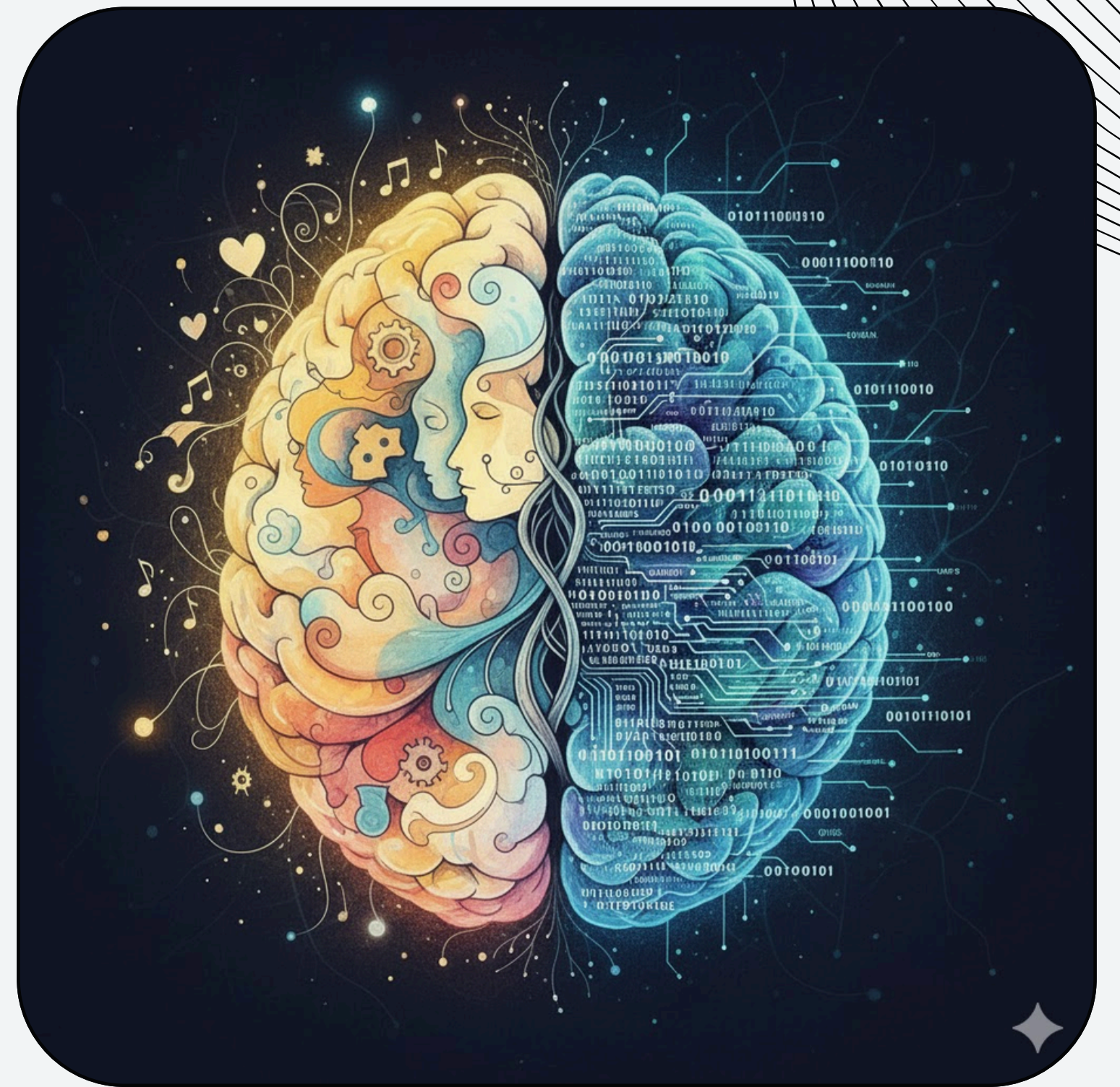


Foundation for a Customer Data Platform (CDP) with Cognitive Ergonomics Evaluation via Pupillometry



Course: Human Technology Interaction

DS4101 | Monsoon 2025

Instructor: Dr. Siddharth

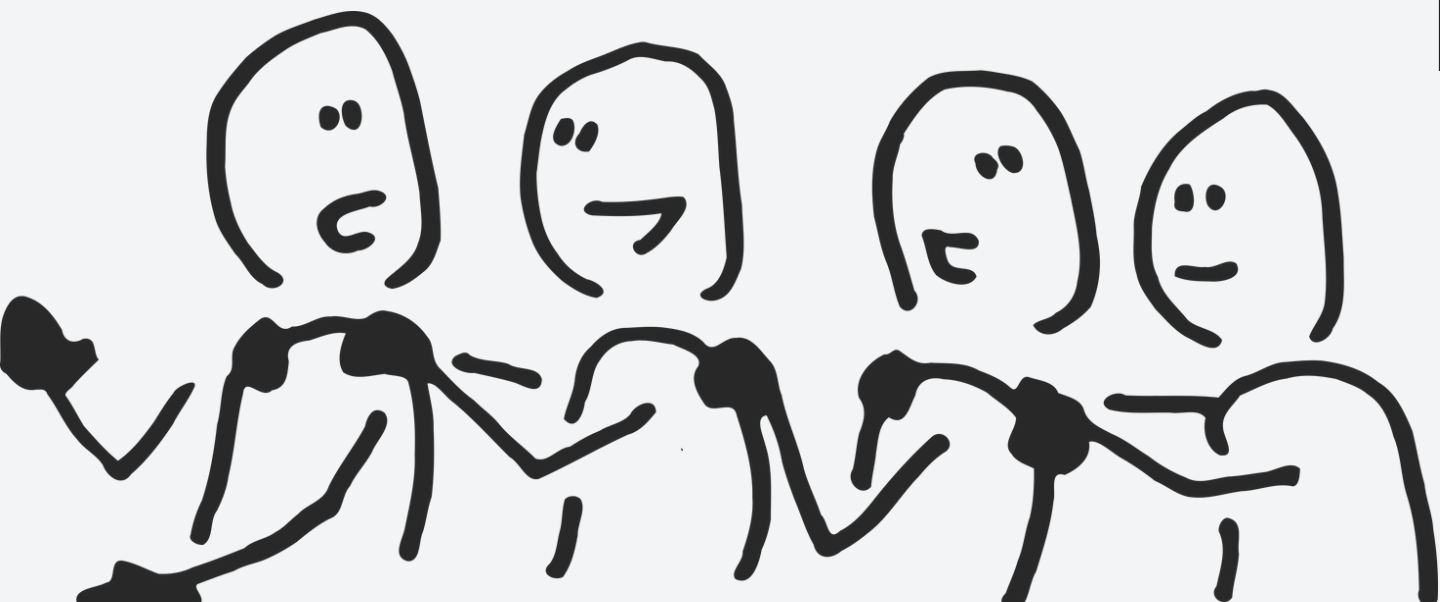
Team Members:

Anirudh Chauhan

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Manan Chawla

Vijeta





Problem Statement

At Altrus Health Care, teams across marketing, sales, and leadership work with data spread across multiple systems – CRM, HIMS, analytics, and campaign tools.

Since these systems operate independently, users often spend time switching between platforms and reconciling data manually.

This fragmented setup makes it harder to get a complete view of patient engagement and slows down data-driven decision-making.

