Tacticycle: Supporting Exploratory Bicycle Trips

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ABSTRACT
Going on excursions to explore unfamiliar environments by bike is a popular activity in many places in this world. To investigate the nature of exploratory bicycle trips, we studied tourists on their excursions on a famous vacation island. We found that existing navigation systems are either not helpful or discourage exploration. We therefore propose Tacticycle, a conceptual prototype of a user interface for a bicycle navigation system. Relying on a minimal set of navigation cues, it helps staying oriented while supporting spontaneous navigation and exploration at the same time. In cooperation with a bike rental, we rented the Tacticycle prototype to tourists who took it on their actual excursions. The results show that they always felt oriented and encouraged to playfully explore the island, providing a rich, yet relaxed travel experience. On the basis of these findings, we argue that exploratory trips can be very well supported by providing minimal navigation cues only.

ACM Classification Keywords
H.5.2 User Interfaces: Haptic I/O

Author Keywords
Handheld Devices and Mobile Computing; Tactile & Haptic UIs; Navigation Systems; Cycling; Exploration; Tourists

INTRODUCTION
Bicycling is a famous vacation activity in many Europe. Individuals, families, and groups often use their bicycle to explore their vacation environment as recreational activity. In this scenario, reaching a specific place is much less important compared to e.g. the daily commute to work. Although one typically choses a destination a little deviation from the route here and there is not a problem. In fact, these deviations can be a vital part of the excursion, as they promote serendipitous discoveries.

However, the fear of getting lost can harm this experience. With the advent of portable navigation systems, it seems that the problem is solved: we just enter the address of the destination and turn-by-turn navigation instructions will guide us there. The problem is that turn-by-turn instructions are known to disengage users from the environment [6] and lead to a significantly worse understanding of the environment [1]. Also, these systems guide travelers along the shortest or fastest route, missing out all the beautiful alternatives that might lie left and right of the optimal path—the opposite of what comprises an interesting and engaging excursion.

Figure 1. Our prototype: a smartphone attached to the handle bar provides the visual feedback. The yellow fabrics wrapped around the handles house the vibration motors.

We set out to explore alternative ways of navigation support for tourists on bicycle trips. Following the philosophy of user centered-design, we initially investigated the nature of exploratory bicycle trips by studying tourists on the island of *Borkum*. We found that these tourists often exhibit a rather errant and spontaneous form of navigation. While they often specify an area as destination, they not always reach it – which is not considered a big problem – and often loose orientation during their trips.

On the basis of our findings, we propose Tacticycle, a prototype of a navigation system that provides a minimal set of navigation information only. On a map, we highlight the available points of interest (POIs), so travelers can quickly browse potential travel destinations. When the user selects a POI as travel destination, the Tacticycle does not provide turn-by-turn instructions. Instead, it conveys the POI's general direction "as the crow flies". To not distract users from the environment, the direction is presented via vibration motors attached to the bicycle's handle bar. The relative intensity of the vibration is used to cue the direction in relation to the bicycle's heading. In addition, vibration is used to notify the user about nearby POIs to encourage spontaneous exploration and deviation from the planned route.

On the island of *Borkum*, we rented the prototype to tourists for their actual excursions. We used GPS tracking, experience sampling (ESM), the SenseCam, and post-hoc interviews to collect data, and found mixed results. While the Tacticycle helped the tourists to remain oriented, some of them initially struggled with the idea of not receiving turn-by-turn instructions. Others, who embraced the paradigm change, highly appreciated the freedom to shape their trip, as they like.

RELATED WORK

Today, navigation support is usually provided in the form of turn-by-turn instructions, such as "In fifty meters turn left into Old Street". While this has proven to be successful in practice in cars, a number of studies highlight the disadvantages of this approach. For example, when people describe routes they rarely use distances and street names. They rather tie their navigation instruction to landmarks, such as "turn left at the shop with the huge red neon sign." [8, 11]. People also are less engaged with the environment [6] and develop less spatial knowledge about it [1]. As a countermeasure Leshed et al. [6] propose i. a. to introduce ambiguity into the navigation instructions to "provoke independent assessment". One solution to navigate by ambiguous information has been around for about a decade: instead of providing instructions on each turn only the general direction of the destination is presented "as the crow flies". This means, on each turn the navigator has to make her own decision about which path might lead to the destination.

On the basis of the observation of tourists who navigated with a map, Brown and Laurier [3] found that tourists tend to "*head in a 'roughly correct' direction, rather than along a specific route.*" They conclude that "*map use involves activities that are not goal-oriented [...] we must be careful to hold on to the image of wandering tourists rather than the lone optimizing tourist*".

Allowing people to freely explore the environment has been proposed to address this issue. Hornecker et al. [5] proposed the Serendipity City Guide, location-based service that provides proximity alerts tourists to make its users aware of nearby POIs. Rider Spoke by Rowland et al. [12] went even one step further. Riders were allowed to freely explore the city and encouraged to record their thoughts about locations they went by. At the same time, riders could listen to previous recordings, which contributed to intensive experiences. Nevertheless, Rowland et al. also found that more than half of the participants lost their orientation at some point. As a consequence, many participants stayed close to "close to home".

This finding suggests that navigation support is still required to support serendipitous exploration. On the basis of Brown's and Laurier's observation that tourists *head in a 'roughly correct' direction*, we believe that cueing the general direction of a travel destination or an orientation landmark is therefore a viable approach. However, unlike turn-by-turn instructions, a general direction has to be available at all time, so navigators can orient themselves at all times. The challenge in implementing this paradigm into a user interface is to avoid distracting the user, e.g. by requiring her to frequently check the display of a handheld device, as this may be considered contradictory to the idea of enjoying a touristic trip.

