KMANPUB | Health Nexus Vol. 1 No. 1 (2023): 64-70

Article history:
Received 23 September 2022
Revised 30 November 2022
Accepted 09 December 2022
Published online 01 January 2023

The Impact of Doing Assignments with Chatbots on The Students' Working Memory

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A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Rostami, M., & Mehdi Abadi, P. (2023). The Impact of Doing Assignments with Chatbots on The Students' Working Memory. *Health Nexus, 1*(1), 64-70.

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A B S T R A C T

This study aimed to investigates the effects of chatbot usage on working memory in students who do their assignments with chatbots. The research employed a Single-Subject AB design involving three participants, with each phase consisting of four measurements. Remarkably, the study revealed diverse outcomes: one participant exhibited no significant change in working memory, another showed a decrease, and the third experienced a gradual increase. These varied results suggest that chatbots can have differential impacts on working memory, potentially explained by cognitive load theory. This theory emphasizes the importance of optimizing technology use in learning environments to support working memory functions. The study's findings indicate that chatbots, as an educational tool, can have complex and varying effects on students' cognitive abilities, particularly in terms of working memory.

Keywords: *chatbots, students, working memory*

1. Introduction

Working memory is a central concept in cognitive psychology and neuroscience, referring to the system responsible for the temporary storage and manipulation of information necessary for complex cognitive tasks. It plays a crucial role in reasoning, decision-making, and behavior. Over the years, various theories have been proposed to explain its structure and function (1-3). In other words, working memory is conceptualized as a system for temporarily storing and managing the information required to carry out complex cognitive tasks such as learning, reasoning, and comprehension. It is often associated with the prefrontal cortex of the brain and is crucial for decision-making and behavior regulation. In sum, working memory is a critical cognitive function that involves the temporary storage and manipulation of information which is influenced by various factors, ranging from genetic to environmental (1, 4, 5).

The advent of technology tools has significantly impacted how this cognitive function operates. The study of Chen (2021) explored DLL from various perspectives, including its cognitive impact. It implied that technology in language learning can influence cognitive functions, including working memory (4). Sweller (2020) provides instructional recommendations based on cognitive load

theory, relevant to technology's impact on reducing working memory load in educational settings (6). Moreover, Squires (2018) investigates Augmented Reality (AR) role in enhancing learning experiences. He suggests that AR can engage users more effectively and improve content recall, indicating a potential positive impact on working memory (7). Monterieux and Schellens (2018) examines how tablet devices affect students' cognitive load and learning. They found that tablets, especially with adapted learning material, can reduce cognitive load and enhance learning, potentially benefiting working memory (8). Price et al. (2016) show that reducing working memory demand through effective information visualization can improve decision accuracy (9).

Therefore, it is expected that chatbots also can have various effects on working memory, which is the part of short-term memory that is concerned with immediate, conscious perceptual and linguistic processing. Still, no studies directly examined the effect of chatbots on working memory of the students. However, some studies are done that indicates other effects of utilizing chatbots in educational context. For instance, in the study of Zhai, Wibowo and Cowling (2022) the focus is on the role of chatbots in language learning, particularly in providing empathetic and culturally sensitive responses. This indicates the potential of chatbots in supporting cognitive processes involved in language learning and memory (10). A review by Ubah et al. (2022) discusses how AI systems, including chatbots, can enhance the efficiency of educational tasks, potentially reducing cognitive load and aiding memory (11). The study of Bohomolova, Kushnir, and Moshkovska (2021) discusses the effectiveness of chatbots in individualizing learning processes. This suggests that chatbots can aid in reducing cognitive load and enhancing memory retention in educational settings (12). The study of Galvao et al. (2019) explores the human-computer interaction aspect of chatbots. It implies that chatbots can influence cognitive processes by altering the way humans interact with information technology (13). The study of Pamina et al. (2019) highlights the use of chatbots in healthcare for information retrieval and interaction, which can influence cognitive load and working memory in medical contexts (14). According to what have been mentioned above, the current study aimed to investigate how using chatbots to do school assignments can influence the working memory of students.

2. Methods and Materials

2.1. Study Design and Participants

This study employs a Single-Subject AB design to investigate the impact of using chatbots with minimal effort on the working memory of three participants aged between 11 and 13 years old in London. The study involves three participants from London, aged between 11 and 13 years old. The participants were selected using an available sampling method, which means they were chosen based on their accessibility and willingness to participate in the study.

