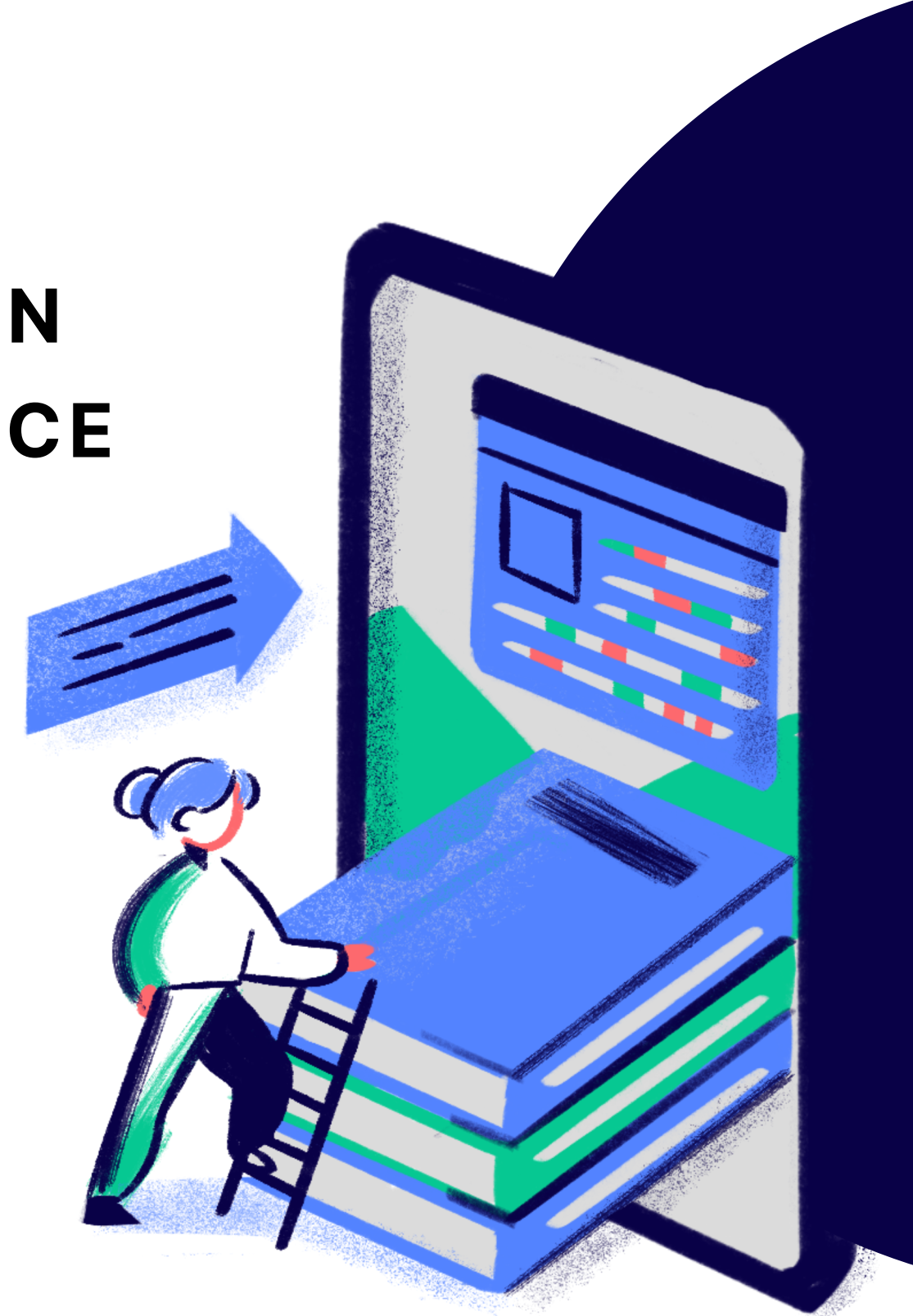


**STUDYING THE EFFECT OF MODALITY & TOPIC ON
AN INDIVIDUAL'S LEARNING EASE & PERFORMANCE
USING PHYSIOLOGICAL BIOMARKERS**

End-semester Presentation

Shruti Laddha, Suhani Jain & Utkarsh Agarwal



STUDIES SUGGEST **NO CORRELATION** BETWEEN PERFORMANCE IN OBJECTIVE TESTS & LEARNING STYLE PREFERENCE

*We identified **two major shortcomings** of these studies*

01

Self reported, subjective tests like VARK, Kolb's Experiential Model, Felder-Silverman, etc. are used as ground truth

02

They overlook fluctuations in physiology. Only few studies examine the true neurophysiological cost of learning across modalities.

1) Krätzig, G. P., & Arbuthnott, K. D. (2006). Perceptual learning style and learning proficiency: A test of the hypothesis. *Journal of Educational Psychology*, 98(1), 238–246.

2) Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest*, 9(3), 105–119

3) Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2015). Matching learning style to instructional method: Effects on comprehension. *Journal of Educational Psychology*, 107(1), 64–78.

PROBLEM STATEMENT

The study explores whether certain learning styles improve **objective performance and ease of learning** tracked through **reduced cognitive load**.

It identifies learner profiles using physiological biomarkers collected while learners engage with **different modalities** of instructional materials.

IMPACT & APPLICATIONS

Reinforces belief in the
“Matching Theory” or
disproves need for
personalized learning

