



MASTER THESIS - USER EXPERIENCE DESIGN

AI-Driven Context-Adaptive User Interfaces for in-car Infotainment Systems

Design, Prototypical Implementation and Evaluation

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Imagine.....🤔💭

- process **dynamic variables**
- figures out how **this specific combination** of variables **affects you** in **this specific moment**
- intelligently **adapts the GUI**



It's **Night** you're **Driving** at **Low fuel** in **Poor weather**

dim non-essential elements

boost contrast of important components

emphasize nearby open gas stations within range



Driving in an **unfamiliar city** in **heavy traffic** & **nervous**

simplifies map, suppresses non-critical info

enlarge navigation related text and icons

reduces animations



Examples of possible adaptations

Motivation



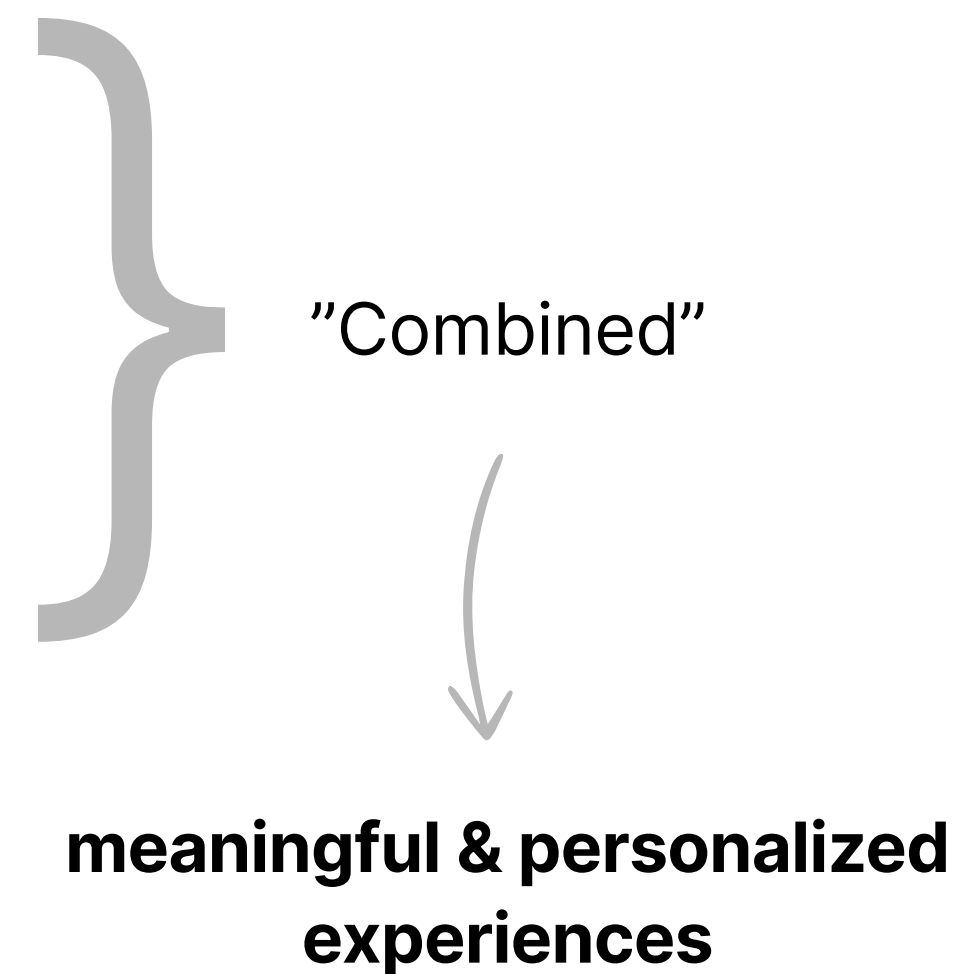
Contextual Variables [7]

Continuous & dynamic variables

speed, traffic, weather conditions, time of day, driving behavior, presence of pedestrians or nearby vehicles, planned maneuvers, etc.

Stable / slowly changing variables

media content preferences, interaction styles, calendar, frequently visited locations, long-term usage patterns, vehicle-specific info



Research Gaps

Current Research in infotainment adaptivity

1. Carried out with:

Mock-ups or Rule-based systems [2, 4, 6],
Traditional machine/deep learning techniques [1, 5]



Modern LLMs?

2. These Addresses:

What to Show.
When to Show.



Detailed adaptation?

3. We found:

Transformer-driven adaptivity algorithms with technical measurements [3]



UX?

Goal: Create something that..

Leverages modern LLMs
+
Scalable & Functional
+
Real-time

Controls
detailed
GUI adaptations

Measure its effect
on UX and Safety

Research Questions

and hypotheses.

AI-assembled: AI-Driven, context-adaptive GUI assembly

Pre-assembled: Pre-designed GUI screens (baseline)

How do AI-assembled and pre-assembled GUIs for in-car infotainment....

