Ubikequitous Computing: Designing Interactive Experiences for Cyclists

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ABSTRACT
This paper charts the distinctive challenges of designing mobile experiences for cyclists and presents two studies of mobile cycle-based experiences: one a heritage tour; the other an exploration of a city at dusk involving recording and listening to personal stories. To understand the cyclists' experiences questionnaires, interviews and observations are drawn on to derive eight lessons for designing cycle-based interaction including: cycling proficiency, physicality, impact of the environment, media and hardware design, collaboration, and safety. The conclusion is that design has to respect the distinctive nature of cycling as a mode of transport and needs to carefully interweave moments of interaction with it.

Categories and Subject Descriptors
H.5.3 [**Information Systems**] Group and Organization Interfaces – *Collaborative Computing*.

General Terms
Documentation, Design, Experimentation, Human Factors

Keywords
Cycling, bicycle, safety, mobile applications, tours, audio

1. INTRODUCTION
Cycling is popular as an enjoyable form of recreation, for health and fitness, and as a sport, and is increasingly attractive as a mode of urban transport, both for reasons of cost and sustainability. Primarily driven by sports cycling a range of cycle-based computing technologies and applications have emerged. These range from simple speedometers such (e.g. CatEye Velo 5), to systems designed for serious athletes which record variables including pedal power, road incline, heart rate etc. and graph them later on a computer (e.g. Polar CS600). GPS navigation devices are also increasingly used by cyclists. More recently, general purpose devices with GPS capabilities such as mobile phones and PDAs have been repurposed by cyclists as devices for tracking performance and navigation (e.g. Nokia SportsTracker, ViewRanger, Memory Map) and several web sites have emerged to support the sharing and rating of bike routes that are recorded using these units [3, 15] but little usability or safety research has been performed regarding such applications. An augmentation of the cycling experience with mobile technology appears to offer the opportunity to promote cycling (as an ecologically sound transport mechanism) to a wider audience. But, as shall be discussed, great sensitivity must be employed in its design and implementation.

In the research community, there are a few examples of bike-based technology. Steven Robert's Winnebiko (1983) and Behemoth (1989) [19] were very early examples of technologically augmented bikes which even had a handlebar mounted keyboard for writing while riding. Other technological work has explored the use of wearable technology for cycle messengers [12] and adding large quantities of sensors to bikes in order to map the cyclists' level of 'joy' [9]. The Hocman project, which provides ad hoc social networking for motorcyclists to communicate with other passing riders provides useful insights into the technical, social and practical design constraints of a related form of transport [10]. Ethnographers have also studied the activity of cycling itself. In particular, Spinney [20] suggests a focus on the effect a mode of transport has on experience arguing that "*we create meaning and belong in a place according to how we are in a place"*.

A broad range of mobile interactive experiences have been developed for pedestrians (e.g.[2, 6, 13, 14]) and a few in cars [11]. A small number also mention cycling; mainly games oriented towards racing, either in real time with the computer running the game [22], or against GPS traces recorded by other riders [16, 23]. However, there has so far been no discussion within HCI of the design issues surrounding cycle-based interaction. It is therefore timely to chart the distinctive HCI challenges of designing mobile experiences for cyclists.

This paper looks beyond current uses of computers on bicycles to consider the potential of cycling to underpin new kinds of mobile interactive experience. The argument is made that cycling introduces a unique set of opportunities and constraints that are substantially different to those of pedestrian or driving experiences. For example, cycling affords a greater spatial range than walking and yet enables more flexible access to and engagement with one's surroundings than driving. It also involves an intimate and deeply physical connection with the world that can stimulate engaging and even profound experiences.

In order to explore these and other issues in practice, two novel experiences have been developed and studied. *The Sillitoe Trail* is a pre-scripted heritage cycle-tour designed for a specific city. *Rider Spoke* is an artistic experience in which participants explore a city at dusk, recording and listening to personal stories, that has toured three cities to date. The following sections introduce each experience in turn, providing an overview of its design and then drawing on questionnaires, interviews and observations to unpack the experiences of its participants. The findings of these studies

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are then distilled into eight key lessons for designing cycle-based interaction that represent a first attempt within HCI to engage directly with the unique challenges that arise from this distinctive mode of transport.

2. THE SILLITOE TRAIL

The Sillitoe Trail was a historical location-based tour for cyclists celebrating the life and works of the writer Alan Sillitoe (1928-). Located in his home town, the tour was based on Sillitoe's book *Saturday Night and Sunday Morning* (1958) which rather appropriately revolves around the life of a worker in a Raleigh bicycle factory. The book was subsequently made into a film, shot at various locations around the city, many of which are currently disappearing under new developments. The Sillitoe Trail took the form of an audio tour that passed through several of these locations, as well as through areas of general connection to Sillitoe. The tour was delivered via a Nokia N95 mobile phone with selected sound clips from the film and an interview with Sillitoe played to the rider through a headset as they cycled a specified circular route around Sillitoe's old haunts. These clips were triggered automatically using GPS positioning. Maps from the present and also from the 1950s were displayed on the N95 for inspection by riders to allow them to check they were still on-course while also turning their mind back to a bygone era.

