From Cursor to Cognition: Clustering Respondent Styles with Neural Embeddings

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Motivation

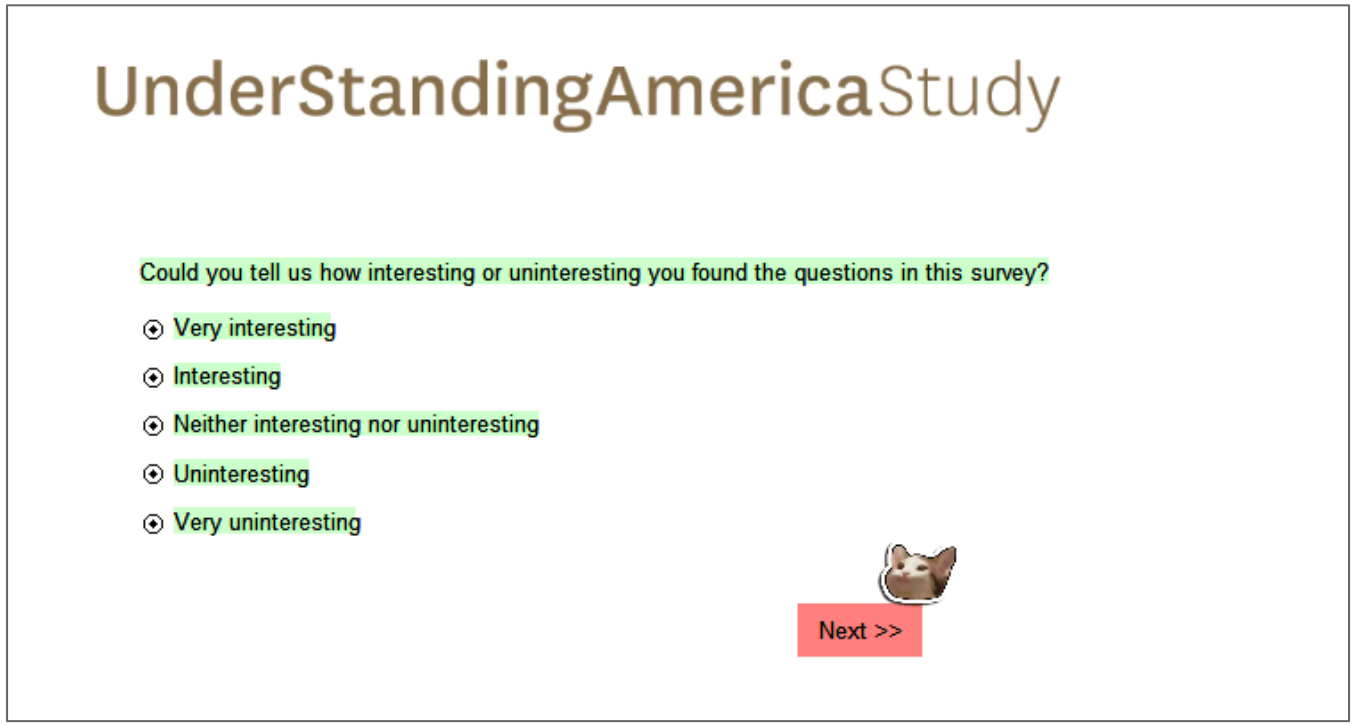
- Survey panels rely on attentive, motivated participants to provide valid, reliable survey data for research and policy decisions.
  - Monitoring this in web surveys is challenging — *no interviewer to ensure attention*.
- Fraudulent responses, bots or disengaged respondents threaten data integrity (Westwood, 2025)

- Research on behavioral signals, like **mouse movements**, to offer insights on:
  - Identifying engagement and question difficulty levels
  - Flag suspicious or automated behavior

Mouse Tracking

- Recording movement, clicks, and hover patterns of a respondent's mouse
- MouseTrap R Package
  - **Movement**: Path of the mouse cursor
  - **Clicks**

