Performance, Workload, Emotion, and Self-Efficacy of Novice Programmers Using AI Code Generation

Nicholas Gardella, Raymond Pettit, and Sara L. Riggs

Introduction

AI is great at simple programming tasks.

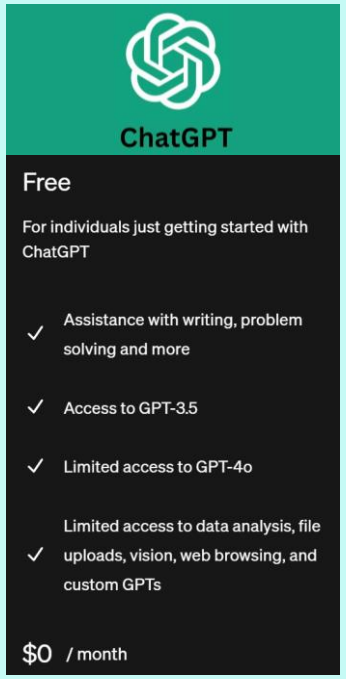
Default (GPT-3.5)

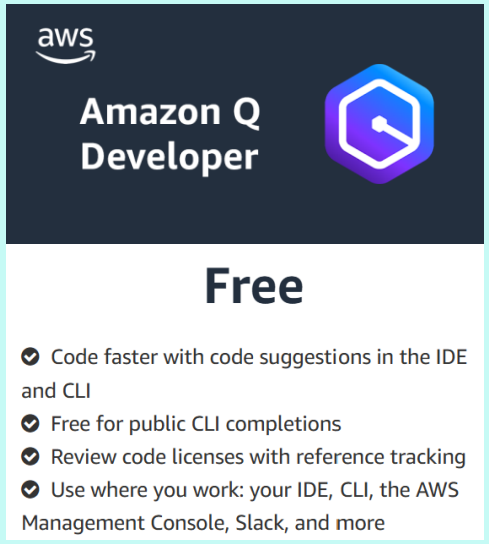
N

write a python script to read in a csv file that contains columns a,b,c and finds a grand sum of all the values of a,b, and c added together by row and then adding up all the rows

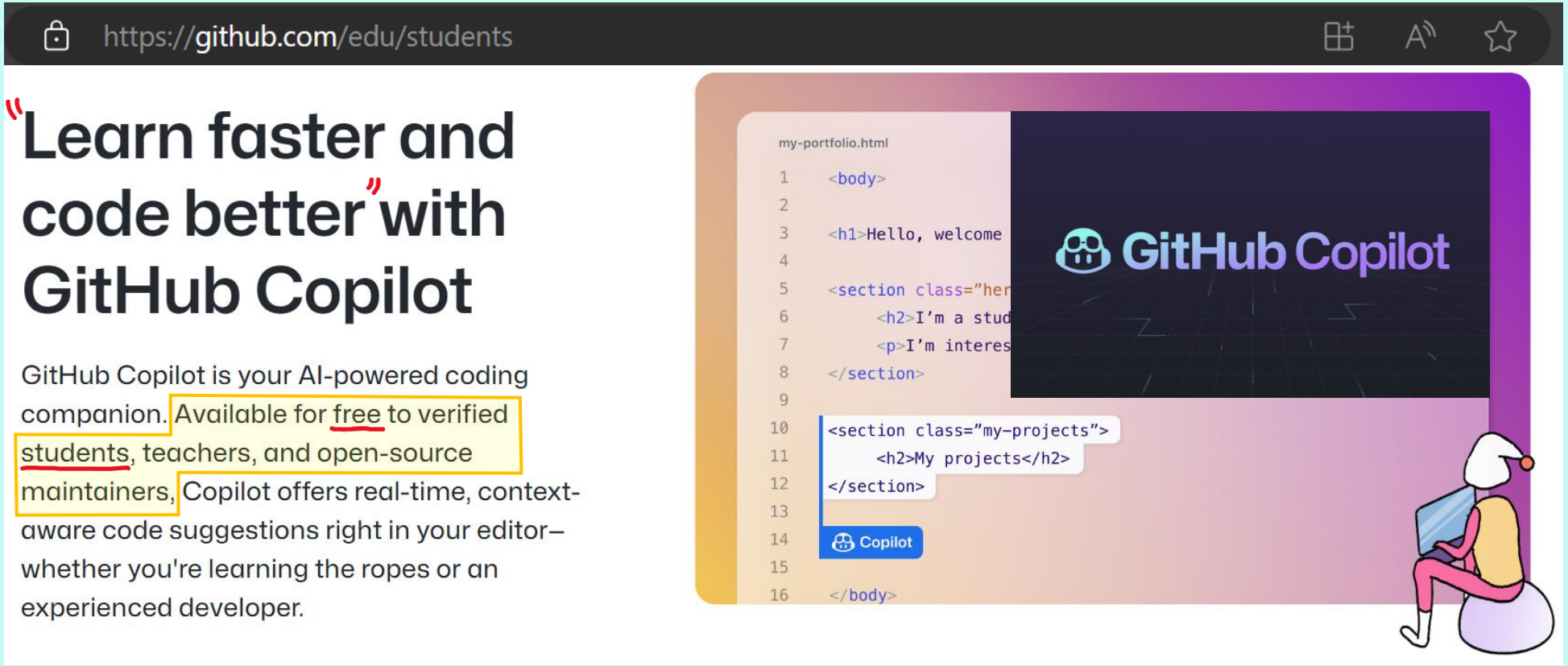

```python
import csv
# Initialize the variables to store the grand sum and row sums
grand_sum = 0
row_sums = []
# Specify the path to your CSV file
csv_file_path = 'your_csv_file.csv'
# Open the CSV file and read its contents
with open(csv_file_path, 'r') as csv_file:
    csv_reader = csv.reader(csv_file)
    # Skip the header row if it exists
    next(csv_reader, None)
    for row in csv_reader:
        try:
            # Assuming that columns a, b, and c are at index 0, 1, and 2 respectively
            a, b, c = map(float, row[0:3])
            # Calculate the sum of a, b, and c for this row
            row_sum = a + b + c
            # Add the row sum to the list of row sums
            row_sums.append(row_sum)
            # Add the row sum to the grand sum
            grand_sum += row_sum
        except ValueError:
            # Handle cases where the CSV contains non-numeric values
            print(f"Skipping invalid row: {row}")
# Calculate the grand total of all row sums
grand_total = sum(row_sums)
# Print the results
print(f"Grand Total of all rows: {grand_total}")
```

