Smart Flashlight: Navigation Support for Cyclists

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Abstract. The number of people commuting by bicycle is constantly increasing, while the ways of navigation for riders have potential safety hazards for they tend to separate the rider from physical environment. We note that safety remains a challenge, as interaction with a device in traffic will generally be less safe than passive, stationary use. For navigation using a map while cycling in an urban environment, we studied an solution: An arrow shaped beam would be projected on the ground in front of the rider and the direction the arrow points at shows the turning direction. (Figure 1). In addition to the conceptual description, we did a user testing, and results showed that the system we designed is much safer, helpful and which kept attention on the route. Every participant was able to reach an unknown destination within an unexplored environment easily. Our findings will be a good reference for designing navigation systems for bikes and even for cars, helping cyclists and drivers be more attentive to their environment while navigating.

Keywords: Projection technique · Bicycle traffic safety · Navigation support

1 Introduction

According to a recent report from the American National Highway Traffic Safety Administration (NHTSA) [1], 17% of reported car crashes are caused by some sort of driver distraction. Navigation systems are among the devices that cause these distractions, and one solution is to apply holographic projection technique to its design. And as a result of advocating a healthy lifestyle and reducing automobile exhaust emission, the number of people commuting by bicycle is constantly increasing.

In addition to, the process of riding requiring a certain amount of concentration, the rider also has to pay attention to the environment, making further actions potentially dangerous. Despite this, the ways we acquire navigation information, especially when maneuvering in transportation modes, are not convenient enough. One suggestion in improvement is through a voice guided system, that needs us to hear out a string of information including the name of the up-coming roads, the distance to them, and the directions to turn. However, information delivered like this could be a cognition burden, especially in busy periods or in a noisy environment. A more simpler suggestion was that one could simply check the route information on the phone whilst stopped at a crossroad, however yet again, the method poses potential safety hazards, as they tend to separate the rider from the physical environment. Thus, a third suggestion is proposed,

A. Marcus and W. Wang (Eds.): DUXU 2018, LNCS 10920, pp. 406–414, 2018.
https://doi.org/10.1007/978-3-319-91806-8_31

what if the environment could instead become a responsive part of the information domain?

Fig. 1. Directions shown by smart flashlight

The prototype we will discuss in the following paper is one demonstration of the idea above. This prototype is designed with bicycle riding in the evening in mind. We have only utalized direction arrows from the map instead of the whole map as we could simplify rider's cognition. We then have the arrows projected on to the ground, and would change according to the navigation app. Since we are supposed to wear use lights on our bikes when we are riding in the evening to ensure safety, this prototype should not be deemed as an extra burden for the riders. With our suggestion, we have conducted some user surveys and investigations to testify some parameters refer to the prototype.

2 Related Work

2.1 Bicycle Dynamic

Bicycles and motorcycles are single track vehicles and the stability of them is related to their self-stability and human-bicycle system. This self-stability is generated by a combination of several effects that depend on the geometry, mass distribution and forward speed, and the human-bicycle system refers to remaining upright whilst riding - the rider must lean forward in order to maintain balance. This forward/backwards lean is usually produced by momentary steering in the opposite direction, called counter steering. Counter steering skills are usually acquired by motor learning and executed via procedural memory. [2–4] In brief, cycling is one sport that needs constant concentration, and, since mobile devices are worn and used at almost all times, designing for interaction in motion is necessary.

2.2 Visual Angle

Similar to the research of Kaufmann and Ahlström [3], our study focused on comparing map navigation using a smart-phone versus a portable projector. However, in our study, we evaluated two alternative display types for map navigation during cycling and factors affecting this task. One such visual-spatial factor was eye-to-digital information distance (EI), which can be understood as the radius of a circle whose center is the cyclist's face and ends at the phone view or the projected view. In our study, the navigation information was either visible at an arm's length from the eyes of the cyclist or on the ground in front of the them. Besides EI, another factor is normal-view-to-digital information distance (NVI). There is thus a distance between the normal view and the information displayed by the mobile and by the projection. For the rider, the normal view is ahead, towards the road. The normal view is characterized by the field of view (FOV) and the line of sight directed ahead. If digital information is presented outside of the FOV, the rider's head is required to move towards that information.