Example 1



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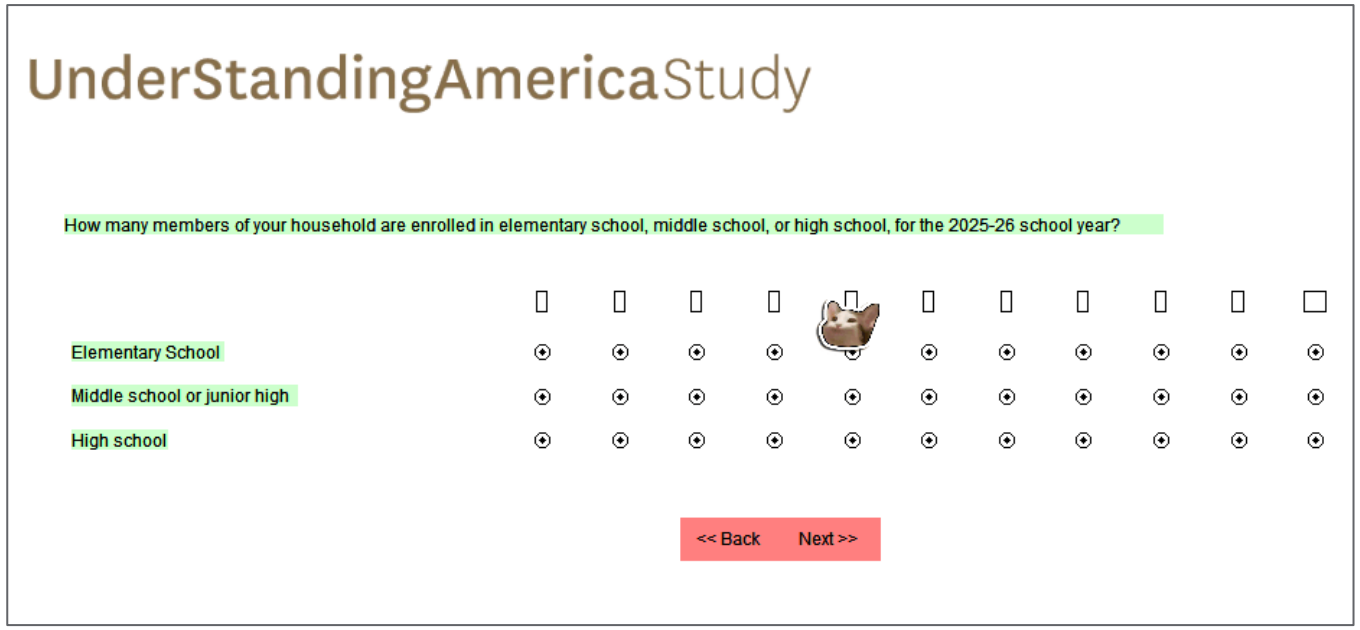
  - **Hover Time**: Instances and time spent hovering over e.g., text or options
  - **X & Y-flips**: Cursor moves back and forth between two or more response options before making a final selection

Example 2



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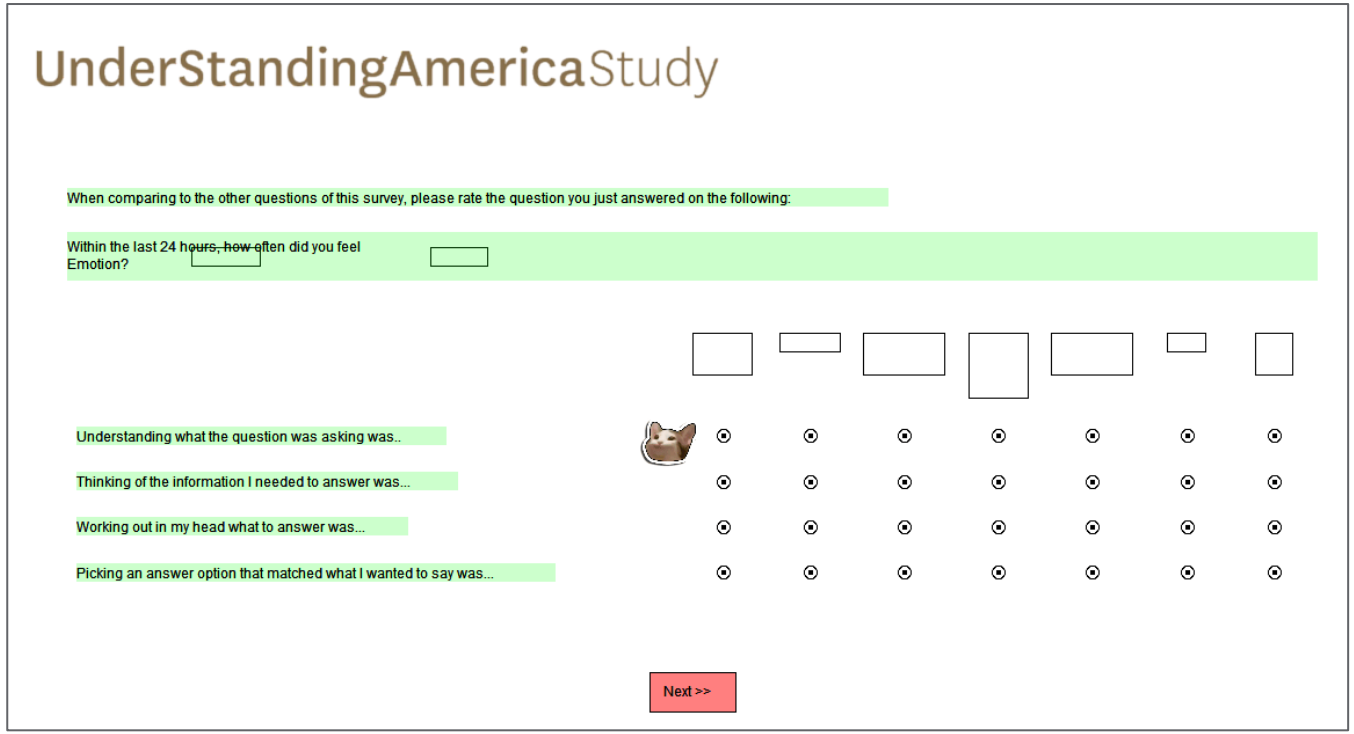
  - **Distance**, **velocity** and **acceleration**