2.1 An overview of the Sillitoe Trail

The trail began and ended at an art gallery and participants brought their own bicycles. Prior to departure, a briefing covered the nature of the project and provided guidance about safe and legal cycling. Each participant was provided with a paper map (in case of system failure), a luminescent outer-jacket to enhance visibility, and a Nokia N95 mobile phone and headset. In the final iteration, the N95 was fixed to the inside of the participant's lower arm using an iPhone arm-band and monaural Bluetooth headsets were used to prevent environmental sounds from being occluded and also to avoid the danger of trailing cables becoming entangled with the bicycle (see Figure 1).

Figure 1. Equipment Employed in the Sillitoe Trail

The design of the route involved a compromise between length (striving for a duration of about one and a half hours); being circular so that participants would arrive back at their starting point without needing to repeat sections; including key locations connected to Sillitoe; comfort and safety by avoiding too many hills (this was a hilly city) and using the local network of cycle-tracks to separate riders from traffic when possible. The final route was a circular 6.2 mile trail incorporating 16 key locations (see Figure 2).

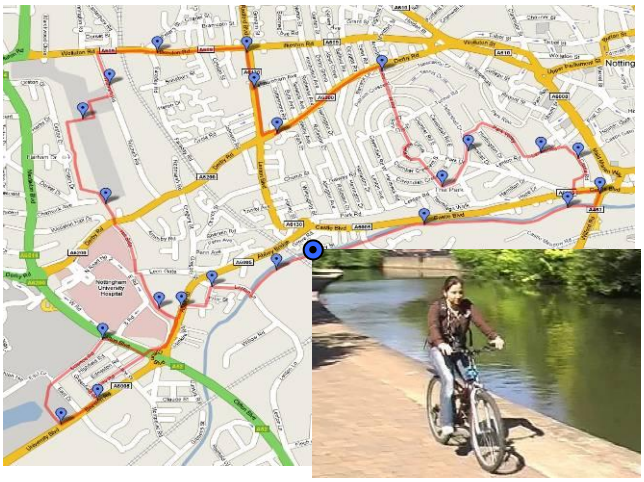

Figure 2. Route Map and Example Trail Location

Nine of the audio clips participants could hear were short excerpts from the film (either situated where the scene was shot, or in an area of similar thematic interest); six were historic information recorded especially for the experience; and one was an interview with Alan Sillitoe regarding his views on smoking, as this features heavily in the film and manufacturing cigarettes was another major local industry at the time. This was deliberately located on an uphill climb during which riders might be expected to be out of breath.

Thirteen additional recordings gave directions en route. These were recorded using a different voice to avoid confusion between directions and the historic narrative. These directions enabled the entire trail to be ridden without a break and without recourse to the visual display of the phone and this was the generally envisaged method of engagement. Alternatively, if riders felt the need for a rest, wished to check on their progress or gain more instruction, the display of the phone could be cycled through three modalities with single button presses (see Figure 3). For each piece of audio content a static image was displayed; for excerpts and the interview this was a frame from the film, while directions were displayed as text. The remaining two modalities displayed zoomable maps with the route overlaid, the first an up-to-date cycle map of the area to aid in navigation and the second a historic map showing the area as it was during the period of the film.

Figure 3. Three Display Modes

2.2 Studying the Sillitoe Trail

In total, 13 participants took part in the trials. Three colleagues tested an earlier version of the experience with ten subjects using the final version All participants reported being regular users of mobile phones and MP3 players, but none was familiar with either

the Nokia N95 phone or with GPS/satnav devices in general. All participants reported having good eyesight, all but one being fluent in English and one having a hearing deficit in one ear. All were vetted for their ability to cycle safely on UK roads. All signed a liability waiver, agreed to abide by the UK Highway Code and gave their informed consent to take part in the study. The 10 participants in the final trials took part in six separate runs: one of three simultaneous users; two of two simultaneous users; and three runs of individuals.

After each trial, participants were debriefed and an interviewer recorded their impression of the experience. A post-event questionnaire captured demographic details and any further information that participants wanted to give anonymously. Photos and videos were captured (keeping at a discrete distance) as was GPS data for each participant. Data from all these sources was iteratively analysed and discussed in debriefing meetings, driving the emergence of common themes as now discussed.

2.2.1 Rider's ability

Participant riders varied in cycling proficiency from frequent expert cyclists to those who rarely cycled. This affected the time that it took to complete the trail:

"...you have to consider that not all the people can, like, make the tour in one hour and a half. Most of the people will need to rest."

There was also an issue of pacing due to different levels of proficiency and fitness within groups.

"I cycle with my friends, they are not from Nottingham, they don't know the movie even – they cycle really slow and they pay more attention to where they're cycling"

Other users mentioned some discomfort due to their fitness levels:

"I think the route was interesting, it was a bit difficult to follow it with the bike because some parts require a lot of strength"

Ability also extended to familiarity with the local environment which affected navigation, with those users who were less familiar with the areas resorting to the map more often than those who knew it well who tended to rely more on the audio instructions.