2.3 Prior Experiment

For in-vehicle systems such as radios and navigation systems, design recommendations have been made by the American National Highway Traffic Safety Administration (NHTSA 2010) and by the European Human Machine Interface Task Force (Godthelp et al. 1998). According to these guidelines, primary task performance (i.e. driving), should not be impaired by the secondary task. While operating a navigation system, the driver has to be able to steer his car with at least one hand, have the ability to interrupt the navigation task at any time, have clear view of the dis-play, and the driver's main focus should be on the road. As display design and driver's focal point are inherently related, these two recommendations have been tested as a separate entity in automobiles (Broström et al. 2016). A similar system to the one demonstrated here used a bike-mounted projector as an augmented headlight to display speedometer data1. Findings from exploratory bike trips using handlebar-mounted smartphones reported that map navigation is possible while cycling. It was reported that by not offering turn-by-turn navigation, the bike rider could be more aware of the environment, but most cyclists had to stop to read the map anyway, "since they found it too small" [5]. In a stationary indoor study involving memorizing locations on a map, smartphone displays were compared with handheld projectors. For that task and context, spatial memory improved 41% when using projectors [5]. We note that safety remains a challenge, as interaction with a device in traffic will generally be less safe than passive, stationary use.

Automotive ergonomics state humans are comfortable with eye movements of 15° above or below the line of sight, and can easily tilt their heads 30° upward or downward [6]. These fields of view parameters are relevant to the. Research on car driver attention and behaviour revealed how map system configuration (audio, visual, or audio-visual) inside a car influences eye glance frequency [7].

2.4 Similar Products

Actually, the design for riding navigation, has many excellent results to give us some thoughts. For example, this Heilos Bars smart handlebar (Figs. 2, 3). You can see in the picture that the LED lights used for navigation are flashing at the two ends of the handle to indicate the direction, and the colour of the lamp can change with the speed. There is also an LED lamp in the front for lighting the road. This product is not yet on the market, so we are looking forward to its reflection. However, this way to get information is not the way we are familiar with. That's why we would like to use the indication arrows that are consistent with the navigation app.

Fig. 2. Heilos Bars smart handlebar (Color figure online)

Fig. 3. Heilos Bars smart handlebar (Color figure online)

3 Prototype Design

To turn our prototype into a real product, the problem of the openness of map software resources would be encountered, but the good news is that these resources are gradually opening up in recent years. For example, Baidu Android navigation SDK provides a simple and easy-to-use navigation service interface for Android mobile terminal applications. As a result, developers can easily achieve accurate navigation function for applications.

So here, we have designed a simulation experiment. The materials of the experiment are the Arduino uno board, the servo motor, the Bluetooth module, a flashlight, and the shading plate printed by the 3D. We send signals through the Bluetooth to the Arduino board. Through the compiled program, the servo motor will control the shading plate to rotate to the corresponding angle according to the signal, so that the arrow shaped beam emitted by the flashlight through the shading plate will point to the right turning direction at the right time (Fig. 4).

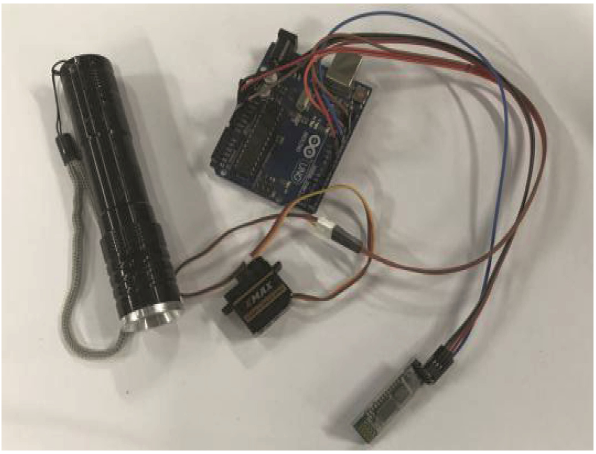

Fig. 4. Prototype

4 Experiment

The international standard ISO 9241 defines product availability as follows: "specific users when use a product for a specific target under the specific use scene feel the effectiveness, efficiency and satisfaction." [8] Effectiveness means that users can reach their target. Efficiency means that users have no need to do idle work to achieve a goal on the shortest path. Satisfaction means that there is no big problem in effectiveness and efficiency. Also, it should be considered from the deeper levels. It doesn't bring the unpleasant experience to users.

Only to conform to the definition of ISO 9241 and satisfy the above-mentioned three elements can it realize the product availability. In measuring problem seriousness, the effectiveness problem should be firstly solved. Then, under the situation of allowable time and costs, efficiency and satisfaction should be solved as much as possible. This time, we tested the product availability and we used the product prototype for design.