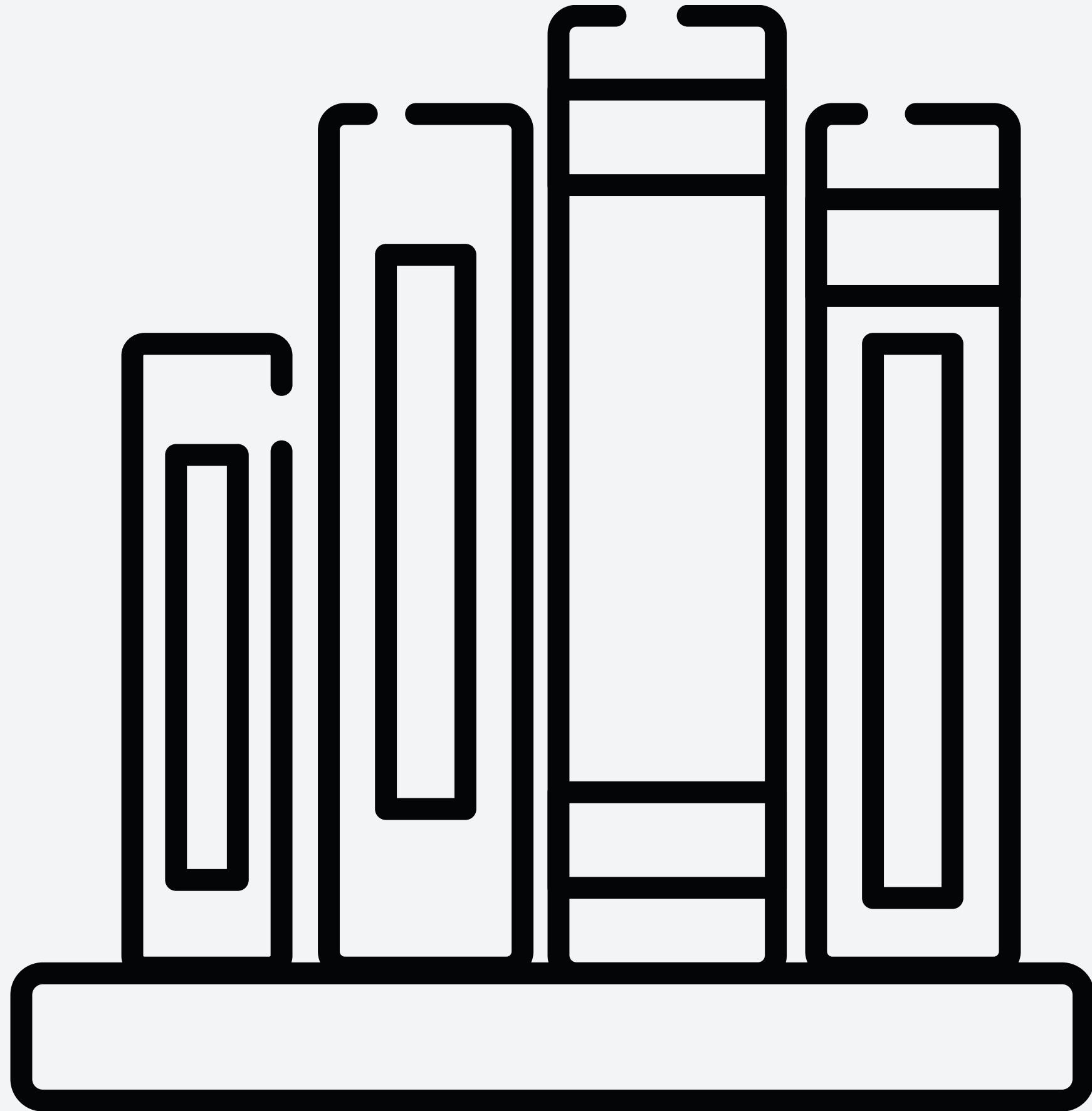
Establishing a unified, well-designed Customer Data Platform (CDP) can streamline this process and create a clearer foundation for insights and action.



Objective

Our project builds the foundation of a Customer Data Platform (CDP) that brings every insight together, so Altrus teams can think less about data and more about people. The aim of the project is as follows:

- Design a unified CDP interface using HTI principles **to reduce cognitive load on the primary users: Marketing team, Sales, and Leadership.**
- Validate cognitive efficiency using pupil dilation and other physiological markers.



Literature Survey

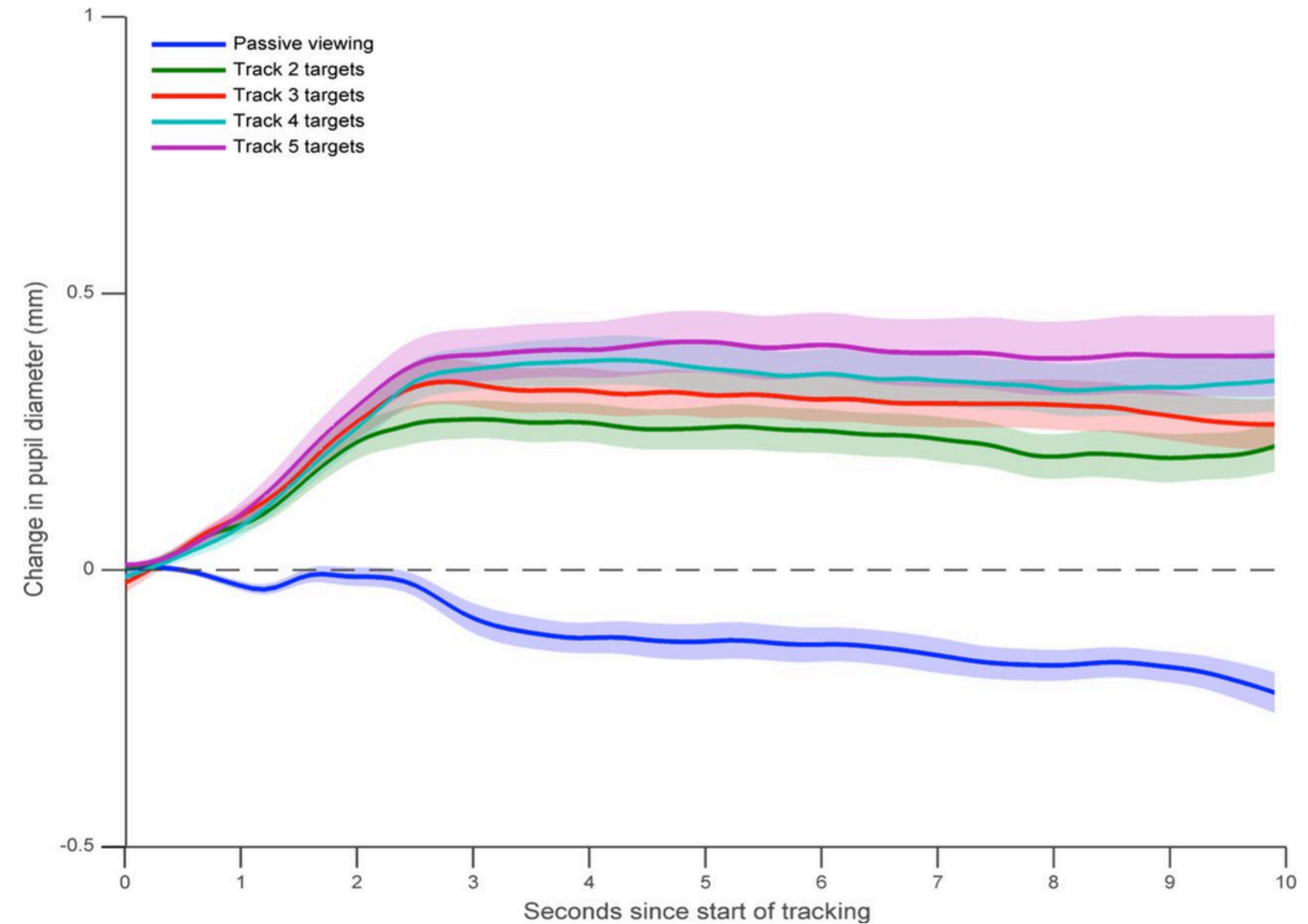
Cognitive Ergonomics in Interface Development Evaluation

