Enhancing Cognitive Focus through Sudoku: A Longitudinal Study

IS4800 Group Research Project

Karen Cheng
Khoury College
Northeastern University
Boston MA USA
cheng.k@northeastern.edu

Allison Li
Khoury College
Northeastern University
Boston MA USA
li.alli@northeastern.edu

Huan Feng Yeh
Khoury College
Northeastern University
Boston MA USA
yeh.hua@northeastern.edu

ABSTRACT

Sudoku, a captivating and widely-played puzzle game, has gained immense popularity worldwide for its simple yet challenging nature. It is a logic-based, combinatorial number-placement puzzle that has been around since the 1980's. Cognitive focus is an essential aspect of mental functioning and is crucial for various everyday tasks and learning processes. It involves sustained attention, concentration, and the ability to manage distractions. Previous studies have suggested that engaging in certain types of mental exercises, such as puzzles and problem-solving games, can help grow and maintain these cognitive abilities. However, there is a need for more focused research to understand the specific impacts of different types of puzzles, like Sudoku, on cognitive focus. This paper presents a longitudinal study conducted on Northeastern students aiming to determine the impact of playing Sudoku on cognitive focus.

INTRODUCTION

The classic Sudoku puzzle consists of a 9x9 grid, divided into nine 3x3 subgrids or "regions." The primary objective of the game is to fill this grid with numbers from 1 to 9 in a way that each row, each column, and each subgrid contains all nine digits, with no repetition.

Our study investigates the cognitive benefits of playing Sudoku, a logic-based, combinatorial number-placement puzzle, on enhancing cognitive focus. Participants were recruited from Northeastern University and engaged in Sudoku gameplay daily over a 15-day period. Our research utilized a within-group experimental design where the participants' cognitive focus levels were assessed at the beginning and conclusion of the study using a focus test. Additionally, surveys were administered every five days throughout the duration of the experiment where participants' self-assessed their own focus and productivity levels. At the conclusion of our experiment, game statistics were collected from Sudoku.com for each participant. Statistical tests were then conducted with the data collected and analysis was also conducted with qualitative data received from the surveys. From these, we were able to reach a conclusion on the impact of Sudoku on cognitive focus.

BACKGROUND AND RELATED WORK

There have been several studies that have demonstrated the potential benefits of playing cognitive games. Sudoku is one of the games that stands out the most in a lot of studies done on cognitive ability. Sudoku is a cognitive, logic-based, number placement puzzle (Lorimer-Derham, 2023). This game requires players to use logical reasoning and deduction to fill a 9x9 grid following certain rules. Each row, column, and 3x3 square in the 9x9 must contain each of the numbers 1-9 with no duplicates.

In a study done by Deary, declines in cognitive functions can start from early adulthood (Deary et al., 2019). However, as shown in the study done by Ferreria, cognitive games can be used as a support tool for maintaining cognitive health (Ferreira et al., 2014d). Additionally, a study conducted by Merilampi shows how games such as sudoku can help improve cognitive functions in memory impaired older adults (Merilampi et al., 2014). Not only can playing cognitive games help subjects with impaired cognitive functions but they can also improve attention and memory functions in healthy subjects as shown in a study conducted by Al-Thaqib (Al-Thaqib et al., 2018).

However, none of these prior studies(Kalia et al., 2019b) (Ferreira et al., 2014d) (Chang & Gibson, 2011b) have focused specifically on computer science college students and how those students could benefit from playing cognitive games. Graduate students, in particular, are a key demographic we are interested in, given that they are often engaged in tackling complex logic and cognitive tasks as part of their academic and research pursuits. In order to address this, we will explore the influential factors to computer science students after playing Sudoku in educational contexts. Here, we will investigate how playing sudoku has changed their cognitive abilities, more specifically, memory.

With this study, we seek to answer the question: Does playing logic based puzzle games like Sudoku correlate to better cognitive performance (specifically memory)in computer science students?

We’ve seen games like sudoku are often used to measure cognitive performance as in the study done by Pahwa where they saw that performance on associative memory decreases from cardiovascular exercise and they came to that conclusion using sudoku as a measure of cognitive performance (Pahwa et al., 2020). Especially for students, we see that recreational math games like sudoku have a large impact on cognitive success for students as seen in Suri’s study of the Importance of Recreational Math (Suri, 2015). In this study we define cognitive performance as things associated with better memory and performance academically. There are pre existing studies that demonstrate sudoku can help with memory as seen in the ‘9 Quick Memory Tips to Help Remember Names’ (Anonymous, 2015).