RQ 1

..differ in terms of **usability, clarity, & value?**

RQ 2

..affect perceived **cognitive load, distraction & situational awareness?**

RQ 3

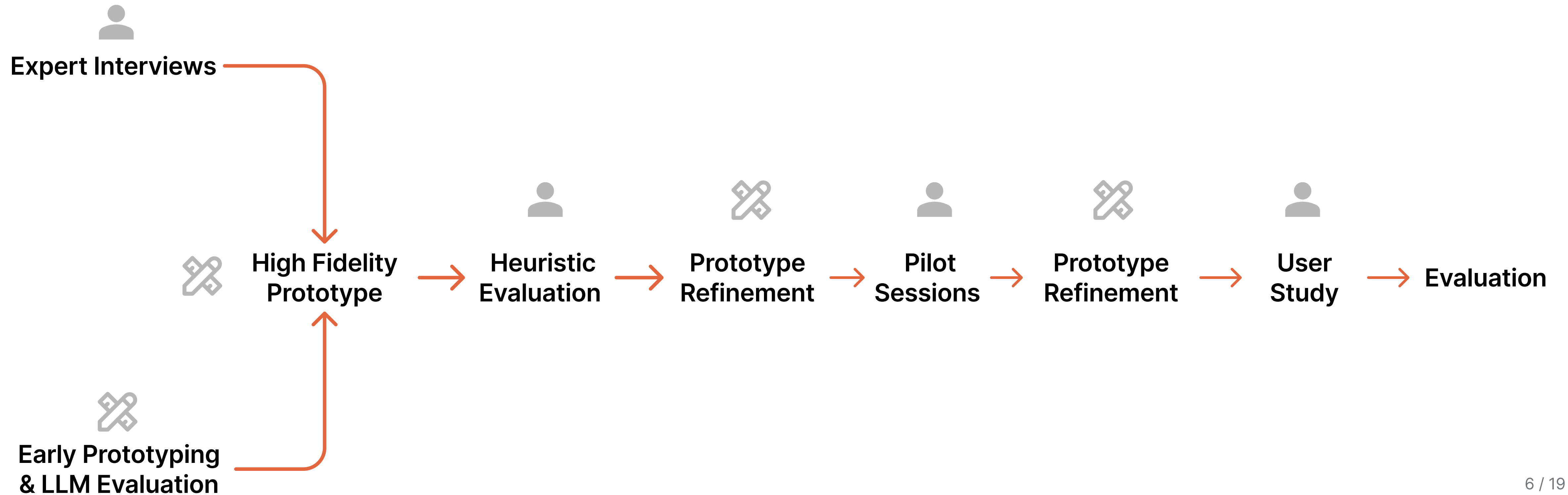
..affect **percieved adaptivity?**

H1: AI-assembled system performs as well as or better than the pre-assembled system.

H2: AI-assembled UI results in equal or lower cognitive load and distraction, and equal or higher situational awareness compared to pre-assembled UI

H3: AI-assembled UI provides significant improvement in perceived contextual adaptivity compared to a pre-assembled UI

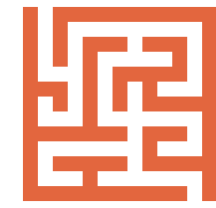
Human centered Research-Through-Design



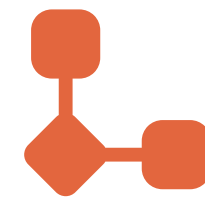
Core Formative Findings

Expert Interviews

- 7 Professionals
- Across 5 Departments
- Semi-Structured
- Thematic Clustering involving 2 researchers



Functions hidden under or split across different levels
→ Frustration / Confusion



Existing adaptive features based on deterministic, rule-based logic

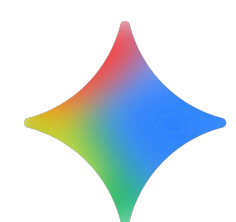
(adding more use-cases = manual work)



High Interest in the topic
Industry actively moving towards the vision of “use-case-less” design

Core Formative Findings

LLM Evaluation via Early Prototype



2.5-pro

Overall Winner

Ø 14s

(diff. reasoning tokens)



8 GUI components



Narrowly defined System Prompt



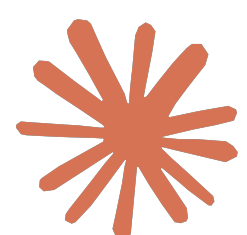
Initial user input

("Bored and Hungry")



Manual contextual trigger

("Accident ahead")



Opus-4

(diff. reasoning tokens)



