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SocialBike: Quantified-Self Data as Social Cue in Physical Activity

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Abstract. Quantified-self application is widely used in sports and health management; the type and amount of data that can be fed back to the user are growing rapidly. However, only a few studies discussed the social attributes of quantified-self data, especially in the context of cycling. In this study, we present "SocialBike," a digital augmented bicycle that aims to increase cyclists' motivation and social relatedness in physical activity by showing their quantified-self data to each other. To evaluate the concept through a rigorous control experiment, we built a cycling simulation system to simulate a realistic cycling experience with SocialBike. A within-subjects experiment was conducted through the cycling simulation system with 20 participants. Quantitative data were collected with the Intrinsic Motivation Inventory (IMI) and data recorded by the simulation system; qualitative data were collected through user interviews. The result showed that SocialBike increase cyclists' intrinsic motivation, perceived competence, and social relatedness in physical activity.

Keywords: Social interaction · Quantified-self · Personal informatics · Motivation · Physical activity · Health

1 Introduction

Health tracking devices and applications have become increasingly ubiquitous. By accurately monitoring and systematically recording personal information, these applications help users manage their exercise, diet, or sleep. In addition to providing feedback to individual users, some applications offer social sharing capabilities (Fitbit, Nike+, Garmin, etc.), including in-app data sharing and data sharing to other social networks such as Facebook, Twitter, and Instagram. Epstein et al. [1] summarized six reasons why people share their personal informatics data: request for information, desire for emotional support, seeking motivation or accountability from the audience, motivating or informing the sharing audience, impression management.

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However, in this form of remote personal data sharing, there are gaps in time and space between the sharer and sharing audience. For instance, people can only share their exercise history after the actual exercise. When the sharing audience sees this information, their psychological and physiological state could be completely different from the sharer. These gaps create obstacles to the establishment of empathy and social connection between the sharer and the sharing audience. In face-to-face social interaction, people can use both verbal and non-verbal cues [2, 3] to communicate with each other, but digital information is hard to be used to facilitate communication, especially in the context of physical activity.

We tried to provide a channel for sharing digital information in a face-to-face social context; in other words, incorporate a digital communication layer into the physical world. Therefore, in this paper, we present SocialBike, a digital augmented bicycle that allows users to show their selected quantified-self data to other cyclists nearby. An experiment was conducted through a cycling simulation system with 20 participants. We examined the effect of SocialBike on increasing cyclists' motivation and social relatedness in physical activity.

2 Related Work

2.1 Quantified-Self Data in Social Contexts

Quantified-self data can be used to support health management or exercise. In addition to applications at the individual level, some studies have also explored the social application of quantified-self data. Epstein et al. [1] presented a design framework for social sharing in personal informatics. Ivanov et al. [4] explored factors that impact sharing health-tracking records; they investigated the influence of health motivation, perceived health status, the severity of health, and age on the sharing of self-tracked information. HeartLink [5] is an application that collects real-time personal biometric data in sports events and broadcasts this data online. "Jogging over a Distance" [6] is a system use spatialized audio based on heart rate to support runners in a different country running together.

Research on sharing quantified-self data is not limited to remote sharing via social networks or mobile applications. Some research applies quantified-self data to face-to-face social context. "Social Fabric Fitness" [7] is a wearable E-Textile display designed to support group running, it provides a shared screen on the back of the wearer's shirt, displaying information such as heart rate and pace. Walmink et al. [8] presented a bicycle helmet that can display heart rate to support social exertion experience. "Race by Hearts" [9] is a mobile application that enables competition based on heart rate data sharing between users in real-time.

2.2 Digitally Enhanced Face-to-Face Social Expression

In addition to quantified-self data, some other innovative digital forms are also applied by researchers to enhance face-to-face social expression. Beilharz et al. [10] presented a wearable device that uses physical analog visualization and digital sonification to convey feedback about the wearer's activity and environment. Walmink et al. [11] explored interaction opportunities around helmet design; they presented the concept of LumaHelm that turns the helmet into a display for communication, expression, and play.