1 METHODS PROCEDURES & ANALYSIS

We want to know if playing cognitive games, more specifically Sudoku (independent variable), will have an impact on the cognitive performance, more specifically focus, of Northeastern students as well as their academic success (dependent variable). We will conduct a statistical test to see if the difference in student’s focus and academic success after playing sudoku for a period of time is significant. Our null hypothesis will be that there is NO difference in student’s focus and academic success after playing sudoku for a certain period of time everyday. Our alternative hypothesis will be that there is a difference in student’s focus and academic success after playing sudoku for a certain period of time everyday. From our statistical test, based on the p-value we find, if it is below our alpha value of 0.05, then we would determine that there is a statistically significant difference from playing sudoku and not playing sudoku in terms of how long people play each day.

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

Figure 1: Sudoku Game (Medium Level)

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1.1 Data Interpretation & Results

In the figures below we made visualizations of our data using R. Interpretations and results will be discussed.

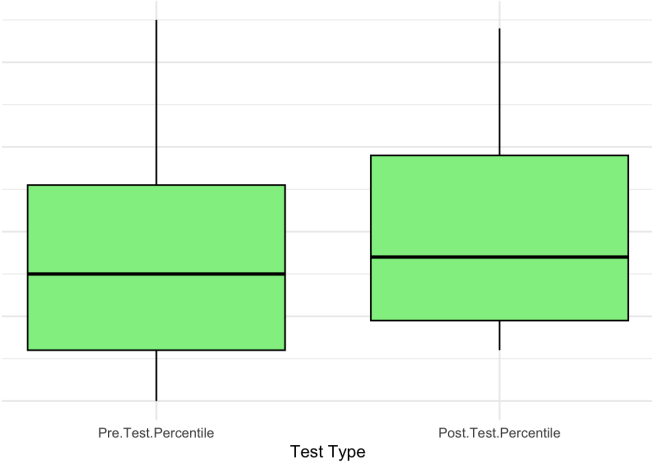

Figure 2: Boxplot of Pre-Test and Post-Test Percentile

The boxplot compares the Pre-Test and Post-Test Percentile scores. And as shown above distributions appear to have a similar median and the range of scores is also similar which means that there is likely no significant difference in the central tendency of the scores from pre to post-test. This led us to conclude that playing Sudoku may not have had a strong impact on the percentile ranks of cognitive performance. There are no evident outliers. This could imply that if Sudoku has any effect on cognitive performance, it does not significantly vary among different individuals in this sample.

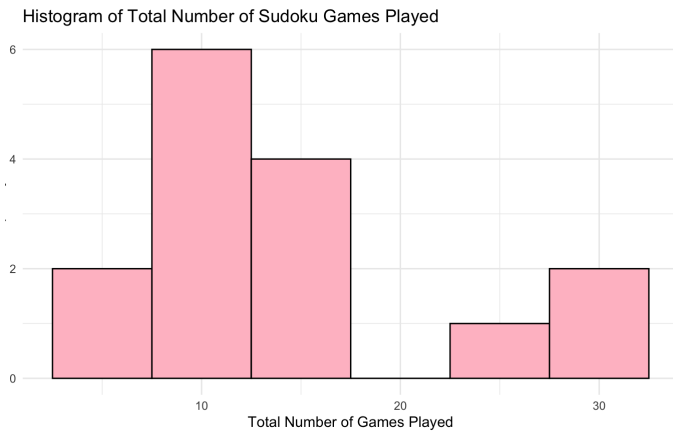

Figure 3: Histogram of Pre-Test and Post-Test Percentile Scores

The histogram displays the frequency distribution of the total number of Sudoku games played by participants. Most participants played between 10 and 20 games, with a few participants playing fewer than 10 or more than 20 games. The distribution is somewhat left-skewed, indicating that while most participants engaged with Sudoku moderately and a smaller number of participants played very few or many more games. This could mean that there was a varied level of interest or availability among the participants for playing Sudoku. Scatter Plot of Total Games vs. Post-Test Percentile

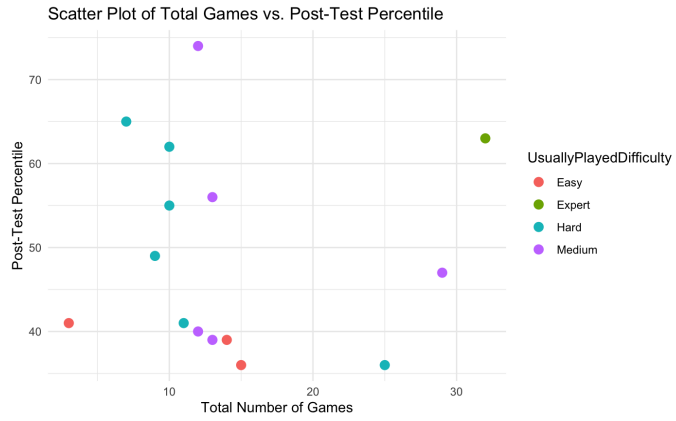

Figure 4: Scatterplot of the Total Number of Sudoku Games and Post-Test Percentile Scores

The scatter plot illustrates the relationship between the total number of Sudoku games played and the Post-Test Percentile scores, with points colored by the difficulty level usually played. There does not appear to be a strong linear relationship between the number of games played and the post-test scores, as the points do not form a clear upward or downward trend. This suggests that there is no relationship between the total number of Sudoku games played and the Post-Test Percentile scores.