Example 3



Our research missions

Set up data collection

Easy data collection and processing of *paradata*

Database of mouse and touch trajectories

Prediction and clustering models

MousePrep R Package

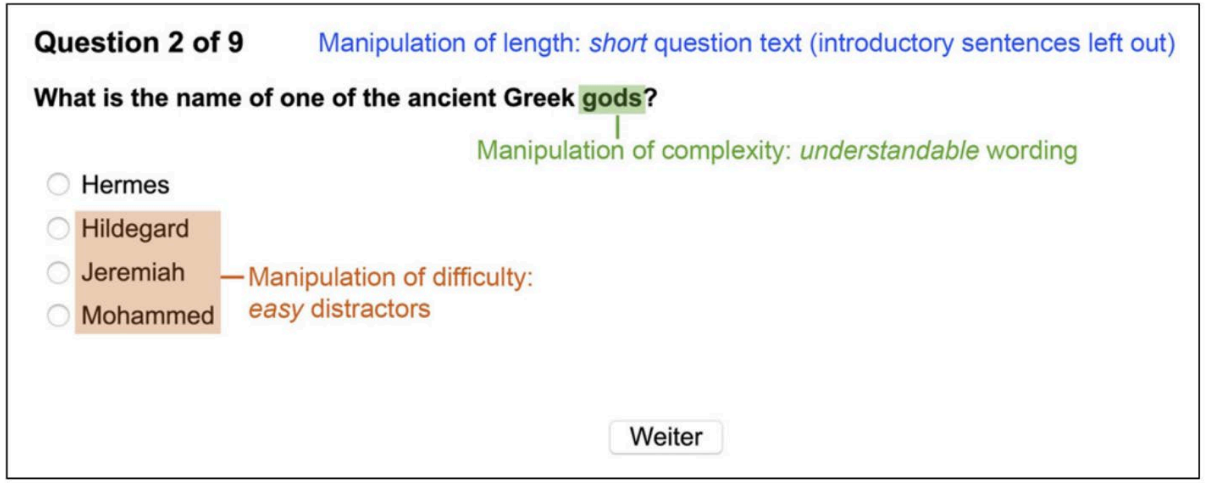
MouseTrap R Package

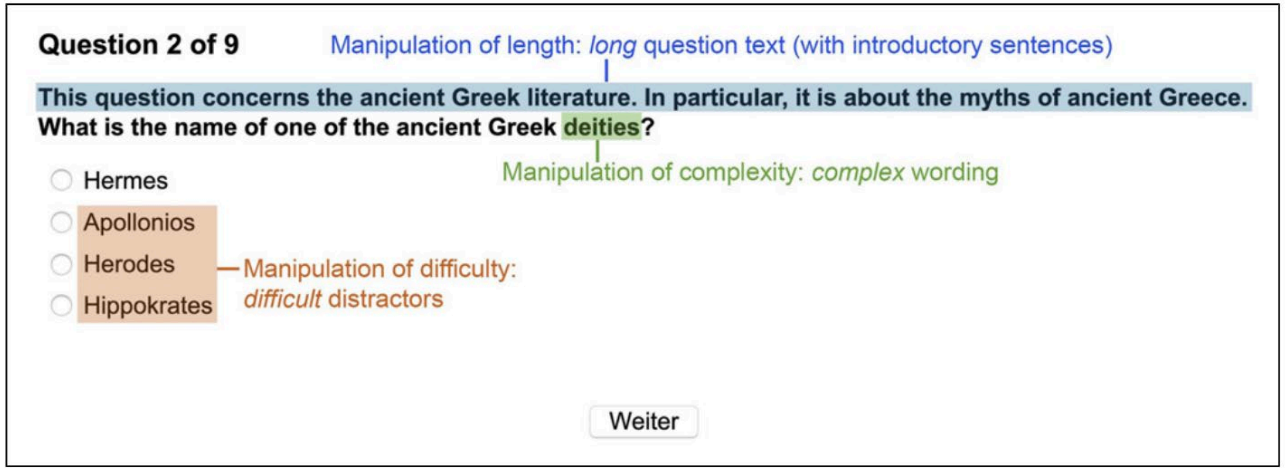
- Identify distracted respondents, difficult questions
- Detect fraudulent and bot responses
- Anything you can imagine

Previous research

- Research shows similarities between mouse tracking and eye tracking in detecting hesitation, attention and cognitive conflict (Freeman & Ambady, 2010; Spivey & Dale, 2006)
- Identify difficult questions (Leipold et al., 2025)

- Current research: Explore whether mouse trajectories reveal distinct **clusters** of interaction behavior
- Examine stability and patterns across:
  - Question types and difficulty
  - Individual respondents – and if so, consistency over time
  - Demographics (age, gender, education)