2.2.2 Environmental factors

A key aspect of the feedback received related to the riders' relationship with their surroundings. Issues included the primary physical characteristics of the terrain, especially the steepness of hills.

Environmental noise was also a problem, including noise from traffic and local construction works.

"Only on the main roads, there was, err, plenty of noise so I couldn't like know what to do exactly because I had to focus my mind in order to like listen to the audio tour, but at the same time I couldn't because there was like a lot of traffic".

"Sometimes when you're cycling and you get the audio it's great, feels best when you are cycling along, no-one else around, you get the audio, it's really lovely… But other times, the sound of traffic near-by, trying to concentrate… but having to stop is also a pain."

Perhaps more surprisingly, the sound of the wind in one's ears could be a problem, especially when cycling downhill. On the other hand, listening to audio could provide a pleasant distraction from the effort involved when cycling *up* a hill, or as a reward for reaching the top.

"I found listening to sound cycling downhill was a bit tricky because you get a lot of wind noise", but *"cycling while going uphill was actually alright…[] it distracts you from the climb, actually makes climbing the hill quite a bit easier because your focus is on the voice, and not on your pain!".*

2.2.3 Choice of hardware and media

In the preliminary tests (where the participants had a good knowledge of the area) the phone was simply placed in a pocket. Participants were very reticent about getting out the phone and looking at it, thereby interrupting the flow of the experience:

"You don't want to get the phone out and look at it"

"Definitely [I prefer] the audio instructions... The map is... [laughing] was too dangerous for me. Trying to see the map while I was on the bike, and I think if you have to stop the bike and then check the map it's not like a riding audio-tour - it doesn't make sense"

This led towards the use of an arm holder in the final trial allowing the phone display to be seen at a glance without requiring the rider to stop. Even so, the audio directions (particularly when they related to obvious landmarks) were better received than the map, and the historic map was scarcely used at all.

"Riding a bike is a nice experience that most of the time requires all your senses fully activated and in alert mode. By using audio track and a visual map sometimes I feel insecure in the bike I didn't know what to do ride the bike, listening [to] the audio, see[ing] the map I think is too much. At the end of the route when I decided to stop watching the map and relying only on the audio instructions the experience was better. I didn't have to worry about dropping the phone and I was able to put more attention to the road."

"I wouldn't advise the use of the map because it's too, I dunno, I didn't like it that much, and it is also confusing […] its better just to have the audio tour […] and when you identify you're on, I dunno, a very straight route, you can start the information about the place."

Feedback on the use of audio was very positive. Several riders commented that the use of different voices helped them distinguish directions from the historic narrative. Some felt that they would like music during the entire experience, suggesting that they were not sure the system was still working after it had been quiet for some time. However, there can be tension between a rider's ability to listen to audio and their ability to cycle safely. Even though the route did not take riders onto the road, the equipment and audio playback was sufficiently distracting on occasion to negatively impact on the experience and potentially the safety of the rider and third-parties.

"...you must concentrate [on] the route, the bicycle, the traffic lights in addition to the tour."

It also appears that a poorly fitting earpiece reduced the tendency to look around, also impacting safety.

"I couldn't keep the phones in, as a result I didn't want to turn my head very much, so I didn't look around corners as much as I should 'cos they'd fallout."

2.2.4 Integration of content

Content was generally very well received. The choice of route seems to have been a major factor in this, including taking people to areas of the city that they would not normally have explored.

"I thought the route was nice."

"The route was really nice. It shows areas from the city [...] that you would not be able to know unless you do a tour like that... There are some areas that [normally] there's no reason to go there, that was good. I like it, I really like it."

The historic narrative was also appreciated.

"The information was quite good, [appealing to] all types of tastes."

Earlier trials attempted to deliver the film narrative in a cut-up style with little additional explanation or interpretation (similar to that attempted by Gysin and William S. Burroughs with audio recordings in their attempts to divine the "material's implicit content" [4]). This received a mixed response; with feedback suggesting that the level of explanation required in order to appreciate the connection between media clips and chosen locations varies according to familiarity with the film.

"The content worked really well for me because I'd seen the film."

"If you haven't seen the film it makes a lot less sense, I've read the book, but not seen the film."

"For people who haven't read the book, or seen the film…" … "It doesn't mean anything."

The final version therefore incorporated a historic narrative as a didactic voice to link the audio clips from the film with the locations being cycled through. This additional support is possibly particularly necessary when the rider is also occupied with the tasks of cycling.

2.2.5 Social Interaction

Where participants had gone out together, there was little tendency for them to interact with other members of their group during the ride. In general, when audio playback started, all discussion stopped. Cycling safely, concentrating on staying on course and listening to the content meant that it was difficult to socialize with others as well as everything else that was going on.

The Sillitoe trail raised a range of issues surrounding users' experience of a guided cycle trail through a city. It illustrated the ways in which the act of cycling and the relation with the environment impacted the user's experience. The second cycling based experience presented in this paper has a distinctly different style.