GPT-5

Best Adaptivity

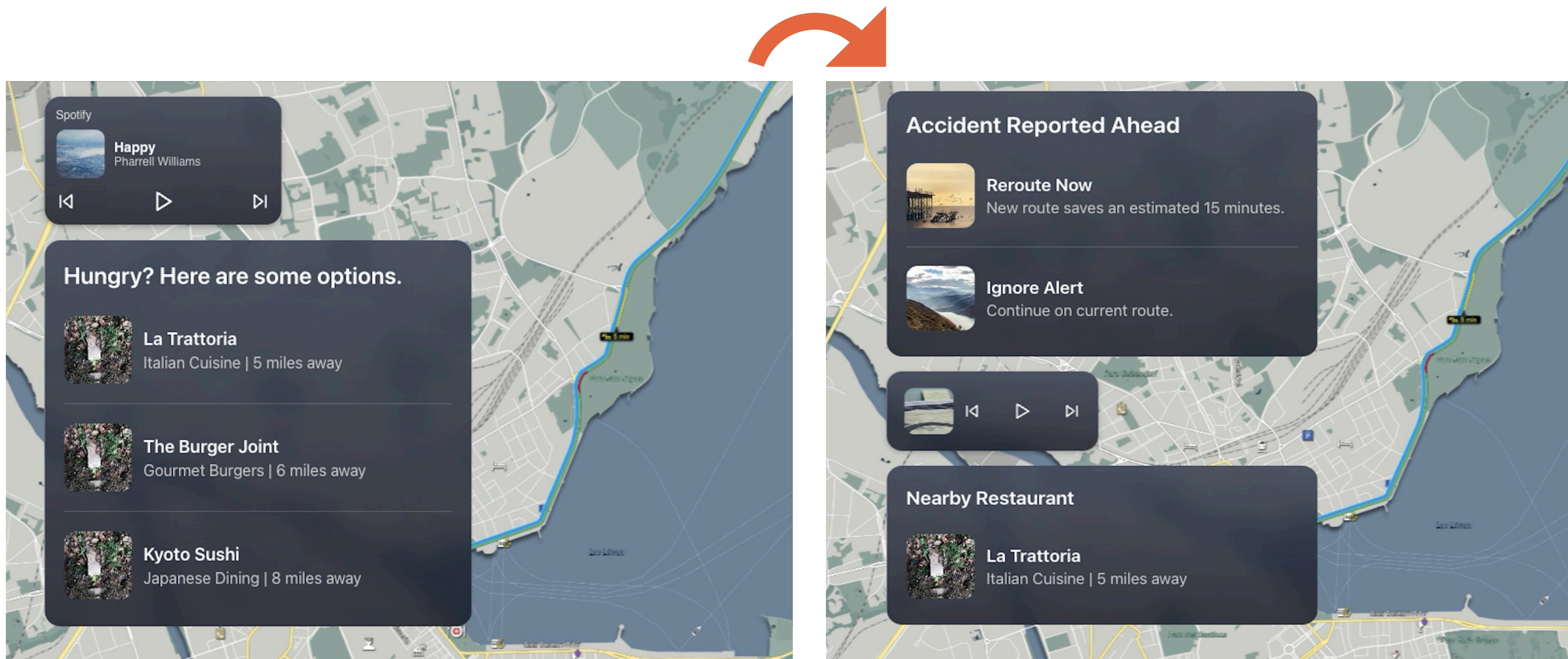
Ø > 60s

GPT-5 mini

(high, mid, low)

Core Formative Findings

LLM Evaluation via Early Prototype (GUI adaptation using Gemini 2.5 Pro)



The Final Recipe

Constrained AI-based Assembly Architecture



Atomic-level, Pre-designed GUI Component Library

This allows us to:

- preserves **Brand Identity**
- comply with **safety guidelines**

Contextual Data & User Input

interpretation

(JSON)

selection

LLM
(Python)

compliance

(JSON)

validation & rendering

Web Frontend
(React JS)

Dynamic context-aware output



System Prompt

Identity, Capabilities & Objective
Layout specifications
Safety Principles
Usability Heuristics
Driver Profile
Output Instructions (JSON)



Push to Talk Integration



Ability to choose between screen space



Final Component Library (Partially Based on MB Design System)

Atoms (Basic building blocks)

App Panel



8 Text Styles

Headline

Ag

Secondary

Ag

Ag

Ag

light
for monospaced numbers

light
continuous multiline text

demi

Tertiary

Ag

Ag

mb / MbSans / tertiary / single_line

Ag

Ag

demi
continuous text

light
continuous text

demi

light

15 Icons (+ Emojis)



Divider



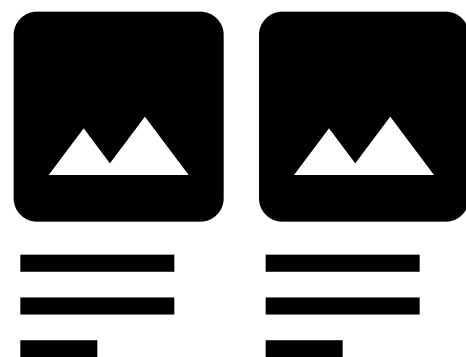
Image Skeleton



Layout Skeletons: Vertical / Horizontal

Organisms (Derived from Atoms)

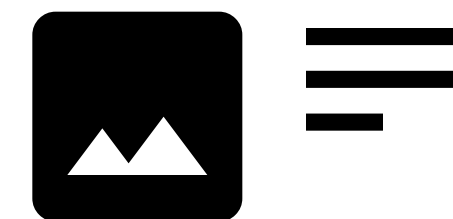
Horizontal List



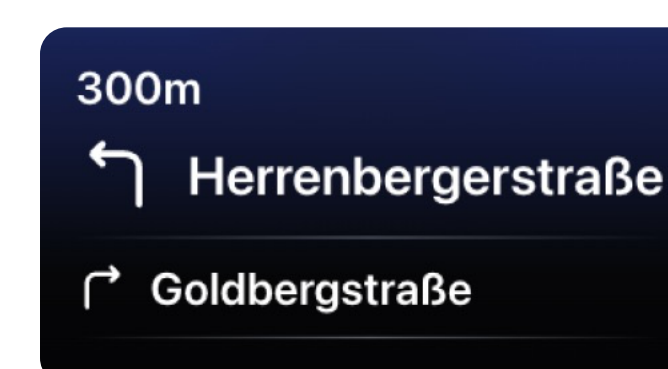
Listitem



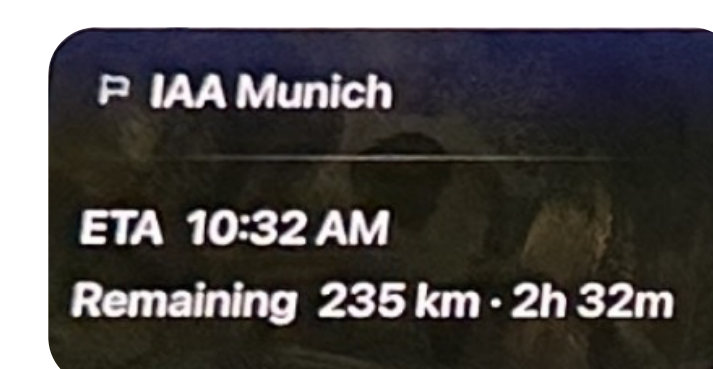
Listitem with Image



Navigation



Additional Navigation



Core Formative Findings

Usability Heuristic Evaluation Exercise

1 Visibility of System Status
The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.

- Does the design clearly communicate its state?
- Is feedback presented quickly after user actions?

