Beyond Symbolic Interfaces: Dual-Task Navigation Support Using Perceptual Information from Motion

Professor, Interfaculty Initiative in Information Studies, The University of Tokyo
Sony Computer Science Laboratories Inc. Fellow / CSO Rekimoto Jun

IoB Middleware

Moonshot Research and Development Program Goal 1 Kanai Project

Overview

Conventional pedestrian navigation relies on symbolic instructions displayed on screens, demanding visual attention from users and making it difficult to perform secondary tasks simultaneously. This study addresses this issue by proposing a wearable directional guidance method that operates without symbols, instead engaging human "kinesthetic perception." By presenting kinesthetic cues such as haptic feedback through a body-worn device, users can intuitively grasp direction without diverting their gaze. Experimental evaluation demonstrated that the proposed method statistically significantly improves performance on secondary tasks compared to conventional visual symbol-based guidance, while maintaining navigation performance. These results contribute to the design of non-symbolic interactions that enable safer and more efficient dual-task environments.

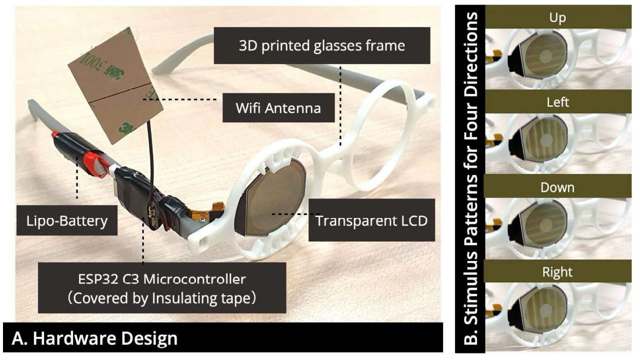

Figure 2: This shows the prototype of the developed wearable device and an image of the light displayed on its screen. (A) This shows the device's internal structure. The frame, which forms the glasses' skeleton, was created using a 3D printer. A transparent liquid crystal display (LCD) is integrated into the lens section on the right. Inside, it houses a small computer (ESP32-C3) that serves as the brain controlling the entire device, a power battery, and a Wi-Fi antenna for wireless communication. (B) This shows the pattern of "motion" displayed on the transparent screen in a frame-by-frame sequence. The brain perceives this as "motion" because the light bars appear to move smoothly. As an example, it illustrates how the four basic directions—up, down, left, and right—are conveyed through distinct light movements.

Background

The proliferation of mobile computing and wearable technology has made navigation assistance accessible to anyone, anywhere. However, the current mainstream approach relies heavily on visual "symbols" such as maps and arrows displayed on smartphone or smartwatch screens. This paradigm inherently poses challenges because it forces users to frequently stare at the screen.

First, human visual attention is a finite resource, and navigation information competes with the surrounding physical environment (other pedestrians, obstacles, traffic signals, etc.) for this resource. This competition significantly reduces the user's situation awareness, increasing risks such as collision accidents. Second, this visual dependency hinders the performance of secondary tasks (dual-tasking) that users naturally wish to perform while moving, such as enjoying scenery at tourist spots or conversing with friends. This is because the sequence of processes—recognizing symbols, interpreting their meaning, and converting that into action—imposes a non-negligible cognitive load on the user.

Therefore, this research aims to redefine a new form of wearable navigation that can support dual tasks more safely and efficiently without consuming limited visual resources, thereby addressing this fundamental challenge of "visual symbol dependency."

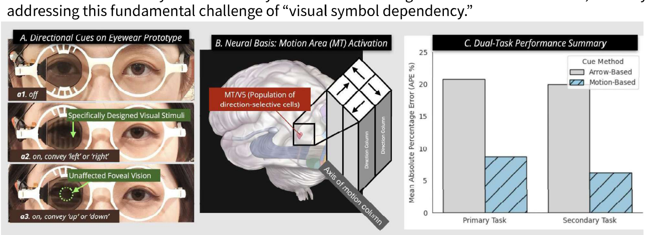

Figure 1: This figure shows our newly developed system that uses "motion" to indicate direction and summarizes the results of its performance evaluation. (A) This shows the device in actual use. A light bar moves at the edge of the field of view to indicate direction, allowing users to understand direction without distracting the central part of the visual field (used for focusing on something) and while keeping their gaze forward. (B) This diagram illustrates the neuroscience mechanism of the system. It is designed so that the "motion" stimulus entering from the periphery directly activates the brain's specialized motion-sensing sensor area (known as the MT field in technical terms). This enables intuitive directional understanding without conscious thought. (C) This graph compares performance during multitasking. Compared to the conventional method of indicating direction with arrows, our motion-based method resulted in fewer errors during tasks (measured by APE: Average Percentage Error).