Novices can use high quality AI for free…



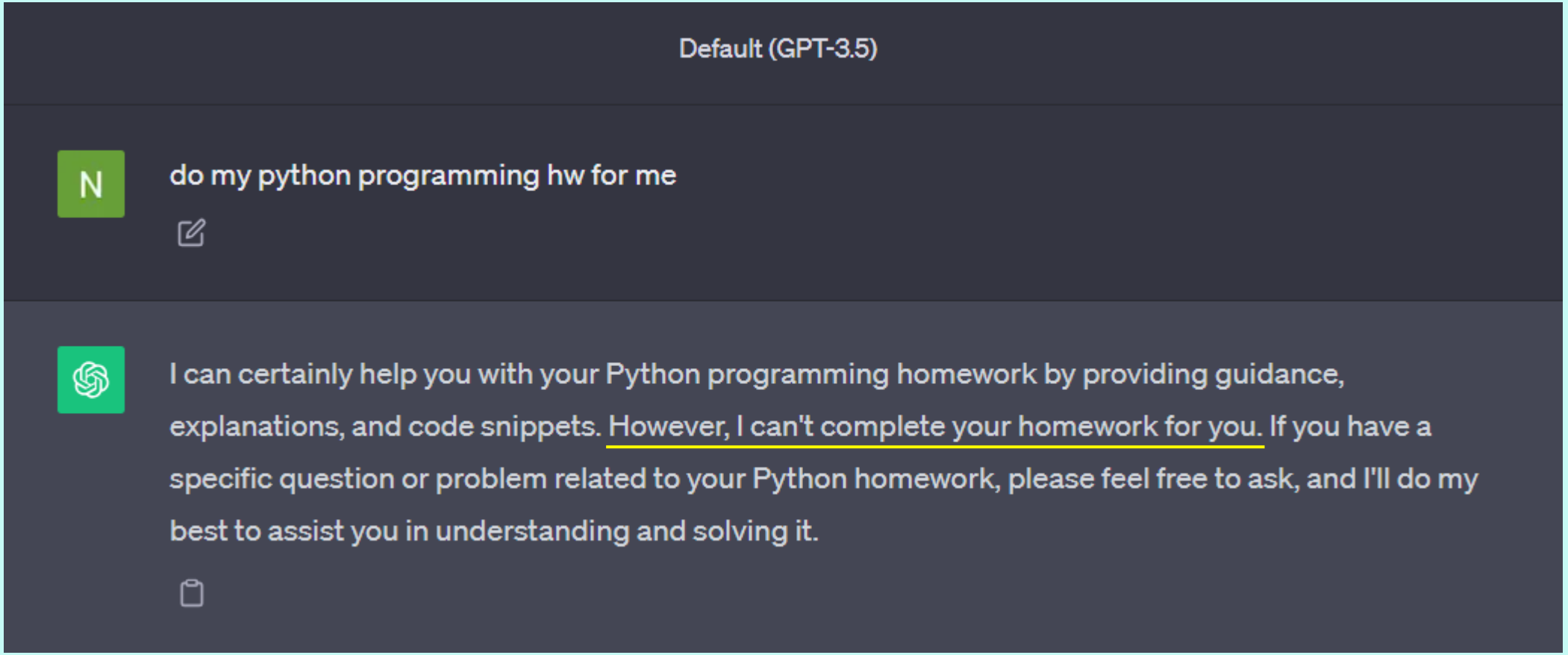


including the powerful GitHub Copilot AIDE



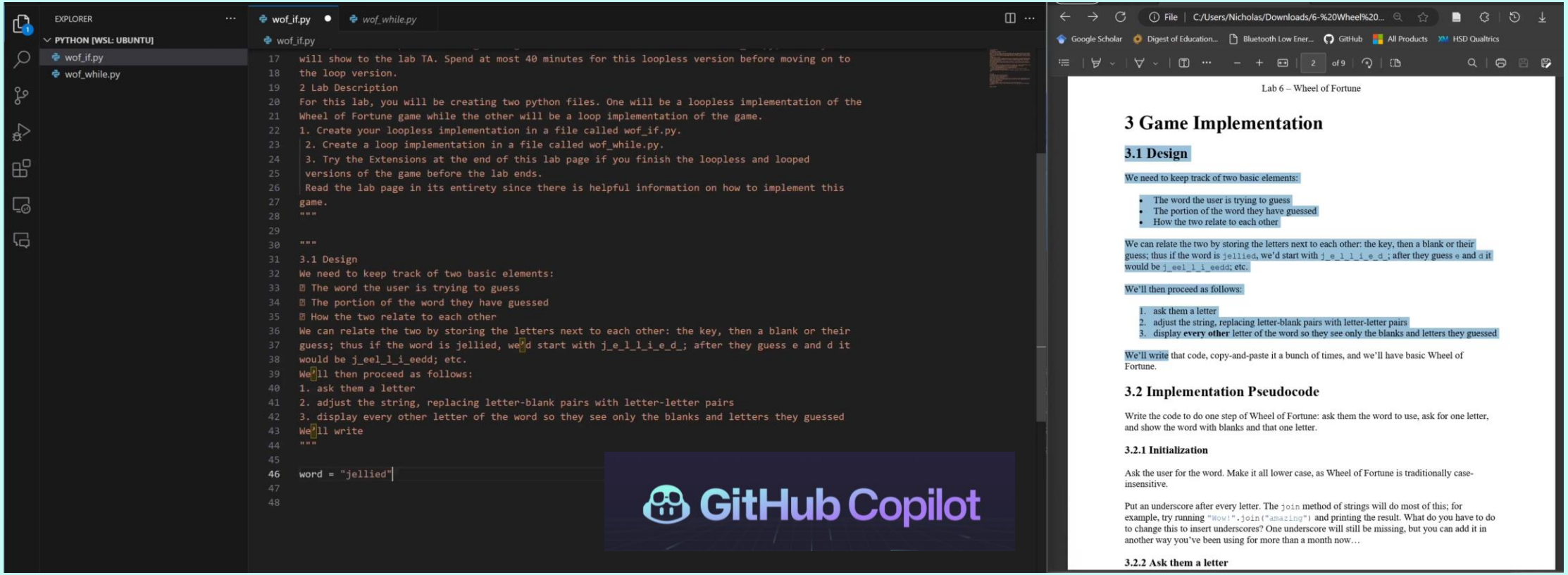
AIDE = Artificial Intelligence-driven Development Environment

But AI won’t do students’ work, right?



Unfortunately, it will…

see Chen et al. [8], Finnie-Ansley et al. [12], Kazemitabaar et al. [21]



So what is the impact of AI on a novice?

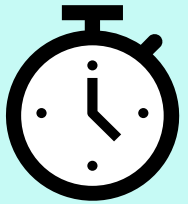
Student

\+

AI

\+

Time Pressure



= ?

Literature at a glance: Performance

Objectively Measuring Performance

Vaithilingam & Glassman [35], Xu et al. [37]

Significant Performance *Benefit*

Kazemitabaar et al. [21]

Literature at a glance: Well-Being

Kazemitabaar et al. [21]
“slightly **less stressed**” (p=.06)
“**more eager** […] to continue learning” (p = **.025**)

Vaithilingam & Glassman [35]
“Participants found code generated by Copilot **more helpful** than code generated by Intellisense” (p < **.001**)

Xu et al. [37]
“participants report having a **neutral** (15/31; 48.4%) **or** at least somewhat **positive** (15/31; 48.4%) experience”

But what measurable effects can we show?

Student

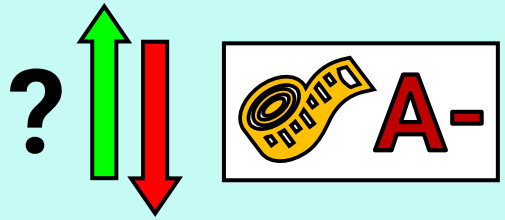
+

AI

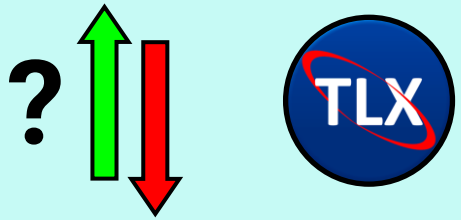
+

Time Pressure

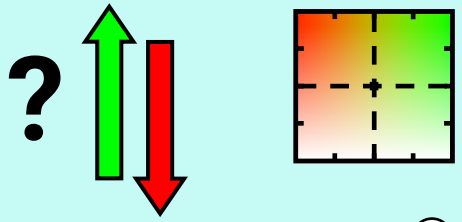
=



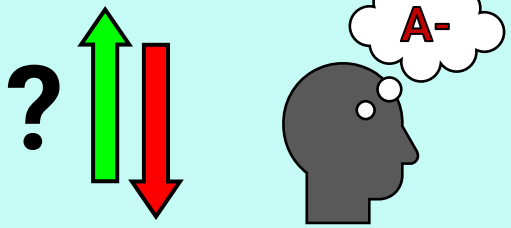
Performance



Workload



Emotion



Self-Efficacy

Research Questions: How do AIDEs…

- **RQ1:** affect performance, workload, emotion, & self-efficacy of novice programmers under time pressure?

- **RQ2:** influence the effects of additional time spent programming on novices' performance and self-efficacy

Method

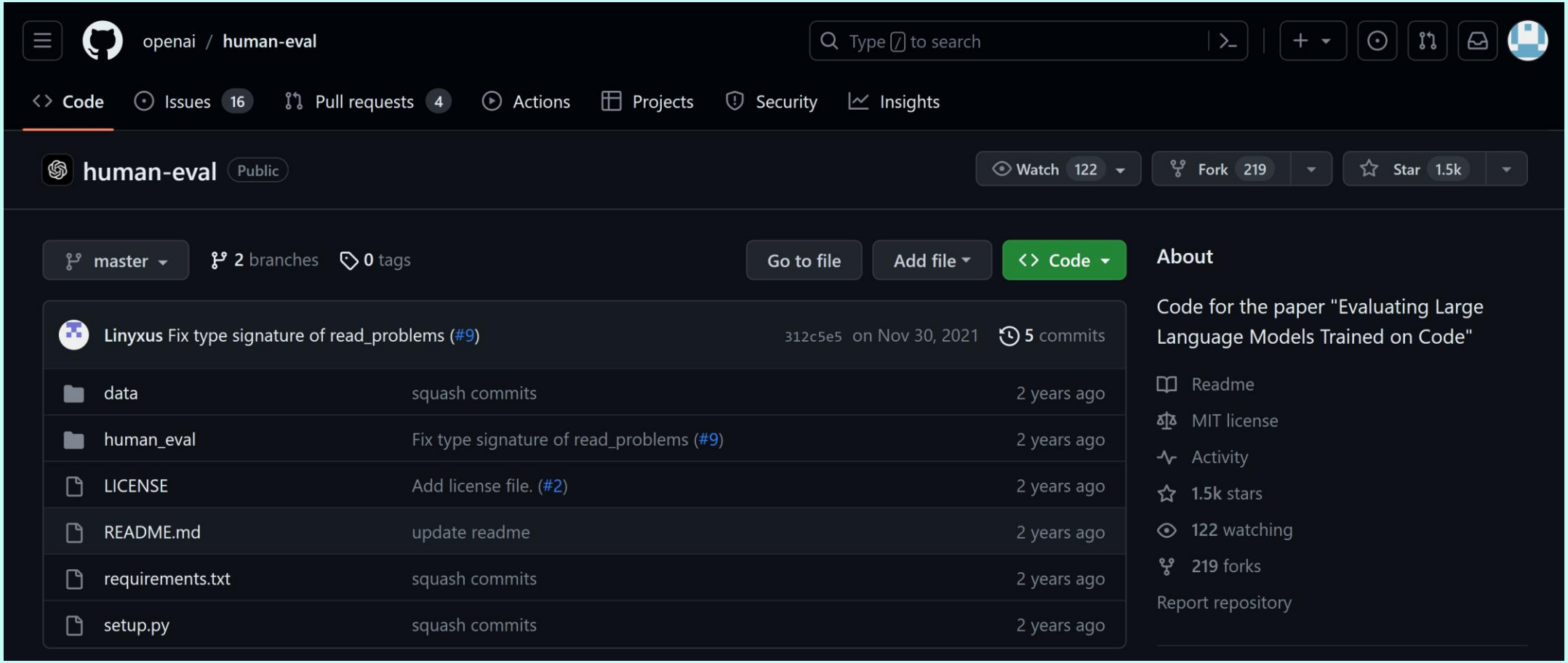
We recruited 17 students from a CS1 course.

- Ability reports (day of participation):

- Gender reports:

- Racial reports:
  - Asian- 11
  - White- 8
  - Hispanic/Latinx- 2
  - Black- 1

Tasks came from the HumanEval dataset.