Fluxa [12] is a wearable device that exploits body movements; it uses persistence of vision (POV) effect to generate mid-air social displays. Lighting effects were also widely used in textile design [13–15] and wearable devices [16–19] to enrich the wearer's social expression.

Some research tried to expand the social attributes of existing personal electronics devices, such as laptops [20] and smartwatches [21].

3 Design and Implementation

3.1 Design of SocialBike

SocialBike is a digital augmented bicycle designed to increase cyclists' motivation and social relatedness in physical activity. It allows users to show their selected quantified-self data to other cyclists nearby.

SocialBike consists of a mobile app based on Google Fit API [22] and an on-bike display. With the Google Fit platform, the mobile apps can get data from any health tracking devices that are compatible with Google Fit API (Fig. 1) [23]. In the mobile app, users can select the type and form of quantified-self data they want to display and send it to the on-bike display (Fig. 2).

The data type that SocialBike can display includes both real-time data such as heart rate and speed, as well as historical data over time, such as total distance, total steps, and total calorie consumption.

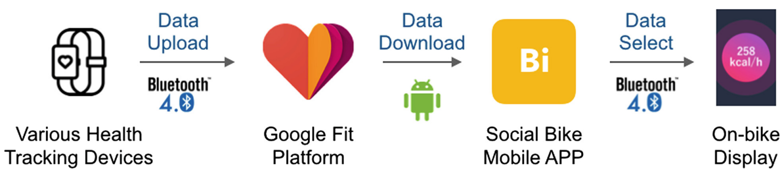

Fig. 1. Schematic of SocialBike's technical system.

Fig. 2. Prototype of SocialBike's on-bike display.

3.2 Cycling Simulation System

In order to conduct rigorous control experiments, a cycling simulation system was built to simulate a realistic riding experience with SocialBike. The hardware composition of the system is shown in Fig. 3.

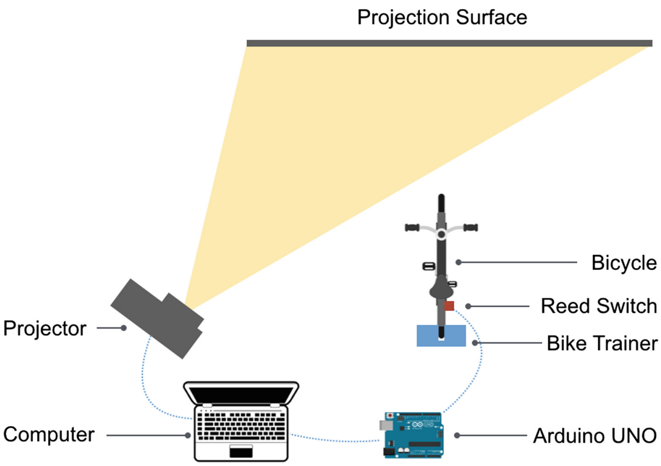

Fig. 3. Schematic of the cycling simulation system (top view).

A reed switch was mounted on the bike frame near the rear wheel, and a magnet was clamped to the spokes of the rear wheel (Fig. 4). Each time the rear wheel turns 360 degrees, the reed switch sends a signal to the Arduino Uno board. Based on the interval between the received signals, we calculated the rotational speed of the rear wheels through an Arduino program. When the system is running, this speed value is continuously transmitted to the computer through a serial port.

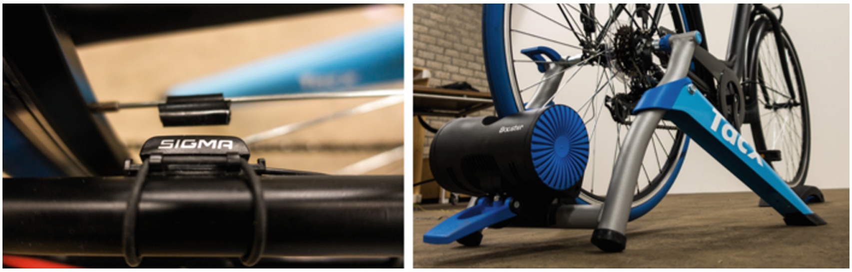

Fig. 4. The reed switch and magnet used to detect the rotational speed of the bike wheel (left) and the bike trainer used to provide resistance (right).