Approach

This study focused on human "motion perception" as a more direct, physical channel of information transmission that does not require the cognitive "decoding" process of symbols. This is a fundamental ability acquired by organisms through evolution to detect and interpret movement quickly and with low cognitive load.

Applying this principle, we designed and developed a wearable device that generates motion perception cues. The prototype is a band-type device worn on body parts like the wrist or waist, containing multiple tactile actuators (ultra-small vibration motors) arranged linearly at equal intervals. To indicate direction, these actuators are activated in specific spatiotemporal patterns (e.g., sequential activation from left to right at 0.1-second intervals). This generates a distinct phantom sensation on the user's skin, as if something were smoothly "moving" across it.

Users can navigate intuitively by simply moving toward the perceived direction of this "motion." This method not only achieves complete Eyes-Free operation without any visual input but also minimizes cognitive load by bypassing higher-order cognitive processes associated with symbol interpretation. Consequently, users can freely allocate their cognitive resources to environmental awareness and secondary tasks.

Results & Purpose

To verify the effectiveness of the proposed method, we conducted a dual-task experiment where participants simultaneously performed pedestrian navigation (primary task) and a visual cognitive task (secondary task), using conventional visual cues (arrows on a smartphone screen) as the control group.

Results: The experiment revealed no significant difference between the two methods in primary task performance metrics such as navigation task completion time and route accuracy. However, for performance on the secondary task (accuracy rate, reaction time), participants using the proposed method demonstrated statistically significantly higher performance. Furthermore, in the post-experiment subjective evaluation questionnaire, the proposed method received significantly higher ratings than the conventional method on items such as "lower cognitive load," "easier to pay attention to surroundings," and "feels safer."

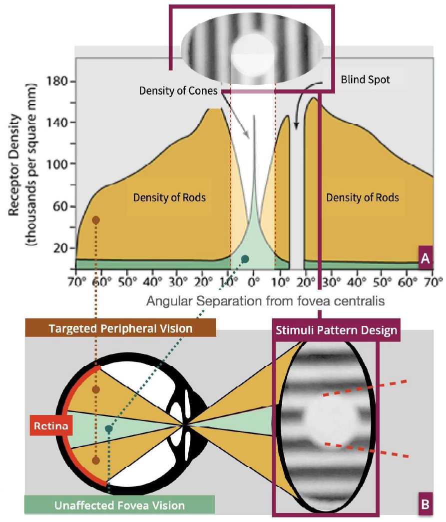

Figure 3: This diagram illustrates how we designed the light pattern to match the structure of the eye. (A) It shows the distribution of light-sensitive cells in the "retina," located at the back of the eye. The central area is densely packed with "cone cells," which are good at seeing fine details and colors. Meanwhile, the surrounding peripheral area contains numerous "rod cells" that are sensitive to light and motion. (B) Our light pattern design cleverly utilizes this mechanism of the eye. It targets the "peripheral area of the eye," where motion-sensitive cells are concentrated, to present motion information. This allows us to convey only the necessary information without interfering at all with the "central area of the eye," which is most critical for seeing objects.

Academic Significance: This study demonstrated the effectiveness of "Perception-Centric Design" in wearable HCI (Human-Computer Interaction), overcoming the limitations of conventional symbolic information presentation. It showed that the information channel of kinesthetic perception is highly efficient, particularly in resource-constrained mobile environments, providing a new theoretical foundation for future non-symbolic interface design.

Qing Zhang
Interfaculty Initiative in Information Studies, The University of Tokyo
Project Assistant Professor

Our research centers on integrating artistic and design methodologies with cutting-edge human-centered technology. We develop wearable systems that enhance human experiential value to address societal challenges such as fostering empathy in inclusive design, preserving expert skills, and enabling human-AI co-creation.

Junyu Chen Master's Student
Graduate School of Information Science and Technology, The University of Tokyo

Yifei Huang Project Researcher
Institute of Industrial Science, The University of Tokyo

Jing Huang Ph.D. Student
Graduate School of Fine Arts, Tokyo University of the Arts

Thad Starner Professor
Georgia Institute of Technology

Kai Kunze Professor
Graduate School of Media Design, Keio University

Jun Rekimoto Professor
Interfaculty Initiative in Information Studies, The University of Tokyo

REKIMOTO LAB
Laboratoire Révolutionnaire et Romantique

Internet of Brains