2 Match Between System and the Real World
The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.

- Will user be familiar with the terminology used in the design?
- Do the design's controls follow real-world conventions?

3 User Control and Freedom
Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.

- Does the design allow users to go back a step in the process?
- Are exit links easily discoverable?
- Can users easily cancel an action?
- Is Undo and Redo supported?

4 Consistency and Standards
Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.

- Does the design follow industry conventions?
- Are visual treatments used consistently throughout the design?

5 Error Prevention
Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions, or check for them and present users with a confirmation option before they commit to the action.

- Does the design prevent slips by using helpful constraints?
- Does the design warn users before they perform risky actions?

6 Recognition Rather Than Recall
Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed.

- Does the design keep important information visible, so that users do not have to memorize it?
- Does the design offer help in-context?

7 Flexibility and Efficiency of Use
Shortcuts – hidden from novice users – may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- Does the design provide accelerators like keyboard shortcuts and touch gestures?
- Is content and functionality personalized or customized for individual users?

8 Aesthetic and Minimalist Design
Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.

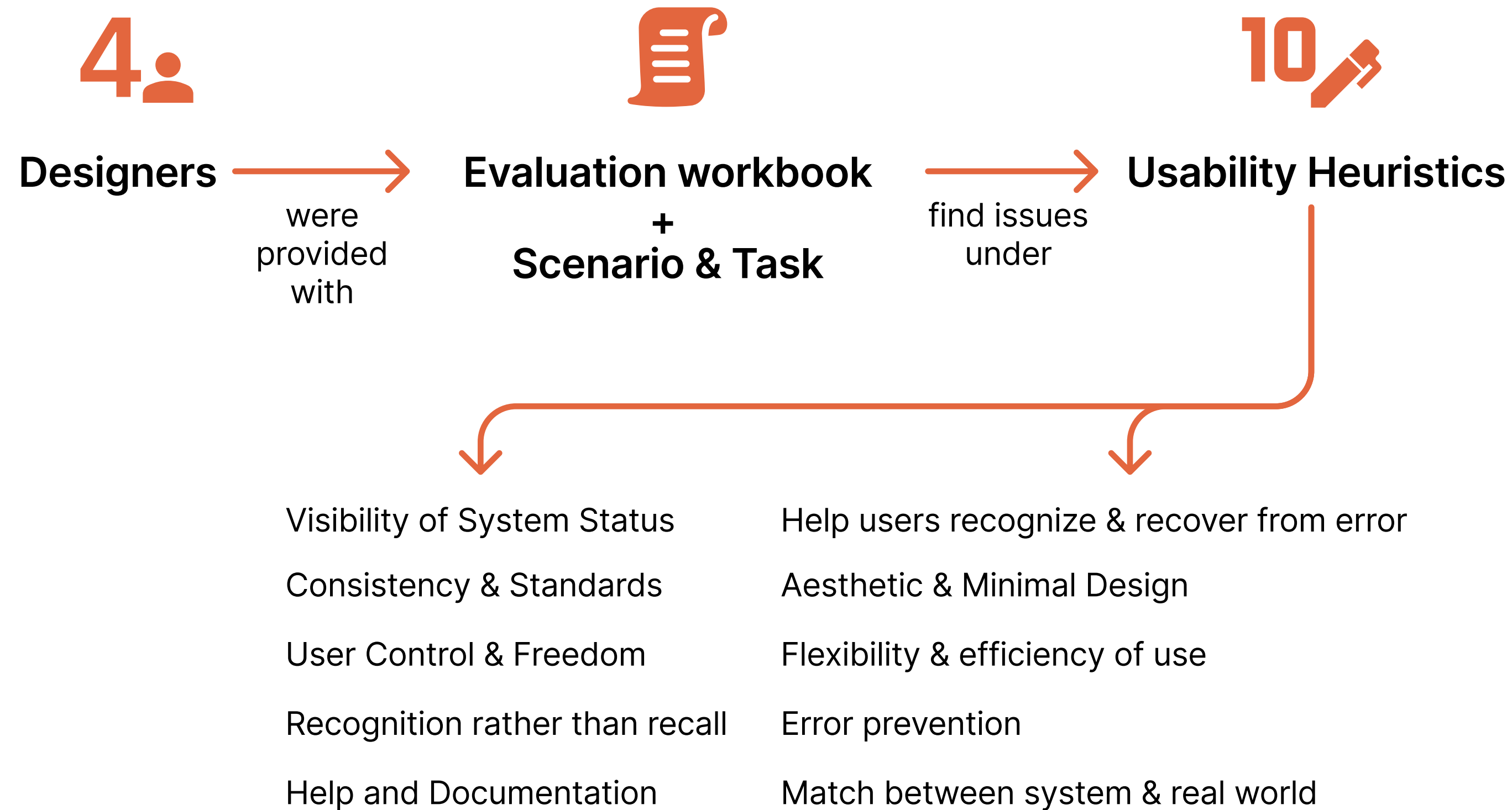
- Is the visual design and content focused on the essentials?
- Have all distracting, unnecessary elements been removed?

9 Help Users Recognize, Diagnose, and Recover from Errors
Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.

- Does the design use traditional error message visuals, like bold, red text?
- Does the design offer a solution that solves the error immediately?

10 Help and Documentation
It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.

- Is help documentation easy to search?
- Is help provided in context right at the moment when the user requires it?