Cognitive Ergonomists perform a cognitive analysis of interaction to: (1) shorten the time to accomplish interaction tasks; (2) reduce the number of mistakes made by humans; (3) reduce learning time; and (4) improve people's satisfaction with a system. An appropriate methodology for performing this cognitive analysis of

Measurement Category	Specific Techniques	Indication of High Cognitive Load
Eye Activity	Eye-Tracking (Fixation, Pupil Dilation)	Intense attention and processing difficulty.
Neuroimaging	Electroencephalography (EEG), Functional Near-Infrared Spectroscopy (fNIRS)	Brain activity patterns in areas governing attention/memory.
Cardiovascular	Heart Rate Variability (HRV)	Mental stress and workload (reduced HRV \rightarrow high load).
Skin Activity	Electrodermal Activity (EDA) / Galvanic Skin Response (GSR)	Emotional arousal linked to mental load.
Movement	Mouse Dynamics	Cognitive uncertainty and planning (less smooth movement).

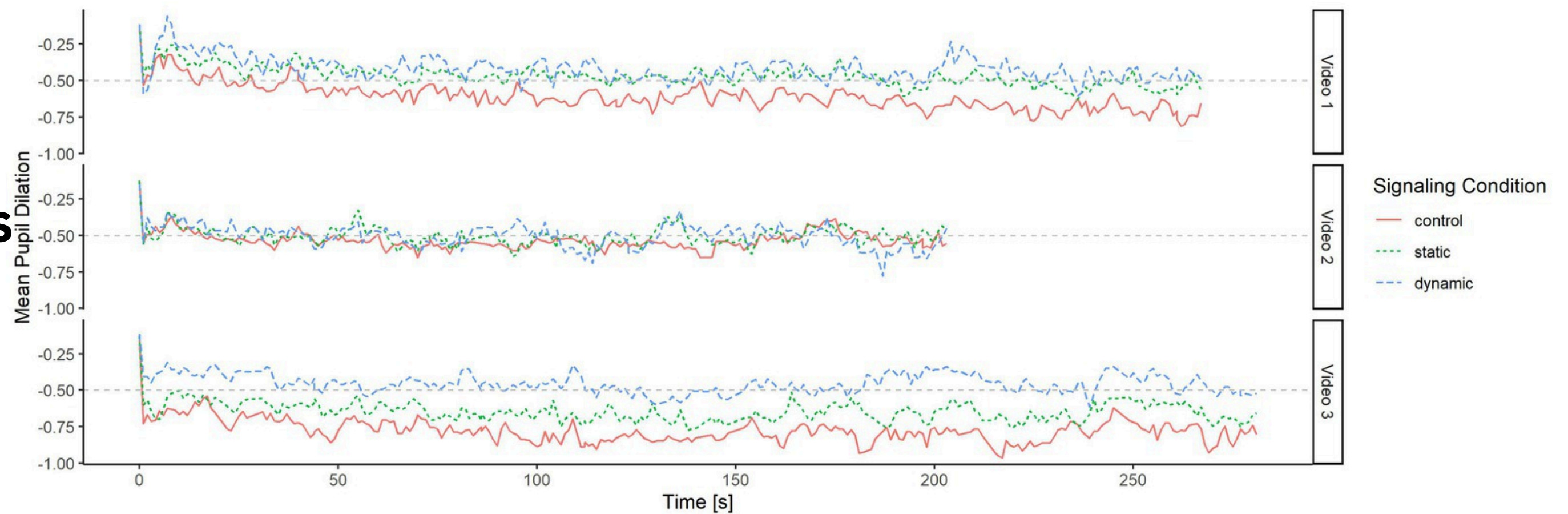
Pupillometry tracks cognitive load and salience network activity in working memory

The pupil diameter increased with the number of objects to be tracked, indicating an increase in mental effort, or allocation of attentional resources, as task demands increased.



Dynamic signaling (animated highlights, guided cues) in instructional videos increased pupil dilation compared to static or no signals. Importantly, self-reported extraneous cognitive load (effort spent overcoming poor design or unclear navigation) dropped under dynamic signaling, while productive cognitive engagement increased.

Pupil dilation as a cognitive load measure in instructional videos on complex chemical representations






Design Strategy Based on HTI Principles



These are few steps to improve visual perception in UX design:

- Using visual clues
- Using direction arrows
- Appropriate spacing and use of whitespace
- Highlighting and boundary outlining
- Eliminating visual distractions
- Dividing the visual task in smaller subtasks

el.com/your-perspective-
-your-perceptions
hgate.net/figure/7-The-two-
sion-note-that-you-can-shift-
fig11_328392085



Task Decomposition

Break complex clinical workflows into clear, sequential steps to reduce cognitive overload.

Consistency & Continuity

Ensure uniform placement, motion, and interaction feedback across the interface to minimize memory load.

Visual Hierarchy

Emphasize critical clinical data through contrast and clear spatial grouping.

Controlled Color Usage

Use low-arousal, neutral tones to create a calm cognitive environment. Reserve high-contrast accent colors strictly for warnings or alerts.



Experiment Design



Hypotheses

H₁ (Primary):

- Marketing, sales, and leadership users will exhibit significantly **lower mean pupil dilation, indicating reduced cognitive load** when using the low-complexity, HTI-optimized CDP interface compared to the existing system during core business tasks.

H₂ (Secondary):

- The optimized interface will **yield faster task completion**, fewer navigation errors, and lower subjective workload scores than the existing CDP system.

Goal: To evaluate whether the Unified CDP (Dashboard 1) provides a better Human–Technology Interaction (HTI) experience than the Existing two dashboard setup (Dashboard 2).

Evaluation Dimensions:

- **Cognitive Load** (Objective: Pupil Dilation, Subjective: TLX).
- **Visual Effort / Eye Strain (Objective:** Number of Fixations).
- **Task Performance & Efficiency** (Objective: Task Duration).
- **Usability & Preference** (Subjective: TLX).

Hypothesis: The Unified CDP (Dashboard 1) will demonstrate significantly lower cognitive load, reduced visual effort, and improved task efficiency compared to the Existing System (Dashboard 2).

Metrics Measured

Pupil dilation (change in pupil diameter from baseline) is a validated physiological indicator of cognitive effort and mental workload.

Fixation durations reflect attention allocation and mental strain during task performance .

Task-performance metrics such as **task completion time and efficiency** are widely used behavioral correlates of cognitive load in usability studies .

