Evaluating the use of tactile navigation for motorcycle taxis and couriers

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ABSTRACT

In this paper we describe the design and evaluation of a simple prototype device that provides tactile cues to support navigation by motorcyclists. A comparative evaluation shows that the device supports equivalent performance to the use of a visual display. The evaluation was performed by licensed motorcycle taxi drivers in Thailand, on a University campus. The evaluation showed that, in terms of journey time and route accuracy, there was little difference between the two technologies. A further evaluation, of the tactile belt, was conducted in a busy town. Participants were able to follow the route and responded positively to the concept and its implementation in our prototype. We propose that tactile navigation aids can help motorcyclists and that, compared to visual displays, these can be used with reduced risk of distraction.

KEYWORDS

Tactile display, route guidance, motorcycles

Introduction

Tactile displays have been developed for walking (Van Erp, 2005; Van Erp and Van Veen, 2004; Van Erp et al., 2005; Van Erp and Werkhoven, 2006) and for cycling (Poppinga et al., 2009; Steltenpohl and Bouwer, 2013). Less work has been directed at the potential use of tactile cues for motorcyclists. One advantage that walking and cycling have (relative to riding a motorcycle) is that the wearer will not be subject to additional vibration or noise from the vehicle and will be travelling slowly enough for the cues to be perceived and acted upon. Riding a motorcycle in busy urban environments is a visually demanding activity, particularly if this also involves driving unfamiliar routes (Prasad et al., 2014). Use of route guidance employing Global Positioning System (GPS) has become a de facto standard in motor vehicles. However, the use of such visual displays could be problematic for motorcyclists, not least because this could be a source of distraction. Concerns over distraction of visual displays mean that auditory presentation of direction information is often preferred over visual presentation (Cao et al., 2010). For motorcyclists, the restricted field of view through the helmet visor makes it difficult to apply visual display route guidance, and the auditory environment might make it problematic to use audio guides. Thus, there might be some benefit in the use of tactile navigation aids for motorcyclists.

The Design Context

Indonesia has the third largest number of motorcyclists in the world (The Jakarta Post, 2016). The motorbike is used not only for private users but also for public transport. There are many motorbike taxis that operate, especially in the capital city, Jakarta. Additionally, there are numerous motorbike courier services.

Figure 1: Using a smartphone to navigate while riding a motorcycle

Previous related work

In-vehicle navigation is well-supported by technologies that use data from GPS to track the vehicle's location and relate this to pre-defined locations and routes. In-vehicle route guidance and navigation systems support route planning and driver guidance (Bengler et al., 2014), with more recent developments supporting dynamic replanning of routes, e.g., if heavy traffic or other causes of delay have been identified. Commercial devices, such as TomTom or Garmin, or apps such as GoogleMaps or Waze, provide visual and auditory displays of route guidance information. As noted in the introduction, visual guidance might be inappropriate for motorcyclists.

Tactile navigation systems for pedestrians, cyclists and motorcyclists

From a review of a series of studies conducted with tactile navigation in a range of domains (from walking to flying to power boating), Van Erp et al. (2006) propose the following considerations for the use of tactile torso displays:

1. They can be employed for local guidance navigation tasks.
2. Their effectiveness is independent of the amount of visual load.
3. They reduce the effect of additional cognitive tasks.
4. They work under the presence of external stressors such as night operations, spatial disorientation and altered G environments. Therefore, tactile torso displays can potentially provide a major workload reduction and safety enhancement.

The number of tactors that have been used range from three (Prasad et al., 2015) to eight (Van Erp et al., 2005) to 12 (Eriksson et al., 2008) to 15 (Van Erp, 2005), and there is some debate as to whether the tactors should be positioned on the back, waist or shoulders. Broadly speaking, the sensitivity of these different body regions will be influenced by the strength of the tactors and the quantity of subcutaneous fat that could absorb the signal. However, most of the reported studies confirm that participants are (a) able to detect vibration of the tactors in each of these body regions, and (b) can associate the location of vibration with a direction of travel in the environment (Van Erp, 2005).