3. RIDER SPOKE

Rider Spoke is a location-based artistic experience in which cyclists traverse a city recording personal stories (leaving them at chosen locations). The riders then locate and listen to the stories of other participants. As a study, the experience complements the Sillitoe Trail in several important regards:

- cyclists explore the city freely, choosing their own key locations rather than following a prescribed route;
- the experience takes place at dusk or night-time and so involves cycling in the dark;
- riders take part as individuals (this is not intended to be a group experience).
- riders are encouraged to stop in order to interact with a device (handlebar mounted), rather than listening to automatically triggered content while riding along;
- participants create their own audio content, responding to a framework of questions posed by the artists;
- the experience tours to different cities.

3.1 An overview of Rider Spoke

Participants arrive at a hosting venue either on their own bicycle or are loaned one. They register at the reception where they sign a disclaimer and leave a deposit. They then receive a briefing that covers the nature of the experience, how to use the technology, how to cycle safely, and also receive an emergency paper map and phone number to be stored under their saddle. A receptionist logs them into the system and then sends them outside where a technician mounts a Nokia N800 device onto the handlebar of the cycle and, for loaned cycles, adjusts their seating position so that they feel comfortable and safe. The device is fastened using Velcro to a plastic mounting that can be readily attached to the cycle. Riders leave the venue individually and the experience lasts for an hour.

Figure 4. Rider Spoke participant listening to audio content

After the first few minutes, music plays, setting the tone for the experience, and a narrator begins giving instructions. The rider's first task is to find an appropriate and valid location, stop, and record a description of themselves:

"This is one of those moments when you are on your own, you might feel a little odd at first, a bit self-conscious or a bit awkward. But you're alright and it's OK. You may feel invisible tonight but as you ride this feeling will start to change. Relax, don't forget to breathe both in and out and find somewhere that you like, it might be near a particular building or road junction, it might be near a mark on a wall or a reflection in a window. When you have found somewhere you like give yourself a name and describe yourself."

In this context, "appropriate and valid" means a location that appeals to the rider, but that is also currently 'empty', i.e., has not already been associated with another message (in general, every new recorded message in Rider Spoke has to occupy a distinct location). Following this initial introduction, riders repeatedly choose whether they would prefer to record an answer to a new question, or instead find and listen to other people's responses, repeating this choice until their allotted time has elapsed. To answer a question, the rider must find a new location that is not already associated with a recording. When listening to responses, riders are allowed to choose from a list of responses that are near to their current location and may cycle through the city to update this, essentially browsing a landscape of stories.

Figure 5. Recording a message

The questions are designed to elicit personal, sometimes even confessional, stories. They encourage riders to seek out locations that might have personal meaning, and reflect on personal issues. Examples include:

"Please will you tell me about your father. You might want to pick a particular time in your father's life or in your life. Freeze that moment and tell me about your dad: what they looked like, how they spoke and what they meant to you. And while you think about this I want you to find a place in the city that your father would like. Once you've found it stop there and record your message about your father at that moment in time."

"I want you to tell me about a party. Perhaps one when you were a teenager, or maybe a bit later. I'd like you to talk about a party where it got a bit out of control, where everything got a bit blurry for a while. Perhaps you did something you shouldn't. Then again you could have been on the outside looking in. Find a place to tell me about it."

When the experience is near its end the narrator gives the rider one final task: to make and record a promise. After this, they return to base where the device is dismounted from the bike and the rider's deposit returned.

Rider Spoke therefore does not involve a predefined route. Rather, riders are encouraged to explore the city freely, choosing locations at which to record and 'hide' their stories for others to find later on. Interaction is kept simple so as to be safe and not interfere with the distinctive solitary experience of cycling through the city at dusk, when the event is staged. Riders interact with the device through a single earpiece headphone with inbuilt microphone and a simple touch-screen interface implemented in Adobe Flash. Although they listen to instructions while cycling along, riders are strongly encouraged to stop to interact with the device and to record and listen to stories. Interaction is through a touch-screen display that allows riders to choose what to do next. They can select and listen to messages, or record a message using an 'artistic' interface based on the metaphor of houses as hiding places. Figure 5 shows an example screen that prompts the user to record an answer.

Locations are determined using a variant of Wi-Fi fingerprinting as described in ([5], [18]). The N800 continually scans for Wi-Fi access points and compares the list of currently visible points (a fingerprint) against its database in order to determine whether the current fingerprint matches a known location or instead represents a new location that this rider has discovered for the first time. This technique also records adjacency relationships between fingerprints as they are encountered, gradually building up a connected graph, enabling location proximity to be deduced. The recordings and fingerprint data generated by each rider are offloaded from their device at the end of the experience and merged with the common database.

