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PEDESTRIAN NAVIGATION ASSISTANCE IN REAL URBAN ENVIRONMENTS

NOVEL GAZE-BASED AND VIBROTACTILE INTERACTION APPROACHES

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1. INTRODUCTION

People use pedestrian navigation assistance systems that help them successfully reach their destination. These systems are in most of the cases developed based on the map-based turn-by-turn instructions approach *("Map")*. However, despite its advantages, this kind of interaction between the user and the device has many limitations: It suffers from ambiguity, it requires user's ability to match the instructions with the surroundings and also distracts the user's attention from the environment. In this study, we introduce the novel concept of *"Gaze+Belt"* navigation that combines characteristics from two approaches:

- *"GazeNav"*, a gaze-based approach for pedestrian navigation
- *"Belt"*, a vibrotactile waist belt approach for pedestrian navigation.

2. CONCEPT

"Gaze+Belt" navigation is a novel interaction concept proposed in this work. Through this approach, a gaze-based and a vibrotactile interaction method are combined. The goal is to take advantage of all the positive characteristics from both approaches and to simultaneously minimize their limitations. *"Gaze+Belt"* navigation communicates the route to the user based on her gaze on a decision point (gaze feedback) and her current location (belt feedback). The user receives the two feedbacks with a short time difference. The belt feedback is received first, when a user approaches a decision point. This feedback provides her a first indication of the direction where the next road that she has to follow lies. When the user arrives at the decision point, she does not have to search the whole space in order to find the correct option to follow. On the contrary, she can only look towards the direction that the vibrotactile belt indicated some moments earlier. When she gazes at the correct road, the gaze feedback is activated to confirm that this is the correct road to follow.

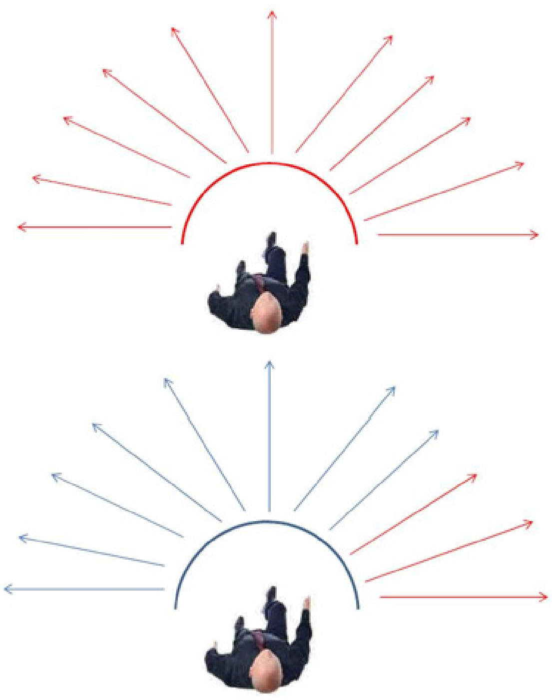


Figure 1: The red arrows indicate the amount of possible options to follow with the *"GazeNav"* (top) and *"Gaze+Belt"* (bottom) approaches

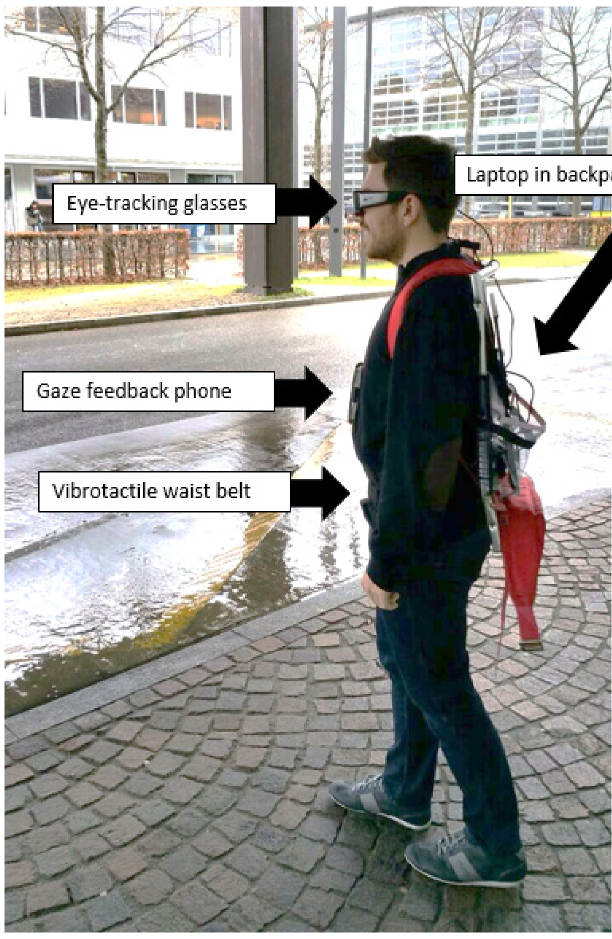


Figure 2: Participant testing the *"Gaze+Belt"* during the experiment

3. EXPERIMENT

In a comparative experiment with 40 participants in real environment, our approach was evaluated and compared against the *"GazeNav"*, the *"Belt"*, and the *"Map"* approach that we used as a baseline. Participants' task was to navigate along the same route in the ETH Hönggerberg Campus. After they had arrived to their destination, the experimenter asked participants to perform several tasks for the assessment of their spatial knowledge acquisition, the user experience and the cognitive load, as well as to fill in a questionnaire with general questions and answer to two open questions.