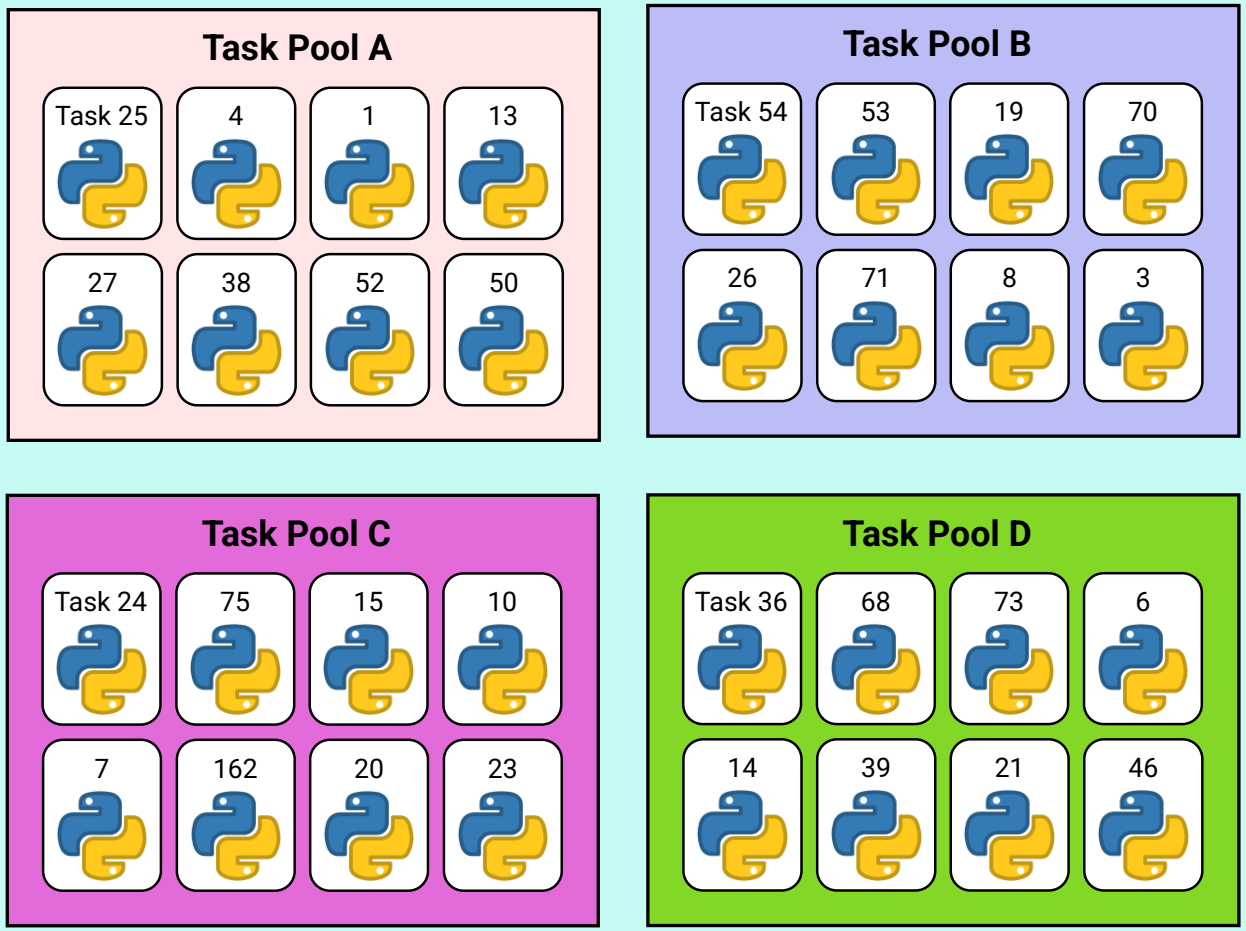


Chen et al. [8]

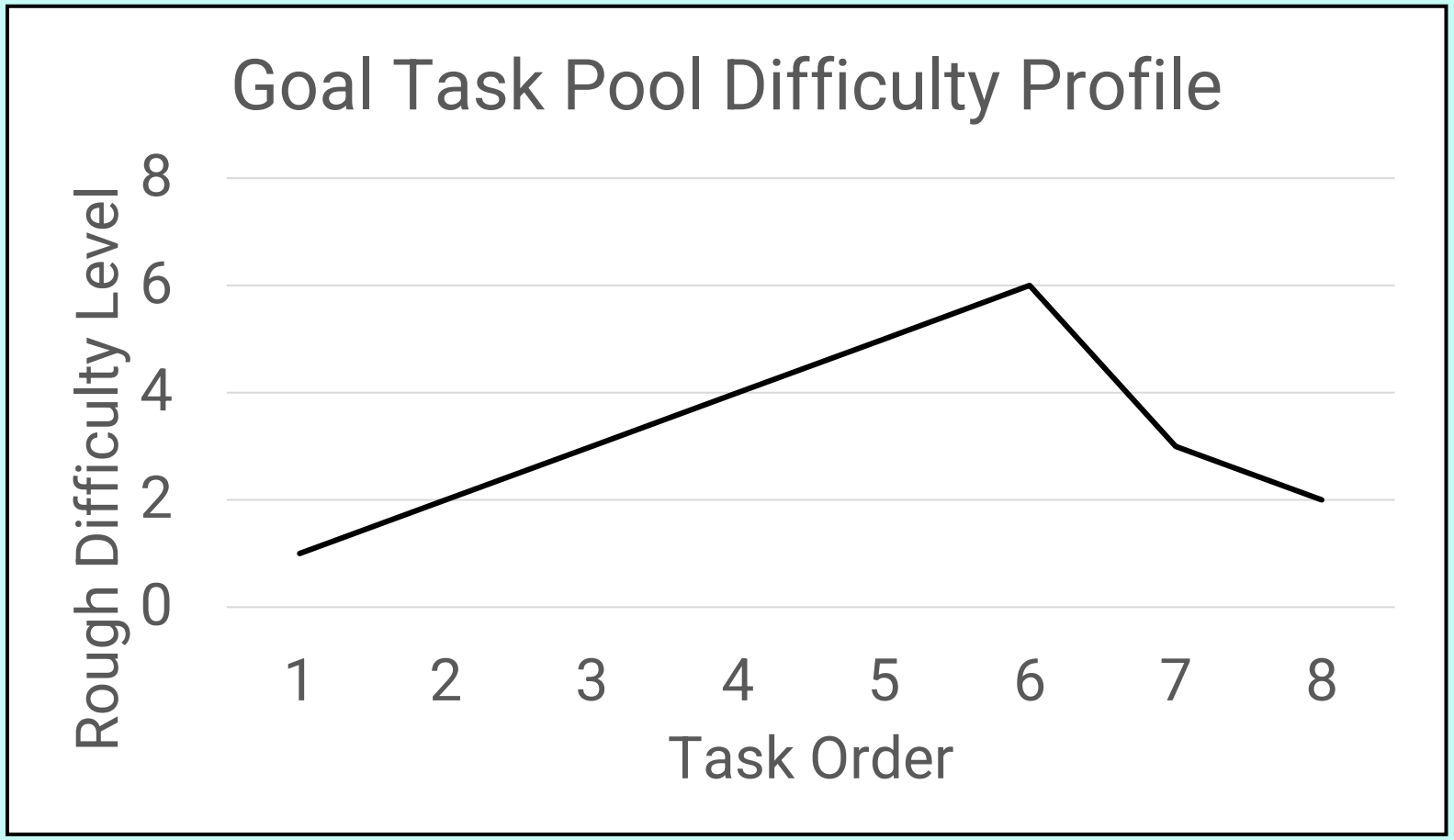
We created four pools of tasks.

164 Tasks

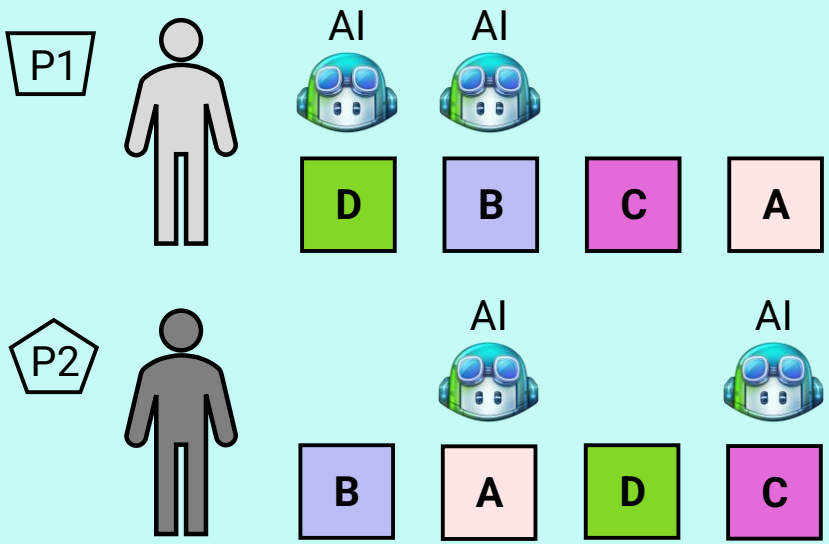
9 x

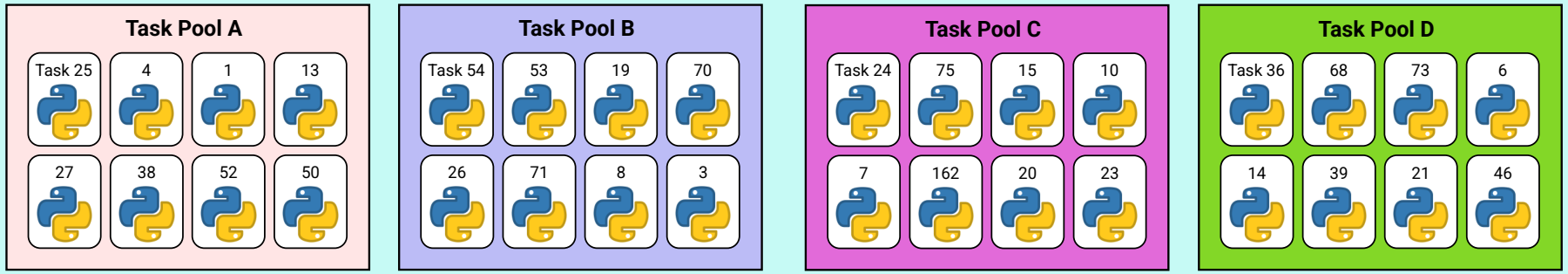


We placed easier tasks early in each pool.