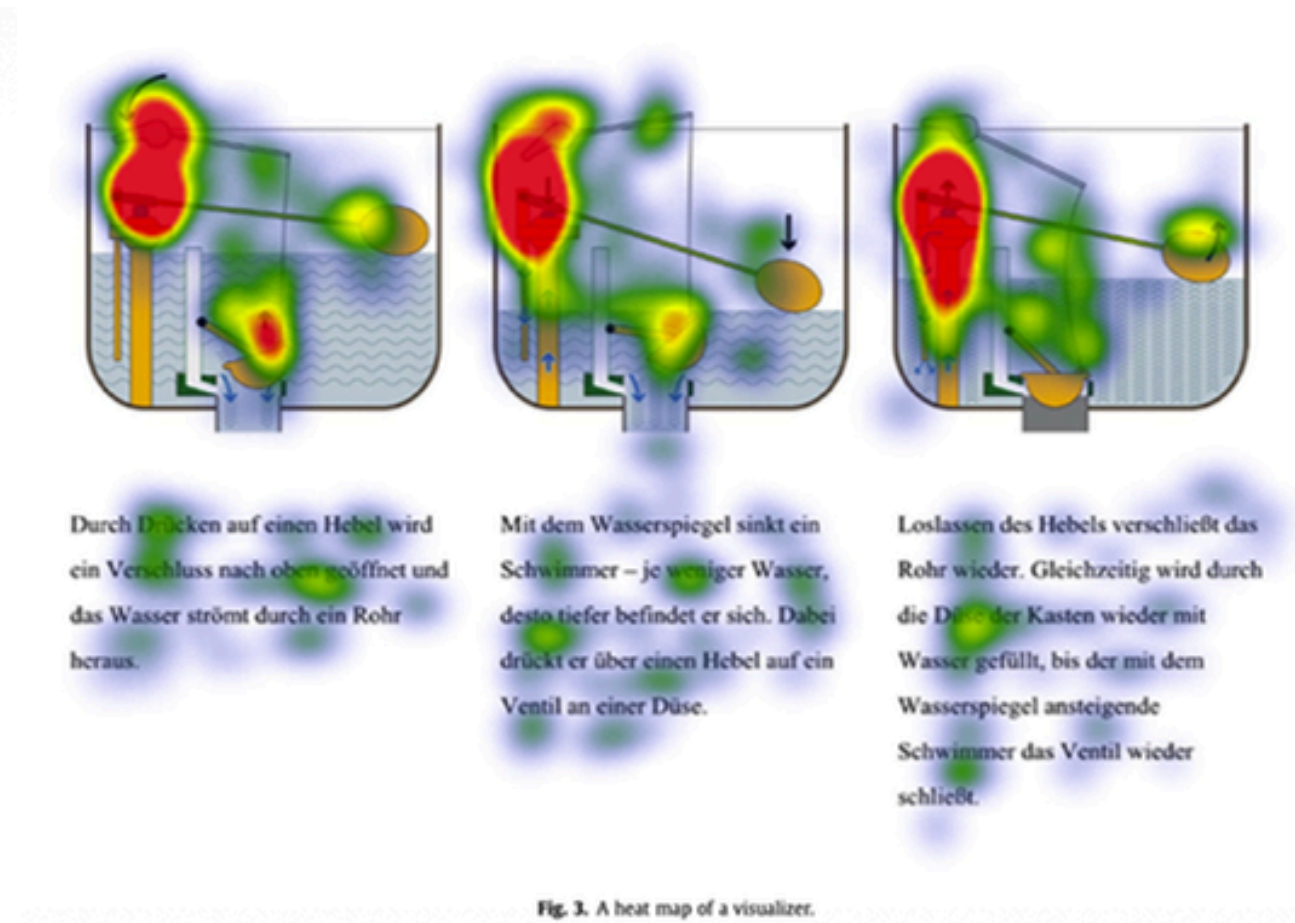
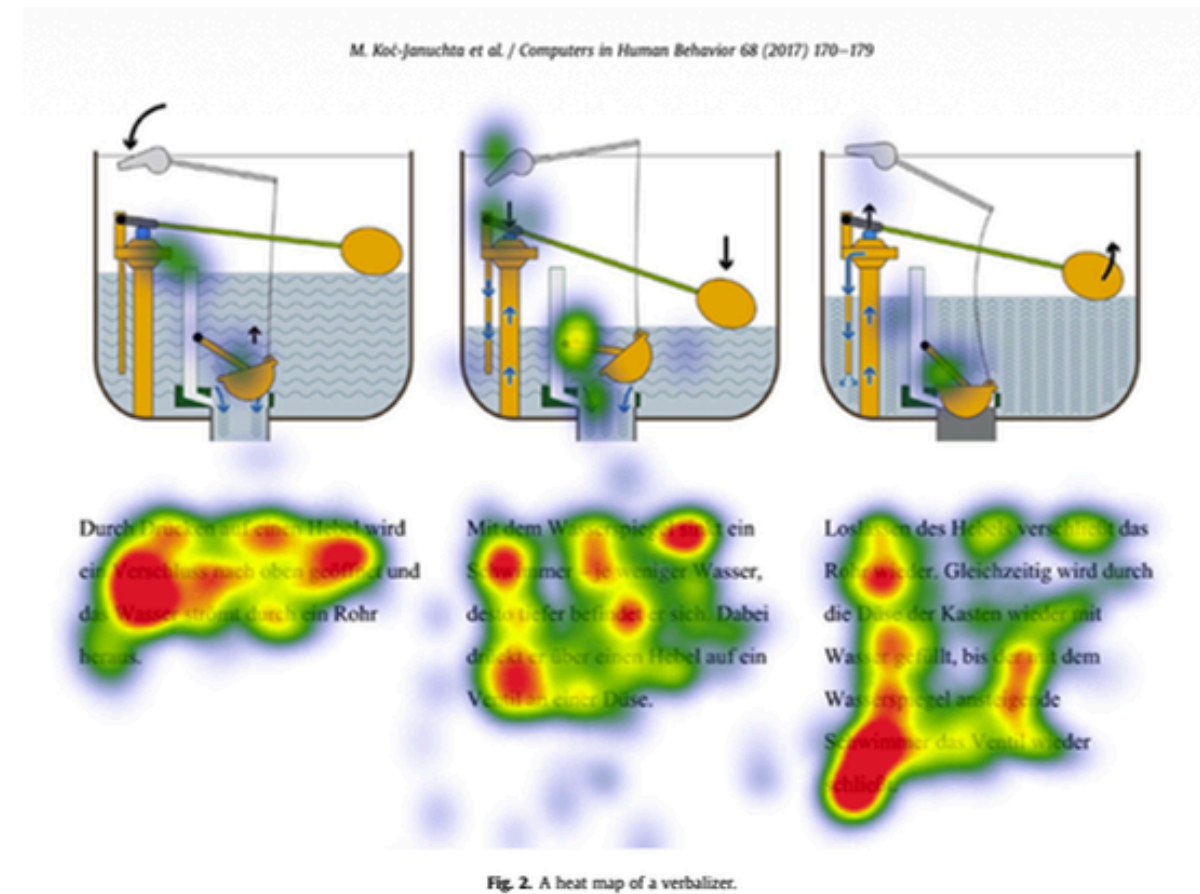
Provides a
scientific method
to assess learning
styles & CL

AI in Ed-Tech
Wellbeing in Education
Adaptive Learning



What are the different modalities?

The VARK model, developed by educational theorist **Neil Fleming** in 1987, is a widely known framework that categorizes learning preferences based on **four distinct sensory modalities**.



1] Koć-Januchta, M., Höffler, T., Thoma, G.-B., Precht, H., & Leutner, D. (2017). Visualizers versus verbalizers: Effects of cognitive style on learning with texts and pictures—An eye-tracking study. *Computers in Human Behavior*, 68, 170–179.