4. RESULTS

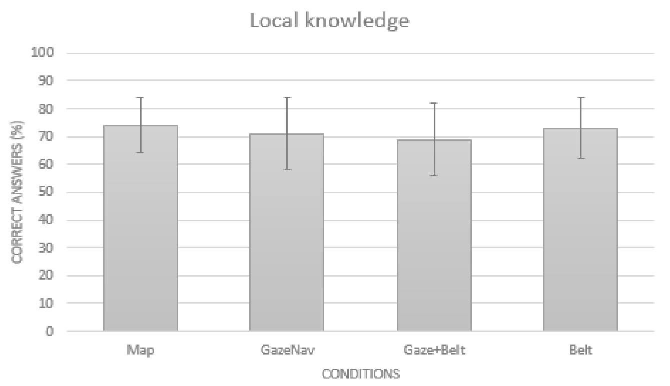
Navigation performance

	Map	GazeNav	Belt	Gaze+Belt
Number of errors	Mean = 0.40, SD = 1.26	Mean = 3.10, SD = 2.33	Mean = 1.80, SD = 1.23	Mean = 2.90, SD = 2.47
Total time (minutes)	Mean = 5.72, SD = 0.66	Mean = 7.34, SD = 1.46	Mean = 6.66, SD = 0.92	Mean = 8.08, SD = 0.81

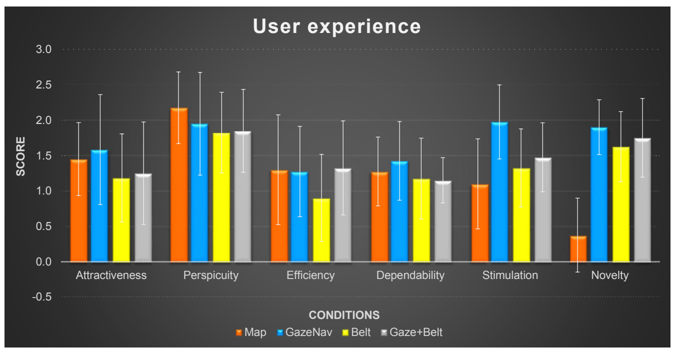
Survey knowledge

	Map	GazeNav	Belt	Gaze+Belt
Bi-dimensional regression	Mean = 0.644, SD = 0.211	Mean = 0.575, SD = 0.218	Mean = 0.762, SD = 0.170	Mean = 0.639, SD = 0.251
Floor level corresponde nce	Mean = 0.890, SD = 0.070	Mean = 0.860, SD = 0.130	Mean = 0.890, SD = 0.050	Mean = 0.840, SD = 0.200
Total corresponde nce	Mean = 0.766, SD = 0.126	Mean = 0.716, SD = 0.147	Mean = 0.822, SD = 0.104	Mean = 0.738, SD = 0.200

Local knowledge



User experience



Cognitive load

	Map	GazeNav	Belt	Gaze+Belt
Mental demand	Mean = 7.20, SD = 4.83	Mean = 6.40, SD = 3.37	Mean = 7.60, SD = 4.90	Mean = 9.40, SD = 4.97
Physical demand	Mean = 4.30, SD = 1.95	Mean = 6.10, SD = 4.93	Mean = 6.80, SD = 4.87	Mean = 6.10, SD = 4.43
Temporal demand	Mean = 8.80, SD = 5.39	Mean = 9.00, SD = 5.60	Mean = 8.90, SD = 3.54	Mean = 10.40, SD = 2.12
Performance	Mean = 6.60, SD = 4.03	Mean = 6.10, SD = 4.46	Mean = 8.70, SD = 4.19	Mean = 7.20, SD = 4.80
Effort	Mean = 8.70, SD = 4.85	Mean = 5.50, SD = 3.41	Mean = 6.50, SD = 3.34	Mean = 10.00, SD = 4.19
Frustration	Mean = 5.00, SD = 3.20	Mean = 6.00, SD = 5.50	Mean = 8.50, SD = 6.31	Mean = 9.30, SD = 4.27
Total load	Mean = 40.60, SD = 11.93	Mean = 39.10, SD = 19.72	Mean = 47.00, SD = 14.03	Mean = 52.40, SD = 16.17

5. CONCLUSIONS

- *"Gaze+Belt"* navigation is as effective as the other three methods
- *"Map"* is the most efficient method
- All approaches had the same effect on spatial learning
- The use of the eye-tracker in the interaction dialog offers a higher sensory excitation due to the novelty of the approaches
- User experience was found similar for all cases
- No significant differences were found in terms of total cognitive load
- Participants that used *"Gaze+Belt"* had to put more effort to use the system and achieve a good performance
- Participants that used *"Belt"* were significantly less confident than those that used "GazeNav" while navigating

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