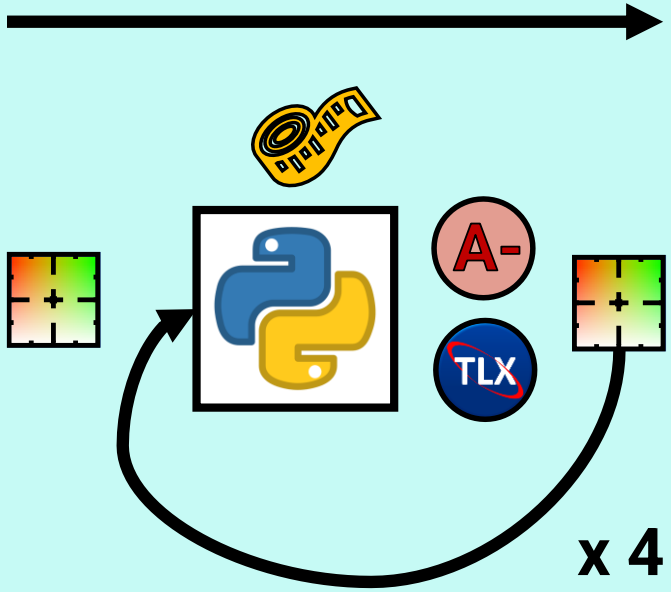


We used a within-subjects design.





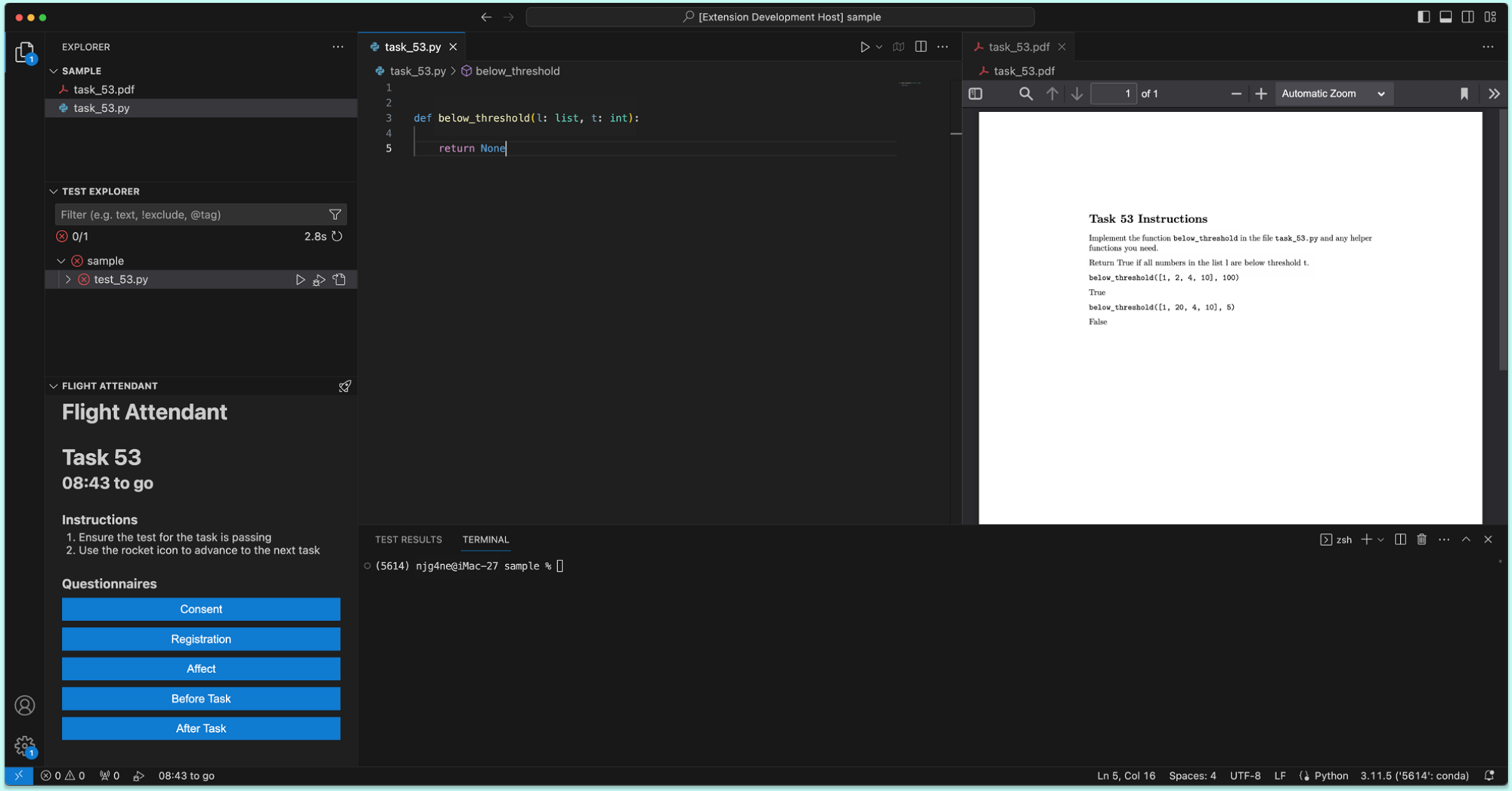
We took repeated measures four times.



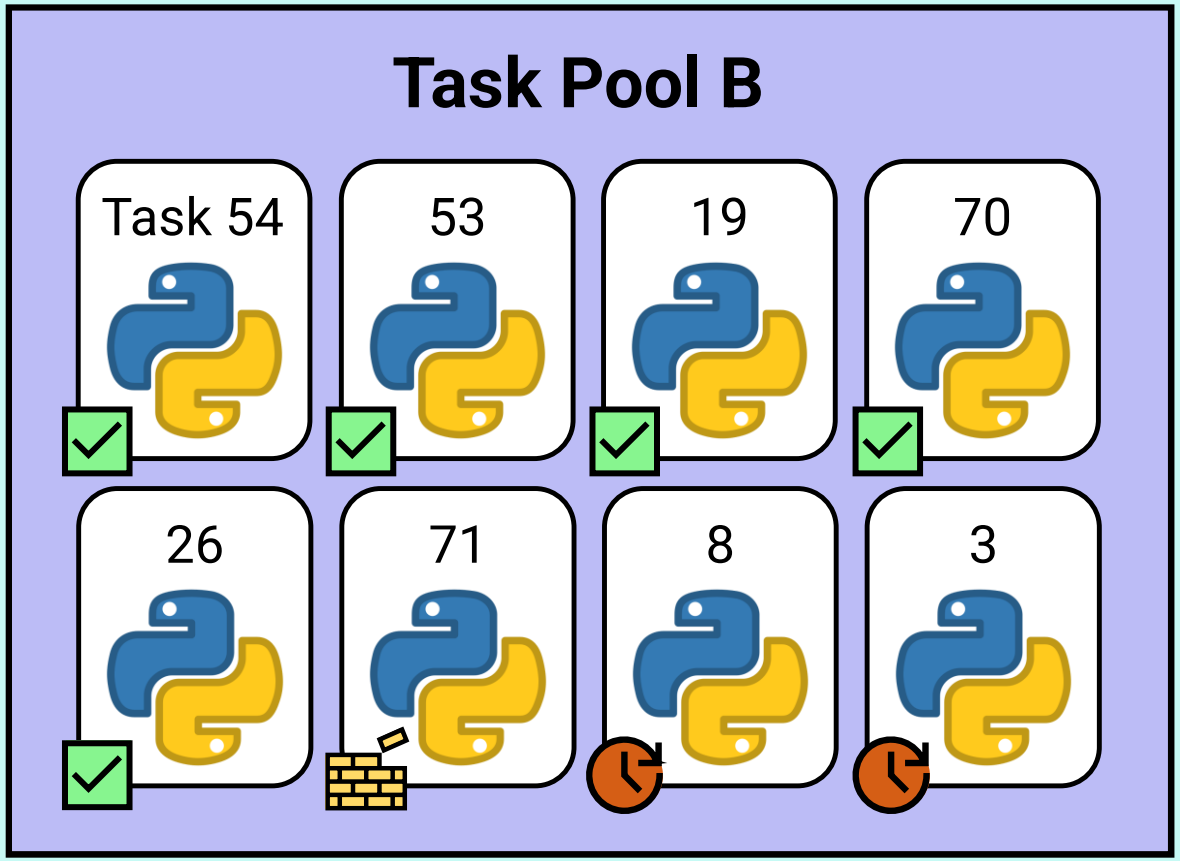
Legend

- Emotional affect
- 20-minute trial
- Ordinal Score
- Self Grade
- NASA-TLX

Participants worked in Visual Studio Code.



We scored task pools ordinally.

