Working Memory Capacity and Cognitive Load

ISYE 348 Fall 2024 Lab 3

Aakash (@nimRobotics)

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This lab assignment is due by 23:59 on 2024-09-30. If you have any questions or need clarification, please reach out to me via email or during office hours. The report will be graded on **20 points** based on the following criteria:

Criteria	Points
Introduction (your own words; 50-100 words)	1
Methods (your own words; 100-200 words)	2
Results	6
Discussion	6
Improvements	2
Conclusion	3

Submission: Please submit your report as a PDF file on Canvas. Make sure to include your name and your partner's name at the beginning of the report. Include any code, plots, or tables as needed to support your answers. Make sure to answer all questions thoroughly and provide detailed explanations where necessary. Cite any external sources used. Submit one single pdf file with all the answers.

Collaboration with your classmates is encouraged, and you will work in pairs for this lab to complete the report. Each group should have data for part 1 (audiogram) from at least one member and part 2 (audiocons) data from all members. Please list your partner's name at the beginning of the report. Only one submission per group is required. Must include data from both partners in the report.

Late submissions will be penalized by a 1 point deduction every hour past the deadline.

Please read the course policy on academic integrity and collaboration on the course syllabus. If you have any questions about what is permissible, please ask before submitting your work.

Introduction

In this lab, we'll explore the relationship between working memory (WM) capacity and performance under varying levels of cognitive load. We'll use the n-back task to manipulate cognitive load, the NASA Task Load Index (NASA-TLX) to measure perceived workload, and additional subjective measures to assess the participants' experiences. This experiment will help us understand how cognitive demands affect performance and perceived effort, which is crucial in designing user interfaces, work processes, and training programs.

Objectives

Our goals for this lab are:

1. To measure individual working memory capacity using a simple span task
2. To assess performance on n-back tasks with varying difficulty levels (1-back, 2-back, 3-back)
3. To assess the impact of dual-tasking on n-back performance

Equipment

We'll be using:

- Online n-back task tool (https://nimrobotics.com/nback/)
- Visual and audio math task stimuli (https://nimrobotics.com/rmathp/)
- Online NASA-TLX tool (https://www.keithv.com/software/nasatlx/nasatlx.html or pdf version)
- Spreadsheet software (or any programming language) for data analysis
- Timer or stopwatch

Procedure

The experiment has three main parts. After each task/trial NASA-TLX scores and subjective ratings should be collected (total six times). The participants should also be given a short break between tasks to avoid fatigue.

Subjective question: How would you rate the overall workload required to complete this task on a scale from 0 to 10? (0 = very low, 10 = very high)

1. Measure Working Memory Capacity:
    a. Use a simple digit span task: read increasingly long sequences of digits, and have the participant repeat them back.
    b. Record the longest sequence correctly repeated (this is the WM span score).
    c. Follow the instructions and carry out the task at https://www.psytoolkit.org/experiment-library/digitspan.html.
2. n-back Task (varying n)
    a. Familiarize participants with the n-back task using the online tool.
    b. Each participant will complete three n-back tasks in random order:

- 1-back task (5 minutes)
- 2-back task (5 minutes)
- 3-back task (5 minutes)

3. 2-back (dual task):
   a. Each participant will go through dual task
      - 2-back task (5 minutes) + one digit visual math task (5 minutes)
      - 2-back task (5 minutes) + one digit audio math task (5 minutes)
4. Data Analysis:
   a. Calculate n-back metrics (see supplementary material), NASA-TLX scores, and subjective ratings for each task.
   b. Create graphs showing the relationships between:
      - WM span and n-back performance
      - N-back level and NASA-TLX scores
      - N-back level and subjective ratings
   c. Compare WM span, n-back performance, NASA-TLX scores, and subjective ratings.

Results

Record your results here:

1. Simple Span Task:

Participant	WM Span Score
1	
2	

2. n-Back Task (varying n):

Participant	N-back Level	n-back accuracy	n-back senstivity	n-back specificity	n-back Delay	NASA-TLX Score
1		1-back				
		2-back				
		3-back				
2		1-back				
		2-back				
		3-back				

3. Dual Task (2-back + Math Task):

Tabulate single, audio, and visual math task results for each participant:

Participant	Task Type	n-back accuracy	n-back senstivity	n-back specificity	n-back Delay	Math Task Accuracy	Math Task Delay	NASA-TLX Score
1	Single Audio Visual							
2	Single Audio Visual							

3. Compare and compute correlations between WM span, n-back performance, NASA-TLX scores, and subjective ratings (report correlation coefficients).
4. Include any additional graphs, tables, or figures that support your analysis (e.g. scatter plot of n-back performance vs. NASA-TLX scores).

Discussion

Consider and discuss the following questions with your group:

1. How did the different measures (performance, NASA-TLX, subjective ratings) align or diverge? What might explain these patterns?
2. What are the implications of these findings for designing tasks or interfaces for individuals with different WM capacities?
3. How might factors like practice, motivation, or individual strategies influence the relationships we observed?
4. Discuss potential applications of these findings in fields such as:
    a. User interface design
    b. Training program development
    c. Workload management in high-stress occupations
5. What are some limitations of this study, and how might they affect the interpretation of the results?

Improvements

How could you improve the experimental design or procedures in the above experiment? Or what would you do differently if you were to repeat this experiment? [please do not include the suggestion to "collect more data" or "collect data in isolated environment"]

Conclusions

Include a brief summary of your findings and any insights you gained from this lab. What did you learn about working memory capacity, cognitive load, and their impact on task performance and perceived workload? How might these insights be applied in real-world settings to enhance human performance and well-being? [you are not required to strictly follow this conclusion outline, feel free to include any other relevant information]

References

1. Baddeley, A. (2012). Working memory: Theories, models, and controversies. Annual Review of Psychology, 63(1), 1-29.
2. Karthikeyan, R., Smoot, M. R., & Mehta, R. K. (2021). Anodal tDCS augments and preserves working memory beyond time-on-task deficits. Scientific reports, 11(1), 19134.
3. Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Advances in Psychology, 52, 139-183.
4. Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. Psychonomic bulletin & review, 12, 769-786.
5. Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. Human brain mapping, 25(1), 46-59.

Supplementary Materials

N-Back Task Analysis Metrics

This section describes the metrics used in the analysis of N-Back task results.

- **Total**: The total number of trials in the N-Back task.
- **TP (True Positive)**: The number of correct responses when the participant should have responded.
- **TN (True Negative)**: The number of correct non-responses when the participant should not have responded.
- **FP (False Positive)**: The number of incorrect responses when the participant should not have responded.
- **FN (False Negative)**: The number of incorrect non-responses when the participant should have responded.
- **P (Positive)**: The total number of trials where the participant should have responded.
- **N (Negative)**: The total number of trials where the participant should not have responded.

Derived Metrics

- **Accuracy**: The proportion of correct responses (both positive and negative) out of all trials.

  - Formula: (TP + TN) / Total
  - Interpretation: Higher accuracy indicates better overall performance.
- **Sensitivity (True Positive Rate)**: The proportion of correct responses out of all trials where the participant should have responded.
  - Formula: TP / P
  - Interpretation: Higher sensitivity indicates better ability to correctly identify target stimuli.
- **Specificity (True Negative Rate)**: The proportion of correct non-responses out of all trials where the participant should not have responded.
  - Formula: TN / N
  - Interpretation: Higher specificity indicates better ability to correctly ignore non-target stimuli.
- **Response Delay**: The average time taken to respond across all trials.
  - Formula: Mean of all response times
  - Interpretation: Lower response delay indicates faster cognitive processing and decision-making.