In previous work, several ways of presenting general directions non-visually have been proposed already. Holland et al. [4] proposed AudioGPS, an auditory user interface that using the panning of an audio signal to encode general directions. In this approach the direction of the sound's panning corresponds to the direction of the destination. The system was found effective in pilot field trials, but due to its rather "sluggish" reaction times (according to the authors) no claims were made about its usability. Strachan et al. [14] investigated a more advanced version of that approach and showed that it enables users to reach "virtual" destinations only by following the panning of the auditory cue. Only recently, Zwindermann et al. [18] showed that this approach also works for cyclists in a city.

However, in a touristic scenario listening the environment, such as singing birds or ocean waves rolling on the shore, may be an integral part of the experience. Also, as observed in [5], auditory notifications may become inaudible in a noisy environment. The sense of touch offers a viable alternative for the information presentation in such situations. As long as the tactile stimuli do not become obtrusive they won't supposedly interfere with the experience of the trip.

An intuitive way of providing general directions with tactile displays is exciting locations around the torso with vibrotactile stimuli [13]. This can done with the help of tactile belts, such as the ActiveBelt [15]. Vibration motors are sewn into flexible fabrics and equally distribute them around the torso. Activating a motor e.g. at the navel is intuitively considered as pointing forward. Van Erp et al. [16] have shown that this kind of information presentation can be used to guide users along a set of waypoints by always pointing into the direction of the next waypoint.

With the increasing prevalence of orientation sensors in Smartphone, researchers have investigated using pointing gestures to convey navigation information [7, 10, 17], such as the location of a travel destination. When the pointing device, e.g. a mobile phone, points into the direction of the travel destination it vibrates. This technique has been found to enable pedestrians to effectively reach the cued location.

Yet, neither a belt nor pointing gestures might be suitable for cycling. The belt needs to be attached and worn all the time, which might be considered disrupting the experience. Pointing gestures can be dangerous to perform on the bicycle and should therefore not be encourage. In our previous work [9], we therefore proposed integrating the tactile display into the handle bars of the bicycle, so it is automatically available when users are riding, but the tourists do not have to worry about an external display. Following a similar approach, Bial et al. [2] have investigated providing turn-by-turn instructions via tactile displays integrated into the gloves of a motorcy-

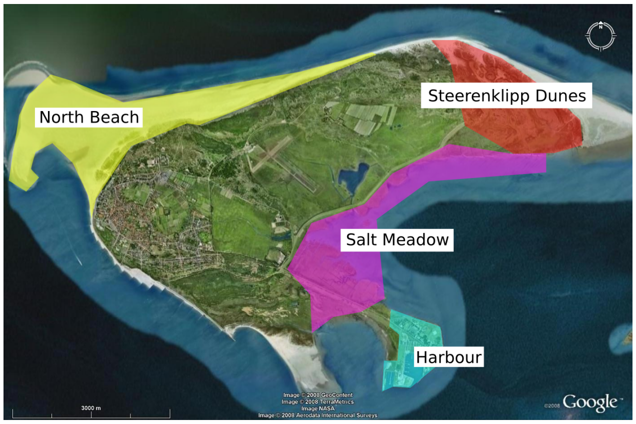


Figure 2. Popular areas that were named by informants of the survey as destinations for their trips.

clist. They found that the tactile signals can be recognized most of the time (87.4%) under real driving conditions.

What is currently missing is evidence that the concept of cueing general directions as orientation cues for serendipitous exploration is helpful for actual tourists. We will advance related work by investigating this concept in-situ with tourists on vacation on their bicycle trips.

ANALYSIS OF EXPLORATORY BICYCLE TRIPS

Following a user centered design approach, we initially conducted user studies to understand tourists on bicycle trips. In this section, we report our findings from these studies. We argue that tourists exploring confined areas, such as an island, are not well supported by predominant forms of navigation aids.

The studies took place at the island of *Borkum*. *Borkum* has about 5300 inhabitants, is about $30km^2$ wide, and has lots of visitor attractions to offer. Typical tourists are families with small children and people with chronic respiratory diseases, who are patients in one of the numerous clinics. Due to the size and the infrastructure of the island, it is very well suited for exploring it by bicycle.

We approached the requirements analysis from two angles. First, we assessed how tourists plan and conduct their bicycle trips through a survey. Second, we shadowed tourist on their trips to learn about the context of use.

Survey

For the survey, a local bicycle renter agreed to issue a questionnaire to tourists renting a bicycle. The tourists were asked to return it together with the bicycle. The questionnaire was split into three sections: the first section asked the tourists about their plans regarding the bicycle trip; the second section focused on the experiences during the planned trip; the third section gathered relevant demographic details.

Ten people completed and returned questionnaire. These people were either tourists or patients of one of the clinics. All of them had stayed at least two weeks on the island. Eight of these informants reported that they used a navigation aid on their trip. These were mostly paper maps and public overview maps. None of the participants used electronic navigation aids. Although eight informants had reported that their excursion had a concrete destination, only five of them stated that they had actually reached that destination. One informant summed it up as: *That's no problem, I am on vacation.* The destinations often described larger areas rather than landmarks, places, or points of interest. The most popular destinations of the area of the study are marked in Figure 2. Seven informants stated that they had lost orientation at least once during the trip. Nevertheless, they still expressed that they found the navigation aids they used to be helpful.

Field Observation

In order to complement the findings from the survey, we additionally shadowed tourists during their actual trips. We randomly picked tourists and more or less secretly shadowed them. We did not attract attention, since, around the time the study took place, the island was full of other cyclists. The tourists were mostly only observed for a part of their route and only in public places. Once they left public space, e.g. when having a break at a cafe, we discontinued the observation for ethical reasons. Findings were noted directly after the observation from the observer's memory. No personally identifiable information was recorded.