In addition, a bike trainer is used to simulate the friction of the bike wheel rolling on the real ground (Fig. 4).

The software part of the cycling simulation system was built with Unity 3D and running on a computer. The simulated scene in the program will be projected on a large surface in front of the bike. When the computer receives the rational speed value from a serial port, the simulation program will convert it to line speed base on the diameter of the bicycle wheel. When the system is running, the user's viewpoint in the simulation program is moving according to the line speed (Fig. 5).

Fig. 5. Cycling simulation system in test.

Since the study was conducted in the Netherlands, and all participants we recruited lived in the Netherlands. Therefore, in the scenario design of the simulation program, we used the elements of the Dutch bicycle lane to make the scene as close as possible to the local appearance (Fig. 6).

In the simulated scenario, the user will see other virtual cyclists riding their own SocialBike. The data displayed on virtual cyclists' bikes also change in real-time based on their riding speed (Fig. 6).

Fig. 6. Screenshots of different scenes in the simulation program.

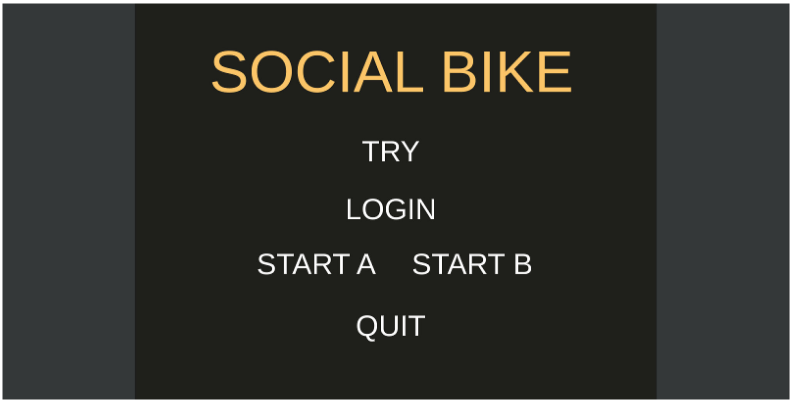

Fig. 7. Start menu of the simulation program.

Since the cycling simulation system is designed for experimentation, it has the ability to record experimental data. Participants' basic information can be entered into the system through the start menu (Fig. 7). At the end of each experiment, the system automatically generates a log file in .csv format. The log file contains all data related to participant's riding behavior in the experiment, such as position, speed, and distance to the virtual cyclist [24].

4 Evaluation

4.1 Subjects

Twenty participants (10 females, 10 males, age range: 27–41 years) participated in the study through informed consent procedures. All participants had experience in riding an ordinary bicycle. Each participant was compensated with 5 euros for their participation.

4.2 Independent Variable

In this experiment, we evaluated the influence of other people's quantified-self data on participants' behavior and mental state. Therefore, the bicycle that the participants were riding do not display their own data, but they can see the data of the virtual cyclist in the simulated scenario.

The independent variable in this experiment is the status of the virtual cyclist's on-bike display in the simulation program.

In the experiment scenario, the interface on the virtual cyclist's bike is showing an animation of his calorie consumption per hour. In the control scenario, the interface is inactive and shows a black screen (Fig. 8).

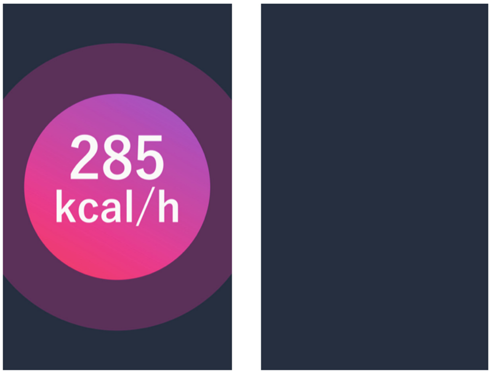

Fig. 8. The status of the independent variable in the experiment scenario (left) and the control scenario (right).