Subjective workload and usability scores, measured via **NASA-TLX** is commonly used to triangulate objective physiological indicators with perceived cognitive load .

van der Wel, P., & van Steenbergen, H. (2018). Pupil dilation as an index of effort in cognitive control tasks: A review. *Psychonomic bulletin & review*, 25(6), 2005–2015. <https://doi.org/10.3758/s13423-018-1432-y>

Ortega, J., Plaska, C. R., Gomes, B. A., & Ellmore, T. M. (2022). Spontaneous Eye Blink Rate During the Working Memory Delay Period Predicts Task Accuracy. *Frontiers in psychology*, 13, 788231. <https://doi.org/10.3389/fpsyg.2022.788231>

Mirabdolah, A., Alaeifard, M., & Marandi, A. (2023). User-centered design in HCI: Enhancing usability and interaction in complex systems. *International Journal of Advanced Human Computer Interaction*, 1(1), 16-33. [van der Wel, P., & van Steenbergen, H. \(2018\). Pupil dilation as an index of effort in cognitive control tasks: A review. *Psychonomic bulletin & review*, 25\(6\), 2005–2015. <https://doi.org/10.3758/s13423-018-1432-y>](https://doi.org/10.3758/s13423-018-1432-y)

Casner, S. M., & Gore, B. F. (2010). Measuring and evaluating workload: A primer (NASA/TM–2010-216395). NASA Ames Research Center. [van der Wel, P., & van Steenbergen, H. \(2018\). Pupil dilation as an index of effort in cognitive control tasks: A review. *Psychonomic bulletin & review*, 25\(6\), 2005–2015. <https://doi.org/10.3758/s13423-018-1432-y>](https://doi.org/10.3758/s13423-018-1432-y)

Data Collection

Participants:



Total Subjects: 9



Gender: 6 Males, 3 Females



Age Group: 19–22 years

The Two Conditions

Visualising the Intervention



Condition A: Dashboard 2 (The "Old Way")

Workflow: User accesses KareXpert (HIMS) → Switches tab → Accesses Salesforce → Mentally integrates data.

High Friction: Requires working memory to hold data from one screen while searching the other.



Condition B: Dashboard 1 (The Unified CDP)

Workflow: Single pane of glass. Data unified by backend logic.

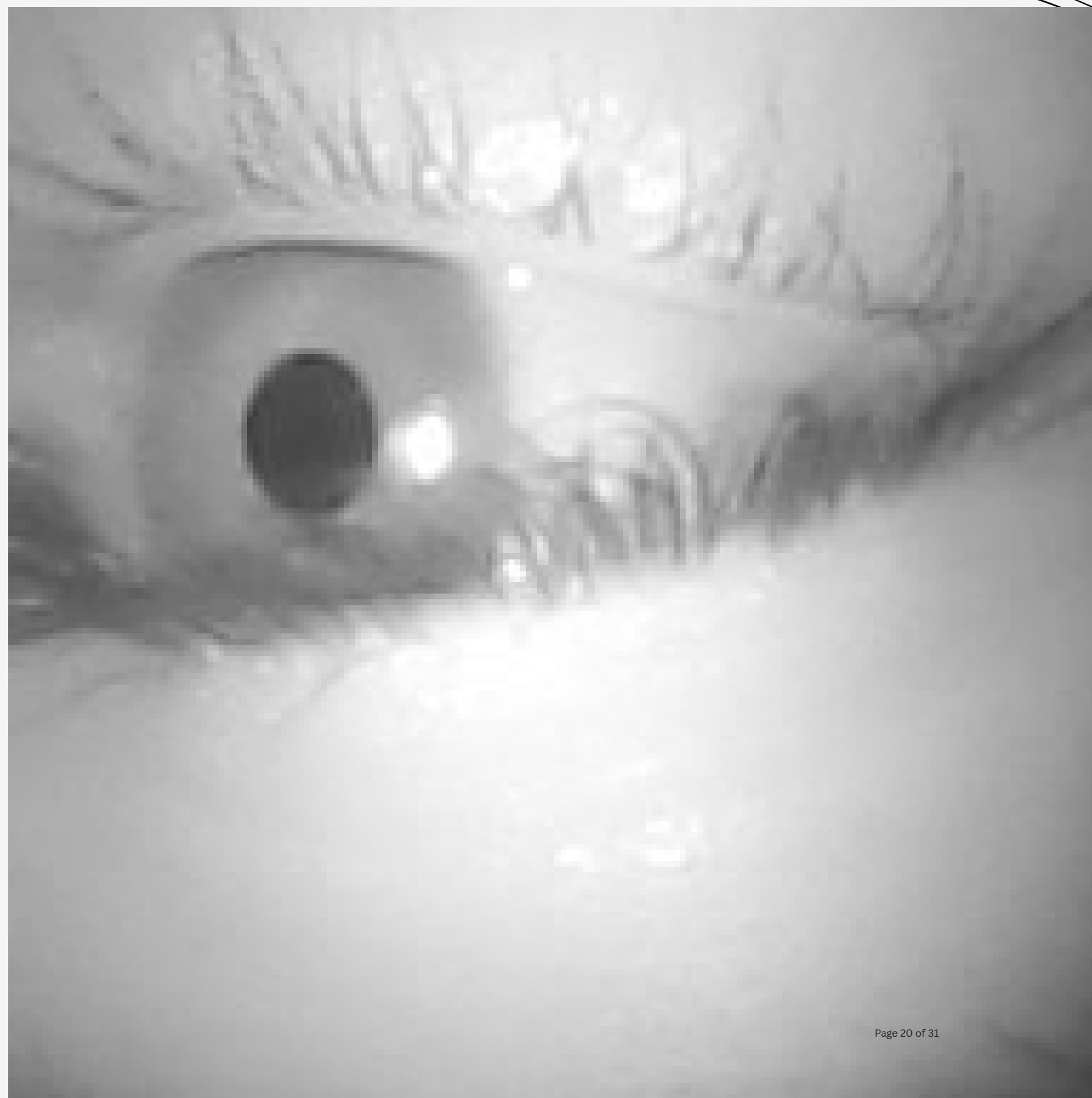
Design: Specific dashboards for **Leadership** and **Marketing** roles to show only relevant info.

Experiment procedure

- **Participant recruitment:** 9 users, consistent with eye-tracking usability studies.
- **Pre-experiment setup:** Obtain informed consent, calibrate eye-tracker, and establish baseline pupil size using a neutral grey screen.
- **Running Experiment:** Give pre-determined tasks to participants and collect data.

Experiment procedure

- **Task battery:** Participants perform total **6 (3 on dashboard 1 and 3 on dashboard 2)** realistic tasks per interface, with tasks randomized per participant.
- **Data collection:** continuous recording of pupil diameter, gaze, blinks, and task performance logs collected for exploratory analysis.
- **Post-task surveys:** Administered NASA-TLX scores for perceived difficulty and confidence (NASA Technical Reports Server, 2008).