Severity Scale

- 0 (No problem)
- 1 (Cosmetic)
- 2 (Minor issue)
- 3 (Major issue)
- 4 (Catastrophe)

Issues Identified

- 1
 - 6
 - 7 ✓
 - 2 ✓
 - 2 ✓
- adjusted**

Icon was used in the list with no information next to it whatsoever

System didn't acknowledge the user input

User Study

A/B Comparison (AI-Assembly vs Pre-defined)

30 (Priori + Sensitivity Analysis)
Participants
18 M, 12 F



Experienced 2 systems in randomized order



2 Preferences collected & entered into the system

2 news topics (Sports, Politics, Automotive)
UI preference (Minimal vs Rich)



Scenario: Drive from BB to MUC (IAA)

- Event -1: Briefing
- Event -2: Intermediate Stop for Breakfast (simulated driving)
→ Videos reviewed by 2 Experts for comparability
- Event -3: Traffic Jam

4 experimental groups → Minimising Order Effects

Group	First Run	Second Run
1	Video 1 + System A	Video 2 + System B
2	Video 1 + System B	Video 2 + System A
3	Video 2 + System A	Video 1 + System B
4	Video 2 + System B	Video 1 + System A



After each event

- Value (UEQ+)
- Clarity (UEQ+)
- Visual Aesthetics (UEQ+)
- Mental Load (NASA TLX)
- Distraction (custom 7-point Likert)
- Open Ended Feedback

After each condition

- Personalization (custom 7-point Likert)
- Adaptivity (custom 7-point Likert)
- UEQ-S

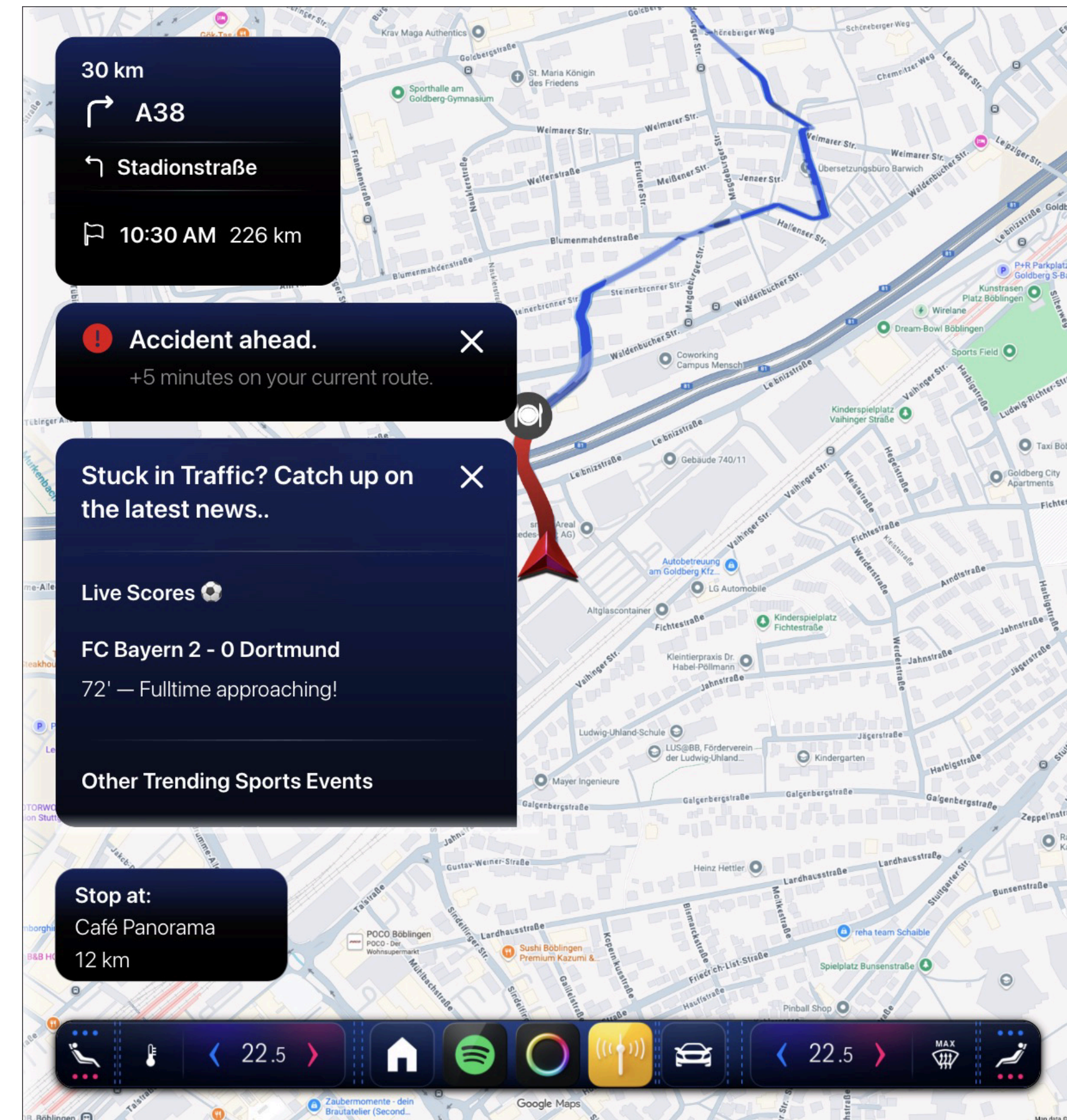
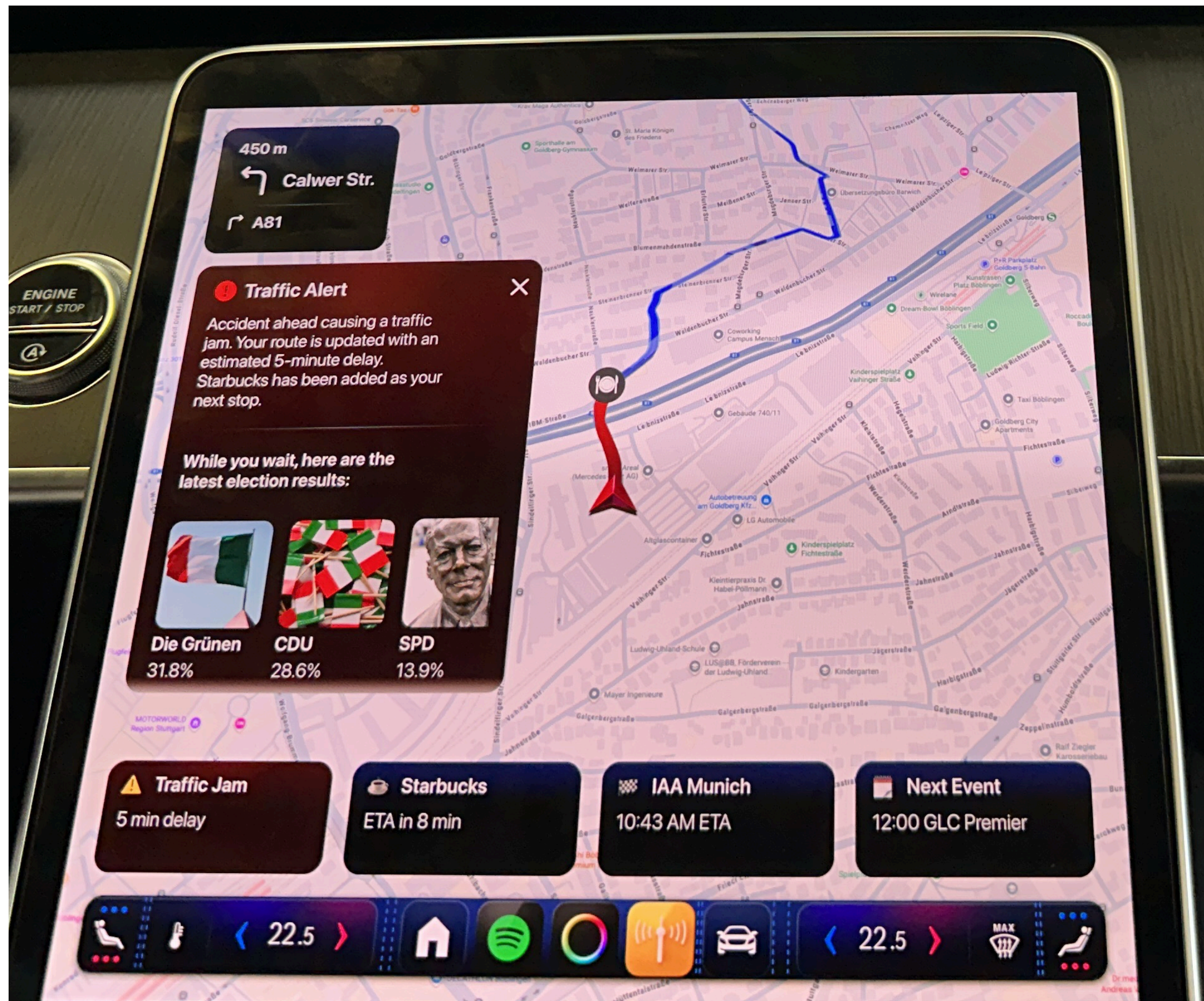
After experiment