4.3 Measurements

The Intrinsic Motivation Inventory (IMI) [25] was used to evaluate the effect of the independent variable on participants' intrinsic motivation for physical activity and social relatedness with other cyclists. According to the instruction of the inventory, there are three questions in subscale "Value/Usefulness" needs to be completed by the researcher base on the questions they are addressing [25]. Therefore, we used "encouraging me to do more physical activity" to complete these three questions.

Participant's riding behavior data was automatically recorded by the simulation system. From the log files generated by the system, we extracted "the total time participant stays with the virtual cyclist within 5 m" as an indicator of social relatedness.

A semi-structured interview was conducted at the end of each experiment. The result of the interview was used to support the quantitative data and provide insights for further research.

4.4 Setup

The experiment was conducted in a laboratory with the cycling simulation system (Fig. 3). The simulated scenario was projected on a large surface in front of the bicycle. The size of the projected area is 291 cm wide and 188 cm high. The distance from the bicycle's front wheel to the projection surface is 160 cm (Fig. 9). All of these dimensions were designed to ensure that the simulated scenario showed to the participant was closest to the real-world perspective. The computer, projector, sensor, and all other devices used in the experiment were placed outside the subject's field of view.

Fig. 9. The experiment setup of SocialBike.

4.5 Procedure

Participants were randomly divided into two groups, group 1 and group 2. Before the formal experiment begins, we gave each participant a brief instruction about the experiment and let them read and sign the consent form. Then participants were invited to ride on the simulator with a free-riding mode for 2 min with the purpose of getting familiar with the riding simulation system.

The formal riding experiment has two sessions. In session A, each participant was introduced to the concept of SocialBike and asked to ride on the experiment scenario for 5 min. After that, they were asked to complete an IMI questionnaire [25] according to their experience. In session B, the participant was asked to ride on the control scenario for 5 min and complete an IMI questionnaire too.

In order to eliminate the influence of the order, participants in group 1 were asked to carry out session A before session B, participants in group 2 were asked to carry out session B before session A. Each participant had a 10-min break between the two sessions. At the end of each experiment, a semi-structured interview was conducted with the participant. Each interview took about ten minutes, and the interview was audio-recorded and transcribed by the researcher.

5 Result

5.1 Quantitative Result

Eight types of quantitative data were collected, including seven subscales in the Intrinsic Motivation Inventory (IMI) (Interest/Enjoyment, Perceived Competence, Effort/Importance, Pressure/Tension, Perceived Choice, Value/Usefulness, Relatedness) [25], and one indicator that we extracted from participants' cycling behavior data (Total time within 5 m). A paired sample t-test was conducted on each type of quantitative data to evaluate the effect of SocialBike.

5.1.1 Interest/Enjoyment

This subscale is considered the self-report measure of intrinsic motivation [25]. Base on the paired sample t-test, participants' feeling of interest/enjoyment in experiment scenario (Mean = 5.087 SD = 0.846) was significantly higher than in control scenario (Mean = 4.171 SD = 1.184), t(19) = 3.180, p = 0.005, r = 0.232 (Fig. 10).

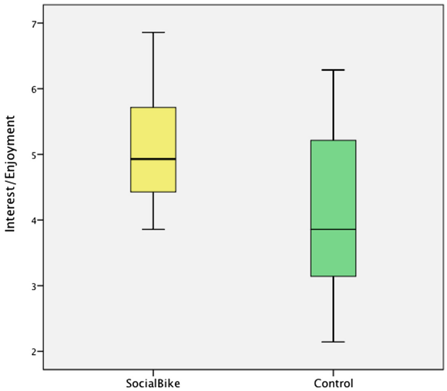

Fig. 10. The result of Interest/Enjoyment (ranges from 1–7).

5.1.2 Perceived Competence

Participants' perceived competence level in experiment scenario (Mean = 5.125, SD = 0.825) was significantly higher than in control scenario (Mean = 4.675, SD = 0.933), t(19) = 2.862, p = 0.010, r = 0.686 (Fig. 11).