In their study of the HaptiMoto vest, Prasad et al. (2014) had motorcyclists wear the 3-tactor set shown in Figure 2. They found that wearers were, for the most part, able to detect tactile cues (in 40/128 cases the wearer was not able to detect cueing and this might be due to a loose fit of garment). They also found that most of the riders were able to respond correctly. Their testing took place in a car park, with turns marked by cones on the ground. When drivers made errors, these tended to be either turning at the first opportunity (after cueing) rather than waiting for the correct turn (9/128 errors) or missing the second turn in a set of two (7/100).

Figure 2: Prasad et al's (2009) HaptiMoto vest for tactile navigation on motorcycles

Design specification and construction

The tactile navigation prototype designed in this research is composed of a belt with four tactors.

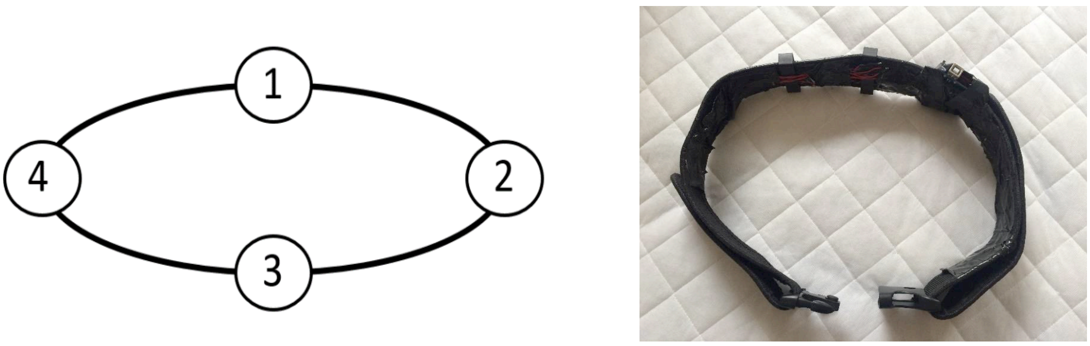

Figure 3: Design of VibroBelt

The system is controlled using an ATmega328P (Arduino Uno), with 10mm disc motor for each tactor. Each motor produces vibrations from a small spring that is attached on an internal mass, and acts as a linear resonant actuator (LRA). Each motor is connected to a Pulse Width Modulation (PWM) port on the Uno. Location is provided by a Sparkfun GPS Logger Shield with an EM-506 GPS module connected to the Arduino Uno. The data obtained from the GPS module are latitude and longitude. These data are used as waypoints to create a route for the experiment.

In this design, there are 4 motors offset by 90 degrees. The reason for using 4 motors rather than 8 or more is partly to keep the design simple (and run the motors from a single processor board). Another reason is because the vibration wave produced when the actuator vibrates is spread in the surrounding belt. This could result in ambiguity if we used more tactors.

Evaluating the design

Initial evaluation was conducted to ensure that the motors were producing detectable output. This involved ten participants wearing the belt and reporting whether they could detect a signal from any of the motors. Some participants needed longer to determine the location of the vibration. This occurred particularly for participants with small waists, which meant that the distance between tactors was smaller. The settings were adjusted so that the signal was detectable but not uncomfortable. A second set of tests (involving the same participant group) was conducted in which one of the motors was kept on constantly and one of the others activated. This was to explore whether a continuous vibration would mask detection of the signal. From this, there was a success rate of 92%. The majority of errors were made by two people. It might be the case that these people had different sensitivity levels, but this was not explored further. However, the overall data showed a promising result.

From both of these experiments, all participants said that the front motor had stronger vibration than other motors. On the other hand, the vibration of the motor in the back felt less intense compared to the front, left, and right actuators. However, all the motors were vibrating at the same frequency, and the reason that the participants felt different intensities of vibrations is because the sensitivity of the human waist is not evenly distributed. We conducted additional tests of the GPS receiver (comparing its readings with a commercial device, the Garmin eTrex10). Comparison of the readings indicated that our GPS unit had an error of around 5 metres. This seemed to be mainly due to drift and deviation in the signal. Applying averaging over 50 readings helped stabilise the signal and reduced the radius to around 2 metres. We felt that this would be sufficient for the intended application.