- Distribution of 100 points between System A and B



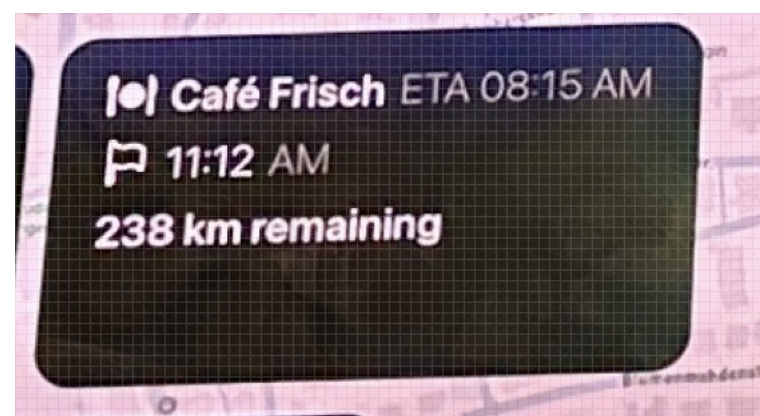
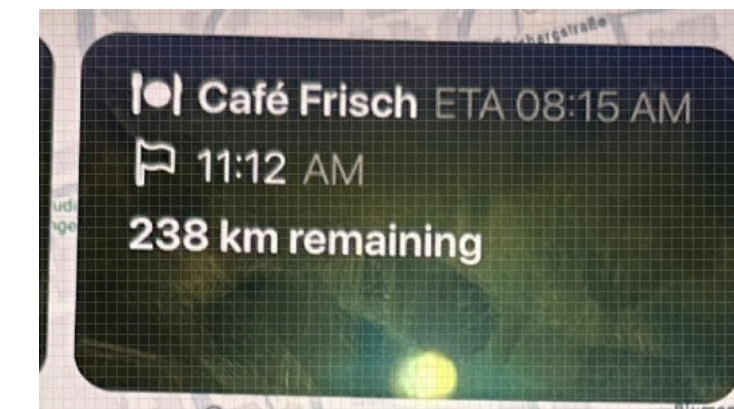
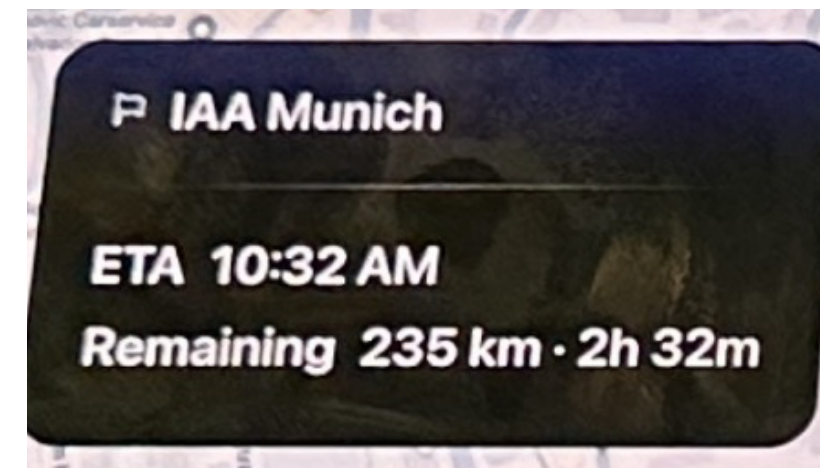
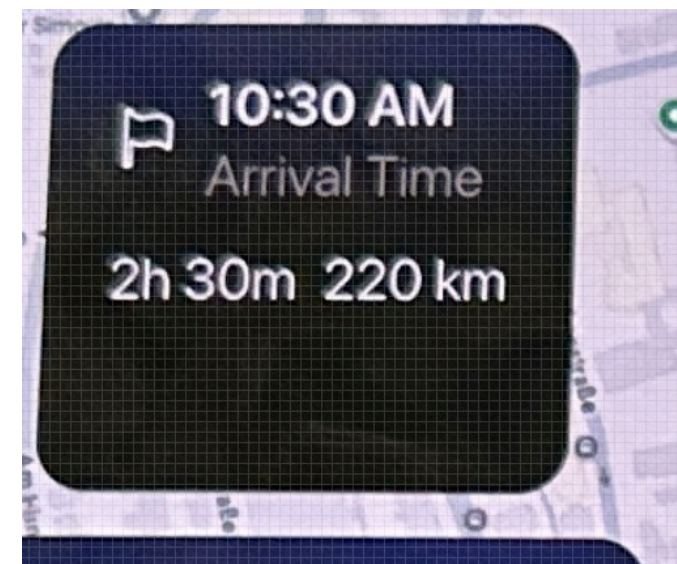