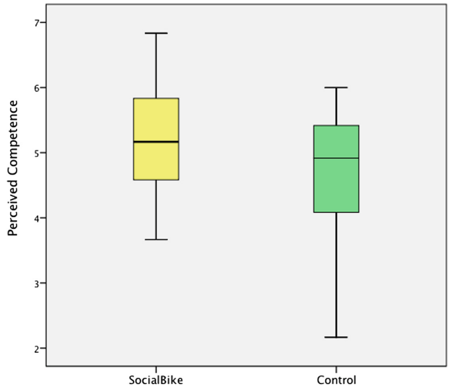

Fig. 11. The result of Perceived Competence (ranges from 1–7).

5.1.3 Effort/Importance

As regards the effort/importance, there was no significant difference between the result in experiment scenario (Mean = 3.920, SD = 0.916) and in control scenario (Mean = 3.750, SD = 0.929), t(19) = 0.923, p = 0.368, r = 0.601 (Fig. 12).

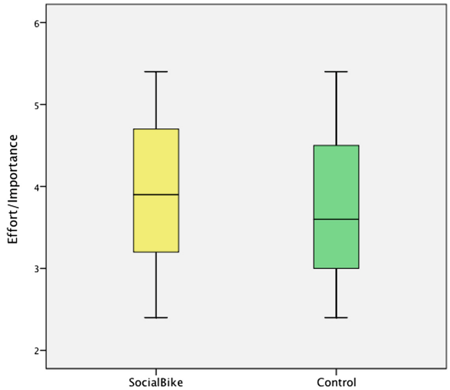

Fig. 12. The result of Effort/Importance (ranges from 1–7).

5.1.4 Pressure/Tension

Participants' feeling of pressure/tension had no significant difference in experiment scenario (Mean = 2.230, SD = 1.001) and in control scenario (Mean = 2.400, SD = 0.902), t(19) = −1.116, p = 0.278, r = 0.748 (Fig. 13).

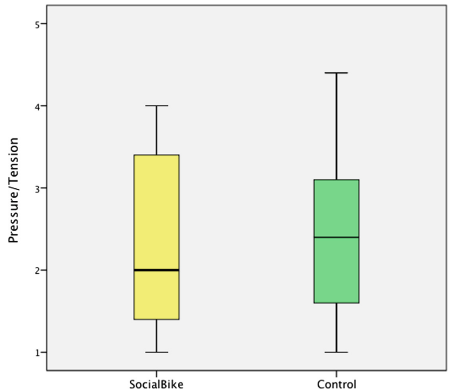

Fig. 13. The result of Pressure/Tension (ranges from 1–7).

5.1.5 Perceived Choice

Participants' perceived choice level had no significant difference in experiment scenario (Mean = 5.185, SD = 0.966) and in control scenario (Mean = 4.757, SD = 1.142), t(19) = 1.949, p = 0.066, r = 0.576 (Fig. 14).

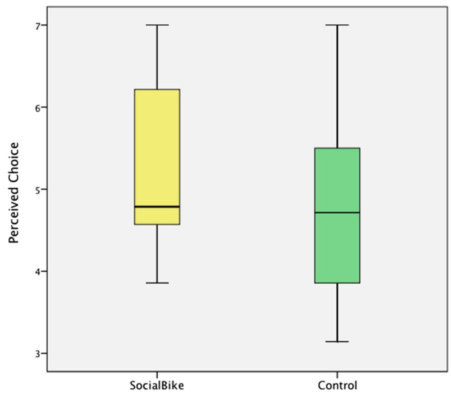

Fig. 14. The result of Perceived Choice (ranges from 1–7).

5.1.6 Value/Usefulness

Value/usefulness perceived by participants in experiment scenario (Mean = 5.643, SD = 0.971) was significantly higher than in control scenario (Mean = 4.743, SD = 1.282), t(19) = 3.846, p = 0.001, r = 0.603 (Fig. 15).