LITERATURE REVIEW: PHYSIOLOGICAL METRICS USED TO MEASURE COGNITIVE LOAD & DETERMINE LEARNING STYLES

Paper	Methodology	Result	Citation
Validation of VARK Questionnaire Using Gaze Tracking Data	Gaze data collected while they read educational materials. Correlation & linear regression used to assess dependencies between Aols & VARK scores.	Results suggest that gaze patterns can validate self-reported learning styles. Linear regression using gaze data predicted VARK modality scores with R² between 0.42–0.55	Baltulionis, S., et al.(2019, April 25). Validation of VARK questionnaire using gaze tracking data. In Proceedings of the International Conference on Information Technologies (IVUS 2019) (pp. 28-32). CEUR Workshop Proceedings, vol. 2470.
Uncovering Learning Styles through Eye Tracking and Artificial Intelligence	Eye-tracking to capture gaze behaviors while interacting with learning materials. AI algorithms then analyzed eye-tracking data & classified learning styles.	Integration of eye-tracking data with AI algorithms proved effective in classifying learning styles, alternative to self-reported methods. SVM: 76.2% accuracy	Dominik Bittner, et al. 2024. Uncovering Learning Styles through Eye Tracking and Artificial Intelligence. In Proceedings of the 2024 Symposium on Eye Tracking Research and Applications (ETRA '24). Association for Computing Machinery, New York, NY, USA, Article 70, 1–7.
The effects of matching/mismatching cognitive styles in E-learning	Randomized lab experiment using Felder–Silverman styles. Learners grouped as holistic vs. serialist; given lessons designed to match/ mismatch their style. Both subjective (NASA-TLX) & objective physiological measures - HRV, GSR, EEG-based attention.	Matched learners had ~18% lower mean NASA-TLX total load, HRV SDNN increased by ~12% , indicating lower stress.	Wu, C. H., Tang, K. D., Peng, K. L., Huang, Y. M., & Liu, C. H. (2024). The effects of matching/mismatching cognitive styles in E-learning. Educational Psychology, 44(9–10), 1048–1072.
Instructional Mode: A Better Predictor of Performance Than Learning Style	Random assignment to Read, Listen, or Read+Listen lessons after classifying students by VARK preference. Self-reported cognitive load.	Instructional mode affected load & performance, but matching style did not reduce cognitive load. Mean CL similar across matched/mismatched (≈ 5.8 ± 1.1 vs. 5.9 ± 1.2; n.s.).	Moussa-Inaty, J., et al.(2019). Instructional mode: A better predictor of performance than learning style. International Journal of Instruction, 12(4), 277–294.

EXPERIMENT DESIGN : SENSORS



Pupil Labs Eye Tracker

Gives insights into attentional allocation & cognitive processing dynamics (Hong, H., et al. 2025). Features:

- Fixation durations (how long gaze stays in a region)
- Number of fixations per Aoi
- Pupil dilation / pupil size changes
- Blink rate / blink duration



ECG gives a physiological measure of mental effort / arousal / stress during each modality (Hirachan et al. 2022). Features:

- Heart rate
- HRV features
- Derived indices of autonomic arousal / stress

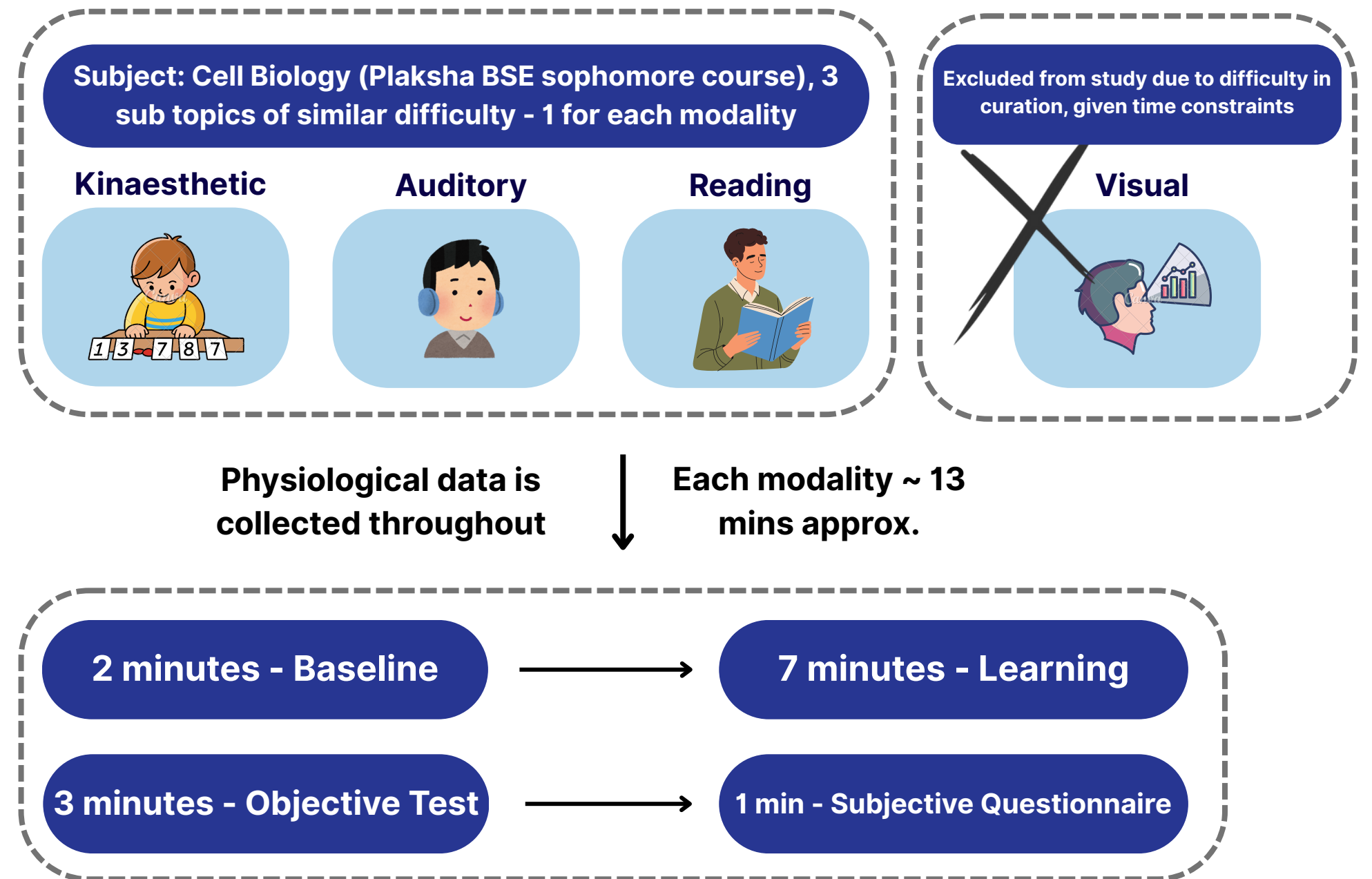
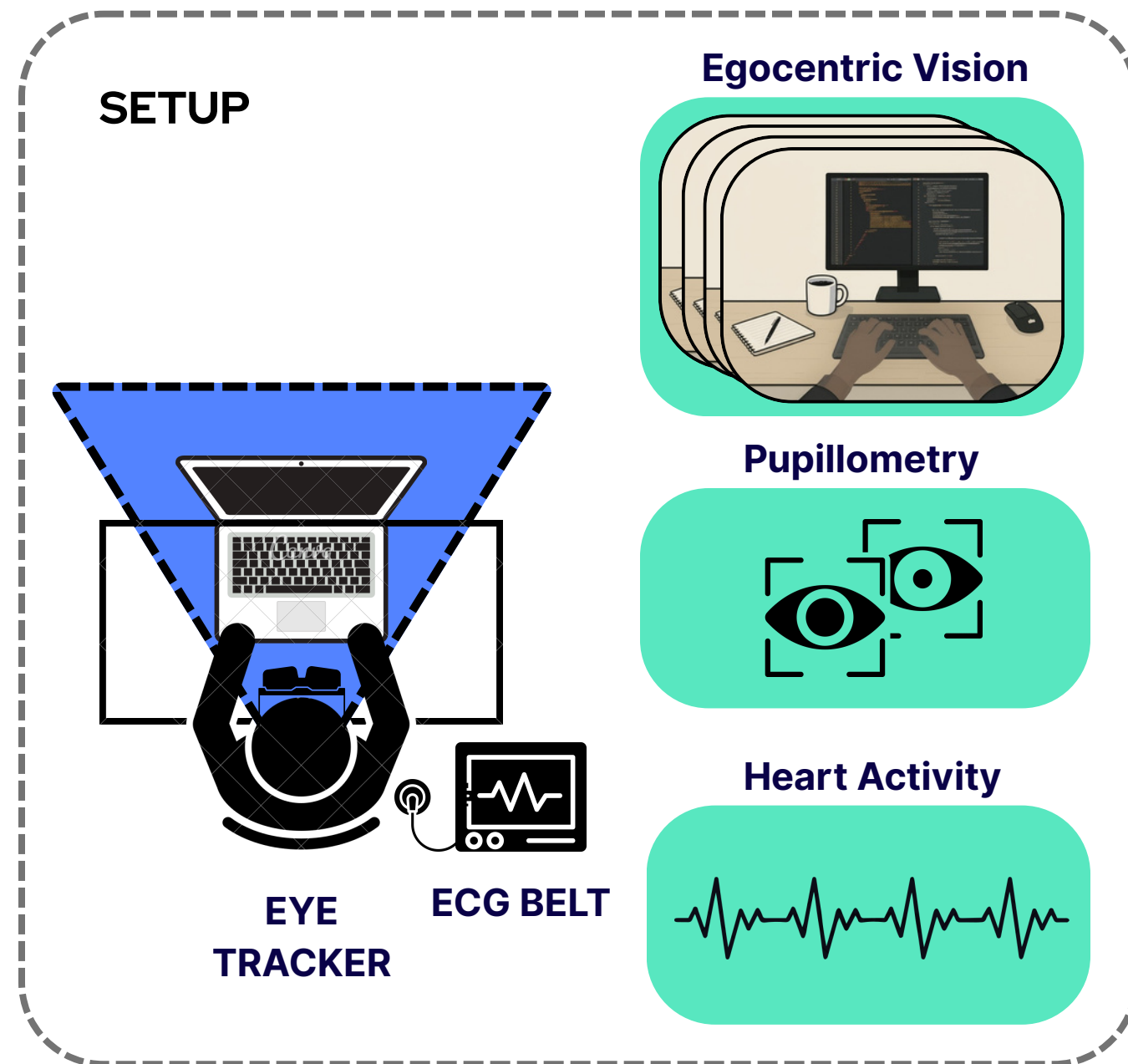


MAX ECG Monitor

1) Hong, H., Dai, L., & Zheng, X. (2025). Advances in Wearable Sensors for Learning Analytics: Trends, Challenges, and Prospects. *Sensors* (Basel, Switzerland), 25(9), 2714.

2) Hirachan, N., Mathews, A., Romero, J., & Rojas, R. F. (2022). Measuring cognitive workload using multimodal sensors. *arXiv preprint arXiv:2205.04235*.

EXPERIMENT DESIGN : PIPELINE







n = 9 participants

counter-balanced order for modalities, fixed order for topics

Note: Informed consent was taken pre-experiment. All collected physiological data was anonymized using randomized unique identifiers to protect privacy. No personally identifiable information was linked to recorded data at any stage of analysis or storage.

EXPERIMENT DESIGN : STUDY MATERIAL

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

The DNA Damage Checkpoint: How Cells Sense, Signal & Stop to Protect Their Genome

1) Reading / Writing

Life depends on one non-negotiable rule: every cell must faithfully copy and distribute its genome before dividing. To ensure accuracy, cells divide through a tightly regulated sequence of stages called the **cell cycle**:

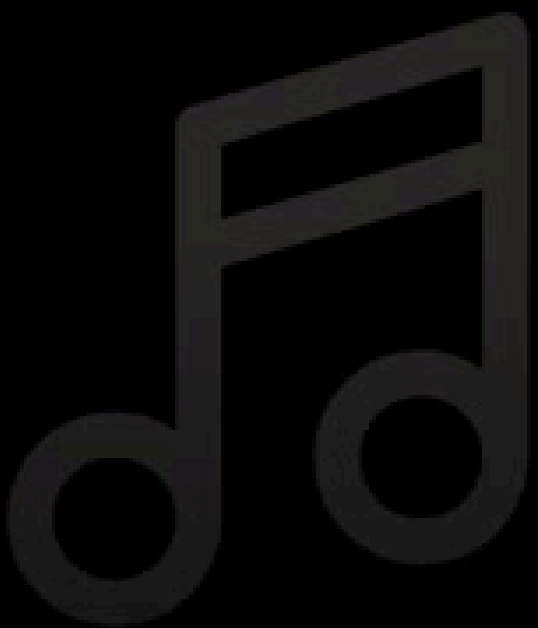
- **G1 phase**: the cell grows and checks if conditions are suitable for DNA duplication.
- **S phase**: the DNA is replicated, each chromosome is copied to ensure that the two daughter cells inherit identical genetic information.
- **G2 phase**: the cell inspects the newly made DNA for errors and prepares for mitosis.
- **M phase**: the duplicated chromosomes are carefully pulled apart and distributed to daughter cells.