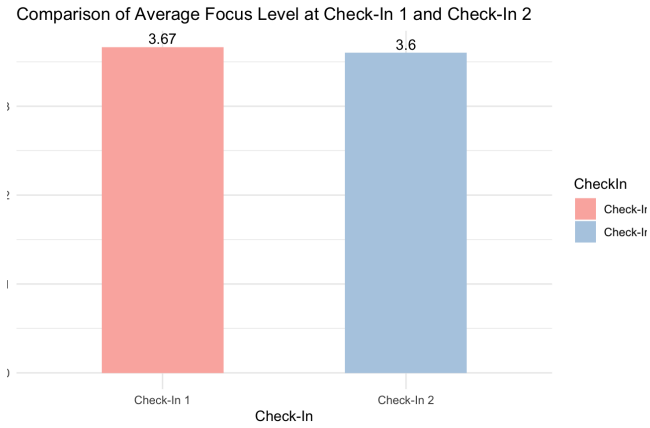

Figure 5: Average Focus Level at Check-In 1 & Check-In 2

We compared the average focus level check-in 1 and check-in 2, the difference in score was only 0.07 indicating that from the data we collected playing sudoku did not have an effect on the focus levels of our subjects.

1.2 Limitations

Our participant pool was mostly computer science majors which may have introduced selection bias in our results. Students in computer science may have specific cognitive skills or problem-solving strategies that differ from those in other fields, which could influence their performance and experiences in ways that are not representative of a more diverse group.

In addition, the small sample size and the short duration of our experiment are significant constraints. Since cognitive ability improvement may not be easily detected, we need a larger group of people and long-term experiments to draw more robust conclusions.

Another limitation is our reliance on self-reported data. It can introduce social desirability bias. Participants might report what they think the researchers want to hear or may lack the self-awareness to accurately assess and report their cognitive states and experiences.

Lastly, using only Sudoku as the cognitive game in our study presents a limitation. Sudoku requires specific types of cognitive processing, such as pattern recognition and logical reasoning. It limits the scope of our findings to the cognitive processes involved in Sudoku. Different games engaging other cognitive skills could yield different results suggesting the need for a more varied set of cognitive tasks in future research to comprehensively understand the phenomena under study.

2 DISCUSSION

Our research revealed that while Sudoku, as a cognitive game, had some impact on the focus and cognitive function of participants, the results were not as significant as hypothesized. This suggested that while cognitive games can have a positive effect, the extent of this effect can vary greatly among individuals. Some participants reported a subjective improvement in their focus after engaging with Sudoku. However, these improvements were not uniformly experienced across the participant group, highlighting the complexity of cognitive processes and the influence of individual cognitive abilities.

2.1 Team Challenges

One of the primary challenges we faced was in the collection of data. Ensuring a sufficient response rate for the surveys proved to be a significant hurdle. Initially, we relied on students in our class for responses. However, due to a lower than anticipated response rate, we had to expand our reach to our personal networks of computer science majors. This expansion, while beneficial in increasing the response rate, introduced a bias in our participant pool towards computer science backgrounds, potentially impacting the generalizability of our findings. Another major challenge was in data interpretation.

Our study involved multiple surveys, which resulted in several disparate datasets. Each dataset had to be meticulously cleaned and then integrated into a master dataset. This process of cleaning individual survey responses and amalgamating them into a cohesive whole was both time-consuming and complex. It required careful consideration to ensure that the integrity and accuracy of the data were maintained.

To address these challenges in future studies, a more diversified recruitment strategy could be employed to ensure a broader and more representative participant pool. Additionally, adopting a more streamlined approach to data collection, perhaps through a single, comprehensive survey tool, could alleviate the complexities involved in data cleaning and integration.

2.2 Future Work

In the future, we want to identify and evaluate other tools or interventions that might be more effective in enhancing focus. This could include comparing cognitive games with other forms of mental exercises or relaxation techniques.