3.2 Studying Rider Spoke

To date Rider Spoke has been experienced by more than 900 riders over three outings. The experience premiered at the Barbican Centre in London in October 2007, where it attracted 500 riders over the course of eight days spread across two extended weekends. Subsequent outings in Athens in March 2008 (three days), and at the Brighton festival in May 2008 (four days) attracted 90 and 340 riders respectively. The following primarily draws upon questionnaires, supported by system logs. With 48 structured questions the questionnaire probed the background of riders, their attitude to cycling and their experience of Rider Spoke. A total of 120 questionnaires were returned; 80 (16% of all riders) for London, 4 (4.4%) for Athens and 36 (10.6%) for Brighton.

As in the case of the Sillitoe Trail, data was iteratively analysed driving the emergence of themes as now discussed.

3.2.1 Riders' ability

The questionnaire probed the riders' experience of cycling during Rider Spoke. As seen with the Sillitoe Trail, the event attracted participants with varying degrees of cycling proficiency. Over half of the respondents to the questionnaire said that they cycle on a regular or daily basis and also brought their own bikes with them, demonstrating a high level of commitment to take part. Four respondents reported that they never cycled, and a further individual refused to cycle, insisting instead to take part on foot – showing that even with an enthusiastic audience a few participants will still have very limited cycling proficiency.

3.2.2 Physical exertion and comfort

Respondents recorded overwhelmingly positive reactions to the physical nature of cycling and seemed to have been energised by their experience. Many commented that they liked being on a bike and felt engaged, awake, relaxed, alive, or excited, while others commented on the positive nature of the physical exertion involved.

"I love cycling and haven't cycled regularly for a while as my bike broke and I have not got round to fixing it! So it reminded me of the freedom I feel when I cycle and to cycle with no destination is wonderful."

"Exhausted, unnerved and moved."

For some riders, physical effort and tiredness was a powerful aspect of the experience, enhancing its emotional impact and possibly shaping their feelings as they answered questions. One rider said the experience had left them *"Emotionally drained"*. While others used the terms, *"frustrated, wound-up."* and *"slightly anxious"*, when asked about how they physically felt during the experience.

However, for others it was more problematic and a third of the respondents said that at some point during their experience they had to get off the bike and walk due to their routes, but also due to fatigue and discomfort.

"Towards the end when the hard seat of the bike started to affect me, and I had to get off and walk."

As the device was mounted directly on the bicycle, riders were effectively tethered to the cycle for the duration of the experience – they could not leave it behind for fear that the equipment or cycle (no lock was provided) might be stolen:

"in desperate, desperate need of the toilet. [...] therefore my main aim rapidly became to get back to the barbican just so I could sign the bike back over and use the loos."

3.2.3 Exploration and getting lost

The use of bicycles in Rider Spoke extended riders' range of movement within the city compared to pedestrian experiences. As the experience did not enforce a prescribed route and indeed, the device did not display a map for navigation, riders were free to cycle where they liked. When asked how they would best describe their manner of exploration, 50% of respondents categorised themselves as "explorers", 24% 'stayed close to home' while 9% 'cycled far away'. Reasons for staying close to home included being conscious of limited time and the fear of getting lost:

"We did explore but were conscious of not going too far given that we only had an hour for the round trip."

"I had no way of telling how to get back; I stayed close so I knew it couldn't be far."

Exploration also involved an altered awareness of the city. More than half of respondents believed that taking part in Rider Spoke made them more aware of their surroundings while cycling. Riders felt more observant than usual, and actively engaged with their location as they took part, cycling more slowly in order to find places that they would not otherwise have seen.

"I loved to use the bike to go places that cars can't go - to go down a one way road the wrong way."

However, 53% of respondents reported that they lost their bearings at some point, with one respondent having to resort to using the emergency map provided and asking passersby for directions in order to return to the venue. For some, the fear of getting lost was enough to prevent them from going too far or too fast. Rider Spoke specifically invites riders to explore and to find new places to leave their recordings, and this feedback suggests that it also needs to provide greater navigational support for the journey back to the venue at the end.

3.2.4 The impact of the terrain

The shape and nature of the terrain had a major impact on the experience, especially on patterns of exploration. Figure 6 visualises system logs to reveal the most visited locations in Brighton over four days. Each circle represents a distinct location (fingerprint), with its size showing the number of times it was visited. Many riders initially gravitated downhill away from the hosting venue towards the seafront, and then spread out from there. Two major vertical roads and the seafront itself (both difficult to cross) constrained exploration to the small network of streets and alleys in between. In London, riders only briefly used main-roads to initially head away from the venue before quickly breaking off to explore side-streets. Indeed, 84% of respondents said that they preferred to cycle through back-alleys, car-parks and underpasses, keeping off the beaten track, gravitating towards areas that were amenable to cycling.

3.2.5 Choosing locations

A key element of the experience was the act of hiding a message in a secret place, with riders cycling to find possible hiding places that were "private", "quiet", and "away from people", in keeping with the isolated nature of cycling alone at night. Riders reported trying to find suitably dramatic locations in which to hide messages, locations that were picturesque or had personal resonance.

"I usually looked for picturesque locations to stop. Places that looked suitable for a bit of reflection. Sometimes I looked for a marriage with the location and the mission - making a promise on the steps of the Old Bailey."