This cycle is **not an automatic loop**; it is governed by molecular “traffic lights” made of Cyclin–CDK complexes that push the cell forward or hold it back.

But DNA is constantly under attack. Chemicals, radiation, metabolic by-products, and normal replication errors can all damage DNA. To prevent passing on broken or mutated DNA, cells evolved checkpoints: quality-control roadblocks that detect problems, pause the cell cycle, and activate repair.

EXPERIMENT DESIGN : **STUDY MATERIAL**

Home | Record Upload Download Move to Copy to ...



Play (Alt + K)

0:00 / 6:19

ATM_p53_The_Cell_Cycle_Brakes

EXPERIMENT DESIGN : STUDY MATERIAL

Almost out of storage If you run out, you can't create or edit files, send or receive emails on Gmail, or back up to Google Photos. Manage storage X

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(apoptosis)-to avoid passing harmful mutations to future cells.

When this checkpoint system is lost or faulty, damaged DNA keeps being copied, leading to **genomic instability**, a major driving force behind cancer. This is why key checkpoint proteins like ATM and p53 are so strongly linked to disease.

Overall, the DNA Damage Checkpoint protects life by ensuring that only healthy, accurate DNA is passed on, making it one of the cell's most important defense mechanisms.

Reading time: 7 minutes
Reading score: 53

2) Auditory

[ATM_p53_The_Cell_Cycle_Brakes.m4a](#)

3) Interactive

<https://chatgpt.com/g/g-6p3679804eb88191907ed5165b0ff08a-hti-gpt-1>

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Document tabs +

- Ideation
- Learning Styles
- Modalities
- Competitors
- Evaluation
- Topic 1 (Final)** ⋮
- Topic 2 (Final)

Headings that you add to the document will appear here.

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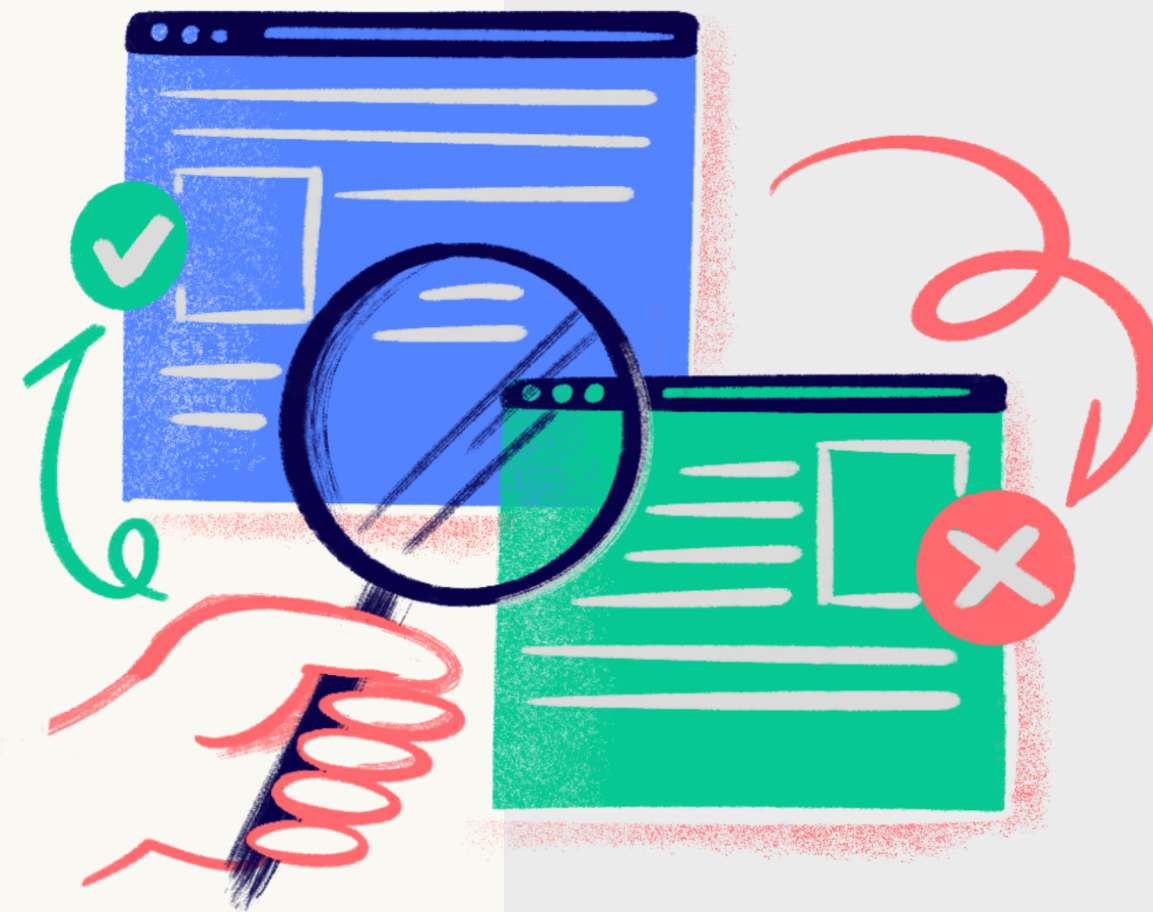
EXPERIMENT DESIGN : TESTS

Subjective Measures

NASA-TLX (Task Load Index): Used in human factors / ergonomics to measure perceived workload across six dimensions: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, Frustration

Likert Scale Questions

- “How well do you feel you understood the material presented?” (1 to 5)
- “How confident are you in your recall or application of the content?”



Objective Measures

Problem-solving transfer tests

Goes beyond simple memorisation and assesses a learner's ability to apply principles learned in one context to solve new & unfamiliar problems.

- 5 MCQs + Fill in the Blanks
- 3 Short Answer Questions

EXPERIMENT DESIGN: DATA PROCESSING

Get data

Eye Tracker: Pupil Diameter

ECG: Heart Rate & HRV

Remove Noise: Identifying & removing artefacts caused by muscle movements, blinks, or poor sensor contact

Physiological Biomarkers - delta values

For pupil size & HR/HRV: subtract 2-min baseline mean to get delta values per task/modality.