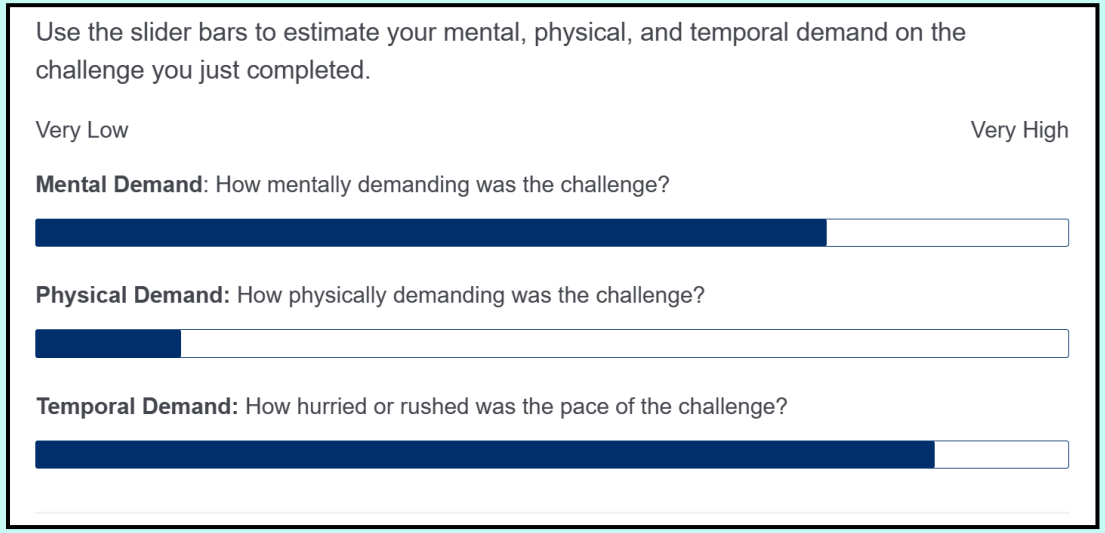


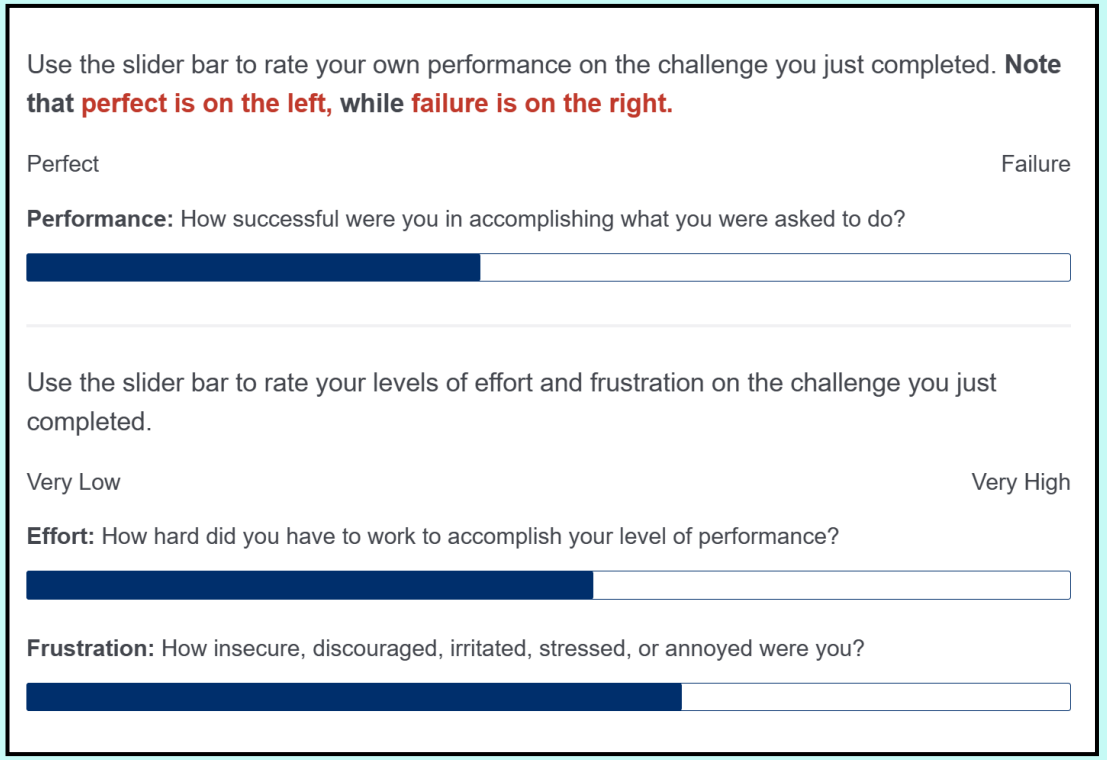
Score = 5

Legend

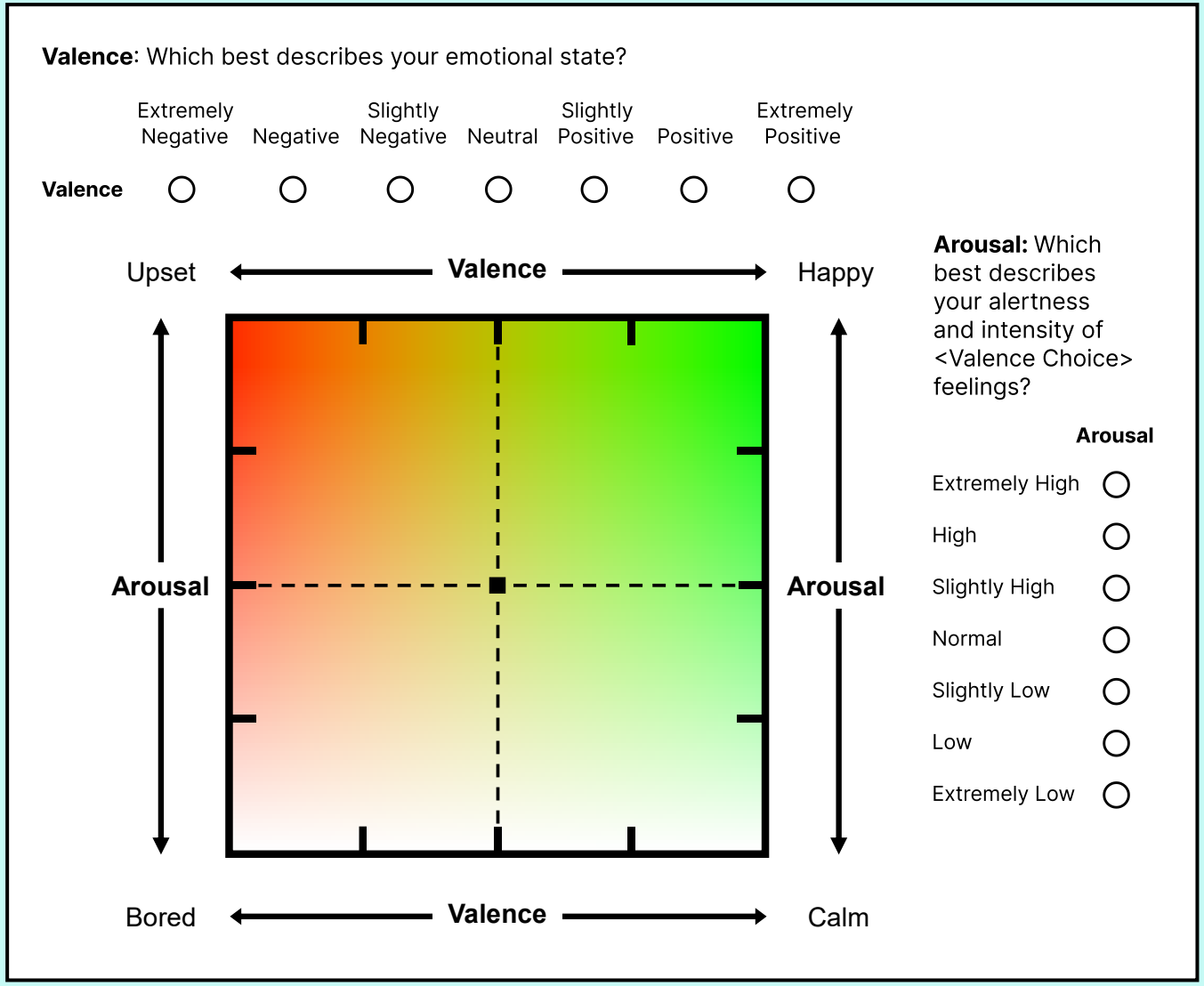
- Passed
- In-progress
- Not started

We measured workload with NASA-TLX.