"...sometimes the background noise or the atmosphere of a particular place really chimed or sometimes jarred with the words I was speaking."

However, there were more practical concerns here too, including perceived safety.

"I wanted to find somewhere suitably secluded, but not so much that I was going to get mugged. Harder than it sounds to someone who doesn't live in London, and therefore assumes everyone there is a mugger."

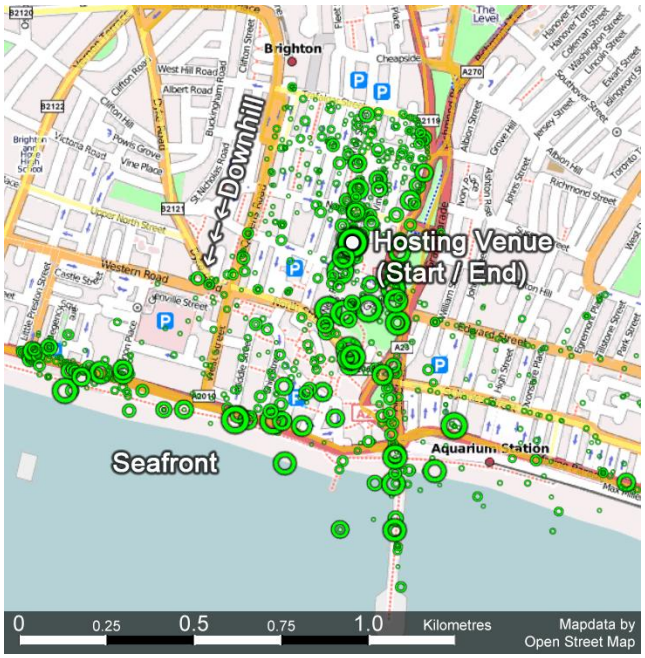

Figure 6. Most visited locations in Brighton

3.2.6 Distractions and boundaries

In spite of a range of precautions, safety was still a concern. While there were no accidents, it is apparent that riders must be made aware of the level of distraction of cycling while listening.

"I was so engrossed with listening to the lady asking me "Have you ever felt alone in a big city...etc" that a truck almost hit me near Holborn."

Some riders also reported a tendency to cross the usual boundaries of cycling behaviour, visiting unusual places, cycling in unusual ways, and sometimes breaking the rules of the road, for example cycling the wrong way along one way streets. It is interesting to consider the extent to which the nature of Rider Spoke might have encouraged such behaviour, though this is currently not clear.

"I loved to use the bike to go places that cars can't go - to go down a one way road the wrong way." One rider reported that they traveled on, *"roof tops, terraces, balconies, underpasses."*

3.2.7 Isolation

Participants in Rider Spoke were at once isolated from one another, cycling through a large geographic area often in the dark, while at the same time listening to personal messages recorded by strangers. The lack of a prescribed route in Rider Spoke meant that riders rarely encountered one another, and the experience was largely a solitary affair that set them apart from other members of the public, especially due to the use of a bicycle. The majority of respondents said that they felt self-conscious during the event, especially when recording a message or interacting with the device when members of the public were nearby.

"Firstly just from cycling around at night with the earphone and microphone, and when I stopped there was often other people walking past nearby, I thought they'd wonder what I was doing. Also I felt self-conscious of what people would think of my answers."

Many respondents referred to feelings of isolation, self-consciousness, and loneliness. However, these feelings, perhaps in combination with the physicality of the experience, appear to have stimulated a high degree of self-reflection and provoked a powerful emotional response:

"It was a very 'moving' experience for me and very memorable. To be alone in the city, holding your bike, blubbing about your father on a Sunday evening is something else....!"

"It was a private moment strangely enough not always in a private space."

Perhaps the combination of physicality, exploration and isolation afforded by cycling brings opportunities for creating new kinds of emotional interactive experiences?

4. EIGHT LESSONS

The findings from the studies are now compared. Eight general lessons for the design of cycle-based interactive experiences are drawn out and their implications discussed.

4.1 Cycling skill varies greatly

Conventional usability design shows that it is important to understand the user's degree of experience and skill with computers. While this is true to some extent of both the studies – since each involves some use of computers – it is clear that proficiency with a bicycle is also a major factor. Both studies involved users with widely varying levels of cycling experience, from highly athletic frequent riders to novices. For example, one Rider Spoke participant covered 10 miles in their hour (including interactions), while 5% claimed to rarely cycle, and one actually refused to cycle. The contention is made here that cycling differs from walking and driving in this respect. With the important exception of people with physical disabilities, walking is an everyday experience for many of us, and we are reasonably proficient at it. Alternatively, most people who drive cars have received considerable training and passed a proficiency test. Cycling, however, falls between these, being a complex skill that is often rarely practiced and may require no formal training.