Objective Scores - percentage

- MCQ + Fill in the blanks: Total Marks = 5
- Short Answers: Total Marks = 6
- Percentage = $\frac{((MCQ + FITB) + SA) * 100}{11}$

Subjective Scores - total

- NASA TLX (Out of 7): sum across all
- Likert Based (Out of 5): sum and inverse

RESULTS: CALCULATING LEARNING EASE

Purpose: Holistic measure of learning experience combining subjective perception and physiological effort

Metric Structure

Subjective Workload

- NASA-TLX Total
- Higher score = higher demand

Subjective Satisfaction

- Inverse Likert Total
- Higher score = lesser satisfaction

Cardiovascular Stress

- Δ HR mean
- Δ HRV mean

Cognitive Effort

- Δ Pupil Diameter mean

1. Standardization

$$Z_x = \frac{x - \mu_x}{\sigma_x}$$

2. Learning Ease

$$(0.125 * Z_{TLX} + 0.125 * Z_{Likert}^{-1} + 0.25 * Z_{\Delta HR} + 0.25 * Z_{\Delta HRV} + 0.25 * Z_{\Delta PupilDiam})$$

Interpretation:

High Learning Ease (+): Low stress, high satisfaction, efficient learning

Low Learning Ease (-): High cognitive/physiological strain

RESULTS: EFFECT OF MODALITY ON PERFORMANCE & EASE

Objective Scores

Normality Check (Shapiro-Wilk)

- Reading: $p=0.2211$ (Normal)
- Audio: $p=0.9379$ (Normal)
- Kinesthetic: $p=0.3265$ (Normal)

ANOVA

- F Value : 2.1286
- p-value : 0.1515

Interpretation:

- No statistically significant difference in Objective Score across modalities.

Learning Ease

Normality Check (Shapiro-Wilk)

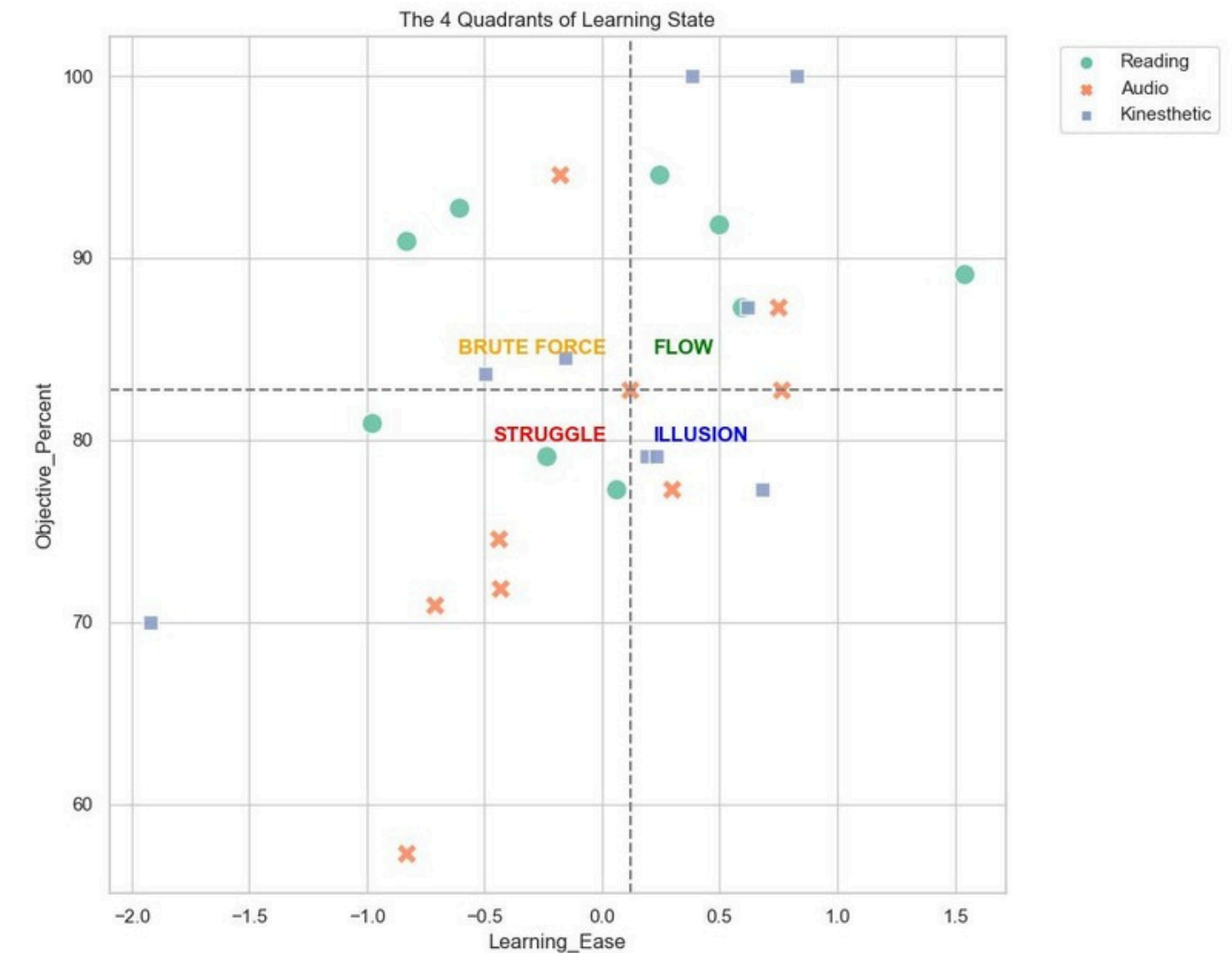
- Reading: $p=0.7687$ (Normal)
- Audio: $p=0.4300$ (Normal)
- Kinesthetic: $p=0.0396$ (Not Normal)

