sample size was nine participants per group for each treatment within the Latin Square, making a total of 27 participants across the three replicates.

This sample size is justified as it provides sufficient power to detect statistically significant differences in memory game completion speed between different exercise conditions. The use of three replicates further ensures the robustness of our data, allowing us to confirm the reliability of the observed effects across multiple trials and settings.

Results and Interpretation

We analyzed the data using ANOVA, which provided a detailed breakdown of the effects of each treatment and the role of other factors. We used a significance level of 0.05 throughout our analysis.

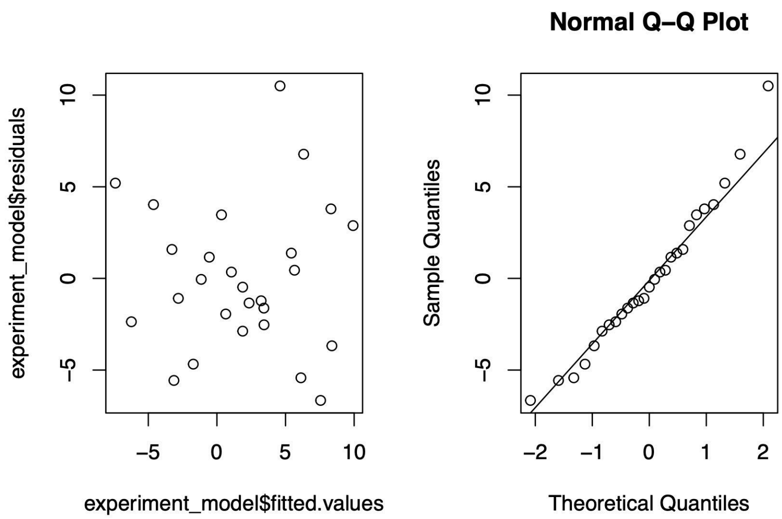
ANOVA Results:

```
##                   Df Sum Sq Mean Sq F value  Pr(>F)
## AgeRange           2    3.1    1.53   0.067 0.93564
## Location           2   81.3   40.64   1.777 0.19753
## LatinReplicate     2  114.4   57.21   2.502 0.10999
## ExerciseTreatment  2  361.0  180.51   7.894 0.00346 **
## Residuals         18  411.6   22.87
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The ANOVA revealed a significant effect of the exercise treatment on memory game completion time ($F(2, 18) = 7.894$, $p = 0.00346$). We can see the exercise treatment is significant as it has a p-value under 0.05 which matches our box plot. This indicates that the type of exercise significantly affected the participants' memory speed. The factors 'Age Range' and 'Location' did not show significant effects, suggesting that these did not influence the outcomes within this experimental setup.

This analysis confirms that the choice of exercise has a measurable impact on cognitive function, particularly in tasks involving memory, while other factors such as age and location within the virtual setting do not alter this outcome. This insight could be crucial for designing cognitive enhancement programs that leverage physical activity to improve mental performance.

Additionally, the assumptions of normality and constant variance are validated in the plots below:



1. Residuals vs. Fitted Values Plot: This plot helps to assess the assumption of homoscedasticity (constant variance) across the range of predictions made by the model. Ideally, the points should be randomly dispersed around the horizontal line at zero, with no clear pattern. From the plot, the residuals appear fairly well dispersed, though there might be slight hints of non-constant variance as some clustering of residuals at certain fitted value ranges can be observed. However, there doesn't seem to be any systematic pattern indicating major violations of homoscedasticity.

2. Normal Q-Q Plot: The Normal Q-Q plot is used to check the assumption that the residuals of the model are normally distributed—a critical assumption for the validity of many inferential statistics in linear models. In the plot, most points lie along the reference line, suggesting that the residuals approximate normal distribution quite well. There are a few deviations at the tails, but these are not extreme, indicating only minor deviations from normality.

These diagnostic plots suggest that the model is reasonably well-specified for the data with assumptions of homoscedasticity and normality largely met. The slight deviations observed do not appear severe enough to undermine the conclusions drawn from the ANOVA results, which found significant effects of exercise type on memory game completion times. The normal distribution of residuals supports the use of parametric tests (like ANOVA) and confidence in the generalizability of the results.

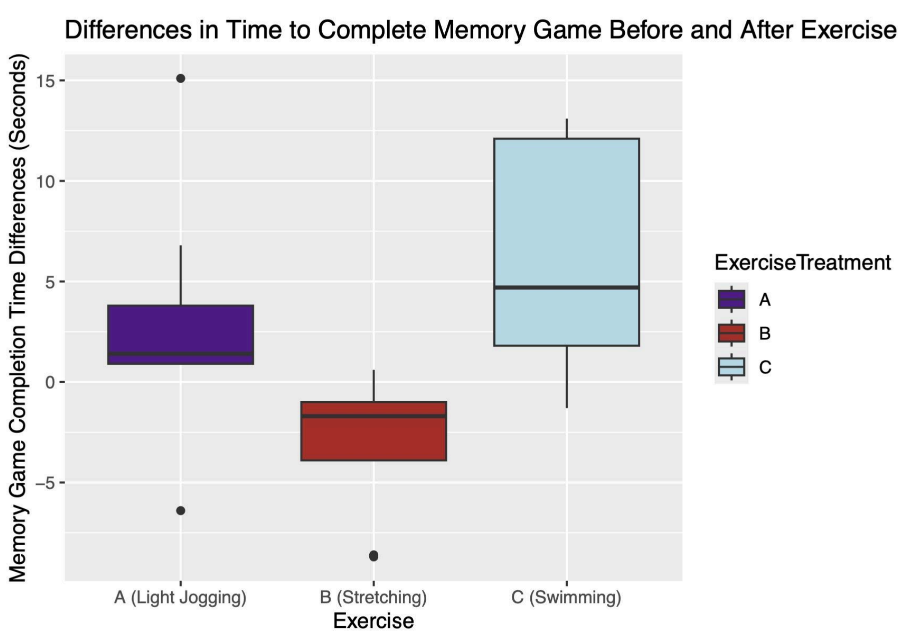
Post-hoc Analysis (Tukey's HSD):