Tactile navigation experiment

The design of the evaluation was approved by the School of Engineering Ethics committee at University of Birmingham. Given the intention to run experiments with motorcycles and in traffic, care was taken to ensure that the protocol did not require any behaviour that the participants would feel was risky or impaired their usual decision making. Thus, a comparison condition (involving a visual map) was not run in traffic but only on a university campus when there was no other traffic. Tests involving the VibroBelt were conducted on the campus and in traffic. Participants were told to drive to a destination, that the route would be provided as they rode along, that the aim was not to drive as quickly as possible but to drive in a manner that they felt was normal, and that they should make turns when they felt that it was safe to do so.

Participants

This experiment was conducted in Jakarta, Indonesia. Seventeen people who are professional motorbike taxi drivers with a driving license and normal vision participated in this research. All of them owned a smartphone and were familiar with navigating using an online map.

Procedure

The experiment was divided into three parts: the first part is testing navigation using Google Maps, the second test was to navigate using a tactile belt on the same route used in the first test, and the third was to navigate using a tactile belt in real traffic. The first and second experiment were performed in a safe area without any traffic and carried out with a maximum speed of 20km/h. The third test was completed on a road with real traffic with a minimum speed of 30km/h.

In the tactile navigation experiment, each participant was requested to answer eight questions in a questionnaire.