To obtain a more accurate assessment of focus and cognitive function,we also want to implement more objective measures. This could involve tracking task completion times, error rates, or using eye-tracking technology and brain imaging techniques. These objective measures can provide a more precise understanding of how cognitive games influence focus and cognitive abilities.

A long-term study is also the thing we want to achieve in the future. it could help to examine the long-term impacts of cognitive game use on productivity, learning outcomes, and user behavior would provide valuable insights. Such a study could help determine if the effects of cognitive games are sustainable over time and how they influence various aspects of daily life and cognitive health.

2.3 Conclusion

In our study, we contribute to the growing body of knowledge on cognitive games and their potential impact on cognitive functions. While the results did not show a significant improvement in focus or cognitive function, It shows the need for further research in this area, particularly with a more diversified participant pool and a broader range of cognitive games. The insights gained from this study lay the groundwork for future research endeavors aimed at uncovering the complex relationship between cognitive games and cognitive performance.

2.4 Contributions

This research work was a collaborative process. Everyone contributed to every phase of the work. Below we discuss each team member’s contribution.

• Karen Cheng formulated the research idea, research plan, and research team. She recruited 6 volunteers to participate in our research. She developed the project's mixed-methods methodology, integrating both qualitative and quantitative research, including pre and post cognitive focus assessments, regular surveys, and analysis of data from Sudoku game plays. She also contributed to preparing the final project report and the presentation slide. She regularly attended weekly meetings with the research team.

• Allison Li formulated the research idea, research plan, and research team. She recruited 6 volunteers to participate in our research. She developed the project's mixed-methods methodology, integrating both qualitative and quantitative research, including pre and post cognitive focus assessments, regular surveys, and analysis of data from Sudoku game plays. She also contributed to preparing the final project report and the presentation slide. She regularly attended weekly meetings with the research team.

• HuanFeng Yeh formulated the research idea, research plan, and research team. He recruited 3 volunteers to participate in our research. He developed the project's mixed-methods methodology, integrating both qualitative and quantitative research, including pre and post cognitive focus assessments, regular surveys, and analysis of data from Sudoku game plays. He also contributed to preparing the final project report and the presentation slide. He regularly attended weekly meetings with the research team.

REFERENCES

[1] Kalia, V., Fuesting, M., & Cody, M. (2019). Perseverance in solving Sudoku: role of grit and cognitive flexibility in problem solving. Journal of Cognitive Psychology, 31(3), 370–378. https://doi.org/10.1080/20445911.2019.1604527

[2] Ferreira, N., Owen, A. M., Mohan, A., Corbett, A., & Ballard, C. (2014). Associations between cognitively stimulating leisure activities, cognitive function and age‐related cognitive decline. International Journal of Geriatric Psychiatry, 30(4), 422–430. https://doi.org/10.1002/gps.4155

[3] Chang, H., & Gibson, J. M. (2011). The Odd–Even effect in sudoku puzzles: effects of working memory, aging, and experience. American Journal of Psychology, 124(3), 313–324. https://doi.org/10.5406/amerjpsyc.124.3.0313

[4] Deary IJ, Corley J, Gow AJ, et al. 2009. Age-associated cognitive decline. Br Med Bull 92: 135–152.

[5] Merilampi, S., Sirkka, A., Leino, M., Koivisto, A. and Finn, E. (2014), "Cognitive mobile games for memory impaired older adults", Journal of Assistive Technologies, Vol. 8 No. 4, pp. 207-223. https://doi.org/10.1108/JAT-12-2013-0033

[6] Pahwa, A. R. R., Miller, D. J., Caplan, J. B., & Collins, D. F. (2020). Performance on an Associative Memory Test Decreases 8 hr After Cardiovascular Exercise. Journal of Sport & Exercise Psychology, 42(3), 219–226. https://doi-org.ezproxy.neu.edu/10.1123/jsep.2019-0224

[7] Suri, M. (2015, October 12). The Importance of Recreational Math. New York Times, 165(57017), A19.

[8] Lorimer-Derham, A. (2023). A Guide to Making Sudo-Clue Puzzles. Vinculum, 60(3), 19.

[9] 9 Quick Memory Tips to Help Remember Names. (2022). Curriculum Review, 62(1), 5. https://link.ezproxy.neu.edu/login?url=https://www.proquest.com/trade-journals/9-quick-memory-tips-help-remember-names/docview/2765804012/se-2

[10] Al-Thaqib, A., Al-Sultan, F., Al-Zahrani, A., Al-Kahtani, F., Al-Regaiey, K., Iqbal, M., & Bashir, S. (2018). Brain Training Games Enhance Cognitive Function in Healthy Subjects. Medical science monitors basic research, 24, 63–69. https://doi.org/10.12659/msmbr.909022