2.2. Measures

2.2.1. N-Back Test

The N-Back test is a cognitive assessment tool primarily used to evaluate working memory and executive functioning. In this task, participants are presented with a sequence of stimuli (such as letters, numbers, or spatial locations) and are asked to determine whether the current stimulus matches the one presented N steps earlier in the sequence. The "N" in N-Back can vary, with common versions including 1-Back, 2-Back, and 3-Back, where the challenge increases with higher N values. The stimuli are presented on a computer screen. Participants respond by pressing a button or key if the current stimulus matches the one from N steps before. Scoring is based on the number of correct identifications of matches (hits) and correct rejections of non-matches. In the current study, 2-Back test has been used which contained 20 trials and the scores range from 0 to 20. The validity of reliability of this test has been confirmed in various studies (15, 16).

2.3. Procedure

In initial phase, the participants' working memory was assessed four times, each measurement occurring at a 1-month interval. This phase served as the baseline against which the effects of the intervention were compared. In the subsequent phase, the participants began completing all their assignments using Chatbots while making the lowest possible effort. During this phase, the participants' working memory was again measured four times, with each measurement occurring at a 1-month interval.

2.4. Data Analysis

In this case, graphical analysis involves drawing plots or charts that display the data collected during both the

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E-ISSN: 2981-2569

baseline and intervention phases. Additionally, RCI was calculated for each participant to determine whether the changes in their working memory scores between the baseline and intervention phases are statistically significant. The RCI compares the observed change in working memory scores to the expected change due to random variability, helping to determine if the intervention had a reliable and statistically significant effect.

3. Findings

The descriptive statistics findings have been calculated for three participants, each 8 times, and are reported in the Table 1.

Table 1

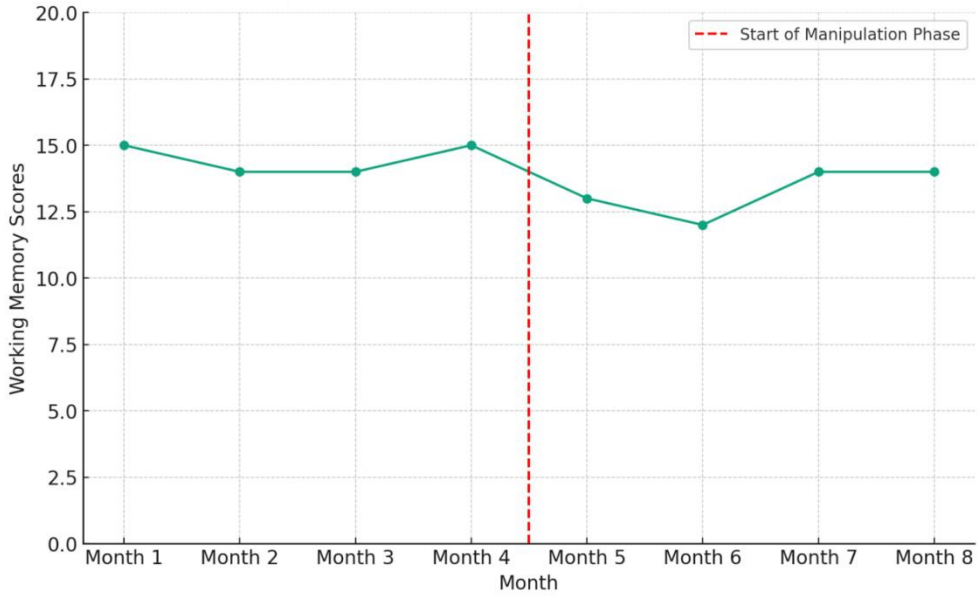
Descriptive statistics findings and RCI for three subjects in two phases of measurements

Month (Phase)	Subject one	Subject two	Subject three
Month one (Baseline)	15	12	16
Month two (Baseline)	14	12	15
Month three (Baseline)	14	13	16
Month four (Baseline)	15	12	16
Baseline Mean	14.50	12.25	15.75
Month five (Manipulation)	13	10	18
Month six (Manipulation)	12	9	17
Month seven (Manipulation)	14	8	18
Month eight (Manipulation)	14	8	19
Manipulation Mean	13.25	8.75	18
RCI	1.12	2.39	2.15

The results showed that the mean of the scores in the baseline phase for subjects one, two, and three were 14.50, 12.25 and 15.75 with the corresponding mean scores of were 13.25, 8.75 and 18, respectively. Moreover, the RCI significance indicates that no significant changes occurred in the scores of the working memory of subject one ($R<1.96$) while the scores of other subjects are changed significantly ($R>1.96$). Three graphs are also presented for a detailed visualization of data and interpretation.

Figure 1

The working memory scores of subject one in 8 steps of measurements



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E-ISSN: 2981-2569

Figure 1 shows the scores of the subject one in N-Back test in 8 months with a 1-month interval of testing. As you can see, the subject's score was stable in the baseline phase but it has slightly changed after manipulation. However, the changes were not stable and the scores raised up to the mean of the baseline phase.