Six groups and four single travelers were observed during the study. Eight of them never used any navigation aid; two used a map. In order to read the map they all stopped. Route choices often seemed intuitive and spontaneous. Sometimes they were heavily discussed within the group. At other times, it did not seem to be much of a deal, which route was actually taken. One family, for example, turned around three times during the observation. They appeared to make those decisions based on how much they liked the environment. Overhearing conversations between the members of these groups, we discovered that sometimes there were no definite destinations for the trips, or that the destination was changed during the trip. People seemed to decide spontaneously to stop at a visitor's attraction or at restaurants.

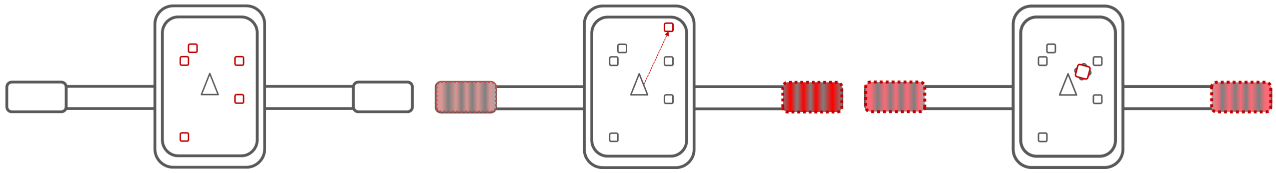
Findings

Map is most prevalent navigation aid

In the survey, eight of ten informants reported to have brought a map. When we shadowed tourists, however, maps were used two times only. The use of other navigation aids was neither reported nor observed. Therefore, we conclude that for our sample maps are the most used navigation aid, though they are not used a lot. The inconvenience of having to stop in order to read the map might be one of the reasons for that.

Loss of orientation occurs frequently

Seven of ten survey participants reported to have lost orientation at least once. During the field observation at least five tourists/groups appeared to have lost orientation, as they stopped for a longer time, turned around, or mentioned this in discussions amongst each other. These results indicate that on *Borkum* loosing one's orientation is a frequent issue for tourists on bicycle trips.



(a) Spontaneous navigation is supported by showing potential travel destinations (POIs) all the time on the display.

(b) Orientation support is provided by cueing the general direction of a POI through directional tactile vibration of the handlebar, here on the right side.

(c) Exploration and spontaneous navigation is supported by highlighting the presence of POIs nearby through visual and tactile alerts on both sides of the handlebar.

Figure 3. Illustration of the three main design concepts.

Reaching the destination is not mandatory

While eight of ten survey participants specified a destination for their trip, only five actually reached that place during their trip. Additionally, most destinations were not specific places but larger areas. From the observed tourists only three of ten seemed to have a specific destination. Therefore, reaching specific places does not seem to be a high priority for tourists. It also shows that those tourists were willing to alter their plans spontaneously.

Spontaneous navigation prevails

The observation showed that if people were uncertain at decision points, they often spontaneously decided how to proceed. From the survey we learned that it did not matter too much if a destination was not reached. We believe that happens because of the relaxed mood people have during their holidays.

TACTICYCLE DESIGN

Our requirements studies showed that tourists on bicycle trips on the island of *Borkum* in general use - if any navigation aid - maps, frequently lose their orientation, navigate spontaneously, and do not consider it crucial to reach their destination if any is specified. In this section we argue that neither maps nor turn-by-turn navigation systems are suited to support the serendipitous, exploratory nature of these trips. On the basis of these findings we propose the Tacticycle, an electronic navigation system for bicycles that focuses on supporting exploratory trips.

Design Implications from Requirements Analysis

From the requirements analysis we learned that efficiency is not a primary requirement for navigation systems for tourists. Rather than guiding the traveler from A to B as fast as possible, a navigation system for cyclists on *Borkum* should have the following properties:

Support spontaneous trips

Trips are rarely planned in advanced. Instead, travelers typically keep heading in the direction of a certain area or point-of-interest, and reaching this place is not always mandatory. Hence, the system should provide the possibility to quickly browse and select alternative travel destinations. To encourage spontaneous exploration, the system should also make the user aware of interesting sights nearby.

Provide orientation support

We also found that the majority of the travelers had lost orientation at least once during their trips. Although this was not considered critical, we believe that a loss of orientation is rather a stressful experience than a positive one. However, providing turn-by-turn direction might contrast the idea of an engaging trip [1, 6]. Instead the system should try to prevent the user from feeling lost in the first place, e.g. by providing the user with simple orientation hints, such as cardinal directions or the directions of relevant landmarks. This approach allows users to keep exploring and to choose whatever route they like without getting lost.

Be simple and easy to learn

In an environment such as *Borkum*, not all of the potential users of the Tacticycle are experienced with technology. Therefore, the system should be kept simple and easy to learn.

Do not require to constantly check a screen

As the observed tourists rarely checked the maps, we assume that the system should not rely too much on visual information presentation. If e.g. a visual display is used it should not require the user to frequently have a look at it. This is also important considering that distracting the user from traffic might lead to dangerous situations.