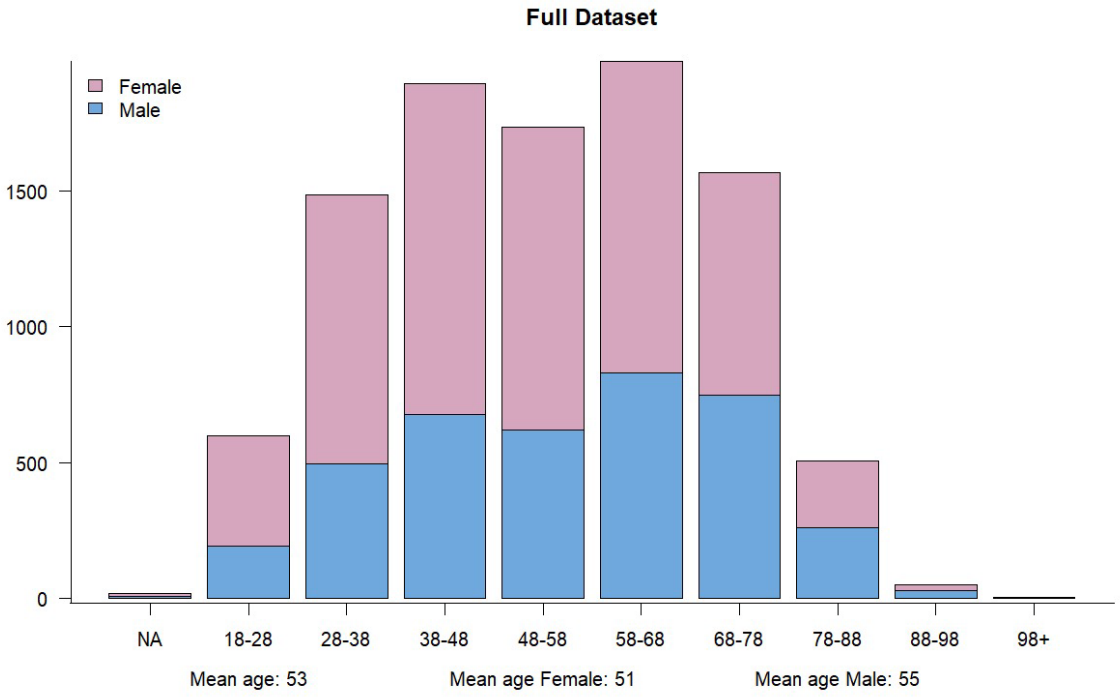


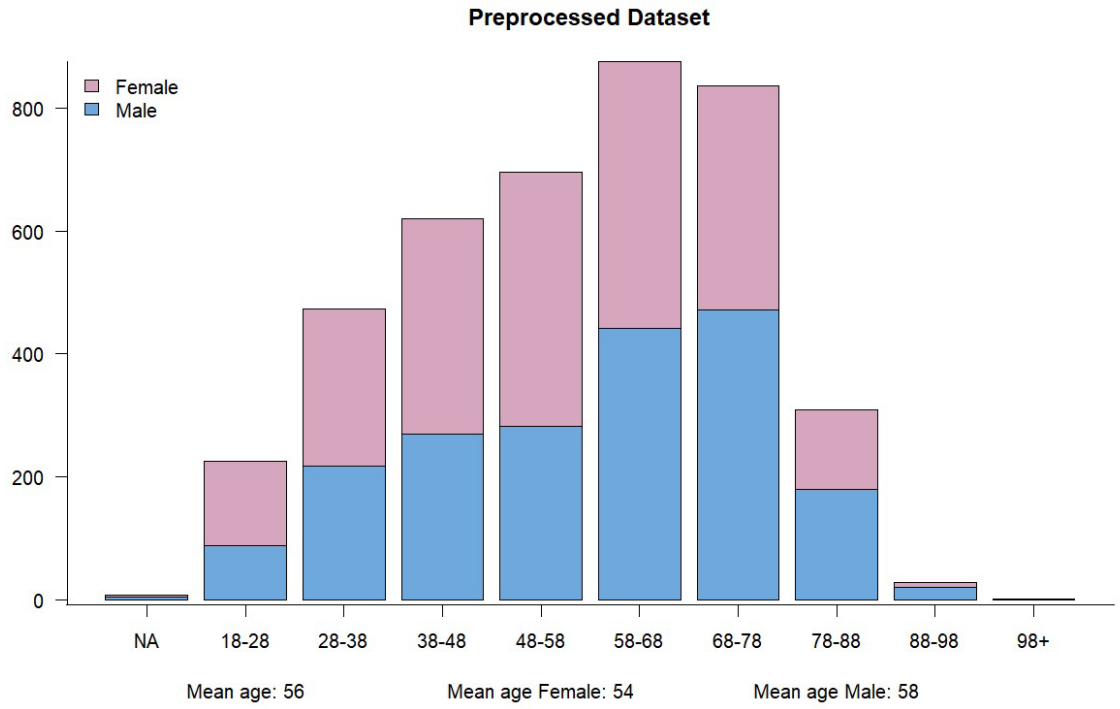


Data collection

Subset sample

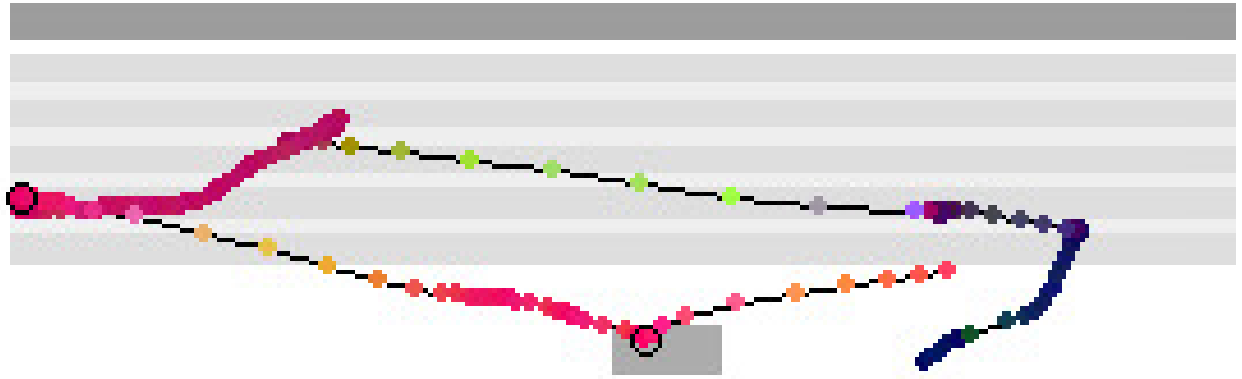
- End of Year survey 2024 (Survey 672): 9953 participants → 4075 participants using mouse/trackpad