Figure 2

The working memory scores of subject two in 8 steps of measurements

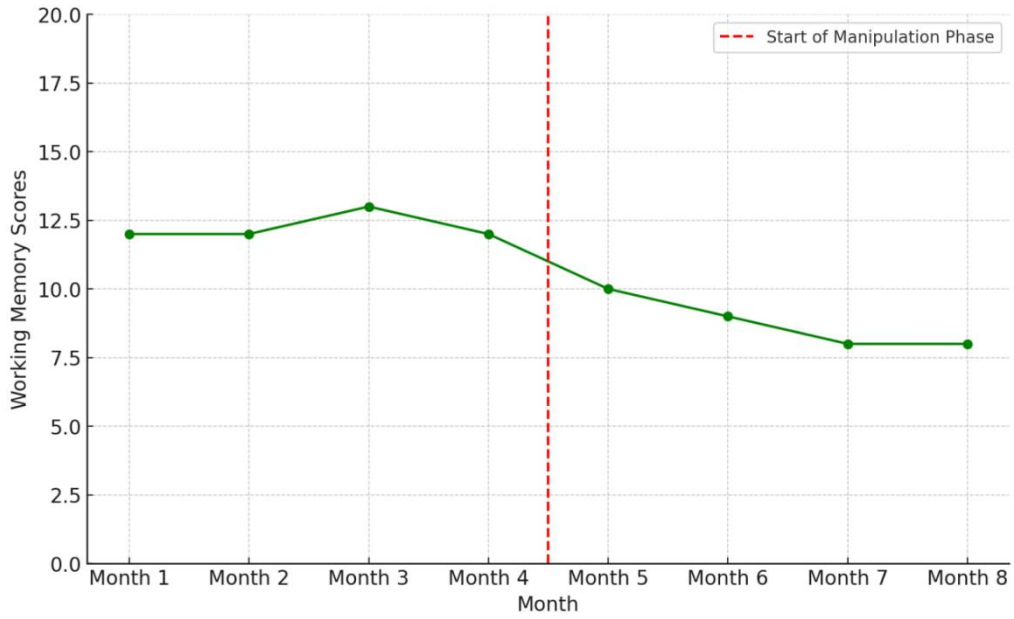
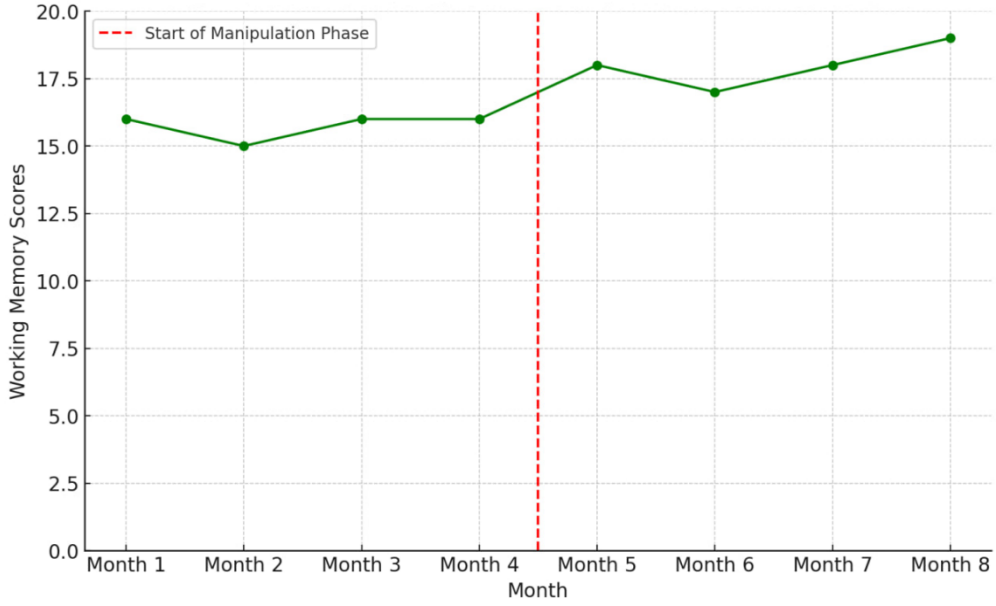


Figure 2 visualizes the scores of the subject two in N-Back test in 8 months with a 1-month interval of testing. As it shown, the subject's score was stable in the baseline phase but it started to get lower from the first measurement of the manipulation phase and reached a significantly lower point than the scores of baseline phase.

Figure 3

The working memory scores of subject three in 8 steps of measurements



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E-ISSN: 2981-2569

Figure 3 shows the scores of the subject three in N-Back test in 8 months with a 1-month interval of measurements. It is obvious that the scores in the manipulation phase are higher than the scores in the baseline phase, overall. Notably, all scores of the manipulation phase measurements are higher than every score in the baseline phase.