Design

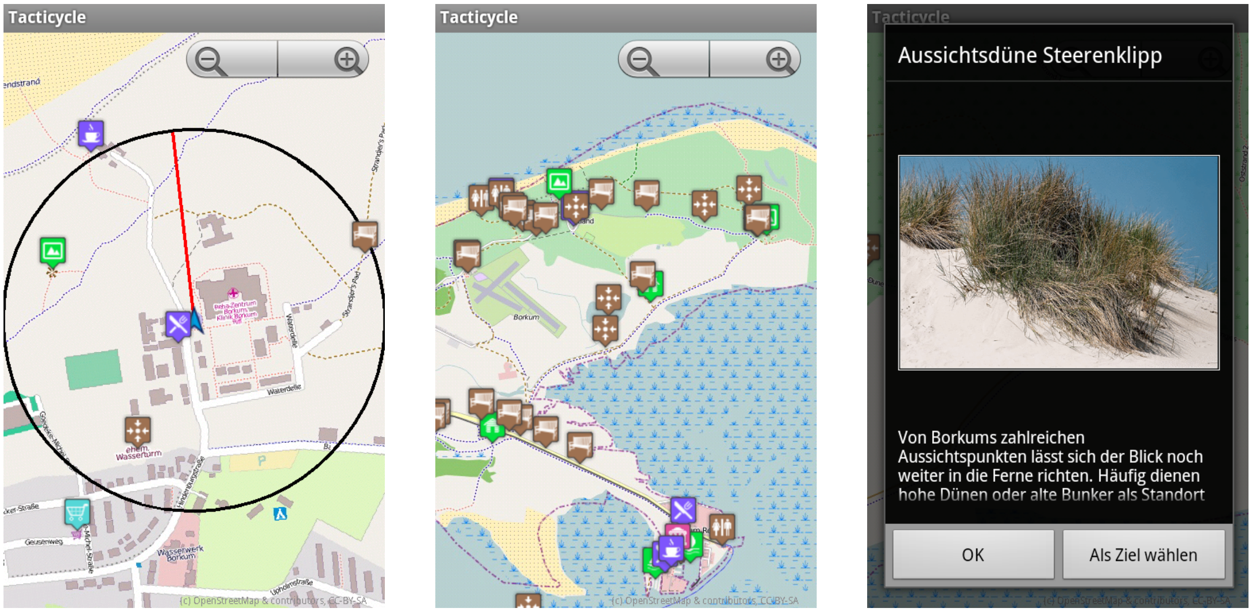
In order to fulfill above requirements we implemented the Tacticycle along the following three design concepts.

Quick access to potential travel destinations

In order to make the Tacticycle easy to use for beginners, we make the selection of the destination as simple as possible. Instead of having to search for a destination via text-entry, we show all points of interests of the categories amenity, leisure, tourism, and historic (from OpenStreetMap) on a map (see Figure b).

The rationale behind that design decision is twofold: first, tourists from our requirement studies often selected general areas as destination. Thus, if users would like to visit a certain area, they can just select a POI from this area. Thus, the location of the POI is important context information, which a list, rather than a map, might not provide. Second, maps were the only navigation aid we saw being used. Hence, we believed that users would desire having a map for their trips.

The left screenshot in Figure shows the user interface that implements this concept. For the technical implementation, we use a mobile device (Android Smartphone), which gets attached to the bicycle's handle bar. By default the map is centered to the user and rotated head-up, meaning that the "up"



(a) In general, the map centers on the user's position and rotates so that "up" corresponds to the driving direction.

(b) To browse the environment and select a travel destination users can scroll and zoom the map.

(c) Descriptions for each POI can be obtained by long-clicking an icon.

Figure 4. Screenshots of the application.

on the map corresponds to the driving direction. The map can be scrolled and zoomed to browse the island. Colored icons indicate the locations of points of interest prominently. Users can select a point of interest as travel destination by simply clicking on it. By long-clicking on an icon the application shows details about the point of interest, which consists of the POI's name, an image, and a textual description.

Convey direction of travel destination for orientation

In order to provide orientation support, we assumed that providing simple hints, such as the direction of a landmark as point of reference, would be sufficient. We therefore designed the Tacticycle to convey the general direction of the POI selected as destination.

To not require the user to constantly check the mobile device's screen, we chose to communicate the direction via the sense of touch. By attaching one vibration motor to each handle bar, we turned the Tacticycle's handle bar into a tactile user interface. We used vibro-tactile actuators, because these are best studied and most robust. The rationale behind using the handle bar is that these - alongside the seat - are the only parts of a bicycle that the rider constantly touches during the ride. We decided against using wearable tactile displays, since tourists often interrupt their ride and would have to stow away and setup up the wearable display in such cases. When a point of interest is selected, the vibration motors start indicating its general direction. As showing in Figure b, the direction is encoded in the relative intensity of the vibration in the two handles. If the destination is 0 degree / straight ahead both handles vibrate with the same intensity. If the destination is to the left, e.g. 45 degrees, the intensity in the right handle increases and the intensity in the left handle decreases. This allows encoding the full 180-degree spectrum of directions ahead of the cyclist. When the cyclist moves away from the destination the vibration remains silent. The handles vibrate constantly in pulses. The length of a pulse is 500ms followed by a 2000ms pause. These timings were chosen, because they continuously convey the direction of the selected POI without reducing the sensitivity of the skin, which would be caused by constant vibration.

Unlike car navigation systems, this design does not provide turn-by-turn instructions. It rather just gives the direction like a compass "as the crow flies", such as "the selected point of interest is 30 degrees to the right-hand side". This can also mean that the system points forward, but there are obstacles (e.g. a lake) in the way. Thus, users may have to find their way around obstacles by themselves. While this renders the navigation support less effective we presumed that it would encourage exploration.

Highlight nearby POIs to encourage spontaneous navigation

To support spontaneous navigation and serendipitous exploration, we aimed at informing the user about nearby points of interest. We used the tactile user interface to deliver tactile alerts, so the user does not have to check the display frequently. Whenever the user passes by a POI in a distance of 50m or less, the handle bars will alert the rider by delivering four short pulses, each with a duration of 500ms followed by a 250ms pause. If a POI is selected as travel destination at the same time, the presentation of its directions through vibration is paused for the alert. Through pilot tests we found out that both patterns can be very well discriminated.

At the same time, the icon of the POI that is highlighted by the tactile interface is briefly enlarged and starts rotating. Hence, even when the display is difficult to read, the icon stands out clearly.

Pilot Study

To ensure that the Tacticycle is sufficiently usable, in particular its tactile user interface, we conducted a pilot study. Six participants, three female and three male, aged between 20 and 26 years (M 23.33, SD 2.32) took part in the study. None of the participants had previous experiences with the tactile or visual information presentation methods described.

