Examining Survey Mouse Movements as Indicators of Individual Cognitive Functioning

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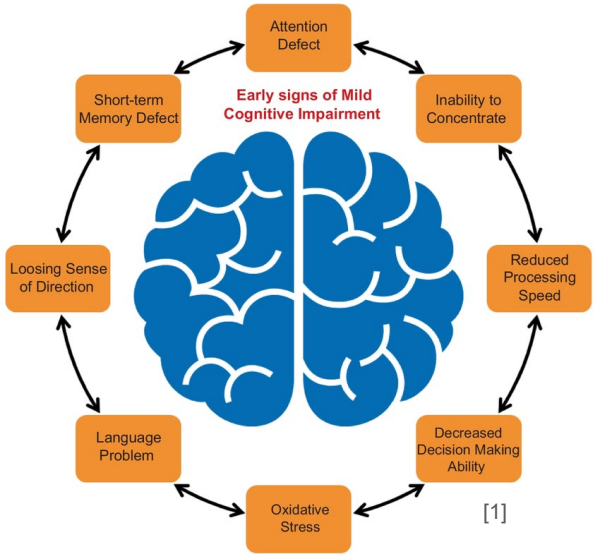
RQ: How can machine learning models predict cognitive functioning scores using demographic and mouse movement features, and which features are most influential?

Mild Cognitive Impairment

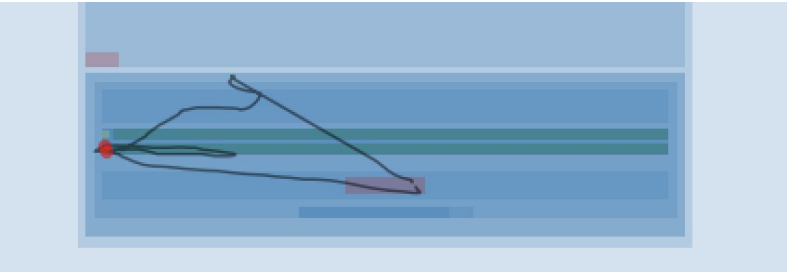
- A condition in which people have more memory or thinking problems than other people their age:
  - Memory lapses (e.g., forgetting appointments or conversations) [2];
  - Difficulty with complex tasks (e.g., managing finances) [3];
  - Preserved independence in daily activities.



[1]

Mouse Movements in Survey: A Window into Cognitive Processes

- Tracking mouse movements (e.g., cursor position, speed, clicks) as a behavioral metric during survey responses.
- Provide insights into respondent engagement and cognitive processing.
- Patterns of movement can reveal mental workload, such as increased hesitation during complex questions [4].
- Back-and-forth movements or repeated clicks may signal uncertainty or difficulty in choosing between options [4].



Demographic and Mouse Movement Features

- Demographic variables: gender, age, education, ethnicity, marital status, labor status, and household income
- Mouse Moverment features: x-/y-filps, response time, idle time, initiate time, hovers, total distance, speed and so on.

UAS 618 Survey

- Topics: Health, Income, and Subjective Well-being
- Excluded incomplete surveys
- Excluded data from touch devices or mobile devices

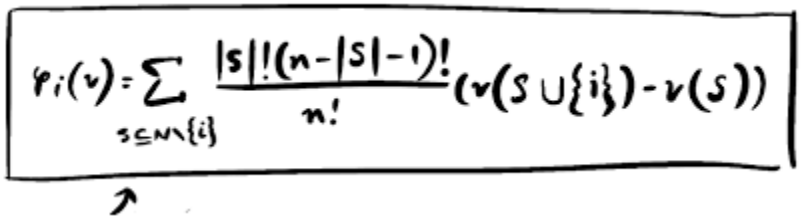
UAS618 - Response Overview	
Size of selected sample	14588
Completed the survey	9883
Started but did not complete the survey	81
Did not start the survey	4624
Response rate	67.75%

Machine Learning Models

- Algorithms that learn patterns from data to make predictions or decisions without explicit programming.
- Predicts outcomes based on labeled data (e.g., classification).
    - Examples: Linear Regression, Decision Trees, Support Vector Machines, **Deep Neural Networks**.
    - Input: demographic variables, mouse movement features, and survey respondense
    - Outcome: probability of mild cognitive impairement (**PCI**)

Expailable Machine Learning: Shapley Value

- A concept from cooperative game theory that fairly distributes the total "payout" among players based on their individual contributions.
- Measures the average marginal contribution of a player (or feature) across all possible coalitions.
- Application in Machine Learning:
  - **Feature Importance**: Explains the contribution of each feature to a model's prediction.



Open Questions

- What are reasonable classification thresholds for PCI?
- How can Shapley values address potential biases in datasets (e.g., age, gender, or ethnicity) when predicting PCI?
- Can Shapley values effectively capture changes in feature importance over time in longitudinal studies of cognitive functioning?

Reference

[1] Javed, Abdul Rehman & Saadia, Ayesha & Mughal, Huma & Gadekallu, Thippa & Rizwan, Muhammad & Reddy, Praveen & Mahmud, Mufti & Liyanage, Madhusanka & Hussain, Amir. (2023). Artificial Intelligence for Cognitive Health Assessment: State-of-the-Art, Open Challenges and Future Directions. Cognitive Computation. 15. 10.1007/s12559-023-10153-4.

[2] Bozoki, Andrea, et al. "Mild cognitive impairments predict dementia in nondemented elderly patients with memory loss." Archives of neurology 58.3 (2001): 411-416.

[3] Berezuk, Courtney, et al. "Managing money matters: managing finances is associated with functional independence in MCI." International Journal of Geriatric Psychiatry 33.3 (2018): 517-522.

[4] Leipold, F. M., Kieslich, P. J., Henninger, F., Fernández-Fontelo, A., Greven, S., & Kreuter, F. (2025). Detecting Respondent Burden in Online Surveys: How Different Sources of Question Difficulty Influence Cursor Movements. Social Science Computer Review, 43(1), 191-213. https://doi.org/10.1177/08944393241247425