4. Discussion

The results show that using chatbots can have diverse effects. In this study, doing assignments using chatbots had no significant effect on the working memory of subject one; It decreased the scores of subject two; and it increased the working memory of subject three, gradually. To explain these findings, it can be referred to cognitive load theory. The cognitive load theory plays a crucial role in understanding and optimizing the use of technology in various learning environments to support working memory functions (6, 8, 17-19). Chatbots can reduce the cognitive load on working memory by taking over routine or repetitive tasks. This can free up cognitive resources for more complex tasks, enhancing overall efficiency and productivity (8). Moreover, chatbots can help manage multiple tasks simultaneously, which might otherwise be overwhelming for working memory. By handling some of the cognitive load, chatbots allow users to focus on more critical aspects of their work. It should be noted that it can also increase the perceived pressure which can impact on brain functioning (20).

Chatbots can also provide emotional support or stress relief, indirectly benefiting cognitive functions including working memory, as stress and emotional distress can negatively impact cognitive performance. However, chatbots can influence cognitive processes by altering the way humans interact with information technology (13). Chatbots can significantly reduce the mental effort required, which can help prevent cognitive fatigue and maintain working memory performance over longer periods. However, it may also prevent working memory training, actions that require a large amount of working memory capacity, which can lead to a decrease in working memory capability (2, 6).

However, there's a risk that overreliance on chatbots for information retrieval and task execution might lead to underutilization of working memory, potentially impacting its efficiency. Regular mental exercises and tasks are important for maintaining a healthy working memory. Moreover, working memory capacity is linked to the optimization of emotion perception, indicating a relationship between cognitive processing and emotional intelligence (3). So, it can be argued that the negative effects of chatbots may come from the overuse. In fact, it can be claimed that using chatbots properly for doing assignments can be harmful if it extends to the other aspects of life and result in an overreliance on chatbots. Thus, according to the abovementioned arguments, chatbots can differently impact on working memory since diverse variables are also associated with the way it can affect the working memory.

5. Conclusion

Overall, the results of this study showed that chatbots can have different effects on the working memory of students. In other words, they can be harmful for one while can improve the other's working memory and, to a greater extent, it also can have no effect for another. However, since research in this domain is emerging the results can be helpful for future studies. In fact, while the current study provides valuable insights, its limitations, particularly concerning design, sample selection, and measurement scope, suggest that the findings should be interpreted with caution. Further research with more robust and diverse methodologies is recommended to better understand the relationship between chatbot interactions and working memory in students. Accordingly, the single-subject AB design, while useful for detailed observation of individual responses, lacks generalizability to a broader population. The findings from a single subject may not represent the varied responses that could occur in a diverse student population. Moreover, this design does not include a control group for comparison. Without a control group, it's challenging to conclusively attribute observed changes in working memory to the intervention (use of chatbots) alone. Additionally, with only four measurements in each phase, the data set is relatively small. This limits the robustness of statistical analyses and may not capture the full variability or trends in working memory over time. A small number of data points increases the risk of measurement bias, where specific instances or outliers might disproportionately influence the study's conclusions. Furthermore, since all subjects had working memory scores higher than average, this introduces a selection bias. The results may not be applicable to students with average or below-average working memory capacities.

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E-ISSN: 2981-2569

Given the diverse outcomes observed this study the following suggestions are proposed for future research and practical applications:

1) Conduct studies with participants having a range of working memory capacities, including average and below-average abilities, to better understand the differential impact of chatbots.

2) Extend research to various age groups, educational backgrounds, and cultural contexts to observe how these factors might influence the outcomes.

3) Implement longitudinal studies to track changes in working memory over a longer period, which can provide insights into the lasting effects of chatbot interactions.

4) Include follow-up assessments after a significant period post-intervention to determine the persistence of any observed changes in working memory.

5) Employ randomized controlled trials to rigorously test the efficacy of chatbot-assisted assignments in enhancing working memory, with control groups for more reliable comparisons.

6) Experiment with different types of chatbot interactions (e.g., varying in complexity, interactivity, and personalization) to identify which aspects most significantly impact working memory.

7) Gather qualitative data through interviews or surveys to gain insights into students' perceptions and experiences with chatbot-assisted assignments.

8) Investigate the effectiveness of chatbot interactions for students with specific learning disabilities or cognitive challenges.

9) Test the integration of chatbot-assisted assignments in different subjects and educational levels to determine the broader applicability in diverse learning environments.

10) Study how different interface designs of chatbot platforms influence student interaction and, consequently, working memory outcomes.

Authors' Contributions

M.R: Conducted the project, supervised the study and wrote the manuscript. P.M.A: Did the experiment, visualization and calculations.

Transparency Statement

The authors are willing to share their data, analytics methods, and study materials with other researchers. The material will be available upon reasonable request.

Acknowledgments

We would like to express our gratitude to all participants helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

This research received no external funding.

Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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