Method

The pilot study was divided into two tasks. In the first task, the participants were asked to interpret directions presented by the tactile user interface. Thirteen random angles had to be recognized. Since different sources of vibration can interfere with each other, and the bicycle itself also vibrates while riding, we conducted the study outdoors. The participants were asked to ride back and forth in an empty parking area. A mobile device monitored the driving speed via GPS. Once the bicycle started moving, a direction was presented via the tactile interface. Once the participants had covered a distance of about 50 meters, they had to stop and estimate the perceived angle on a clock face. The vibration stopped when the bicycle stopped, so the participants could not "cheat" and listen to the vibration while standing still. The system did not provide any feedback about the correctness of the judgment.

In the second task, we asked the participants to reach a given destination. We therefore selected a POI, which was about 2 km away from the parking area, and asked the participant to ride there. None of the participants was familiar with the streets between the destination and the parking area. Hence, they had to rely on the visual and the tactile feedback given by the application. One experimenter followed the participants on another bicycle to make observations and to listen to any in-situ comments of the participants.

Results

The results of the first task (identifying given directions on a clock face) show that users struggle with giving a correct estimate. As shown in Figure 5 users can best identify the cardinal directions (left/right/ ahead = 9/12/3 o'clock). 12 o'clock was recognized in 44.4% of the trials. Left and right (9 and 3 o'clock) were recognized in 58.3% of the trials. The intermediate directions (10/11/1/2 o'clock were recognized in only about 10 to 20% of the trials. The majority of misjudgments were adjacent angles.

In the second tasks (reach a given destination) all participants arrived at the destination without difficulties. One participant primarily used the visual display to find his way (the application had a visual cue which we removed later: a line drawn from the own position to the location of the POI). Five of the six participants mainly relied on the tactile feedback. They explicitly appreciated the increased awareness for the environment or the decreased need to check the handheld device's screen.

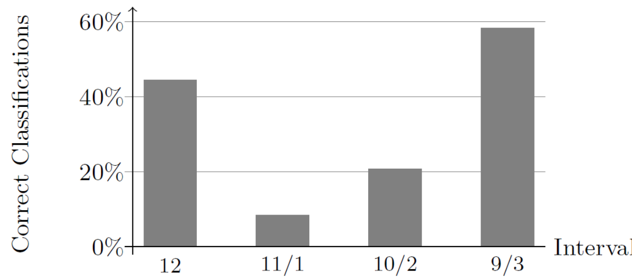


Figure 5. Recognition rates by presented direction.

Discussion

The pilot test indicates that cueing general directions in vibration intensities, although being quite coarse, resembles an effective and usable navigation and orientation aid. The participants reported no difficulties in understanding the general concept of mapping vibration intensities to directions, though their estimates were only roughly correct. Nevertheless, the results from the second task hint that these rough directional cues are sufficient to guide cyclists to a given destination in an unfamiliar environment.

IN-SITU FIELD STUDY

To study the prototype in-situ we conducted a field study. During a period of seven days we gave it for free to tourists to use it for leisure time trips. The aim was to investigate whether the underlying concepts are useful, usable, and whether they match the desires of tourists to improve the experience of the trip.

Method

Venue & Participants

For the study we received support from a local bicycle rental attached to a rehabilitation clinic for respiratory and dermatological diseases. Patients usually stay at the clinic for two to four weeks. Many of them rent a bicycle for their whole stay, so they can run errands, explore the island, or go on trips. The owner had arranged that all newly arriving patients found a handout in their rooms informing them about the opportunity to take part in the study. We set up an info booth at the bicycle rental where interested patients could approach us to arrange an appointment for their participation.

Eleven patients decided to take part in the study. Their age ranged from approx. 20 to 55 (M 43.18, SD 10.55) years. Seven of them were female, four male. All of them had just arrived to the island in the past few days and were not yet familiar with the area. They all rented a bicycle for their whole stay. For our study, we asked them to use our prototype instead of the rented bicycle on one of their trips they would be doing anyway.

Material

To be able to reconstruct the trips and understand how participants used the Tacticycle we implemented a set of logging methods. First, the application logged the route via GPS. Second, we used a SenseCam to get pictures of the trip. The *SenseCam* is camera developed by Microsoft Research with the size of a cigarette box. It is worn by a cord around the

Figure 6. Cyclists exploring the island with the Tacticycle (2nd bicycle).

neck. For the study we configured it to take one picture every five seconds. Third, we used the experienced sampling method (ESM) to acquire in-situ feedback. Every 30 minutes a dialog popped up and asked the participants to rate how much they agree two on of the following statements: *I feel oriented and know where I am*, *I feel distracted by the system*, or *I feel relaxed*, and were randomly selected. The statements were chosen randomly and the rating was entered using a five-point Likert scale.

These three data sets, namely the GPS track, the SenseCam photos, and the ESM responses, could be imported into a custom made application that called *Context Player*. Timestamps in all three data sets allowed the Context Player to synchronize the data. The Context Player (see Fig. 7) allows to play back the route and to browse back and forth, similar to a video player. For each point in time of the trip it shows the participant's position on a map, the recent picture taken by the SenseCam, and the recent ESM statement along with the recorded response (or the message that the statement had been ignored or discarded).

