

Location-Independent Indoor Navigation Using Established Interaction Reflexes

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January 15, 2026

Abstract

We present a location-independent indoor navigation approach that guides users without relying on explicit localization. The system issues sequential instructions that guide users through a predefined path in a supermarket. The users confirm the instructions with a familiar swipe-up gesture. In a within-subject study ($N = 12$) we compared two instruction modalities: a map-based display and a directional-arrow display. The map condition yielded faster navigation (18.5% improvement), higher instructional clarity (8.25 vs. 5.58 on a 10-point scale) and less difficulties in execution (4.67 vs. 7.25). NASA-TLX results show reduced mental demand (5.50 vs. 7.17) and lower frustration (3.25 vs. 5.83) for the map condition, while physical demand remained low for both methods (2.7), indicating the swipe-up confirmation imposes negligible physical cost. Findings indicate that indoor navigation without explicit localization is effective when instructions are presented with spatial context, purely directional cues increase cognitive workload and reduce performance.

1 Introduction

Finding one’s way from one point to another is a challenge we encounter every day. Modern technology offers reliable navigation systems that provide precise step-by-step directions to reach a desired destination. Most well-known systems (Google/Apple Maps) are designed for outdoor navigation and rely heavily on GPS localization.

In contrast, our project focuses on an orthogonal challenge: indoor navigation without localization. Determining one’s exact position inside a building is a highly complex process and often prone to noise and inaccuracies. Our system therefore takes a different approach, it provides clear instructions that guide the user through a building to their point of interest, without depending on precise location data.

A common example of such a scenario is the experience of getting lost in a large supermarket with a detailed shopping list in hand. Since our system does not use localization, it simply generates instructions for every intersection or decision point, starting from the building’s entrance. To ensure a smooth interaction, users must confirm each instruction before receiving the next one. For this interaction, we were inspired by the intuitive and widely adopted swipe gestures used in popular social media applications (Instagram, Tiktok). These gestures promise to provide a familiar, simple, and efficient way for users to interact with the system, enabling a natural navigation experience.

2 Related Work

Fallah et al. [FABF13] provide an overview of Indoor Human Navigation Systems, showing that many solutions rely heavily on infrastructure-based localization such as Wi-Fi, beacons, or visual markers. While these systems can provide accurate guidance, they require costly infrastructure, additional hardware and are sensitive to noise and calibration errors, limiting their scalability and robustness.

Beyond localization, prior work highlights the importance of instruction representation for navigation performance and cognitive load. Visual instructions that provide spatial context, such as maps or landmark-based representations, support cognitive map formation and reduce mental effort, whereas purely directional cues (e.g., arrows or turn-by-turn commands) can increase cognitive workload despite their simplicity. Interaction techniques range from visual and audio feedback to haptic guidance,

with evidence suggesting that simple, familiar input methods improve usability while imposing minimal physical demand.

An interesting example was published by Löchtefeld et al. [LGSK10], who introduce Pedestrian Indoor Navigation, without Infrastructure, PINwI, demonstrating that navigation without explicit localization is feasible when clear, human-centered guidance is provided. These works support our approach of designing an instruction-based navigation system that operates independently of localization technologies.

3 Methodology and Experimental Framework

In this section we first explain the two distinct methods of communicating the navigation instructions and the common interaction gesture we propose to receive and confirm those navigation instructions, followed by our prior-experiment hypothesis and expectations. Then we explain our experimental setup in detail and the values we measure to evaluate our methods.

3.1 Methodology

The study evaluates two distinct navigation delivery methods in an offline environment.

Method A: Map-Based Navigation Displays an oriented map of the environment overlaid with directional arrows (1c). This provides spatial context to guide the user to the next point of interest.

Method B: Arrow-Only Navigation Delivers directional arrows without a map interface (1a, 1b). This method requires users to track their location independently, potentially increasing cognitive load.