Model input and neural networks

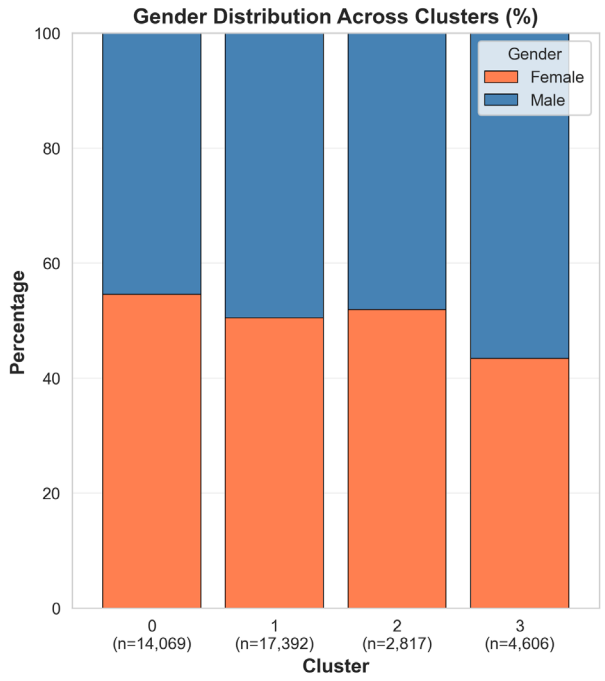
- Each image represents: one respondent × one question
- Trajectories encoded as RGB images
  - Red: time
  - Green: velocity
  - Blue: acceleration
  - Black circles: clicks