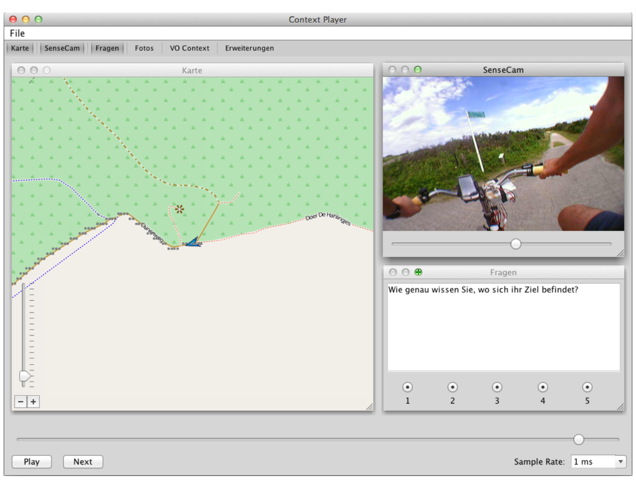


Figure 7. The Context Player application that was used to play back the trials to the study participants.

Procedure

Initially, we gave the participants a quick introduction to the background of the study. Then, we explained the Tacticycle to the participants by giving them a guided walkthrough. We asked them to browse the map, select different POIs, and test the tactile feedback. We asked them to select a POI so they could experience the vibration feedback. We explicitly mentioned that the system does not work like common turn-by-turn navigation systems, but that it only displays the general direction of the POI. We stressed that it even might happen that they approach an intersection where the system tells them to go straight while the streets only lead left and right. We told them that they would have to find their own route in such cases. To avoid accidents, the participants were instructed to only interact with the mobile device when halting. We also informed them about the logging methods. We explained that the GPS track would be recorded, that the SenseCam would take pictures every few seconds, and demonstrated an ESM dialog. We said that responding to an ESM dialog was encouraged, but it also was allowed close them or ignore them. We also told the participants to not depend on the system and always carry a map or similar as fallback. All participants signed an informed consent form. They were informed that all personally identifiable information, if recorded at all, would be treated confidential and that they could stop their participation at any time.

After the instruction they departed on their trips. Eight participants went alone, three together with another person. For 7 participants we conducted the interview directly after they returned. The others made an appointment and came back for the interview within 24 hours. During the interview we first asked the participants to reconstruct the trip by indicating visited places on a timeline (see Fig. 8). Second, we asked how they had used the Tacticycle and what their impressions on the different features were. In the meantime, we had imported the log data to the Context Player. Once finished we showed the Context Player to the participants and used it to replay the route to trigger additional feedback.

As a reward, each participant received a USB stick with the SenseCam photos from their trip after the interview. They also received a discount worth about $10 on the fee for the "ordinary" bicycle they had rented.

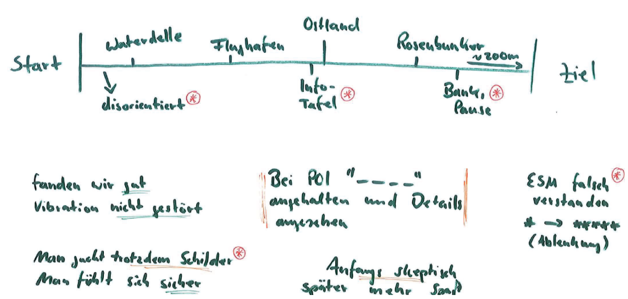


Figure 8. Snippet of a timeline sketched during the post-hoc interview to reconstruct the trip.

Characteristics of the Trips

Figure 9 shows the routes travel by our participants. The trips took between 20 minutes and 2.5 hours (M 74.6 min, SD 46.0 min). The distance covered ranged from 1.7 to 17.8 (M 9.77, SD 5.34) km.

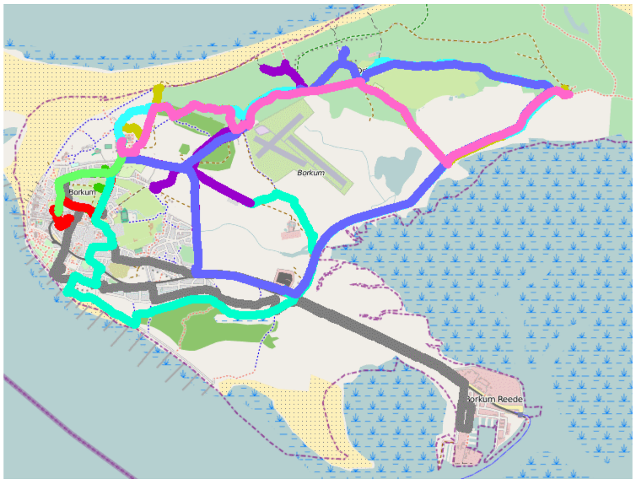


Figure 9. Plot of the recorded GPS tracks.

Multiple Destinations Visited

23 destinations (2.3 per traveler) have been specified. 17 of these were reached. There were two types of trip destinations: the countryside and the city center. 6 participants visited the almost uninhabited east side of the island, 1 participant went to the harbor on the south side of the island. On 5 tours participants visited destinations in the city center, including the tourist info, a supermarket, an official beach, a light house, and a war memorial. The system highlighted 63 POIs (5.7 per traveler) of which 2 were visited.

Participants Felt Relaxed and Oriented

43 statements were prompted via the Experience Sampling Method (ESM). 20 were answered, 19 were overseen/ignored, and 4 were actively dismissed. In average, the participants did not feel disoriented (2), were neutral about the level of distraction (2.8), felt supported in their exploration (4.25), and relaxed (4.5).

All values are means. The ESM questions were answered via 5-point Likert scales, where 1 = strongly disagree and 5 = strongly agree.

Interview Results

In the following we report our findings from the interviews. We only report these aspects that were spontaneously mentioned by the participants. So, if for example we report that 2 participants disliked the system, this might mean that all others did, too, but they did not mention this by themselves.

Vibration Needs Short Learning Period

7 participants found the vibration odd in the beginning. But once they got used to it 5 named it unobtrusive and 4 said that it boosted their confidence. 3 participants considered positively that it was unnecessary to watch the map.