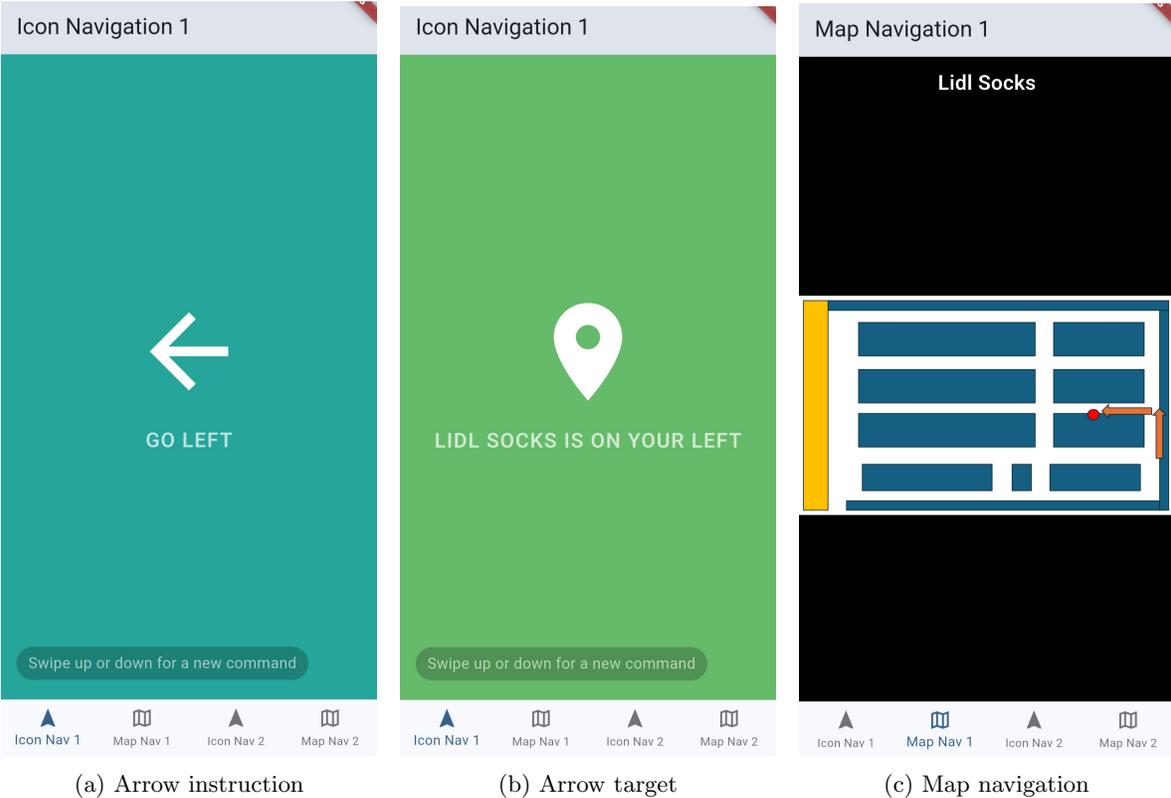


Figure 1: User interfaces of both methods

Navigation initializes at the building entrance, synchronized with the user’s starting position. Both methods utilize a **Swipe-Up Confirmation Mechanism** for instruction acknowledgment. This

interaction, standardized in social media interfaces, is used to stimulate the existing interaction habits of users.

Our prior-experiment hypothesis are:

1. **H1 (Efficiency and Effectiveness):** Method A will result in shorter execution times and higher comprehension than Method B on identical paths.
2. **H2 (Acceptance):** The swipe-up confirmation mechanism will achieve high user satisfaction and acceptance.

3.2 Experimental Framework

The study employs a **within-subject design**, requiring every participant to evaluate both, Method A and Method B. The participants were chosen from our personal social contacts.

Testing occurred in a supermarket setting using two separate routes: **Path 1** and **Path 2**. Both paths were designed with equivalent complexity, each requiring the retrieval of five distinct products. To ensure consistency, data collection was restricted to off-peak hours to minimize interference from other shoppers.

To neutralize learning effects and subjective bias, the order of methods and paths was rotated across participants using the following permutations:

- Method A (Path 1) → Method B (Path 2)
- Method B (Path 1) → Method A (Path 2)
- Method A (Path 2) → Method B (Path 1)
- Method B (Path 2) → Method A (Path 1)

The study reached a total sample size of $N = 12$. This represents three complete rotations of the four combinations. This ensures a balanced distribution of conditions across the participant pool. Additionally, $N = 12$ was chosen for practical feasibility, as it allowed for data collection within the operational constraints while resulting in sufficient data for analysis.

Each experimental trial consists of three sequential phases:

1. **Pre-experiment Phase:** Participants receive a detailed explanation and demonstration of the experimental tasks, followed by a clarification period for any remaining questions.
2. **Experiment Phase:** The trial begins at the supermarket entrance upon application activation. Task performance is quantified by recording the total duration from initiation to the participant's arrival at the cashier.
3. **Post-experiment Phase:** Participants complete the NASA Task Load Index (NASA-TLX) to assess cognitive workload and a user satisfaction questionnaire to evaluate the specific navigation method used.

4 Results

The performance of Method A (Map) and Method B (Arrow) was assessed through completion times. The cognitive workloads were quantified using the NASA Task Load Index (TLX) [Har86]. Additionally the usability of these methods were also evaluated in a separate form about subjective understanding and difficulty.

4.1 Performance Metrics

Navigation efficiency was measured by completion time in seconds across two distinct paths through the supermarket environment. Method A consistently yielded lower completion times than Method B (figure 2, table 1).