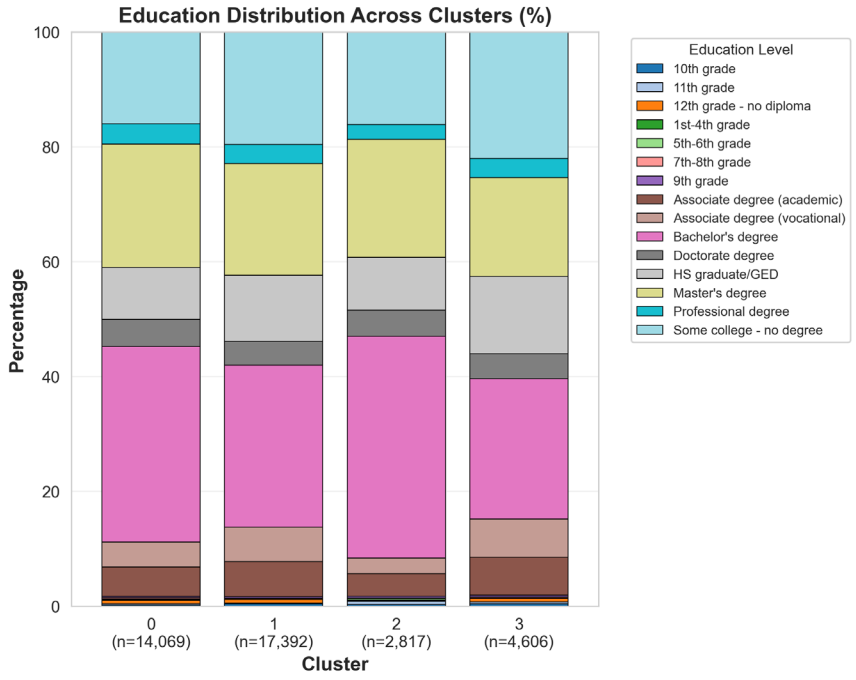


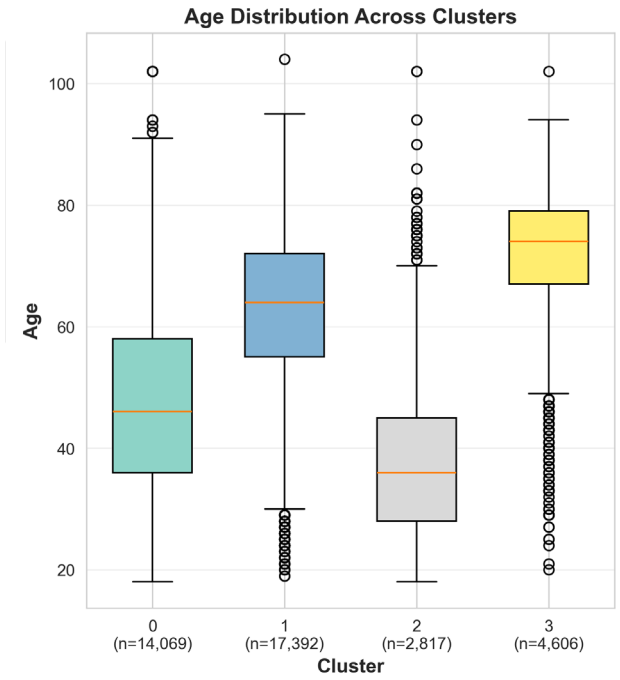
- Feature extraction with ResNet
- Images processed with:
  - Pretrained ResNet model
  - Mouse-specific fine-tuned ResNet
- Output: embeddings (numeric summaries of behavior)

Data analysis

- Mouse-specific ResNet model & K means clustering (k=3, 4, 5, 7)
- Identifying distributions of
  - Demographics (gender, education, age)

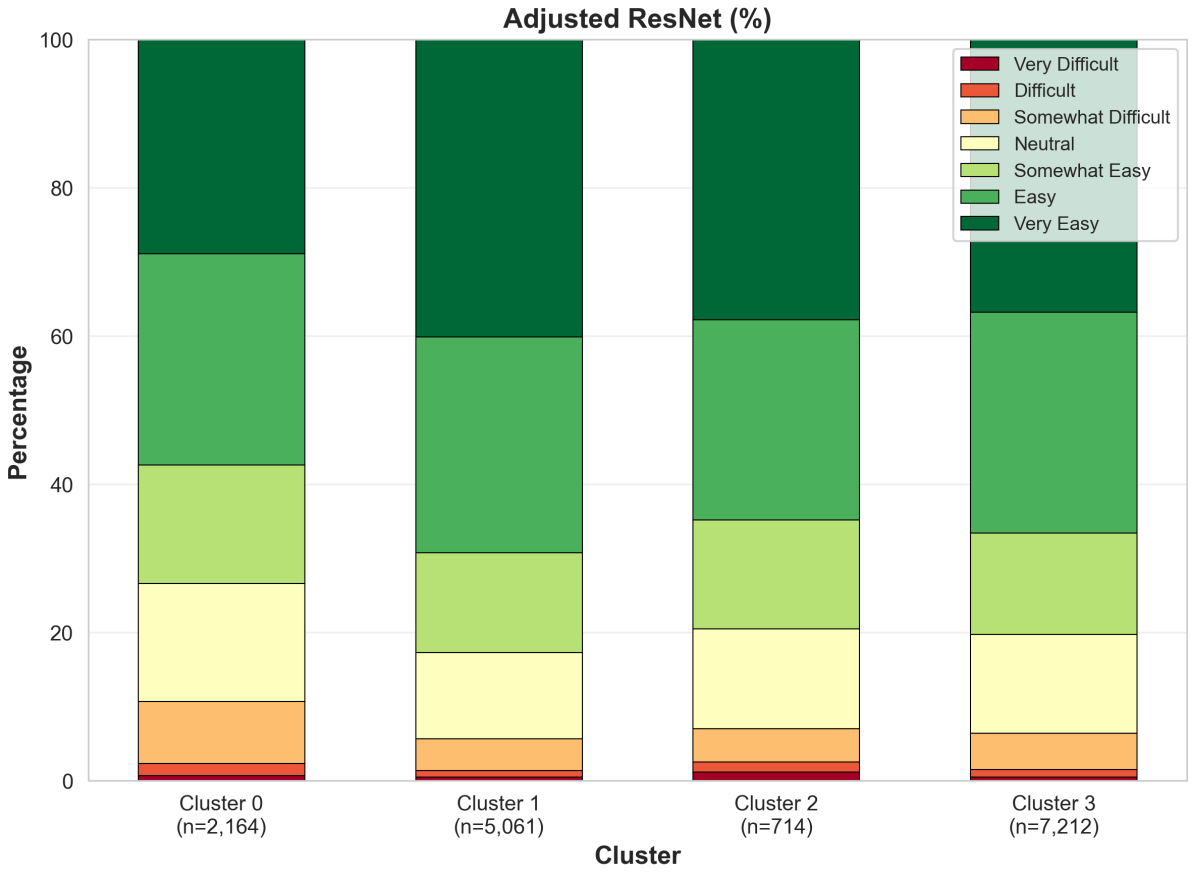






Data analysis

- Mouse-specific ResNet model
- K means clustering (k=3, 4, 5, 7)
- Identifying distributions of
  - Demographics (gender, education, age)
  - Self-assessed question difficulty