Friedman Test Results

- χ^2 : 0.667
- p-value : 0.7165

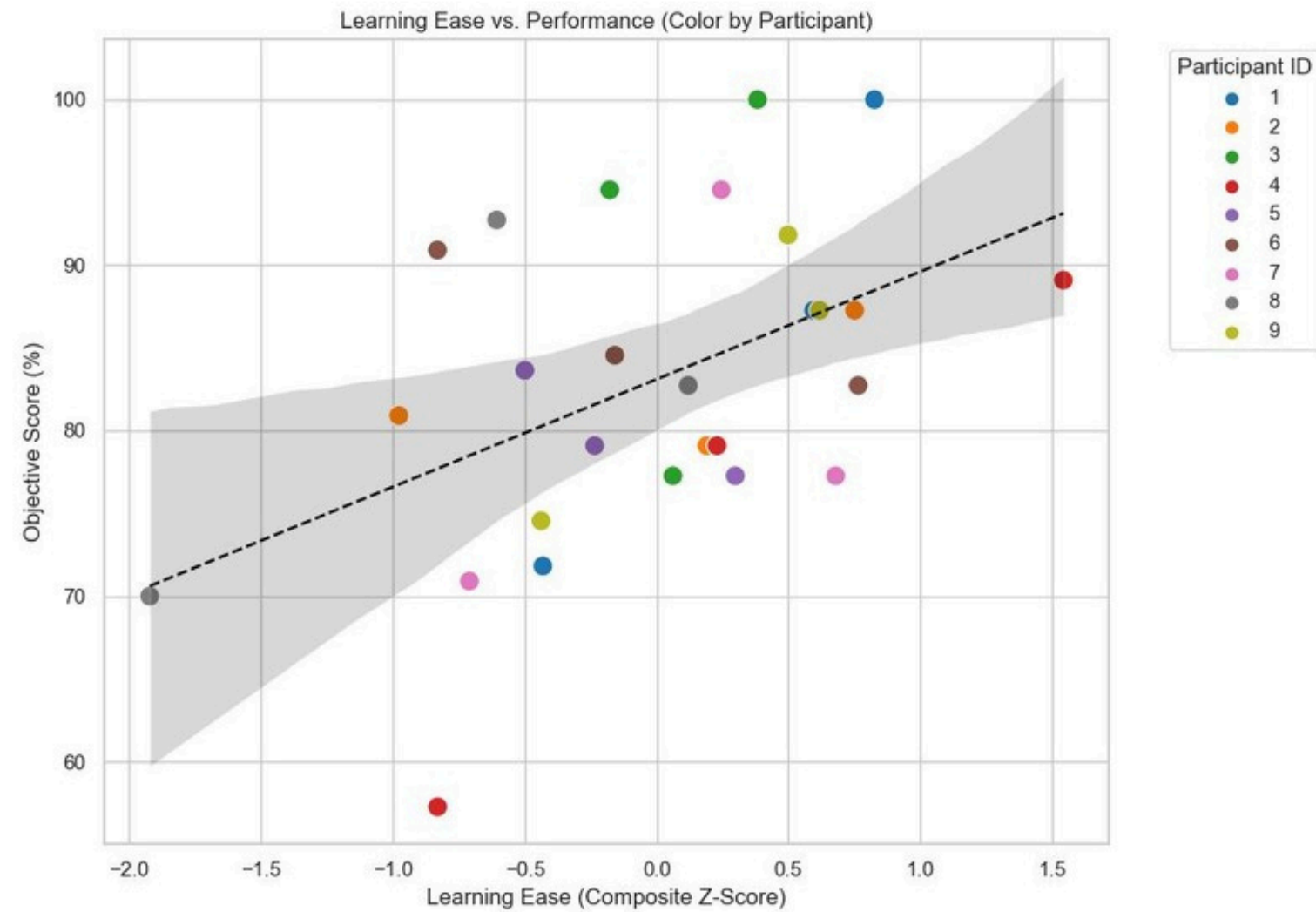
Interpretation:

- No statistically significant difference in Learning Ease across modalities.