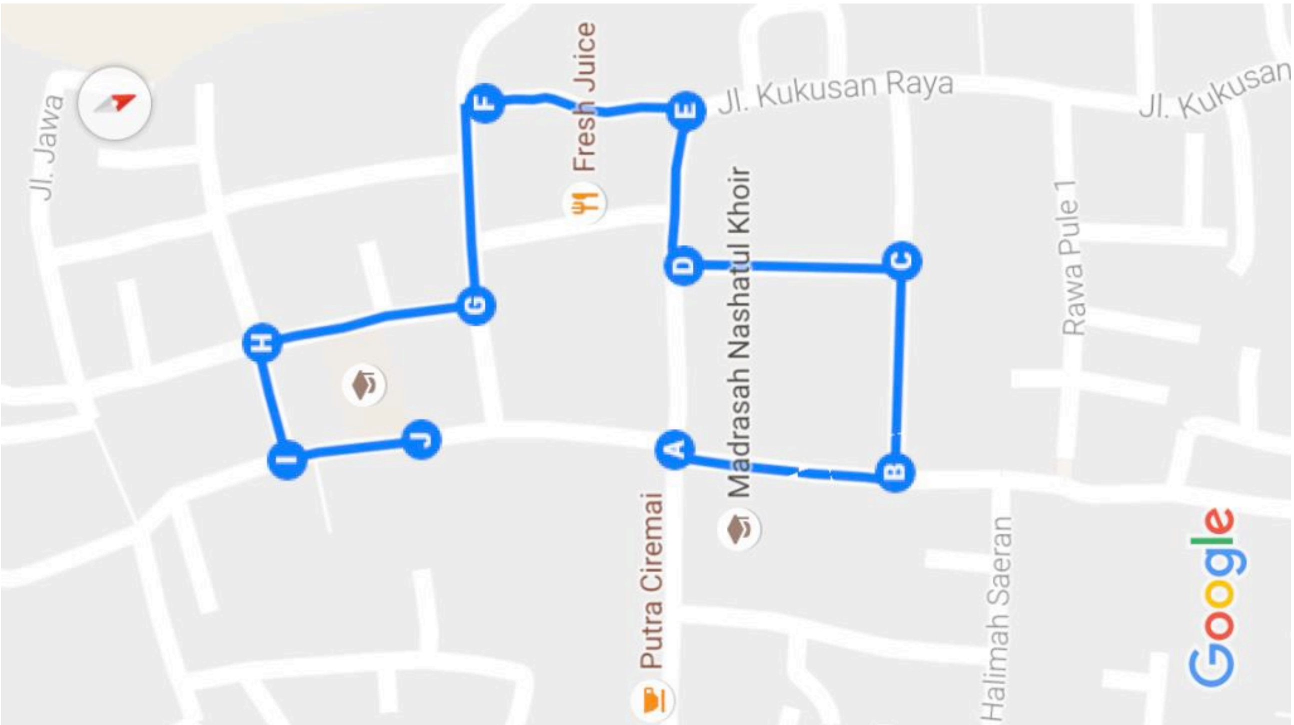

Figure 4: Map of campus route

GoogleMap navigation condition

There are six participants involved in this experiment, and all of them are requested to follow the predetermined path. There is a total of eight turns, and all turns were 90 degrees. Since riding while navigating with the map could be risky, this test was performed by participants who are professional motorbike taxi drivers and who use such maps on a daily basis to navigate in a real traffic. To manage risk, the experiment was conducted in a safe area (on a university campus), free from any vehicles and pedestrians.

VibroBelt condition

The VibroBelt was tested with the same route as the Google Map condition. Another six professional motorbike taxi drivers were requested to wear the VibroBelt and were asked to navigate based on the vibration they sensed from the belt. Before the experiment started, a belt calibration was conducted to ensure the actuator was in the correct position on each participant's waist. All participants were unfamiliar with the route and they were informed to stop when all actuators were vibrating, which indicates that they already reached the destination or endpoint of the track.

VibroBelt Experiment in real traffic

In the third experiment, the VibroBelt was tested on a real road with real traffic. It was decided not to compare this with a map display for two reasons. First, the previous study had already shown that there was little difference between the two systems. Second, we were concerned that the visual distraction that the map could induce could have had an impact on driver safety. The route is shown in Figure 5. There are seven waypoints in this route, shown by the red circles. The front actuator was used when there is a turn near a way point that is not the correct path. The front motor vibrated to guide and gave confirmation to the user to keep moving forward. This is shown as a red rectangle on Figure 5. There were five participants in this experiment and all of them rode their motorbikes at a minimum speed of 30km/h. All of them were not familiar with the route. Similar to the previous condition, a calibration test was conducted before each test began.

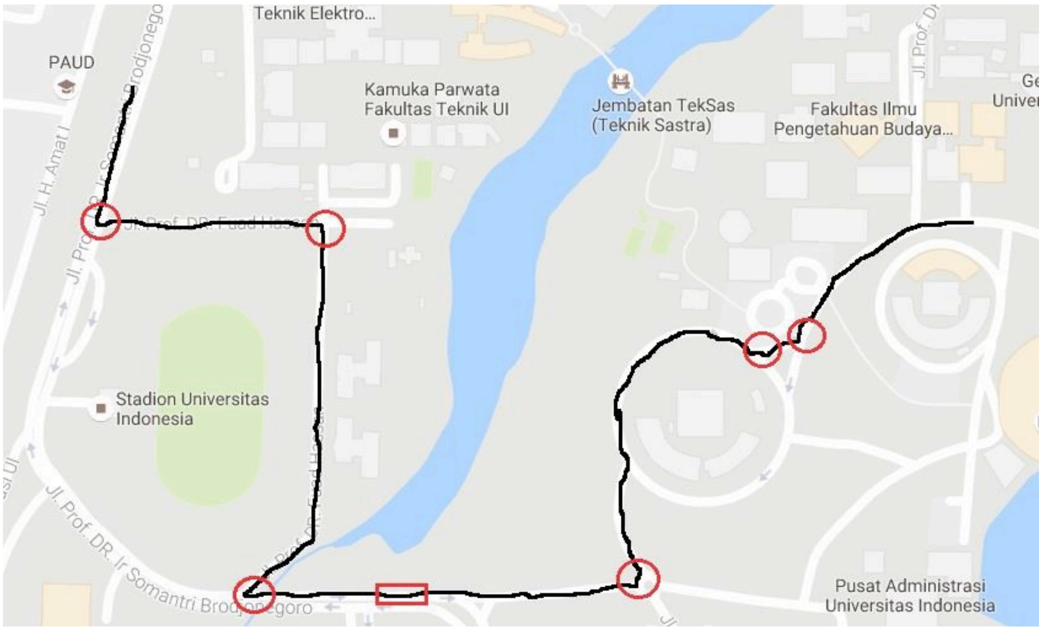

Figure 5: Traffic route

Results

In the map (campus) condition, all participants reached the destination. Although we did not stipulate that time would be recorded, the average time to complete the route was 4.6 minutes. One participant made several errors in turning and corrected these (this person's time was not used to calculate the average).