Results

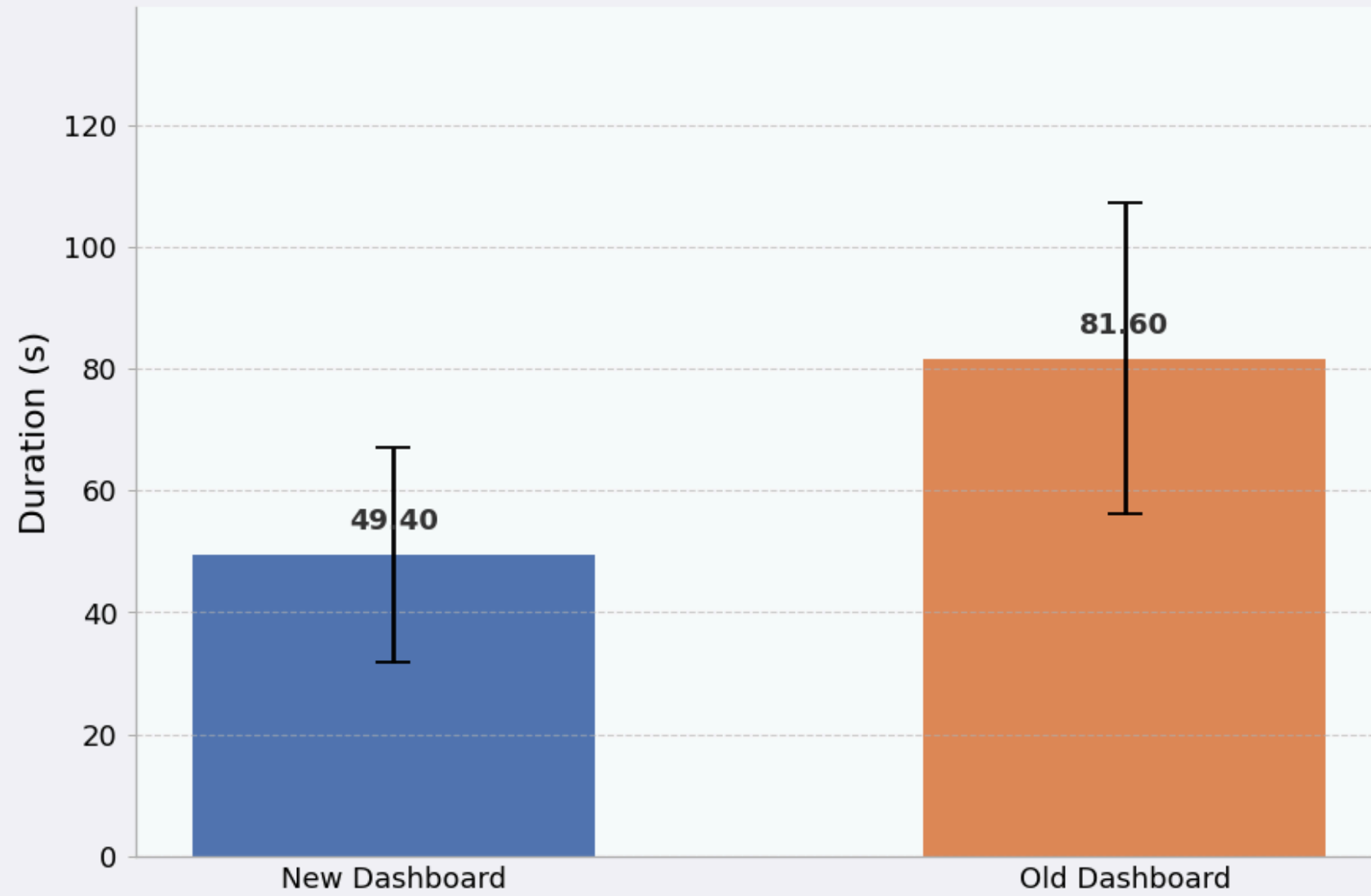
Subjective Cognitive Load (NASA-TLX): Dashboard 1 showed significant improvements across nearly all TLX factors:

- **TLX Mental Demand:** 59.09% improvement ($p = 0.0002$).
- **TLX Physical Demand:** 61.40% improvement ($p = 0.0010$).
- **TLX Effort:** 65.62% improvement ($p = 0.0002$).
- **TLX Frustration Level:** 69.23% improvement ($p = 0.0001$).
- **TLX Temporal Demand:** 55.00% improvement ($p = 0.0032$).

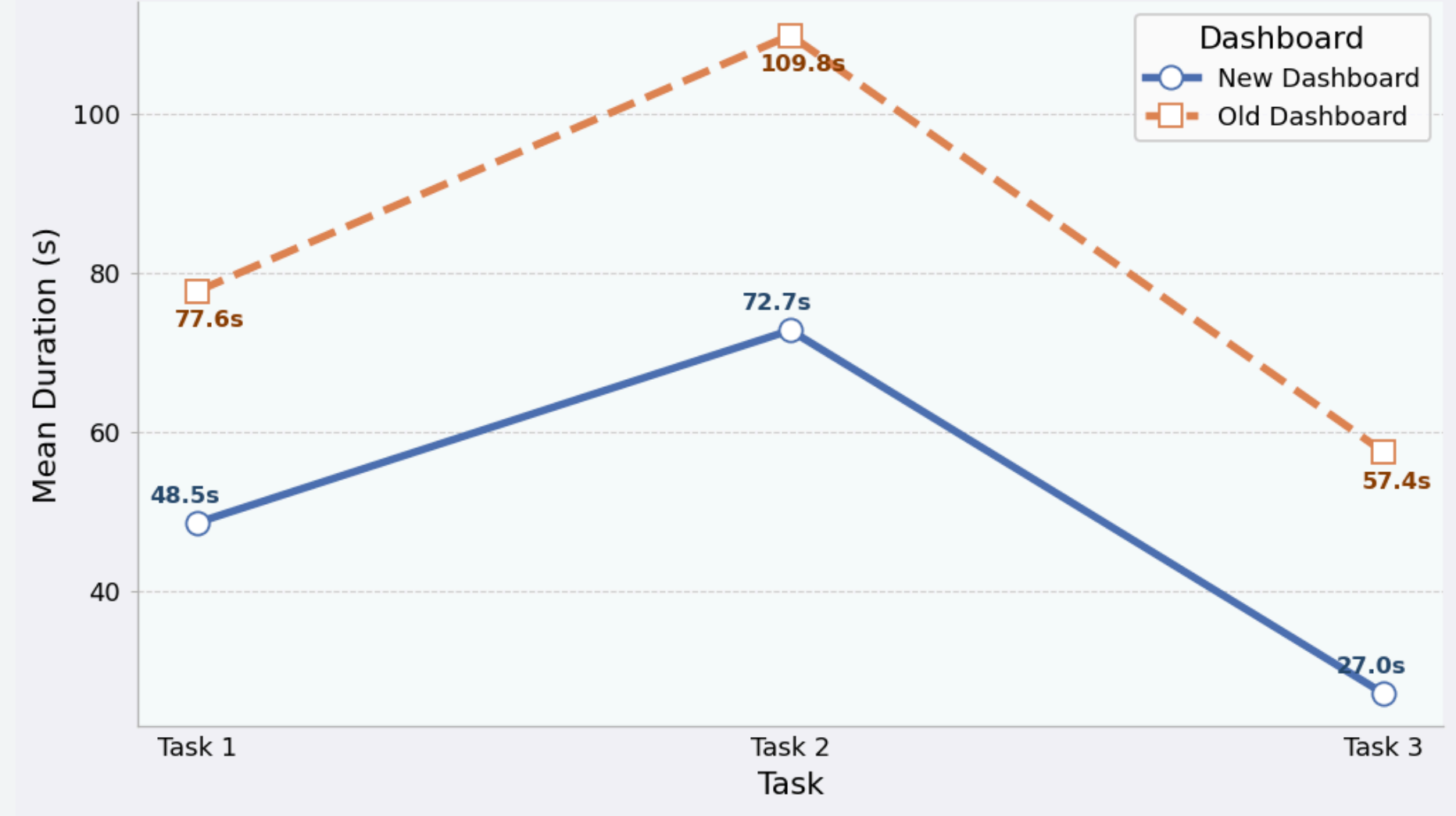
- **Key Finding:** The Unified CDP dramatically reduced the perceived mental workload and frustration of the participants.