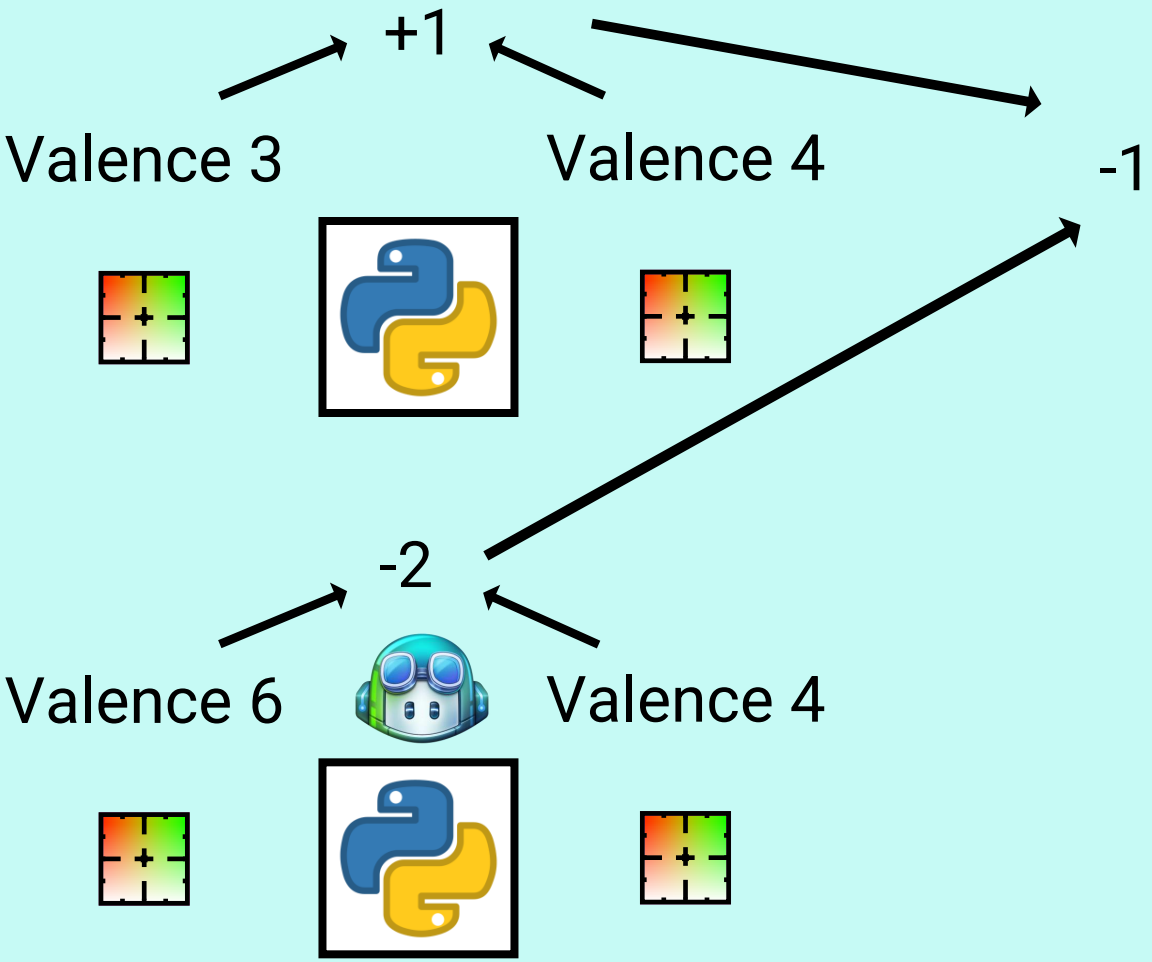




We measured emotion on two dimensions.



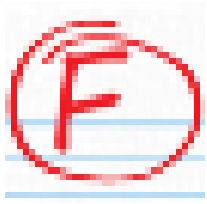
We measured **changes** in emotional state.



We measured self-efficacy with a letter grade.

If you had to give **yourself** a grade for your work on the last challenge, what would it be?

If you had to give **GitHub Copilot** a grade for its contribution to the last challenge, what would it be?



What percentage of the work for the challenge do you think **GitHub Copilot** was responsible for?

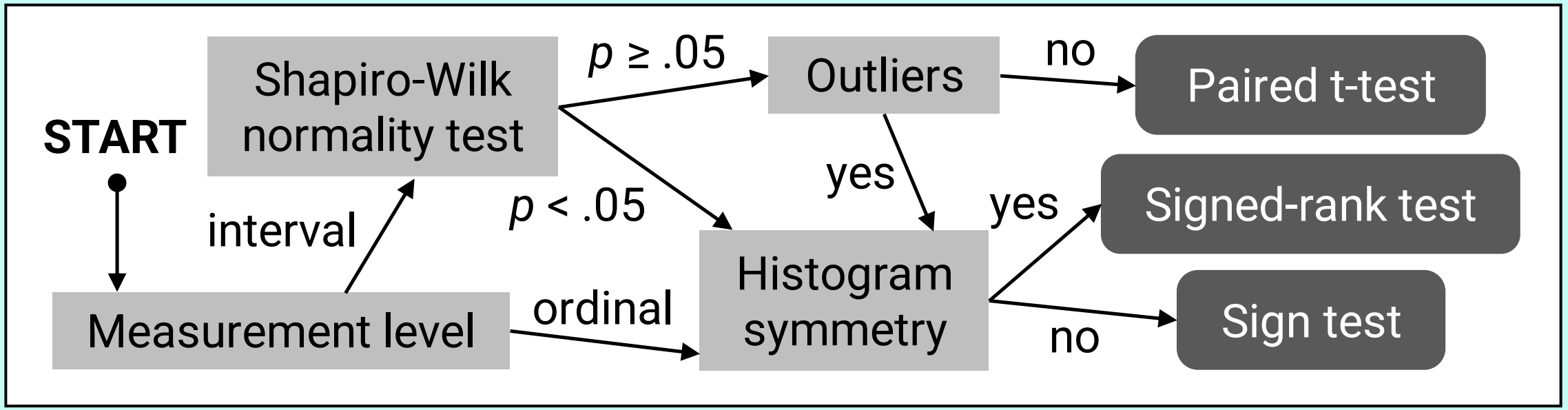
0% 100%

75

% of Work done by Copilot

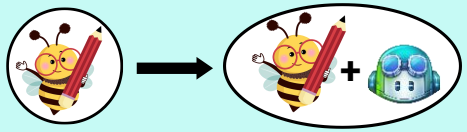
Grade	Value
A+	13
A	12
A-	11
B+	10
...	...
D	3
D-	2
F	1

We took a conservative statistical approach.



Results

RQ1 Results



	Change	p	
Score	$\widetilde{\Delta x} = 1$	$\mathbf{.001}*$	**Be more successful**
Δ Valence	$\overline{\Delta x} = 0.206$	.436	Feel better
Δ Arousal	$\widetilde{\Delta x} = -.5$	.191	Feel more relaxed
TLX Mental	$\overline{\Delta x} = -8.971$	$\mathbf{.024}*$	**Think less hard**
TLX Physical	$\widetilde{\Delta x} = 0$	.773	Exert no differently
TLX Temporal	$\overline{\Delta x} = -5.294$	.200	Feel less rushed
TLX Performance	$\overline{\Delta x} = -6.029$	.230	Feel more successful
TLX Effort	$\widetilde{\Delta x} = -5$	$\mathbf{.043}*$	**Try less hard**
TLX Frustration	$\overline{\Delta x} = -2.206$	.581	Feel less frustrated
Self-Grade	$\overline{\Delta x} = .265$	.455	Feel more successful

RQ2 Results

		1st Trial → 2nd Trial	Change	*p*	
Solo 	 Score	—	$\widetilde{\Delta x} = 0$	1.000	Plateau over time
	 Self-Grade	—	$\widetilde{\Delta x} = 0$	.594	Feel the plateau
with AI 	 Score	↗	$\widetilde{\Delta x} = 1$	**0.046***	**Improve over time**
	 Self-Grade	↗	$\overline{\Delta x} = 1.588$	**0.021 ***	**Feel the improvement**

Discussion

Internet may explain performance differences.

Objectively Measuring Performance

Vaithilingam & Glassman [35], Xu et al. [37]

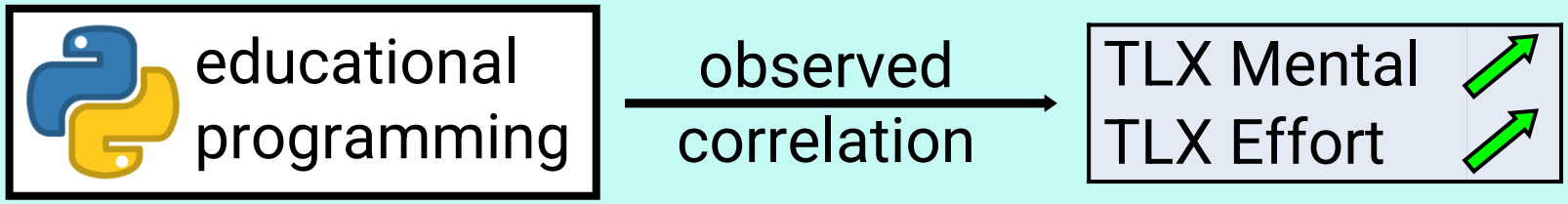
Significant Performance *Benefit*

Kazemitabaar et al. [21]

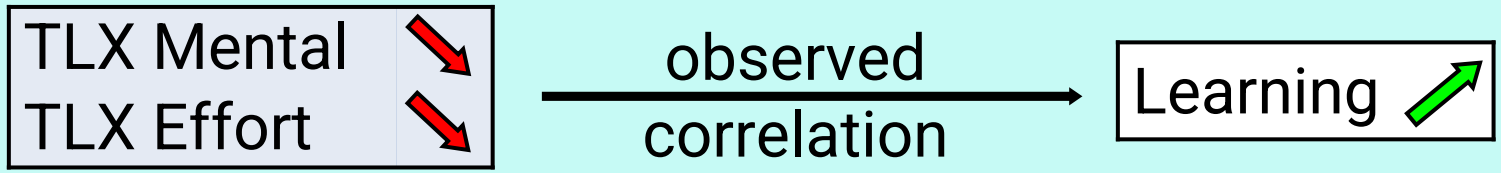
Our study

Workload decreases could aid learning.

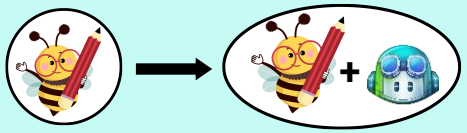
Al Madi et al. [2]



Gerjets et al. [13]

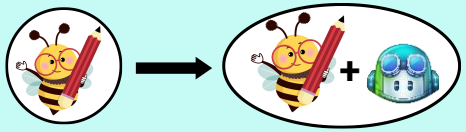


AI may not make you feel much better.



		Change	*p*	
Δ Valence	↗	$\overline{\Delta x} = 0.206$	.436	Feel better
Δ Arousal	↘	$\widetilde{\Delta x} = -.5$	.191	Feel more relaxed
TLX Frustration	↘	$\overline{\Delta x} = -2.206$	.581	Feel less frustrated

Novices don’t take credit for AI’s work.