In the VibroBelt (campus) condition, all participants reached the destination in an average time of 4.9 minutes. Half of the participants failed to make the fifth turn, and this was because the GPS did not seem to be responsive in the presence of several large trees at this location. So, the GPS used for the belt was not as good as that used on the iPhone. However, both map and VibroBelt produced a similar number of correct turns (Figure 6).

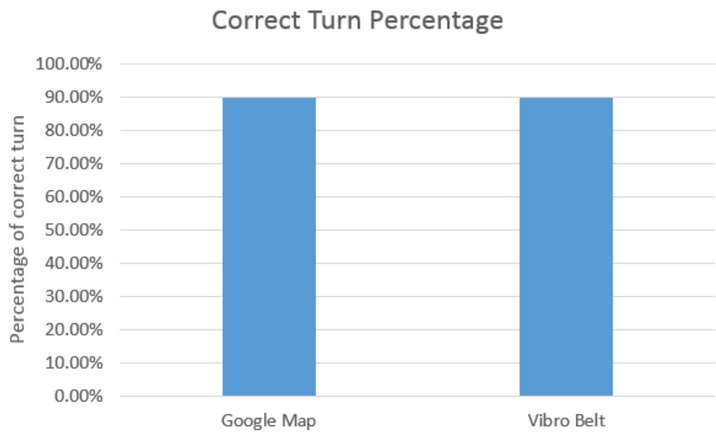

Figure 6: Comparison of correct turns made in the campus route (no traffic)

In the VibroBelt in traffic condition, 94.2% of the total waypoints were successfully recognised. The result showed that all the riders could reach the finish and they could detect the endpoint signal, which is indicated by the vibration of all the motors.

Qualitative Result

Participants were asked how they felt about all of the tasks and the use of the VibroBelt. A summary of comments in presented in Table 1.

Table 1: Summary of Participant Comments (number of participants out of 11 who mentioned this)

#	Statement			
1	Difficulty using visual display of map	Sunlight and glare affects screen (11)	Small screen difficult to read (2)	Other (6)
2	Interacting with map	Navigate while driving (9)	Stop to check route (5)	Audio navigation could be useful (2)
3	VibroBelt use	Easy (9)		Not easy (2)
4	Navigation with VibroBelt	Easy (11)		Not easy (0)
5	Confidence in navigation with VibroBelt	Average rating 7.8 / 10		

The most common problem that the participants experienced while navigating using the map was the glare from sunlight which made it difficult to see the phone screen clearly. Another problem when using the screen was the small size of the phone screen. Provision of tactile cues removed these visual problems, and none of the participants using the VibroBelt mentioned problems perceiving the tactile cues. Participants using the screen also reported problems in seeing the exact location of the destination. Interestingly, this problem was not mentioned when using the VibroBelt, as participants felt more confident because of the clear vibration signal.

In post-trial interviews with all participants, we asked whether they preferred to have route information continuously while riding or whether they preferred to stop and check the route. Around half of them (9 out of 17 participants) said that they preferred to navigate while riding rather than stopping periodically to check the route. We also asked about attitude to the use of audio cues (as in automobile SatNav systems) and only two participants felt that the use of audio navigation could be useful (6 others felt that it would be difficult to hear clearly due to traffic noise, and eight felt that it would be inconvenient to use an earphone while wearing a helmet).

From the feedback about VibroBelt, the overall results are positive. In terms of user interface and experience of using a new technology, 9 out of 11 people agreed that the VibroBelt was easy to use. In fact, they all agreed that this way of navigating helped them navigate an unfamiliar route. The vibration signal given by the belt was clear and easy to identify. In terms of confidence using VibroBelt for navigation, participants gave an average rating of 7.8 points out of 10.