Cycling proficiency can affect many aspects of an experience including pace (as noted by one Sillitoe participant), distance traveled, tiredness and comfort, ability to concentrate on media while cycling, confidence in traffic, and of course, safety. Experiences targeted at family groups could involve very diverse levels of cycling skill. Designers need to be aware of likely variations in cycling proficiency and adopt strategies such as providing multiple/alternative routes for different levels of skill (the Sillitoe Trail would perhaps have benefited from a simple novice route for beginners) as well as advertising difficulty, duration, conditions and required proficiency in advance.

4.2 Cycling is a demanding physical activity

Cycling can be a demanding physical activity, with profound consequences for an experience. The studies presented in this paper show that some participants were tired and even in discomfort by the end of their experience. This implies a need to design in clear opportunities for rest, or to enable riders to curtail their journey and easily return to base. However, taking rests can be difficult if riders are required to leave behind their bike and/or equipment, as seen with the Rider Spoke participant who felt unable to take a comfort break.

However, tiredness is not always a problem. Feedback from Rider Spoke often mentioned tiredness and exhaustion alongside feelings of exhilaration and even a sense of a cathartic or confessional experience. The suggestion is made here that moments of relaxation after physical tiredness may provide ideal opportunities to reward riders with experiences, and that they may feel more moved or engaged by these due to their physical and mental state. For example, reaching the summit of a hill may provide a perfect moment to deliver audio while the rider is recuperating and enjoying the view.

4.3 Close connection with the environment

Cyclists have a close relationship with their surrounding environment. Cycling is a visceral experience, with riders being physically connected to the underlying terrain, its surface details, the weather, and other environmental factors that have a profound impact on their experience. Hills are a major feature of cycling and feedback from the Sillitoe Trail shows how this affected the experience. Listening to the audio while traveling quickly downhill was problematic due to wind noise and potential distraction. In contrast, there would appear to be a possibility that audio might even enhance the experience of cycling uphill. Wind is also a major factor in cycling and there is evidence that this, as well as environmental noise from traffic and construction works, needs consideration. Finally, time of day is also a factor, for example in the distinctive experience of cycling through central London in the dark. Designers need to be able to imagine the situation of the cyclist at each moment: are they moving up or down hill, how will they be lit, what might the weather be like, will there be traffic jams or road works? In addition, it has also been seen how the shape of the terrain, major roads, water and other key boundaries constrain and guide where cyclists will go and this may also need to be factored into a design.

4.4 Cyclists can cover wide areas

Rider Spoke showed that cyclists enjoy the freedom of movement offered by cycling; one can travel a long way compared to pedestrians and yet enjoy relatively free access to the city when compared to cars. This leads to the potential to get lost (as demonstrated in Rider Spoke), requiring designers to provide navigation support, even if only in the form of a back-up paper map and telephone number to call in case of difficulties. A second problem is the temptation for riders to break the 'rules of the road' by cycling in inappropriate places. Indeed, designers should consider the possibility that by taking part in their experience, especially one such as Rider Spoke that encourages exploration, riders may feel that they have been given special license to behave in unusual ways. The Sillitoe Trail on the other hand adopted the contrasting approach of asking players to follow a well defined

trail. However, this now places important responsibilities in the hands of the designer. They need to determine whether such a trail should be circular or linear; must think carefully about its length, duration and short cuts, and need to strive for a balance between points of interest for the content and places where it is good to cycle.

4.5 Digital media must adapt to cycling

Both studies point towards audio being the medium of choice for cycling experiences, mostly due to its 'heads up' nature, minimizing the problem of distractions due to looking at screens. This mirrors the findings from some previous pedestrian experiences that also tried to maintain a heads-up approach [17]. However, it is clear that audio is sensitive to external interference and there remains the risk of not being able to hear traffic and pedestrians (which led both experiences to use single ear-pieces). It is also important not to use audio continuously, but rather try to save it for those particular moments when distraction and environmental noise will be at a minimum. Where visual interfaces are used or direct manipulation is required then the experience should encourage participants to stop before interacting. Indeed, the use of positioning technologies such as GPS might even make this technically enforceable.

4.6 Computers tether people to cycles

Cycles are a part of the interface hardware as well as computers and so need to be carefully integrated into the overall hardware design. A key choice is whether to mount the computing technology on the rider or the cycle. This is not a straight-forward decision (indeed the two experiences opted for contrasting approaches) and there are multiple factors to consider. A device that needs to be readily viewable might best be cycle-mounted, but this may be difficult when the rider brings his or her own equipment and also hinders temporarily leaving the bike (as previously discussed). Cycles might also offer a stable platform for mounting other equipment and potentially powering it (dynamo-driven mobile phone chargers are currently available). Equipment mounted on riders needs to be secure, with headphones being a particular concern as these are often loosely fitting, and fear of them falling out may restrict riders' head movements and hence put safety at risk.