Availability testing and in-depth interview are used as our testing method.

4.1 Participators

We recruited 7 participators in the campus (4 men and 3 women). The mean age of 7 participators was between 20 years old and 45 years old. The mean age was 29.1 years old. Three of them are professors and the rest are all college students.

4.2 Props

We select a common bicycle as the experimental bicycle. We put the product prototype on the flashlight support. The experimental route was constructed by Map application program. The flashlight would display the route information on the ground, shown in

Figs. 5, 6. The arrow shaped beam emitted by the flashlight through the shading plate will point to the right turning direction at the right time.

Fig. 5. Forward sign

Fig. 6. Left sign

4.3 Assignment

The experimental time was arranged in the evening. Volunteers who were invited were required to arrive in another unknown place that they haven't been there before from a place. Volunteers must arrive at the assigned destination in line with the route direction provided by the product prototype on the bicycle. Before the experiment, we would show the rough position of the destination on the Map app first, but the specific direction and riding route should be pointed out by the product prototype during the riding. In the route selection, we designed a 1.6 km route, which includes 7 corners.

For safety reasons, we selected a route inside the university to do the experiment. Before starting a task, users could adjust the angle of the flashlight. When volunteers rode a bicycle, they received the navigation instruction to arrive at the destination as riding a bicycle, hoping that they will realize their surroundings and use their visual spatial function, instead of blindly following up with orders. Thereafter, they were asked to complete a questionnaire and we subsequently conducted an interview, taking into account their questionnaire answers. We used the collected data for an informal assessment of our prototype to incrementally adjust the system and the experiment.

The experiment also had two recorders. One person should observe the testing task when users operated a product and recorded information on the experimental process (distance, time and speed). Another one is supposed to perform an in-depth interview.

4.4 Measures and Analyses

Effectiveness. Measurement of task completion: we marked operational result of each volunteer as failure, partial completion or all completions. In the route, including 7 corners in 1.6 km, the success rate of volunteers completing the turning operation in each corner was calculated.

Efficiency. Efficiency could be measured by time. We started to time when volunteers took the task card and finished timing when volunteers announced that we have already completed it. As calculating the efficiency of each task, we used users' mean timing divide by times of common users' skillful riding. The larger numerical value is, the lower efficiency will be.

Satisfaction. The satisfaction gets involved in the users' subjective evaluation, thus it should be collected through users' self-evaluation scale. Here, we referred to the single-item seven-point user experience measurement scale used by Jakob Nielsen [11]. [9] The project took eight component scales (shown in Fig. 7), such as "complicated—simple" and "traditional—novel", which belong to 7-score system. Top four projects stand for the practical product quality scale, and the last four projects represent the enjoying quality scale. In the end, volunteers were asked their favorite one in the riding navigation equipment used in the process, as well as whether our product concept could help them a lot.

obstructive	o o o o o o o	supportive
complicated	o o o o o o o	easy
inefficient	o o o o o o o	efficient
confusing	o o o o o o o	clear
boring	o o o o o o o	exiting
not interesting	o o o o o o o	interesting
conventional	o o o o o o o	inventive
usual	o o o o o o o	leading edge

Fig. 7. User experience questionnaire [11]

5 Results

5.1 Effectiveness

Experimental results indicated that 7 volunteers could complete the task, but 2 of them slightly paused in the experimental process at one complex intersection. They stopped a little while because they were not sure of the direction which they need to turn to.

We also tried to use the flashlight under different environments to check the directional readability of display. Only when there are vehicles with high beams passing by, our navigation system would fail to be distinct on the ground.

5.2 Efficiency

We started to time from riding from start to finish of the task for volunteers. Baidu navigation app showed it takes 7 min to finish the task on average. Through the navigation system, 7 respondents completed a task for 5.8 min averagely, which was much faster than the app suggested. The experiment indicated the flashlight projection scheme had the higher efficiency for traditional users who directly used a mobile phone. In interviewing users who used a mobile phone for navigation in the past, majorities of them indicated that they had to stop their bicycle to check the mobile phone map, because they couldn't ride while operating a mobile phone. Stopping to operate a mobile phone could reduce their riding efficiency and is also quite dangerous. The navigation form of the flashlight projection could make them pay more attention to the surroundings, thus they could greatly use their visual spatial function and improve the overall riding efficiency.