Discussion

The trials conducted in the first study compared the performance of motorcyclists navigating using Google Maps and VibroBelt on a traffic-free campus. The results showed that the systems produced similar performance. The GPS in VibroBelt was less accurate than that used in the smartphone and this caused errors during the experiment. For users with the map, the visual display allowed the user to see the route even when the GPS was lost.

In terms of completion time, there was no difference in time. However, using the map required visual attention that made riders take their eyes off the road. In the experiment, participants in the map condition would look at the smartphone at least 8 times while riding the motorbike to make sure of the route and when they should turn. This means that in real traffic, motorcyclists could be distracted by the map. The VibroBelt does not make any visual demands. There were occasions when participants looked at the speedometer and the surrounding environment while the trial was conducted, but it did not divide their visual attention in the same way that the map navigation required. Furthermore, when the VibroBelt was tested on a road with real traffic, participants agreed that it enabled them to observe the traffic more. In terms of safety, the VibroBelt is a solution for a much more secure way of navigating with a motorbike. Tactile navigation is a promising technology to help improve the way people navigate while driving a motorbike. In the future, the VibroBelt could be integrated with a map interface to give a better performance to the user. Since different people have different sensitivities in their waists, an adjustable vibration frequency will also be a future feature where users could set the intensity of the vibration they want.

References

Aaltonen, I. and Laarni, J. (2017) Field evaluation of a wearable multimodal soldier navigation system, *Applied Ergonomics,* 63*,* 79-90

Bengler, K., Dietmayer, K., Farber, B., Maurer, M., Stiller, C. and Winner, H. (2014) Three decades of driver assistance systems: Review and future perspectives. *IEEE Intelligent Transportation Systems Magazine*, 6, 6-22

Cao, Y., Mahr, A., Castronovo, S., Theune, M., Stahl, C. and Muller, C. (2010) Local danger warnings for drivers: the effect of modality and level of assistance on driver reaction, *Proceedings of the 14th International Conference on Intelligent User Interface*, 239-248

Eriksson, L., Berglund, A., Willen, B., Svensson, J., Petterstedt, M., Carlander, O., Lindahl, B. and Allerbo, G. (2008) On visual, vibrotactile, ands 3D audio directional cues for dismounted soldier waypoint navigation, HFES 2006, 1282-1286

Gallace, A., Zeeden, S., Roder¨, B., and Spence, C. (2010) Lost in the move? secondary task performance impairs tactile change detection on the body. *Consciousness and cognition*

Poppinga, B., Pielot, M., and Boll, S. (2009) Tacticycle: a tactile display for supporting tourists on a bicycle trip. In *MobileHCI*

Redden, E. S. (2006). Findings of a multi-year investigation of tactile and multi-modal displays. In *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting* (pp. 1697-

1700). Santa Monica, CA: Human Factors and Ergonomics Society - better performance with tactile in forest at night…

Steltenpohl, H., and Bouwer, A. (2013) Vibrobelt: tactile navigation support for cyclists. IUI

Streefkerk, J.W., Vos, W., Smets, N. (2012) Evaluating a multimodal interface for firefighting rescue tasks. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, pp. 277e281 (Streefkerk et al., 2012) Firefighters' 75% of users preferred the tested system over the baseline. The users commented on information overload, and the interface presented inaccurate or irrelevant information for the task

Van Erp, J.B.F. (2005). Presenting Directions with a Vibro- Tactile Torso Display. *Ergonomics,* 48, 302-313

Van Erp, J.B.F. & Van Veen, H.A.H.C. (2004). Vibrotactile in vehicle navigation system. *Transportation Research part F: Human Factors,* 7, 247-256

Van Erp, J.B.F., Van Veen, H.A.H.C., Jansen, C. & Dobbins, T. (2005). Waypoint Navigation with a Vibrotactile Waist Belt. *Transactions on Applied Perception,* 2 (2), 106-117

Van Erp, J.B.F. and Werkhoven, P. (2006) Validation of principles for tactile navigation display, HFES 2006, 1687-1691