```
##           diff        lwr         upr       p adj
## B-A -5.800000 -11.553293 -0.04670686 0.047983742
## C-A  3.011111  -2.742182  8.76440425 0.394449360
## C-B  8.811111   3.057818 14.56440425 0.002813398
```

The Tukey's HSD test for multiple comparisons highlighted significant differences between the exercise treatments:

1. Stretching (B) vs. Light Jogging (A): The mean difference was significant (p = 0.04798), indicating that stretching significantly improved memory speed compared to light jogging.
2. Swimming (C) vs. Stretching (B): Also showed a significant difference (p = 0.00281), with stretching leading to better memory performance compared to swimming.
3. We also notice the mean of B is negative, whereas the means of A and C are positive. Using this, we can conclude stretching decreases the time it takes to do the memory game, thus having a positive effect on memory speed and swimming and light jogging increase the time it takes to do the memory game, thus having a negative effect on memory speed.
4. A has a slightly less negative effect of memory speed than swimming as its mean is lower but since the pair A&C was not significant we can't conclude their effects are significantly different.

Boxplot Visualization:



The boxplot also validates the differences we found in memory game completion times across the three exercise treatments: light jogging (A), stretching (B), and swimming (C).

1. Stretching (B) shows the most beneficial effect, with a median difference below zero, indicating faster memory game completion after stretching. This suggests that stretching may enhance cognitive performance, likely due to its mild intensity and stress reduction benefits.

2. Light Jogging (A) results in a slight increase in completion time, suggesting a moderate negative impact on memory speed immediately following the exercise.

3. Swimming (C) exhibits the highest median and greatest variability in completion times, indicating the most significant negative impact on memory performance. This could be due to the higher physical exertion required, which might temporarily divert resources away from cognitive processes.

These observations support the idea that less intense exercises like stretching could be beneficial for cognitive functions, especially in settings where mental performance is critical. Conversely, more strenuous activities might be less favorable for immediate cognitive tasks but could still be beneficial when scheduled appropriately. These insights can inform exercise recommendations tailored to optimize cognitive health and performance.

Discussion

This research, using the virtual population on The Islands, examined how exercise types of different intensities—light jogging, swimming, and stretching—impact memory recall speed. Based on ANOVA tests under a Latin squared design, we found that stretching significantly enhances memory recall while swimming and jogging appear to impair it. These results highlight the complex relationship between physical activity intensity and cognitive performance, suggesting that not all exercise types benefit cognitive functions equally.

While it is increasingly recognized among the public that exercise has some benefits on cognitive functions broadly, our result demonstrates the importance of a careful selection of exercise types. The result that mild exercise instantly enhances memory may be relatable to some people, and extant scholarship provides further credence. According to recent studies, light and brief exercises can significantly boost memory by enhancing activity in the hippocampus, a brain region critical for memory processing (Inoue et al., 2015).

The primary limitation of this study is its virtual setting, which may only partially simulate real-world physiological responses. Furthermore, it remains unclear from the study whether habitual engagement in the same types of exercise affects the more durable measure of cognitive function. While our results indicated that intensive exercise may decrease memory recall in the short run, some evidence suggests that higher intensity can eventually enhance concentration and overall cognitive performance (Audiffren & André, 2019), which can be even more critical for adolescent brain development (Jeon & Ha, 2017). Yet, there is also countering evidence that consistently show both short-term and long-term exercise regimens positively influence memory and cognitive health over time (Loprinzi et al., 2021). Future studies aim to replicate these findings in real-life settings, extend the investigation to the long-term effects of varied exercise types, and explore the underlying physiological mechanisms in a broader demographic spectrum. This approach will help validate and potentially expand the applicability of our findings to diverse populations

This study significantly contributes to exercise psychology by demonstrating that different physical activities distinctly influence cognitive performance. In the sedentary era where many people have no choice but to sit and work for long hours a day, it is good news that a short period of stretch enhances performance. These findings can help inform exercise recommendations tailored for cognitive enhancement, providing valuable insights for both individuals and health program developers focused on improving mental health and productivity.

Citations

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