Direction "as the crow flies" Considered Controversial

4 participants appreciated that presenting the direction "as the crow flies" allowed them to choose the route freely, e.g. decide between paved road and forest trail depending on the situation. 2 participants found the concept of presenting the direction "as the crow flies" to odd and rather expect navigation systems to present turn-by-turn instructions. In particular, one participant desired detailed guidance in the case of getting lost. 2 participants mentioned that they found it annoying when the system pointed to the side for a long time, but there was not path leading into that direction.

No Loss of Orientation with Tactile Feedback

None of the participants reported to have felt disoriented. Also, the play back of the trips with the context player showed no signs of a loss of orientation when the tactile display showed the direction of a POI. However, P9 failed to enter a proper POI on her way back, so she received no vibration feedback. Playing back the route on the Context Player it was obviously that she was lost at that time, since she desired to come back to the home base but took a detour of about 30 minutes and had to turn around.

Situation-induced impairments occurred frequently

6 participants reported from problems reading the display due to different reasons. Two complained that it impossible to read the display when sunshine was reflecting on the display. Another participant faced a rainstorm, which made it also impossible to read the display. Two participants mentioned that they were not able to read the map on the move, since it was too small for them. One participant mentioned that on rough roads the device would shake so much that it became difficult to read the display.

Spontaneous Navigation only Observed at Some Trips

7 participants only used the POI radar to specify the initial destination, but not anymore afterwards. 4 participants used it in a playful way, i.e. they went to an area with a lot of POIs and visited a large number of them in a short period of time. 1 of these participants noted that offering only a limited number of potential destinations helped in deciding for a new destination.

Paper Map Considered Less Helpful

All but 2 participants said that they would usually keep a paper map with them. In contrast to the paper map, 3 participants appreciated that the Tacticycle allowed faster orientation and did not require stops. 5 participants said that maps can be difficult to read at times, e.g. when there are no landmarks to determine one's location. In these situations, an egocentric cue as provided by the Tacticycle would be most helpful.

Navigation System Considered Overkill

All participants had experience with car navigation systems. Only one participant had been using a bicycle navigation system as well. 5 participants stated that a navigation system providing turn-by-turn instructions would be overkill and annoying for such tours, since they did not find it important to reach a specific destination quickly.One participant appreciated that he was more conscious about the environment compared to a navigation system. However, 2 participants pointed out that turn-by-turn instructions might become handy when getting lost.

Discussion

In brief, all participants were able to use the Tacticycle in a meaningful way. Although many participants had no previous experience with Smartphones and touch screens, all were able to browse and select POIs. The tactile direction cueing was in general well received and proofed to be understandable and effective. None of the participants lost orientation as long as haptic feedback was provided. Our findings suggest that it helped overcoming situational impairments and improved the user experience.

Tactile Direction Cueing

The tactile direction cueing was perceived as the most helpful and exciting feature. All participants tried to follow the navigation instructions delivered by the tactile user interface. Most participants appreciated receiving directional cues throughout the ride. It boosted the confidence, in particular of those who believed in having a bad sense of orientation. In general the tactile cues were described as unobtrusive or even too weak. We could confirm the findings from the pilot study that the accuracy of the display was rather coarse, but we could also confirm that this hardly leads to any notable difficulties in the navigation. In brief, the study provides evidence that cueing the direction of a destination in vibration patterns works well for longer tours in unfamiliar environments, and with people that are not necessarily experienced with smartphones and similar technology.

Our findings confirm the motivation for using a tactile display. For example, the participants mostly stopped to read the map, since they found it too small. When it was sunny or raining they struggled with reading the display at all. We also received the feedback that it was easy to stay aware of the environment compared.

One issue we found is that many people today are used to turn-by-turn car navigation systems and find it difficult to understand and/or accept another concept than turning instructions. During the explanation, we very explicitly stated that the system would show directions ”as the crow flies”, we illustrated this with examples, and we said that the system might tell to go ahead when there is actually a huge obstacle (e.g. a lake) ahead. Nevertheless, some participants found this very hard to grasps and presumably still expected to receive turning instructions. We still received complaints that ”the system did not show that turn”. Yet, even those who did not grasp the concept still were able to navigate by the tactile cues. They obviously explained unexpected turning instructions as system malfunctions and otherwise followed the tactile cues if they found them to be logical.

Spontanous Navigation

Providing quick access to potential travel destinations was most helpful in the beginning, when the participants needed to select their initial destination. Two third of the participants only used it to be guided to their trip destination and back to the bicycle rental. The remaining third used it for spontaneous navigation and exploration. They reported to have developed a game-like attitude and selected POIs nearby ”just for fun” or out of curiosity. These results show that the POI selection method can assist spontaneous navigation and exploration, but is only used by a minority of the users.

As no experimenter was present during the study and the study equipment was not found to be obtrusive, our participants were not constantly reminded that they were part of a study. However, to achieve this we had to refrain from accompanying and observing them on their trips. Instead we had to rely on the collected data and the post-hoc interviews. The quality of interviews, however, depends on the ability of the participants to recall important events and thoughts. Being able to replay the tour (GPS, SenseCam, Experience Sampling Questions) via our application was indispensable to elicit rich feedback. It helped to uncover a lot of events the participants ”forgot” to report. Hence, we believe that not shadowing participants was the right choice, since this increases the ecological validity of our findings.

Limitations

The study took place in an environment that had a lot of alternative paths and that was geographically constraint. Thus, our participants would usually find a way to their destination as long as they kept going roughly into the right direction, and they did not have to be afraid of getting lost by going into the wrong direction for too long. This might raise the question, to what extent the results can be applied to other environments. Yet, we believe that these limitations can be addressed by technology. Constraining the exploration environment can be achieved virtually by using boundary notifications, as proposed by Hornecker et al. [5]. In areas with few alternative paths intermediate landmarks could be used to guide the users through the bottlenecks. For example, if the selected destination is on the other side of a river, the system could automatically place an intermediate destination at the nearest bridge.