4.7 Cycling limits social interaction

Both experiences revealed how cycling limits social interaction and so can constrain a multi-user experience. Unsurprisingly, in the Sillitoe Trail, riders found it difficult to concentrate on cycling, listening to audio and talking to one another at the same time. As a result, social interaction was mainly (though not exclusively) reserved for stops. This is perhaps one particular limitation of a bike-based tour as other systems have shown the benefits of multiple users joining the same virtual tour. One way to enhance social interaction might be to enable riders to eavesdrop on each others' experiences, an approach previously explored by the Sotto Voce museum visiting experience [24] which might be adapted to suit group cycling tours. Rider Spoke took this further, deliberately fostering social isolation so as to create a powerful reflective experience. The relatively individualistic nature of cycling (at least compared to walking with others) lends itself well to such an aesthetic.

4.8 Safety matters

Finally, the critical issue of safety has run throughout much of this discussion and is a challenging issue. Local laws and regulations may vary and so need to be checked on a location by location basis. Even so, the following observations are intended to highlight some general insights that should be of practical concern when designing in this space.

Both experiences took safety seriously, including briefing participants as to safety and legal issues and offering them safety equipment such as luminescent jackets, helmets and lights (when appropriate). Research into use of mobile technology in cars suggests that the timing and frequency of distractions have a large impact on safety [7]. Research on mobile phone use in cars also suggests that active interactions with a device whilst in traffic will be significantly more unsafe than passive consumption of media [21]. The use of audio versus visual media reflects these concerns, as does Rider Spoke's 'stop to interact' approach that is particularly suited to cycling where it is relatively easy to stop frequently in comparison to driving.

Although there have been no injuries across hundreds of players, it may well be that further safety mechanisms are needed – with special attention paid to any inexperienced cyclists. Another possibility would be to limit the interactive experience to areas of low-risk cycling, such as cycle paths – ensuring that the experience would be suspended when near traffic.

5. THE DISTINCT NATURE OF CYCLING

Stepping back from the fine detail, what more general conclusions can be drawn from these studies? The first is to note that for many, cycling is an enjoyable activity in its own right. This is probably even more the case for those who choose to take part in a cycling experience, as demonstrated by the questionnaires from Rider Spoke, where the majority of the respondents were keen cyclists. When designing a cycling experience, it is therefore important not to hinder this basic underlying enjoyment of cycling. It may also be acceptable to have even quite long gaps in the interactive aspects of the experience as the person may still enjoy cycling in between.

Drawing these findings together, it is suggested here that an overall design strategy could be to identify those (possibly few) critical moments at which it is ideal to deliver some content or interaction, taking account of multiple factors such as terrain, the rider's likely physical state, and potential traffic, wind and other environmental conditions. Conversely, content delivered at the wrong time will at best be ignored, may reduce the pleasure of cycling, or at worst threaten safety. Good design will be about picking just the right moment, for which an appreciation of the fine details of the nature of cycle-based interaction is important. In the Sillitoe Trail it is down to the designer of the trail to do this in advance. Rider Spoke is interesting because it places the decision of when and where to stop to interact in the hands of the rider. In this regard, integrating interactivity with cycling is a good example of the need for context-awareness in computing [8]; it is vital that either the designer or perhaps ultimately the system adapt to the dynamic context in which the cyclist finds themselves.

It is possible to frame both the Sillitoe Trail and the Rider Spoke experience within a traditional interaction-paradigm framework. The usual differentiation between searching and browsing is further delineated to divide between "directed" and "undirected" information seeking behavior with each being possible in an "active" or "passive" manner [1]. Context aware applications, such as Cheverst's tourist guide [6], can be interpreted as using situational information as part of the index for information retrieval. The experiences presented here can generally be thought of as passive (since the user is not actively hunting information, rather information is being automatically presented where and

when appropriate) – so, although a participant in Rider Spoke is involved in seeking the location of a piece of content, they are not directly seeking the content itself. Moreover, it maybe that once a location has been found that the rider will upload new content (rather than retrieve) and so the mechanic of seeking a location is variously directed or undirected depending on the precise activity of the user. Similarly, because most of the content is delivered via an automatic "push" the main opt-out control given to the user is to simply ignore the device. The restricting nature of bike riding means a minimal amount of interaction can be expected, so a manually requested "pull" could only be initiated during times when the rider were stationary and not occupied with the activities of riding safely.

The final summary point presented here emphasises the distinctive nature of cycling as a mode of transport. Although many of the detailed observations presented above may appear to be common sense (at least with hindsight), when viewed together they paint a picture of cycling as being a highly idiosyncratic way of traversing and experiencing the world. In short, cycling is neither walking nor driving. In many ways (mobility, speed, access to the environment) it lies somewhere between the two and in others (the effort required and the visceral connection to the world) it is unique. In order to successfully interweave interaction with cycling, designers must appreciate the nature of this mode of transport in fine detail, to which the studies described in this paper are intended to contribute.

In conclusion, this paper suggests that designing successful location-based and context-aware experiences requires more than just knowing where you are or where you are going; it is also vital to appreciate how you are getting there. In the long term, it is likely that mobile devices will see increasing use on all forms of transportation. HCI must be supported by studies concentrating on all the different modes, since each will have its own distinctive nature. Clear implications for experience design need to be drawn-out and highlighted for each type. The aim of this paper has been to begin this process for cycling.

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