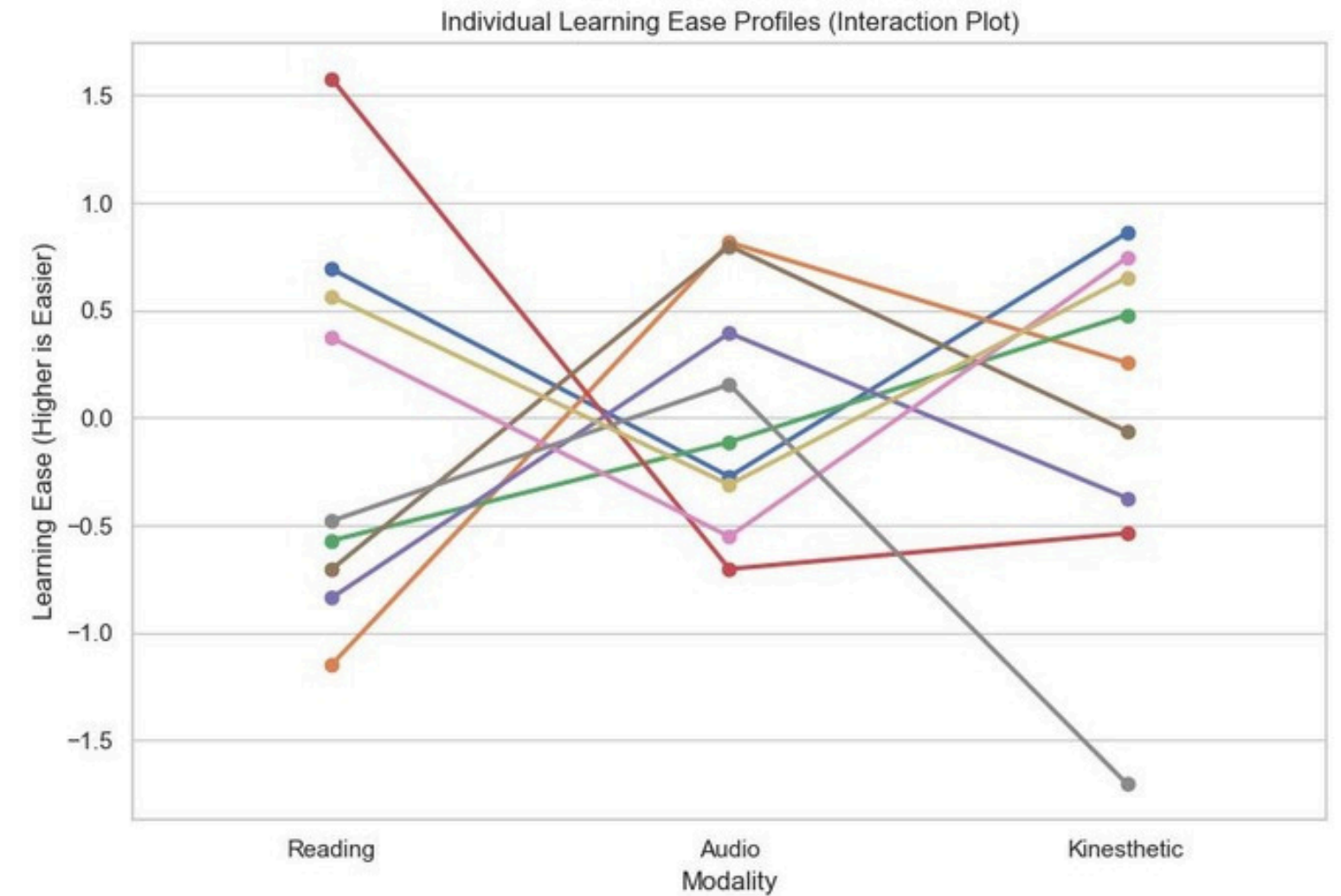


No discernible trend between modality and quadrant

RESULTS: EFFECT OF LEARNING EASE ON PERFORMANCE



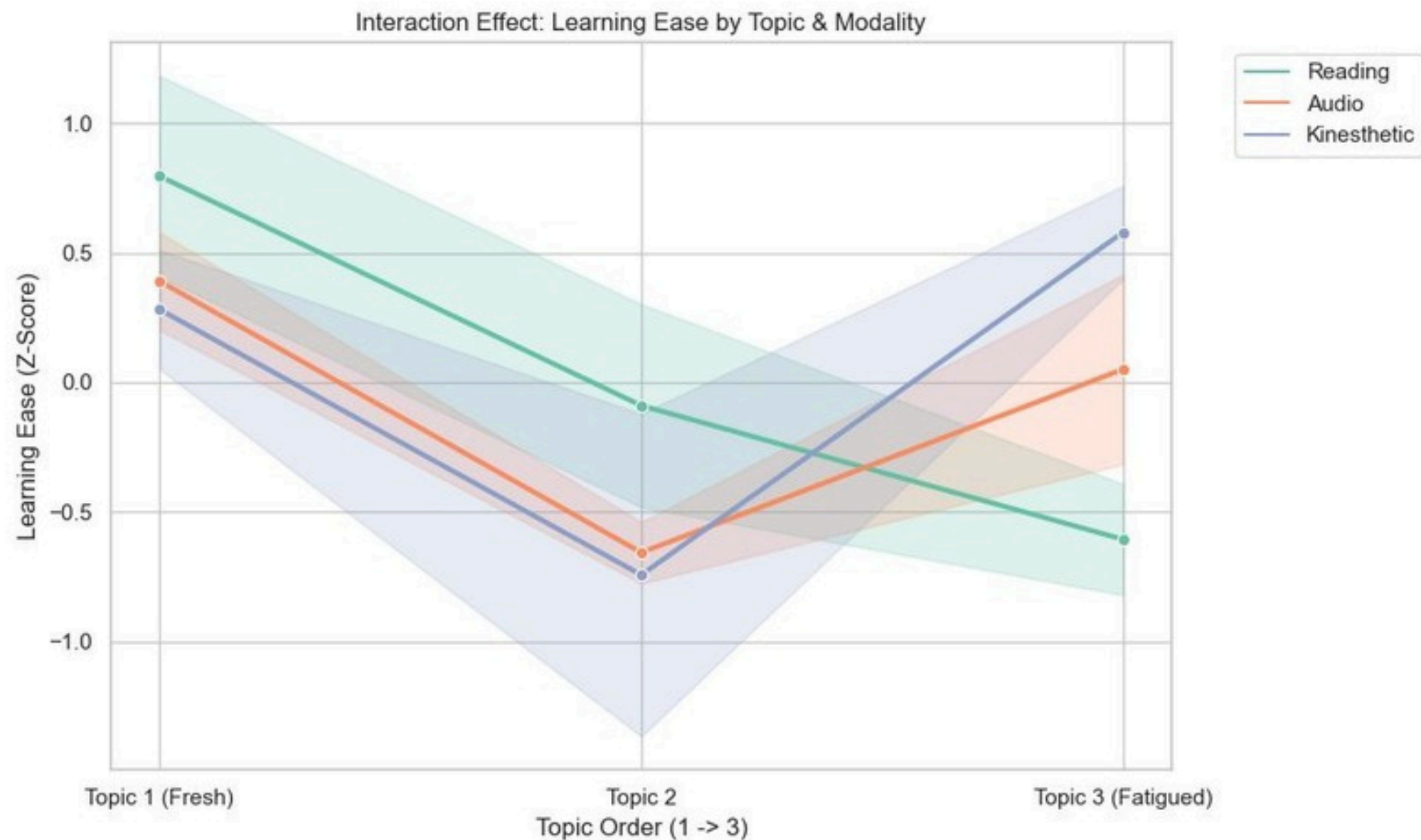
Learning ease DID show a positive correlation with objective performance.
 $R^2 = 0.58$



There is variability in learning ease due to modality across individuals

We got curious: If not modality then what causes the lesser cognitive load?

RESULTS: LEARNING EASE & MODALITY ACROSS TOPICS



Interaction Effect: Context × Modality
One-Way ANOVA on 9 Topic-Modality combinations
(e.g., Topic1-Reading, Topic3-Kinesthetic)

Statistical Result
 $F(8,18)=2.87, p=0.03$
Significant effect of Topic-Modality combination on Learning Ease

Conclusion: *Modality effectiveness changes depending on context (topic order / fatigue). Effective learning depends on when a modality is used-not only which modality is used.*

LIMITATIONS & FUTURE SCOPE



Visual Modality Not Included

Even though very important, we couldn't include visual modality in our study due to difficulty in isolating visuals from audio & text



One Subject, Fixed Topics

The study wasn't topic or subject agnostic. The fixed sequence of topics may lead to familiarity & skew results.



Assumed standard content quality

For all modalities, we have tried to keep content quality & depth the same, however, we couldn't measure if it is actually the same.

Impact & Deployability

- Shifts Focus from “Learning Styles” to “Learning States”
- Reaffirms findings from literature - learning style/modality alone does not lead to better performance.
- Shows that context & fatigue matter - one learning style now might not be optimal later
- Helps designers optimize content sequencing instead of over-optimizing content format alone

The experiment requires advanced sensors & hence will be difficult to deploy at scale, however, the design can be very easily replicated to further this study - developing EdTech models, validation with a larger subset, making it topic agnostic

APPENDIX

- [Learning_Topics.pdf](#)
- [Consent Form](#)
- [Post-Session Questionnaire — Workload & Learning Experience](#)



The screenshot shows a GitHub repository page. At the top left, the repository name is 'suhanijain1/Learning-Styles-Cognitive-load-...'. To the right is a repository icon with a green grid pattern. Below the name is a description: 'Checking if learning styles can influence the efficacy and cognitive load experienced while learning something new.' Underneath the description are statistics: 2 Contributors, 0 Issues, 0 Stars, and 0 Forks. A GitHub logo is on the right. Below this is a search bar with the text 'suhanijain1/Learning-Styles-Cognitive-load-eval: Checking if learning styles can influence the efficacy an...'. At the bottom left is the GitHub logo and the text 'GitHub'.

**THANK YOU FOR AN
INSIGHTFUL 4 YEARS :)**