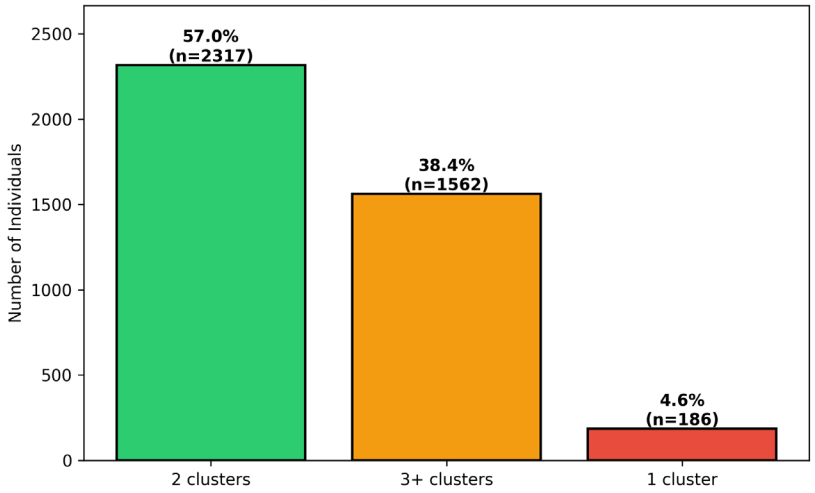


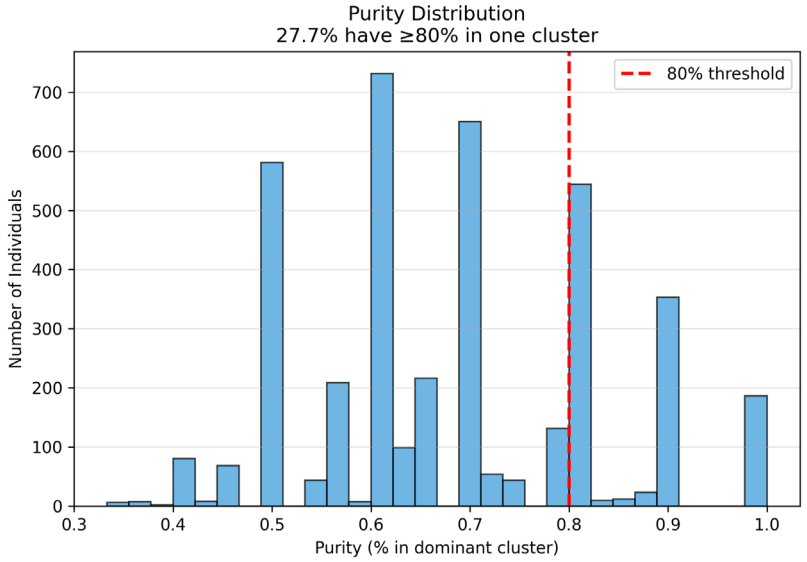
Data analysis

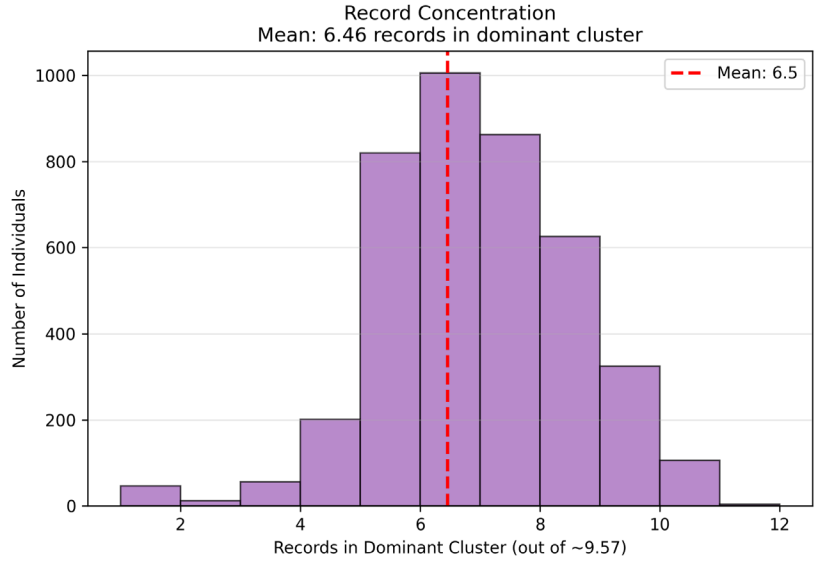
- Mouse-specific ResNet model
- K means clustering (k=3, 4, 5, 7)
- Identifying distributions of
  - Demographics (gender, education, age)
  - Self-assessed question difficulty
  - Individual respondents

K=4: Individual clustering patterns

- ~10 questions per respondent







67.8% purity → 106x random

→ people are somewhat consistent but definitely not locked into one cluster

Next steps

- Expand analysis to full data set → individuality over time
- Assess how representation choices (e.g. embeddings) influence clustering outcomes

- Survey bots in the literature rarely generate *realistic* mouse trajectories
  - Collecting larger behavioral datasets makes automated imitation harder
  - Develop predictive models to detect bots or anomalous behavior

→ If anyone is interested in collecting mouse movements in their surveys, experiments & panels, please reach out!

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mouseprep Package

mousetrap Package

Thank you!