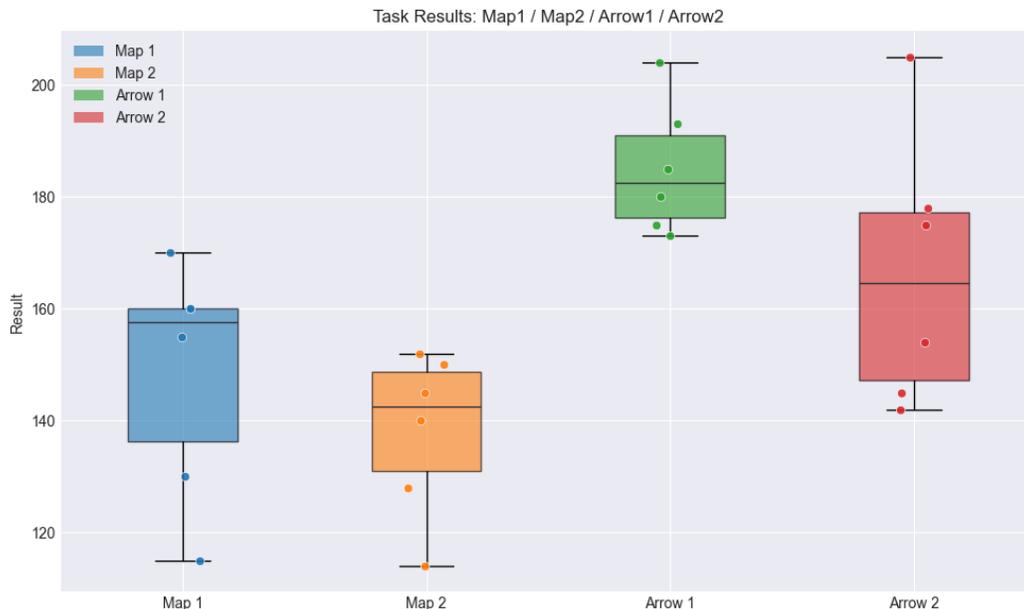


Figure 2: Navigation Completion Times by Method and Path

Method	Path	Mean (s)	Min (s)	Max (s)
Arrow (Path 1)	1	185.00	173.00	204.00
Arrow (Path 2)	2	166.50	142.00	205.00
Map (Path 1)	1	148.33	115.00	170.00
Map (Path 2)	2	138.17	114.00	152.00

Table 1: Navigation Completion Times by Method and Path

The aggregate mean for Method A ($M = 143.25$) represents an 18.5% improvement in efficiency over Method B ($M = 175.75$).

4.2 Subjective Understanding and Difficulty

Participants evaluated the interaction based on two metrics using a 10-point scale:

- **Instructional Clarity:** "How well did you understand the navigation instructions?"
- **Difficulty of Execution:** "How hard was it to execute a single navigation instruction?"