5.3 Satisfaction

On a whole, user experience questionnaire and interview results indicated that, comparing to the existing form of navigation, our new scheme was more attractive, stimulating, high-efficient and novel. (Table 1) All volunteers could arrive in the destination in line with the direction projected by flashlight. In addition they also showed that this design could make them pay more attention to surrounding environment. Users had the higher satisfaction for our flashlight navigation system.

Table 1. User experience questionnaire [11]

	Pragmatic quality				Hedonic quality			
	Supportive	Easy	Efficient	Clear	Exiting	Interesting	Inventive	Leading edge
Mean	2.3	1.0	2.3	2.6	2.1	2.0	2.4	2.3
Variance	0.6	2.3	0.2	0.3	0.5	0.7	0.6	0.9

Notes: For the user experience scales average values per scale are shown. All scales have a range from −3 to +3.

5.4 Improvement

Some volunteers suggested that our navigation system could be made as a part of the bicycle, instead of an extra flashlight installed on the bicycle. In this way, it can reduce users' trouble in carrying the flashlight when going out. They also noted that in addition to the direction, more road information should be added, such as danger and the sketch of a complex intersection to show more clearly of the exact road we should turn on.

6 Conclusion and Future Work

In this paper, we have discussed a navigation system that improves the traditional navigation scheme, and have tested it. The prototype might be insufficiently elaborated, however the testing results were unexpectedly satisfactory. All testers indicated that this was a very effective navigation mode. In future research, a larger focus on artificial engineering study will be added, such as the relationship between bright degree and identification of projection lamps, placement angle of projection lamps and projection information contents, and so on. At present, holographic laser projections have already been used for the brand-new navigation mode of automobile design. This might be similar to the prototype that we discussed. It is therefore possible to realize safer navigation modes through the vehicle design like bicycles.

References

1. National Highway Traffic Safety Administration, Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices, Notice of proposed Federal guidelines, 77 FR 11199, pp. 11199–11250 (2012). https://federalregister.gov/a/2012-4017. Accessed 11 Aug 2012
2. Kooijman, J.D.G., Meijaard, J.P., Papadopoulos, J.M., Ruina, A., Schwab, A.L.: A bicycle can be self-stable without gyroscopic or caster effects. Science **332**(6027), 339–342 (2011). https://doi.org/10.1126/science.1201959. Bibcode:2011Sci…332.339 K
3. Meijaard, J.P., Papadopoulos, J.M., Ruina, A., Schwab, A.L.: Linearized dynamics equations for the balance and steer of a bicycle: a benchmark and review. Proc. R. Soc. A **463**(2084), 1955–1982 (2007). https://doi.org/10.1098/rspa.2007.1857. Bibcode:2007RSPSA.463.1955 M
4. Sharp, R.S.: Motorcycle steering control by road preview. J. Dyn. Syst. Meas. Control. ASME. **129**(1), 373–381 (2007). https://doi.org/10.1115/1.2745842
5. Jensen, B.S., Skov, M.B., Thiruravichandran, N.: Studying driver attention and behaviour for three configurations of GPS navigation in real traffic driving. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2010, pp. 1271–1280. ACM, New York (2010)
6. Dancu, A., Franjcic, Z., Fjeld, M.: Smart flashlight: map navigation using a bike-mounted projector. In: SIGCHI Conference on Human Factors in Computing Systems, pp. 3627–3630. ACM (2014)
7. Kaufmann, B., Ahlström, D.: Studying spatial memory and map navigation performance on projector phones with peephole interaction. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2013, pp. 3173–3176. ACM, New York (2013)
8. Peacock, B., Karwowski, W.: Automotive Ergonomics. Taylor & Francis, London (1993)
9. Jensen, B.S., Skov, M.B., Thiruravichandran, N.: Studying driver attention and behaviour for three configurations of GPS navigation in real traffic driving. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2010, pp. 1271–1280. ACM, New York (2010)
10. Gediga, G., Hamborg, K.-C., Düntsch, I.: The IsoMetrics usability inventory: an operationalization of ISO 9241-10 supporting summative and formative evaluation of software systems. Behav. Inf. Technol. **18**(3), 151–164 (1999)
11. Schrepp, M., Hinderks, A., Thomaschewski, J.: Applying the user experience questionnaire (UEQ) in different evaluation scenarios. In: Marcus, A. (ed.) DUXU 2014 Part I. LNCS, vol. 8517, pp. 383–392. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-07668-3_37