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References

- **Westwood, S. J. (2025).** The potential existential threat of large language models to online survey research. *Proceedings of the National Academy of Sciences, 122*(47), e2518075122. https://doi.org/10.1073/pnas.2518075122
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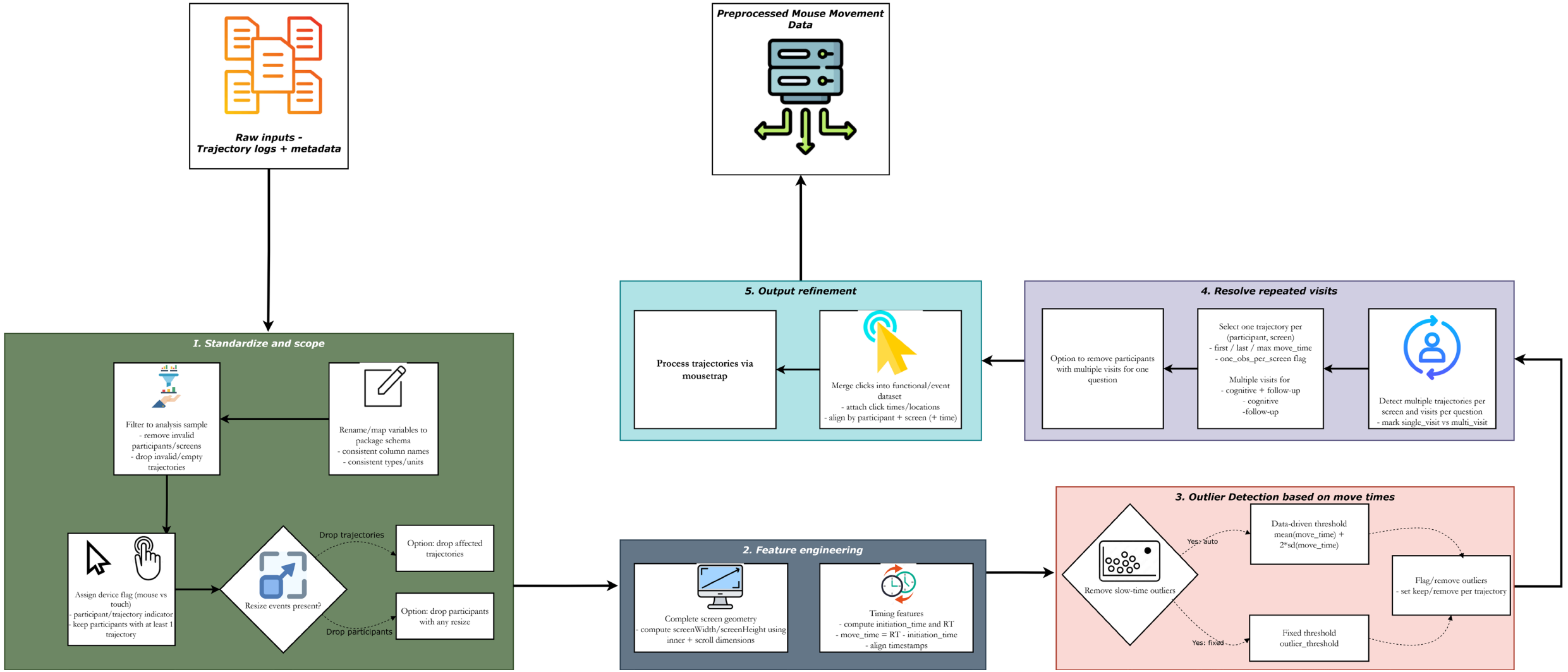
- **Leipold, F. M., Kieslich, P. J., Henninger, F., Fernández-Fontelo, A., Greven, S., & Kreuter, F. (2025).** Detecting respondent burden in online surveys: How different sources of question difficulty influence cursor movements. *Social Science Computer Review, 43*(1), 191–213. https://doi.org/10.1177/08944393241247425

MousePrep


Raw inputs -
Trajectory logs + metadata
Preprocessed Mouse Movement Data
I. Standardize and scope
Filter to analysis sample
- remove invalid participants/screens
- drop invalid/empty trajectories
Rename/map variables to package schema
- consistent column names
- consistent types/units
Assign device flag (mouse vs touch)
- participant/trajectory indicator
- keep participants with at least 1 trajectory
Resize events present?
Drop trajectories
Option: drop affected trajectories
Drop participants
Option: drop participants with any resize
2. Feature engineering
Complete screen geometry
- compute screenWidth/screenHeight using inner + scroll dimensions
Timing features
- compute initiation_time and RT
- move_time = RT - initiation_time
- align timestamps
3. Outlier Detection based on move times
Remove slow-time outliers
Yes: auto
Data-driven threshold
mean(move_time) + 2*sd(move_time)
Yes: fixed
Fixed threshold
outlier_threshold
Flag/remove outliers
- set keep/remove per trajectory
4. Resolve repeated visits
Detect multiple trajectories per screen and visits per question
- mark single_visit vs multi_visit
Select one trajectory per (participant, screen)
- first / last / max move_time
- one_obs_per_screen flag
Multiple visits for
- cognitive + follow-up
- cognitive
-follow-up
Option to remove participants with multiple visits for one question
5. Output refinement
Merge clicks into functional/event dataset
- attach click times/locations
- align by participant + screen (+ time)
Process trajectories via mousetrap