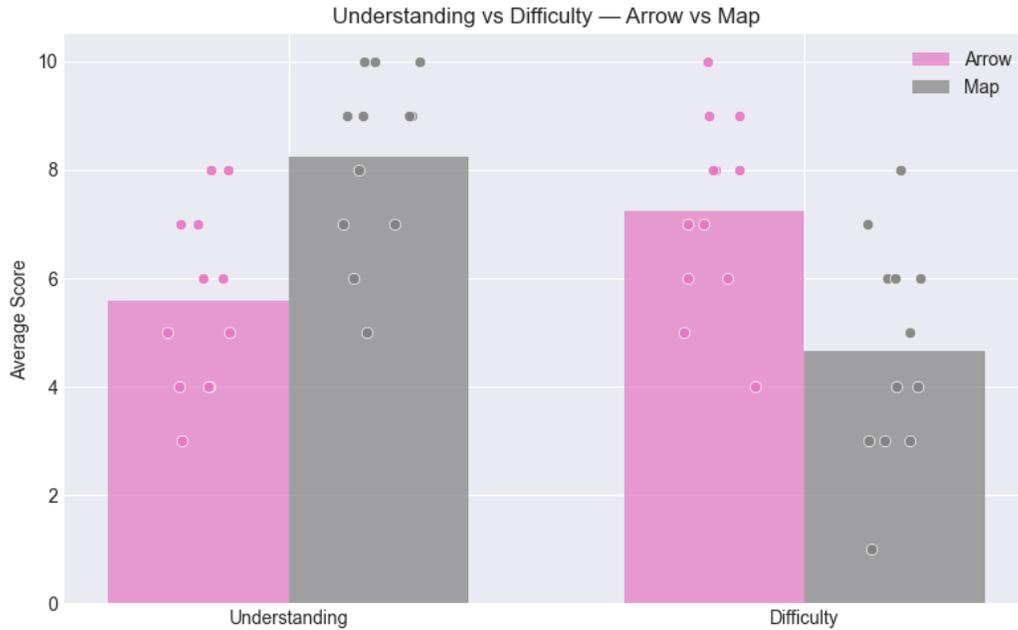


Figure 3: Subjective Usability Rankings

Metric	Arrow (B) Mean	Map (A) Mean
Understanding	5.58	8.25
Difficulty	7.25	4.67

Table 2: Subjective Usability Ratings

The Map method (A) outperformed the Arrow method (B) in both instructional clarity (+47.8%) and perceived ease of use (+55.2%) as shown in figure 3. These results indicate that providing a spatial map effectively reduced the cognitive overhead required to correlate the instructions with the physical environment.

4.3 NASA Task Load Index (TLX)

The NASA TLX scores (1–10 scale) provide a detailed view of the cognitive and emotional demands imposed by each navigation interface (figure 4).

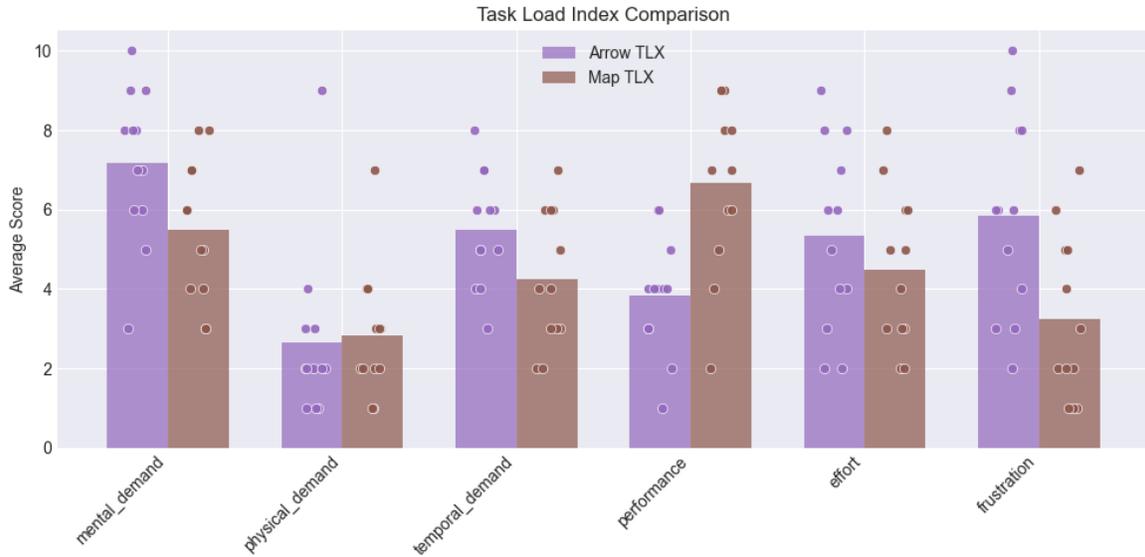


Figure 4: NASA TLX Dimension Scores

Dimension	Arrow (B) Mean	Map (A) Mean
Mental Demand	7.17	5.50
Physical Demand	2.67	2.83
Temporal Demand	5.50	4.25
Self-Rated Performance	3.83	6.67
Effort	5.33	4.50
Frustration	5.83	3.25

Table 3: NASA TLX Dimension Scores

Method B resulted in higher levels of mental demand ($M = 7.17$) and frustration ($M = 5.83$). Method A significantly improved the users' self-rated performance ($M = 6.67$ vs. $M = 3.83$), indicating a higher level of confidence in the navigation task. Physical demand remained low and stable across both methods (< 3.00), confirming that the swipe-up gesture does not significantly impact physical workload. Method A effectively minimized cognitive friction and emotional frustration compared to the arrow interface.

5 Conclusion

The experimental results demonstrate that providing spatial context through map-based visualizations (Method A) significantly optimizes navigation performance compared to isolated directional instructions (Method B). Method A achieved a reduction in mean completion time, with an aggregate mean of 143.25s against Method B's time of 175.75s.

The NASA Task Load Index (TLX) data reveals (Method B's high mental demand (7.17) and frustration levels (5.83)) that directional instructions without spatial context push users into a high-effort state of cognitive mapping. In contrast, Method A's static map facilitates the matching of instructions with physical environments without requiring active localization as shown by the improved self-rated performance of 6.67.

The integration of swipe-up gestures as a confirmation mechanism proved highly effective. Physical demand remained consistently low on both methods (2.67, 2.83), confirming that transposing interaction paradigms from social media to utility applications reduces instructional overhead. This research concludes that while localization is not strictly necessary for indoor navigation, the delivery of instructions must be supported by spatial references to maintain cognitive efficiency.

References

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