Results

Comparison of Average Task Duration (Efficiency)

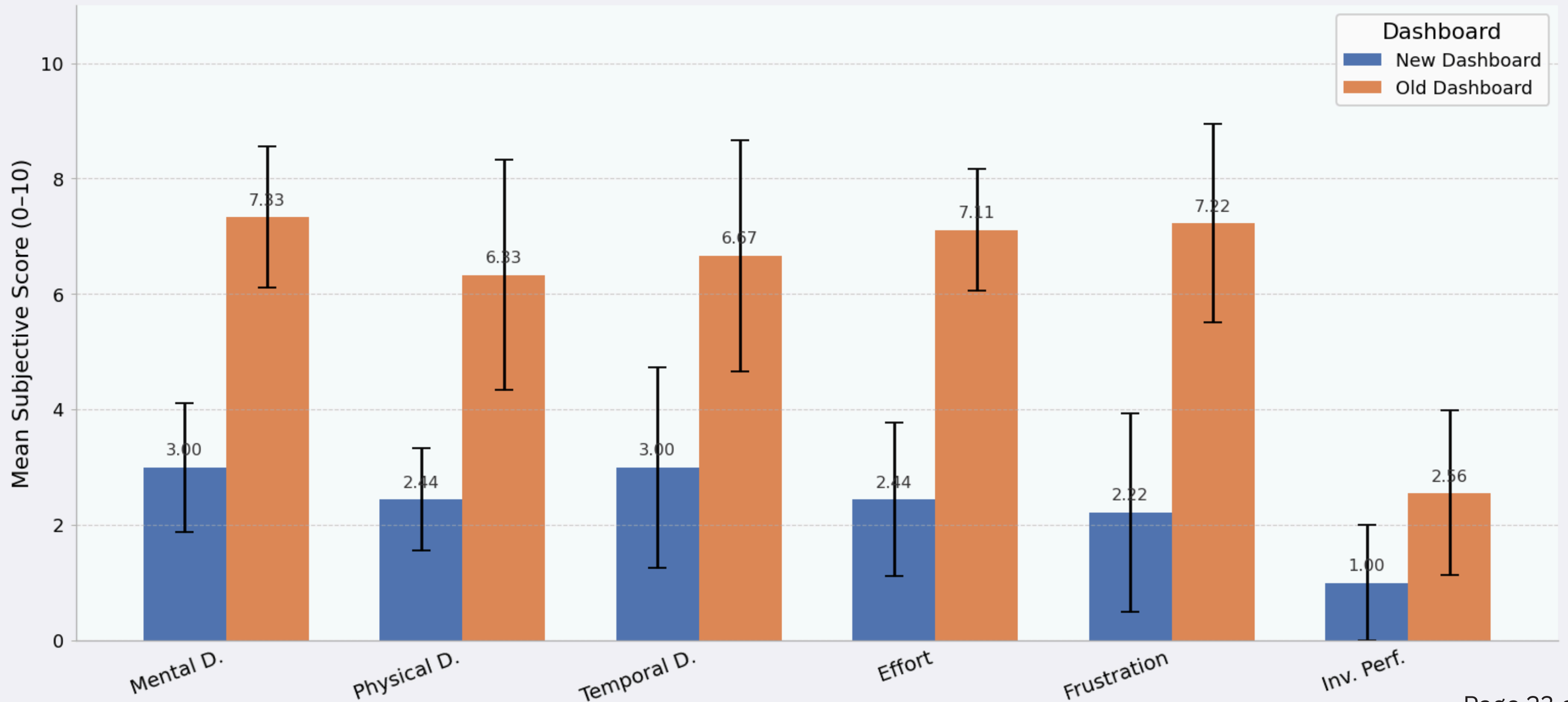


Task Completion Time Trend (New vs Old)