		Change	*p*
TLX Performance	↘	$\overline{\Delta x} = -6.029$	.230
Self-Grade	↗	$\overline{\Delta x} = .265$	.455

Feel more successful

Novices take credit when they use AI better.

1st Trial → 2nd Trial

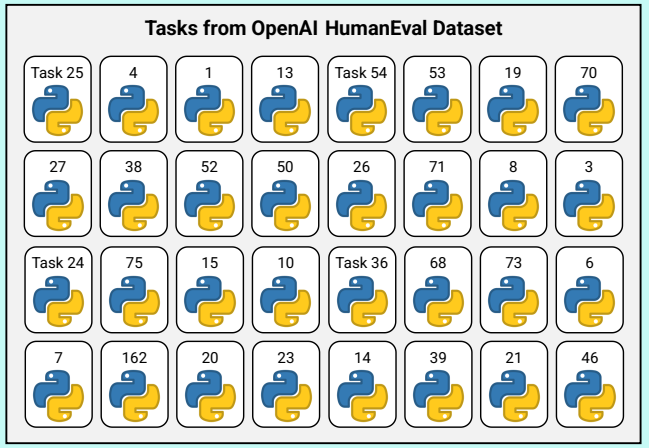
		Change	*p*	
with AI 	 Score	↗ $\widetilde{\Delta x} = 1$	**0.046***	**Improve over time**
	 Self-Grade	↗ $\overline{\Delta x} = 1.588$	**0.021 ***	**Feel the improvement**

Conclusion

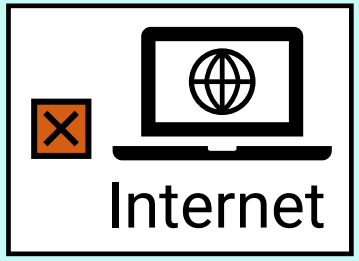
Ecological and external validity are concerns.

Training Data

contained?



n = 17 all from UNIVERSITY of VIRGINIA



Key Takeaways

- Novice programmers…
  - can **be more successful** with AI
  - can **think and try less hard** with AI
  - can **improve** at using AI **over time** and **take credit for the improvement**
- But…
  - **don’t take credit** for AI’s work
  - **don’t feel much better** using AI

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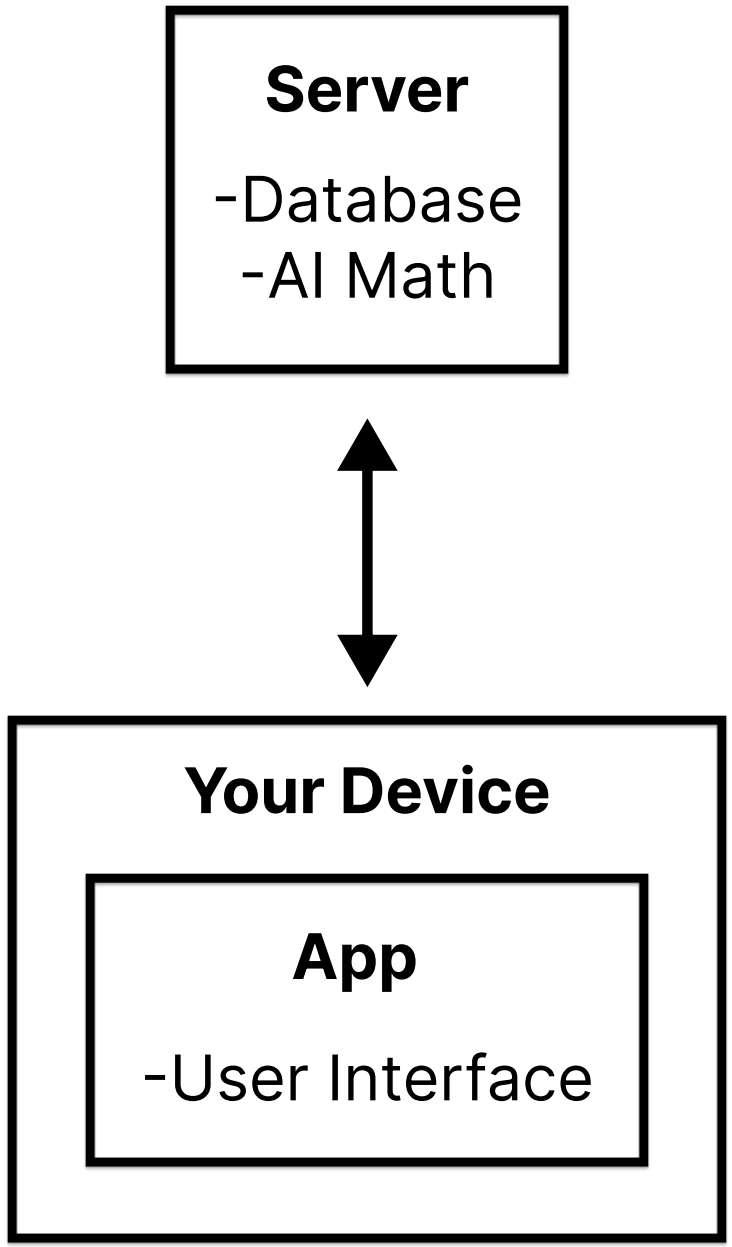
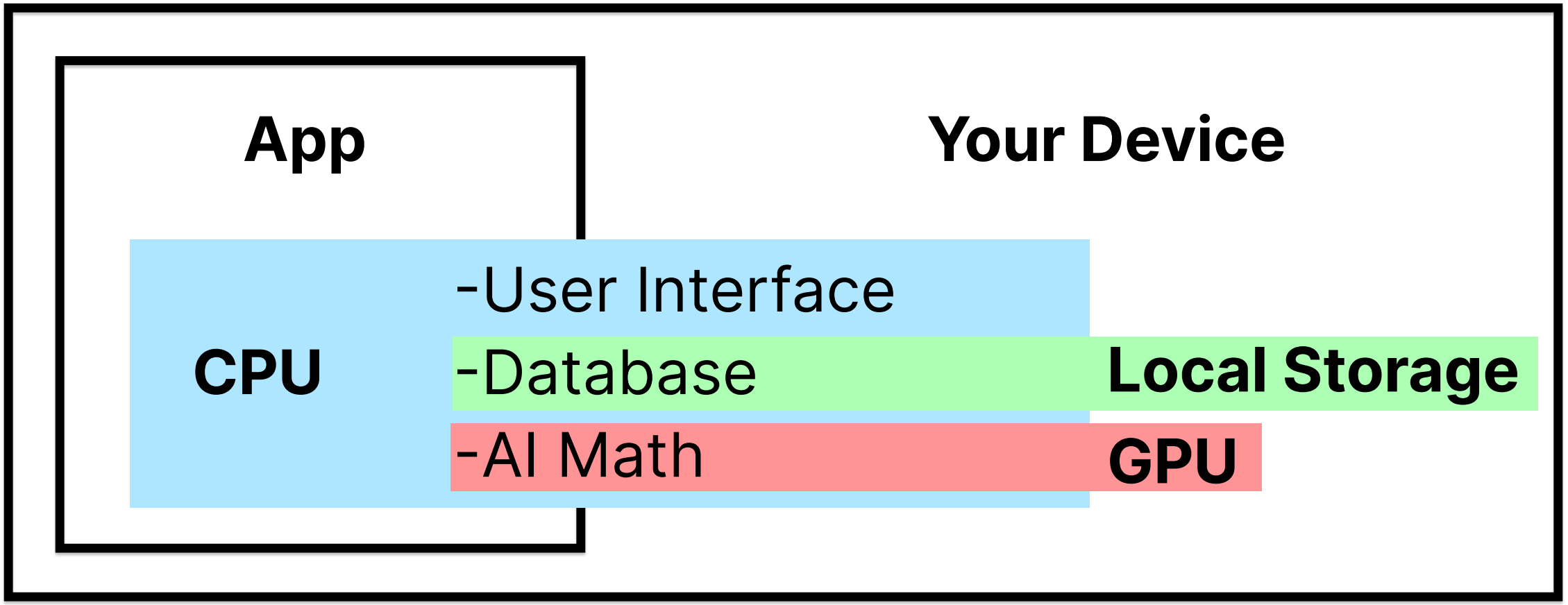
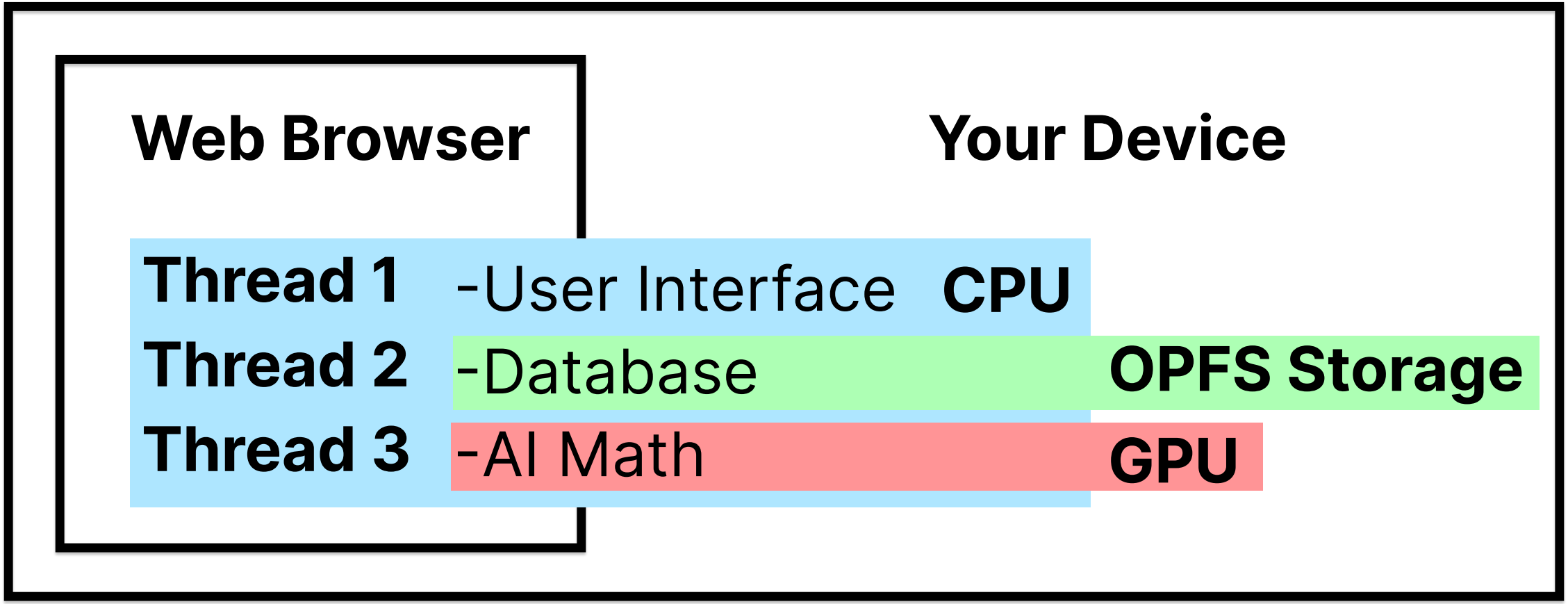
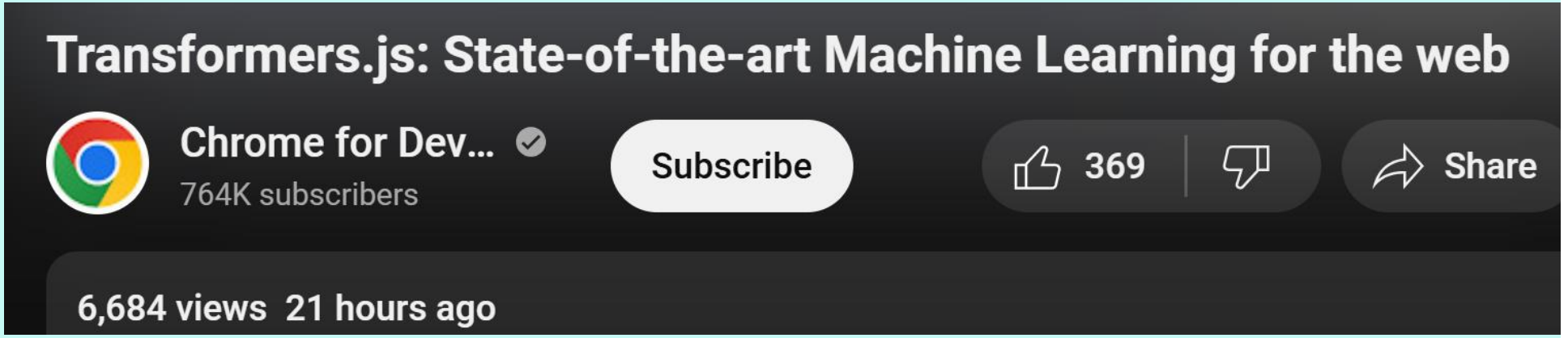
Appendix