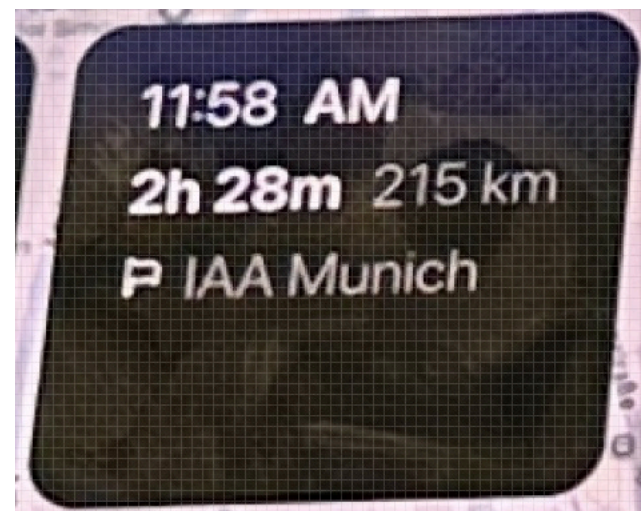
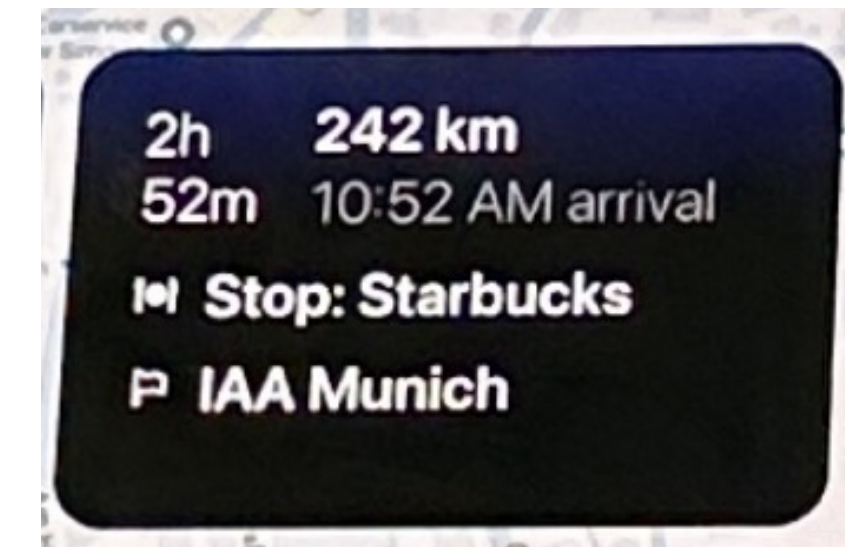
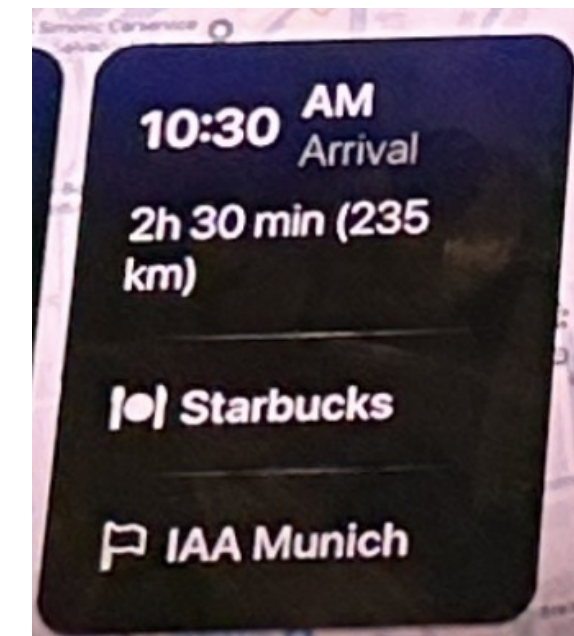
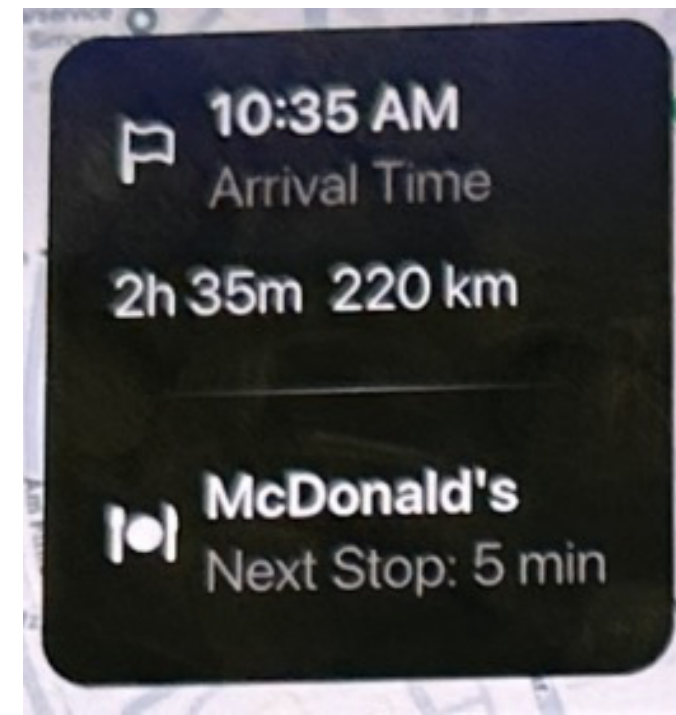
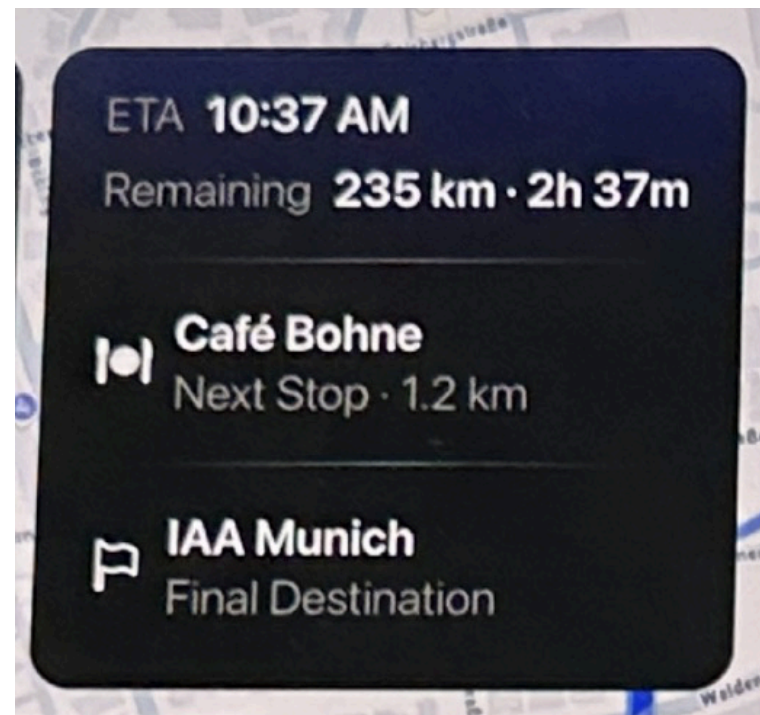
Example Outputs