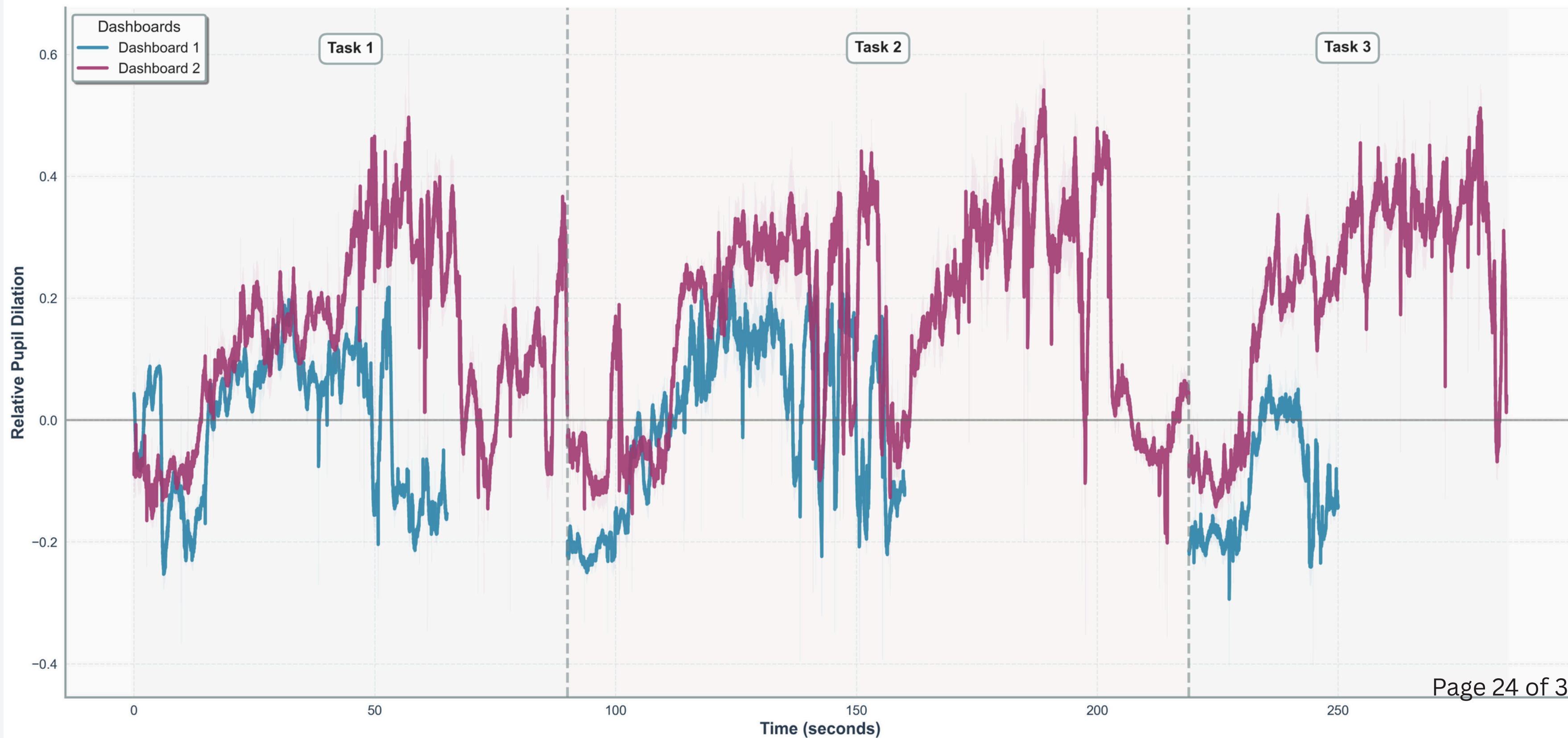
Results

NASA-TLX Dimensions: New vs Old Dashboard

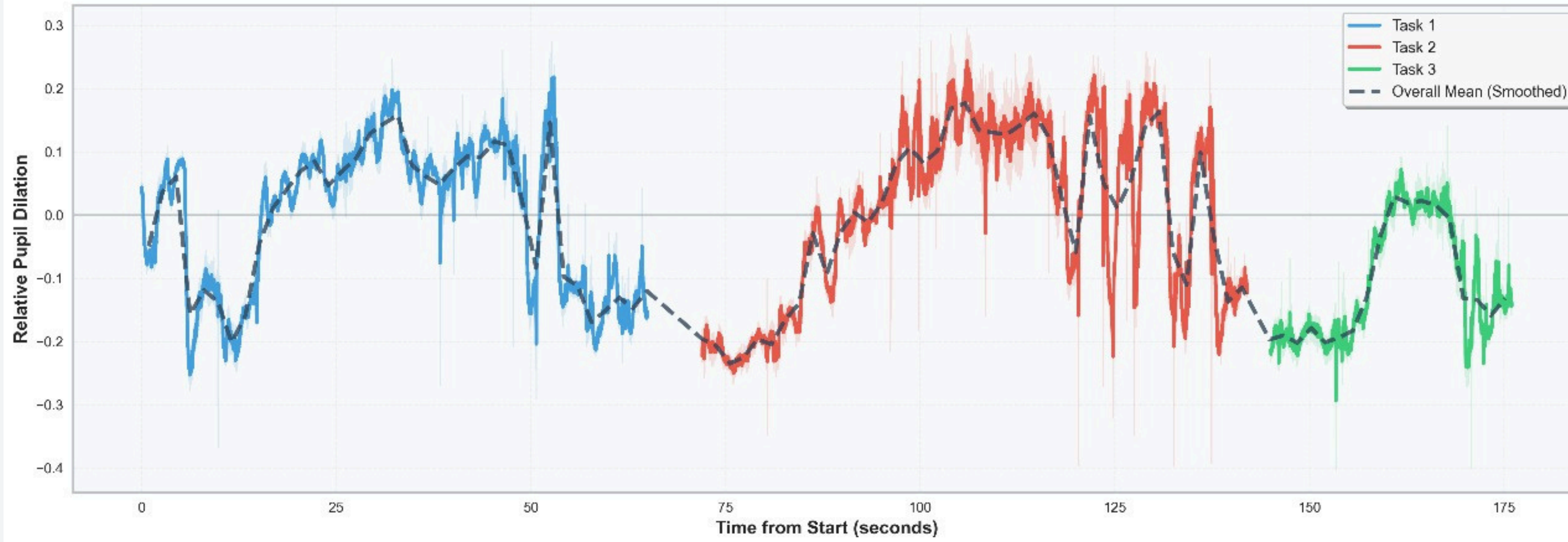


Results

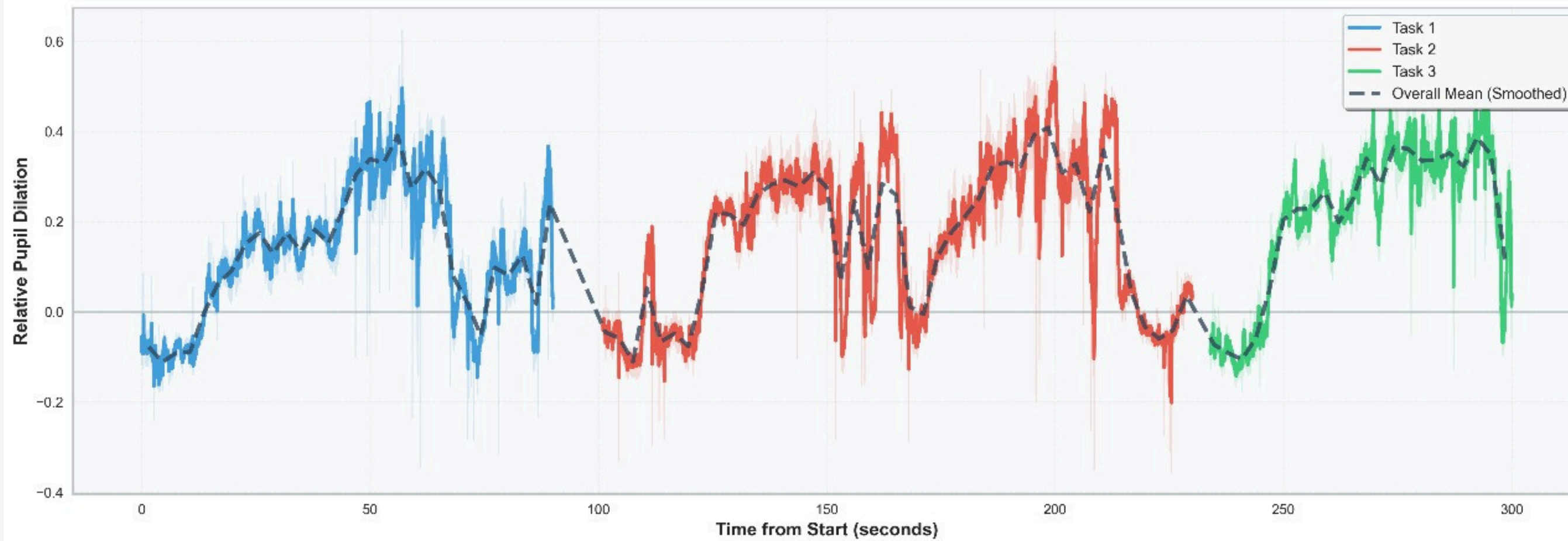
Complete Session: Dashboard Comparison - anirudh



anirudh - Dashboard 1 - Combined Task Timeline



anirudh - Dashboard 2 - Combined Task Timeline



Results



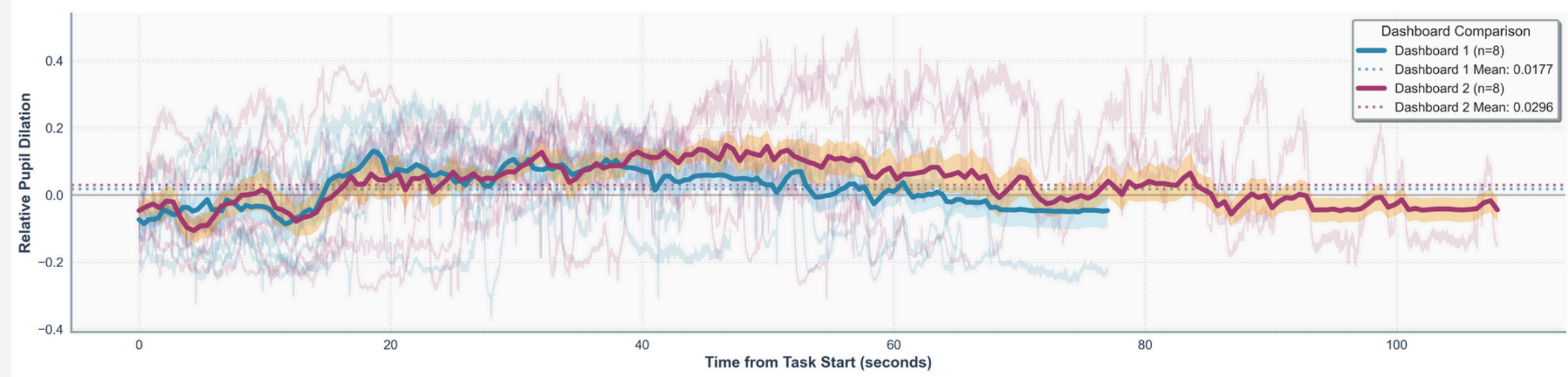
Results

Objective Cognitive Load (Pupil Dilation):

- Pupil Dilation for all three tasks was lower in **D1**, but these results were not statistically significant (p-values ranged from **0.2949 to 0.4902**).