Server
-Database
-AI Math
Your Device
App
-User Interface


App
Your Device
CPU
-User Interface
-Database
-AI Math
Local Storage
GPU


Web Browser
Your Device
Thread 1
-User Interface
CPU
Thread 2
-Database
OPFS Storage
Thread 3
-AI Math
GPU



https://n.gardella.cc/rag/

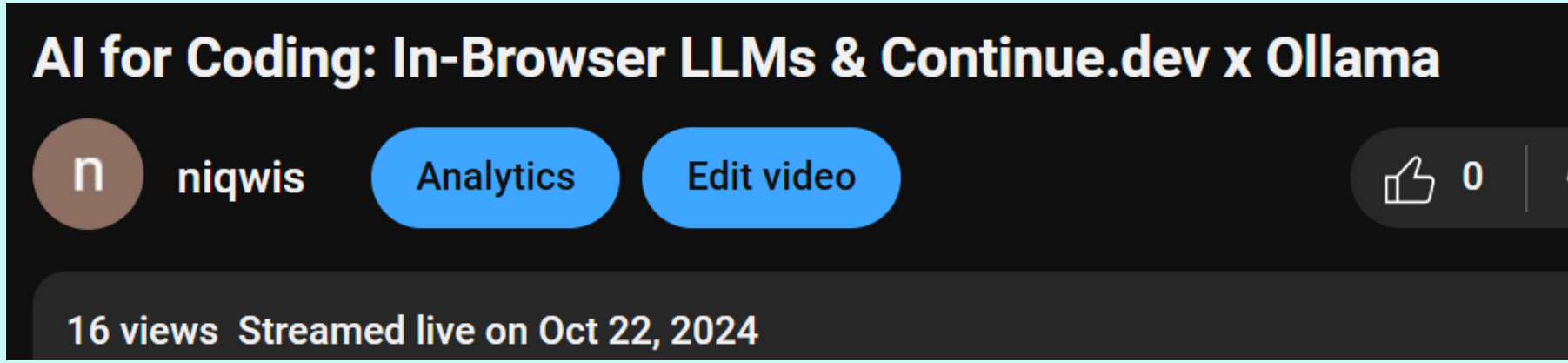


Table 1

	Solo	with AI	Change
Score	$\tilde{x} = 2$	$\tilde{x} = 2.5$	$\widetilde{\Delta x} = 1$
Δ Valence	$\bar{x} = -.088$	$\bar{x} = .118$	$\overline{\Delta x} = 0.206$
Δ Arousal	$\tilde{x} = 0$	$\tilde{x} = -.5$	$\widetilde{\Delta x} = -.5$
TLX Mental	$\bar{x} = 58.382$	$\bar{x} = 49.412$	$\overline{\Delta x} = -8.971$
TLX Physical	$\tilde{x} = 5$	$\tilde{x} = 2.5$	$\widetilde{\Delta x} = 0$
TLX Temporal	$\bar{x} = 54.559$	$\bar{x} = 49.265$	$\overline{\Delta x} = -5.294$
TLX Performance	$\bar{x} = 61.912$	$\bar{x} = 55.882$	$\overline{\Delta x} = -6.029$
TLX Effort	$\tilde{x} = 62.5$	$\tilde{x} = 55$	$\widetilde{\Delta x} = -5$
TLX Frustration	$\bar{x} = 47.059$	$\bar{x} = 44.853$	$\overline{\Delta x} = -2.206$
Self-Grade	$\bar{x} = 7.647$	$\bar{x} = 7.912$	$\overline{\Delta x} = .265$

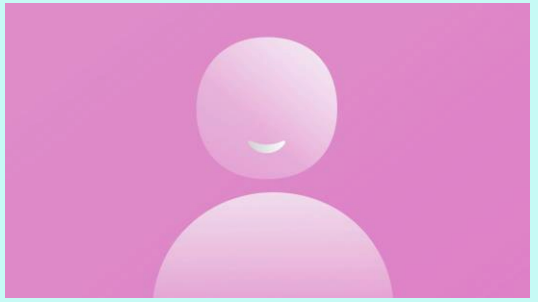
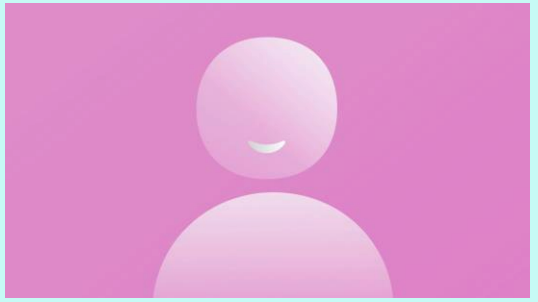


Table 2

	Statistic	*p*	d
Score	$\mathbf{z_{Wilcoxon} = 3.012}$	$\mathbf{.001*}$	$\mathbf{.368}$
Δ Valence	$t(16) = .800$	$.436$	$.098$
Δ Arousal	$z_{Wilcoxon} = -1.329$	$.191$	$-.162$
TLX Mental	$\mathbf{t(16) = -2.487}$	$\mathbf{.024*}$	$\mathbf{-.304}$
TLX Physical	$z_{Sign\ Test} = -.289$	$.773$	$-.035$
TLX Temporal	$t(16) = -1.338$	$.200$	$-.163$
TLX Performance	$t(16) = -1.248$	$.230$	$-.152$
TLX Effort	$\mathbf{z_{Wilcoxon} = -2.023}$	$\mathbf{.043*}$	$\mathbf{-.247}$
TLX Frustration	$t(16) = -.563$	$.581$	$-.069$
Self-Grade	$t(16) = .765$	$.455$	$.093$



Tables 3 & 4

		1st Trial	2nd Trial	Change
Solo	Score	$\tilde{x} = 2$	$\tilde{x} = 2$	$\widetilde{\Delta x} = 0$
	Self-Grade	$\tilde{x} = 8$	$\tilde{x} = 7.25$	$\widetilde{\Delta x} = 0$
with AI	Score	$\tilde{x} = 2$	$\tilde{x} = 3$	$\widetilde{\Delta x} = 1$
	Self-Grade	$\bar{x} = 7.118$	$\bar{x} = 8.706$	$\overline{\Delta x} = 1.588$

		Statistic	*p*	d
Solo	Score	$z_{Wilcoxon} = .090$	1.000	.016
	Self-Grade	$z_{Wilcoxon} = -.517$	.594	−.091
with AI	**Score**	$z_{Wilcoxon} = 2.029$	**0.046***	.348
	Self-Grade	$t(16) = 2.567$	**0.021***	.440