AI-assembled (Left), Pre-assembled (Right)



High Variance

in the Organism-level component with the most freedom



Results

Overall preference

Dividing 100 points between A/B

AI-assembled GUI

Ø 48.73

14 People (> 50 Points)

↳ 4 People (>70 Points)

Pre-assembled GUI

Ø 51.27

15 People (> 50 Points)

↳ 5 People (>70 Points)

Point Distribution $p=.707$

Individual Metrics

RQ 1

Usability

$p=.514$

No sig. diff.

Clarity

$p=.089$

H1: 👍

AI-assembled \geq Pre-assembled

Value

$p=.872$

RQ 2

Distraction

$p=.146$

No sig. diff.

Situational awareness

$p=.310$

H2: 👍

AI-assembled \geq Pre-assembled

Cognitive load

$p=.235$

RQ 3

Personalization

$p=.909$

No sig. diff.

Contextual Adaptivity

$p=.911$

H3: 👎

AI-assembled $>$ Pre-assembled

Take Away

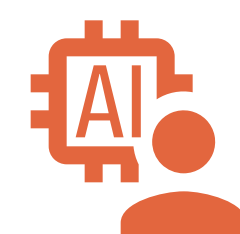
Performance

- AI performed on par with the baseline
- No improvement in adaptivity observed.....
 - Most likely due to very limited user data (one input - one output)
 - Repeated interactions may change outcomes

Safety Insight

- UI variation acceptable for supplementary content
- Variation in critical-components may introduce safety risks

Our Recommendation



Hybrid Strategy

Humans

critical components (e.g., navigation)

AI

Non-critical, supplementary components and areas

→ **AI-based assembly = curator and builder constrained within safe boundaries.**

→ **Leverages Data = Personalized Experience**

→ **Potentially simplifies Development Processes**

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