Collective Cognitive Load Analysis - All Users

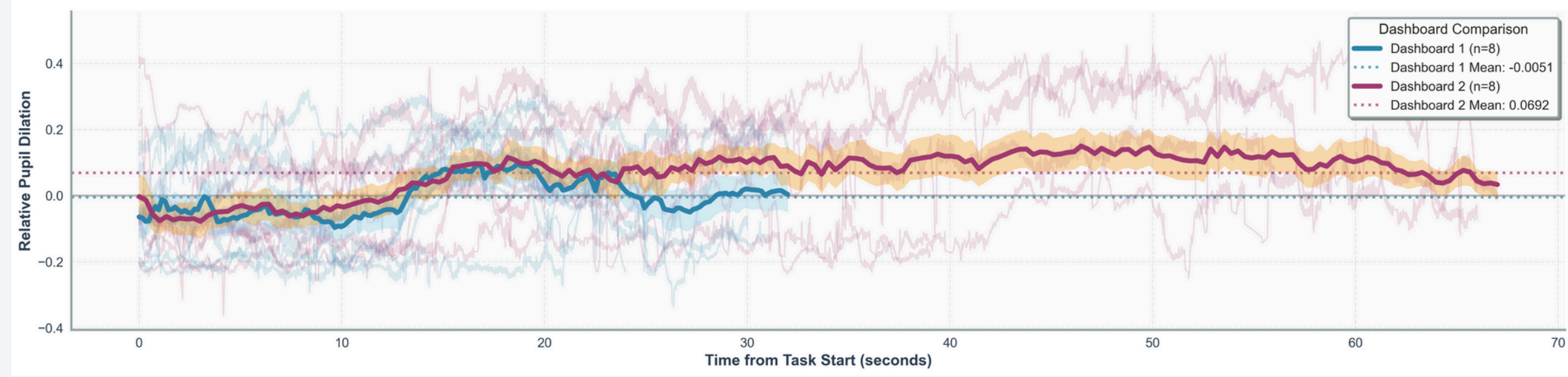
Task 1 - Collective Dashboard Comparison (All Users)



Task 2 - Collective Dashboard Comparison (All Users)



Task 3 - Collective Dashboard Comparison (All Users)

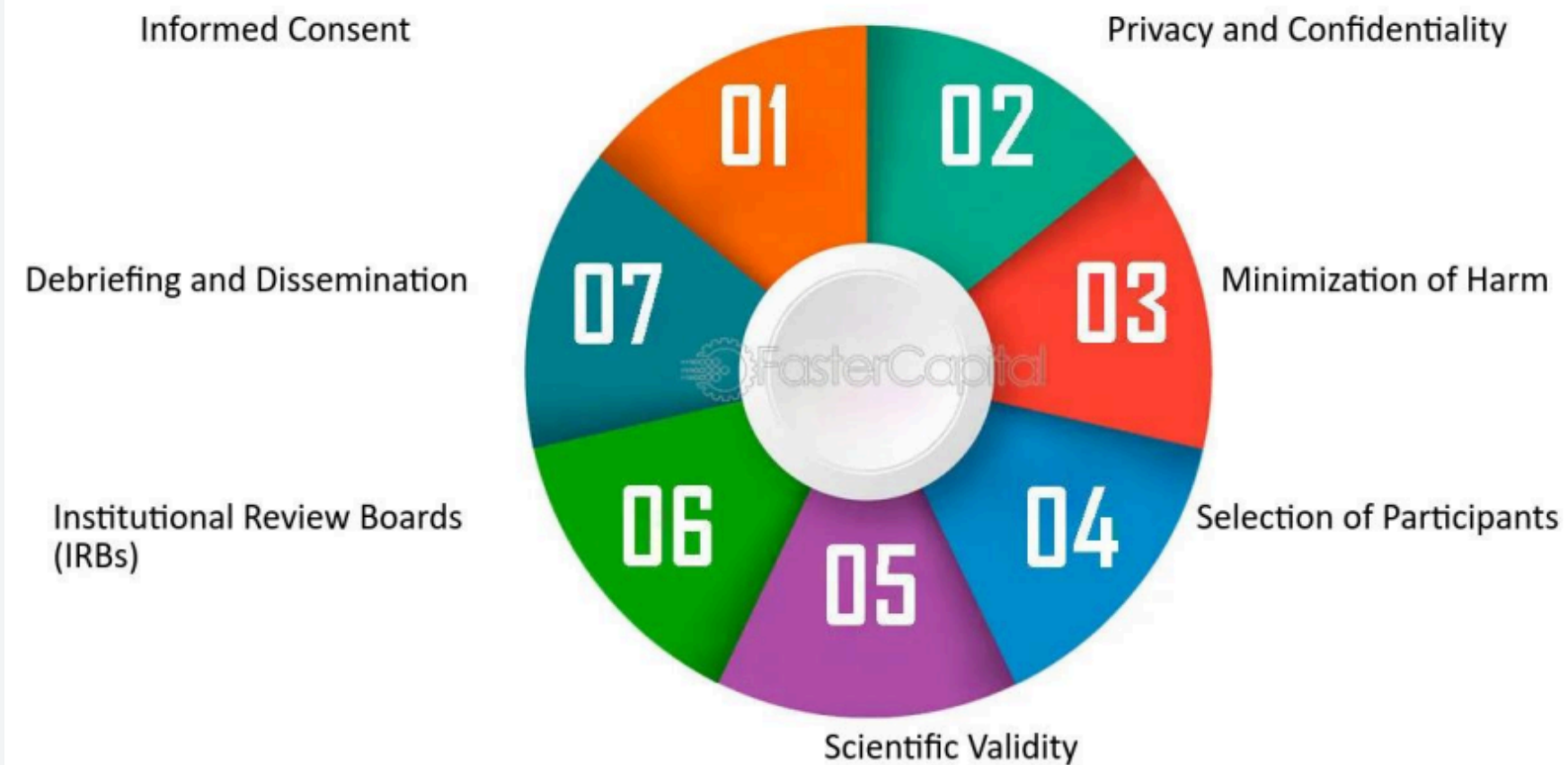


Potential Applications & Impact

- Standardized patient view for faster risk assessment and intervention prioritization.
- Reduction in decision fatigue through interface ergonomics.
- Establishes a data backbone for personalized care, predictive analytics, and clinical automation.
- Higher staff well-being.

Ethical Considerations

What are the ethical considerations when conducting experiments involving human subjects



Graphics Courtesy: <https://fastercapital.com/content/Ultimate-FAQ-Experiment--What--How-- Why--When.html>
Courtesy : Dr. Siddharth, HTI Course

Deployability & Challenges

Real-World Implementation

Feasibility

The solution is deployed as a web-based layer over existing APIs (Salesforce/HIMS), making it scalable without replacing core backend systems.

Scalability

- **Immediate:** Altrus HealthCare marketing/leadership teams.
- **Future:** Triage nurses and patient support desks.

Challenges

- **Data Privacy:** Aggregating data requires strict HIPAA/GDPR compliance.
- **Data Quality:** The "Unification" relies on accurate UHID/Phone matching; dirty data in HIMS will break the CDP view.



Conclusion & Impact

The "So What?"



Quantifiable Impact

- **50% Reduction** in time-to-insight for marketing leads.
- **~60% Reduction** in staff cognitive load (Mental Demand).



Broader Implication

Moving healthcare from "System-Centred" (forcing humans to adapt to software) to "**Human-Centred**" (software adapting to cognitive limits).



Final Verdict

The Unified CDP validates that reducing screen toggling is not just a UI preference—it is a **physiological necessity** for efficient healthcare operations.

THANK YOU