The study offers no baseline. Thus, we cannot be sure to what extent our findings are caused by the Tacticycle or by other factors. Yet, our findings show that the novel concept of cueing directions ”as the crow flies” through vibrating handle bars is sufficiently easy to use for non-tech-savvy people and that it is highly appreciated for not requiring to stop to check the map and for allowing to freely chose the actual route. Therefore, the study provides important evidence for the emerging approach of cueing directions ”as the crow flies” as navigation aids, to eventually overcome the *tyranny of turn-by-turn navigation* [10].

CONCLUSIONS

This paper reports from the user-centered development of the Tacticycle, a navigation system that specifically targets the needs of tourists exploring constraint environments, such as an island. The contribution of this paper is three-fold:

- We argue that maps and navigation systems are not always the right tools to provide navigation support, in particular if the goal is to explore confined areas as a tourist. We base our argument on related work, a survey, and a field study.

- To fill this gap, we propose the Tacticycle, the concept of a minimal set of navigation cues for cyclists on exploratory bicycle trips. For quick browsing of potential travel destinations is shows POIs on a map. Further, it uses a tactile display to convey the general direction of the travel destination as orientation guide and highlight nearby POIs to encourage spontaneous exploration.
- From a field study with actual tourists we provide evidence that with the Tacticycle cyclists feel oriented and encouraged to explore the environment. They also appreciate the eyes-free use and have a relaxed travel experience.

Our findings suggest that a minimal set of navigation instructions is sufficient if exploration rather than reaching a destination as fast as possible is the traveler's goal. They show that cueing general directions is a powerful and elegant, yet effective complement to providing turn-by-turn instructions for cyclists. The work shows that instead of only striving for the most accurate and detailed navigation aid only we should not easily neglect how to leverage the human's inherent navigation skills. We should allow for "mistakes" and encourage exploration, as many roads ultimately lead to Rome. Nevertheless, many situations will still require the efficiency of turn-by-turn navigation or the overview that a map provides. However, we have shown that a third way is possible and can be beneficial.

Future work needs to clarify, which of the concepts are superior in which situations. Our participants had surprisingly few problems with the information presentation, which makes us wonder to what extend this concept can keep up with turn-by-turn instructions when efficient navigation is desired.

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REFERENCES
1. Aslan, I., Schwalm, M., Baus, J., Krüger, A., and Schwartz, T. Acquisition of spatial knowledge in location aware mobile pedestrian navigation systems. In *Proc. MobileHCI '06* (2006).
2. Bial, D., Kern, D., Alt, F., and Schmidt, A. Enhancing outdoor navigation systems through vibrotactile feedback. In *Proc. CHI '11* (2011).
3. Brown, B., and Laurier, E. Maps and journeys: an ethnomethodological investigation. *Cartographica 4*, 3 (2005), 17–33.
4. Holland, S., Morse, D. R., and Gedenryd, H. Audiogps: Spatial audio navigation with a minimal attention interface. *Personal and Ubiquitous Computing 6*, 4 (2002), 253–259.
5. Hornecker, E., Swindells, S., and Dunlop, M. A mobile guide for serendipitous exploration of cities. In *Proc. MobileHCI '11* (2011).
6. Leshed, G., Velden, T., Rieger, O., Kot, B., and Sengers, P. In-car gps navigation: engagement with and disengagement from the environment. In *Proc. CHI '08* (2008).
7. Magnusson, C., Rassmus-Grhn, K., and Szymczak, D. The influence of angle size in navigation applications using pointing gestures. In *Proc. HAID '10* (2010).
8. May, A. J., Ross, T., Bayer, S. H., and Tarkiainen, M. J. Pedestrian navigation aids: information requirements and design implications. *Personal and Ubiquitous Computing 7*, 6 (2003), 331–338.
9. Poppinga, B., Pielot, M., and Boll, S. Tacticycle: a tactile display for supporting tourists on a bicycle trip. In *Proc. MobileHCI '09* (2009).
10. Robinson, S., Jones, M., Eslambolchilar, P., Murray-Smith, R., and Lindborg, M. "I Did It My Way": Moving away from the tyranny of turn-by-turn pedestrian navigation. In *Proc. MobileHCI '10* (2010).
11. Ross, T., May, A., and Thompson, S. The use of landmarks in pedestrian navigation instructions and the effects of context. In *Proc. MobileHCI '04* (2004).
12. Rowland, D., Flintham, M., Oppermann, L., Marshall, J., Chamberlain, A., Koleva, B., Benford, S., and Perez, C. Ubikequitous computing: designing interactive experiences for cyclists. In *Proc. MobileHCI '09* (2009).
13. Srikulwong, M., and O'Neill, E. A comparison of two wearable tactile interfaces with a complementary display in two orientations. In *Proc. HAID '10* (2010).
14. Strachan, S., Eslambolchilar, P., Murray-Smith, R., Hughes, S., and O'Modhrain, S. Gpstunes: controlling navigation via audio feedback. In *Proc. MobileHCI '05* (2005).
15. Tsukada, and Yasumura. Activebelt: Belt-type wearable tactile display for directional navigation. In *Proc. UbiComp '04* (2004).
16. van Erp, J. B. F., van Veen, H. A. H. C., Jansen, C., and Dobbins, T. Waypoint navigation with a vibrotactile waist belt. *ACM Transactions on Applied Perception 2*, 2 (2005), 106–117.
17. Williamson, J., Robinson, S., Stewart, C., Murray-Smith, R., Jones, M., and Brewster, S. Social gravity: A virtual elastic tether for casual, privacy-preserving pedestrian rendezvous. In *Proc. CHI '10* (2010).
18. Zwinderman, M., Zavialova, T., Tetteroo, D., and Lehouck, P. Oh music, where art thou? In *Proc. MobileHCI '11* (2011).