Basic Study of Haptic Navigation for Electric Scooter

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E-scooters are expected to play an important role in short-distance urban mobility, particularly in sharing services. They are useful for first- and last-mile transportation because they allow users to reach destinations that are not easily accessible from railway stations or bus stops. In Japan, some models equipped with a 6 km/h mode can also travel on sidewalks, which further increases their flexibility in urban areas. At the same time, the growing use of e-scooters has been accompanied by an increase in traffic accidents, and inappropriate rider behavior has been identified as one of the contributing factors. One possible cause is smartphone use while riding, including the use of navigation applications. Conventional navigation apps mainly present route guidance through visual displays and audio prompts, which may increase visual and auditory workload during riding.

Haptic presentation is a promising alternative because it can reduce reliance on vision and hearing and is less affected by environmental noise. This advantage is especially important for e-scooters, which do not have an enclosed cabin. In addition, e-scooters differ from bicycles and motorcycles in ways that may make visual navigation more problematic. Because the front wheel is relatively small and handlebar sensitivity is high, looking away from the forward scene can make the vehicle less stable. Moreover, riders maintain an upright posture, so checking a display near the center of the handlebar requires a relatively large downward gaze shift. These characteristics suggest that haptic navigation may be particularly suitable for e-scooter riding. In this study, we applied a handlebar-based haptic navigation system to an e-scooter and compared it with conventional smartphone-based visual navigation in an outdoor riding experiment conducted in an environment close to real traffic conditions.

To evaluate the proposed method, we developed a handlebar-based haptic navigation system for an e-scooter. Two vibration motors were attached to the left and right sides of the handlebar using grip tape. Directional information was presented by activating the motor on the corresponding side, so that left and right turns were indicated through left and right vibration, respectively. The vibration frequency was approximately 240 Hz.

The experiment was conducted on an approximately 800 m outdoor route. This site was safer than public roads while maintaining road surface conditions similar to ordinary streets. Although there were no traffic signals, pedestrians and other vehicles were present, making the environment reasonably close to real traffic.

Fourteen healthy adults participated in the study. Before the formal trials, all participants completed a practice session to become familiar with both scooter operation and the navigation interface. Two experimental conditions were compared. In the Haptic Condition, participants used the smartphone navigation app together with haptic turn cues presented through the handlebar. In the Visual Condition, participants used a map app in the ordinary way and visually checked the smartphone screen while riding. Participants rode two routes in counterbalanced order. After the trials, cognitive workload was evaluated using the NASA Task Load Index (NASA-TLX).

Table 1 shows the comparison of NASA-TLX raw scores between the two conditions. Wilcoxon signed-rank tests were conducted for each questionnaire item. The results showed that, for the Effort subscale, the score in the Haptic Condition was significantly lower than that in the Visual Condition ($p < 0.05$). The results did not indicate a reduction in overall cognitive workload with the haptic cues. However, the haptic feedback was not perceived as noise and did not adversely affect the overall riding experience. This suggests that appropriately designed vibration stimuli can be used without imposing additional burden on the user.

Table 1 Results of NASA TLX Raw Score

Index	Haptic Condition	Visual Condition	P-value
Mental Demand	9.79	9.93	0.53
Physical Demand	9.10	9.34	0.51
Temporal Demand	10.86	10.63	1.00
Performance	9.50	9.93	0.68
Effort	8.29	11.14	0.03
Frustration	11.36	10.57	0.84