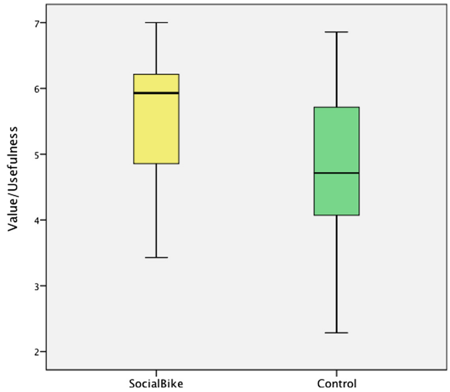

Fig. 15. The result of Value/Usefulness (ranges from 1–7).

5.1.7 Relatedness

Participants felt significantly stronger relatedness with other cyclist in experiment scenario (Mean = 4.481, SD = 1.209) than in control scenario (Mean = 3.519, SD = 1.033), t(19) = 3.115, p = 0.006, r = 0.248 (Fig. 16).

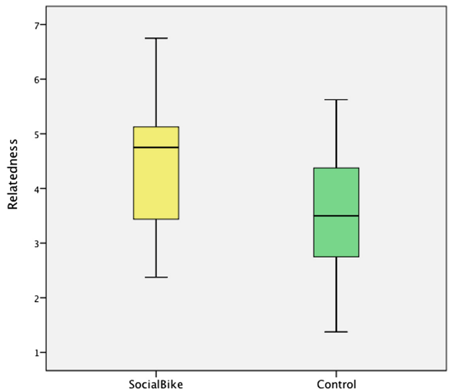

Fig. 16. The result of Relatedness (ranges from 1–7).

5.1.8 Total Time Within 5 m

The total time that participants keep within 5 m with the virtual cyclist in experiment scenario (Mean = 126.200, SD = 85.189) is significantly longer than in control scenario (Mean = 72.050, SD = 61.381), t(19) = 3.226, p = 0.004, r = 0.515 (Fig. 17).

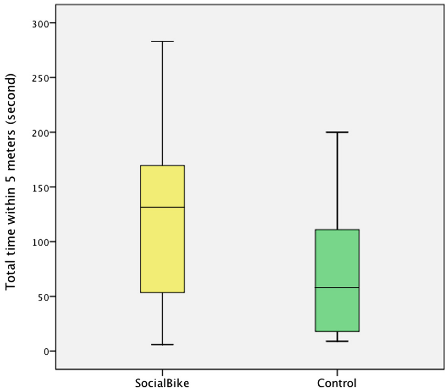

Fig. 17. The result of Total time within 5 m (ranges from 0–300).

5.2 Result of Interview

Motivation. Eighteen participants (out of 20) reported that SocialBike increased their motivation for cycling. Eight participants stated that they felt a competitive relationship with the virtual cyclist during the experiment. "With this data, I paid more attention to him. I regarded him as a competitor and wanted to take over him." (P20). "I was motivated. I tried to ride faster and beat the other cyclist." (P1). Ten participants reported that the virtual cyclist's data display provided a reference for them so that they can better understand their own riding state. "I want to follow this person; on the one hand, I am curious about his value so I can estimate my own value." (P5). "I am concerned about this value, I kept the same speed as him, so I can know how many calories will be consumed at that speed." (P16).

Social Interaction. Sixteen participants stated that SocialBike Increased their desire to communicate with other cyclists. They provided two different explanations. 10 participants mentioned that SocialBike could be a trigger to start a conversation, for instance, "…it opens up the possibility for interaction, if there is no information, I don't feel connected with him, if there is information, I think it could be a starting point that I can cycle with him, or have a talk later." (P8) "Without this display, I wouldn't have a point to start talking to him." (P9). Six participants reported that they believe this person is willing to interact with others because he has actively shown his personal data. "He chose to show the information, means that he is a relatively open person; he wants to interact with others." (P10). "I saw that he showed some data; I felt a little closer to him. Showing this information will affect the sense of distance between him and me.

I think he showed a friendly intention, which may have an icebreaking effect." (P15). "He shared this information, meaning he is willing to communicate with others." (P20).

Data Display. Seventeen participants stated that real-time calorie consumption data is helpful for their cycling. However, 3 participants reported that they did not know the exact meaning of this value, and they preferred a more intuitive presentation of calorie consumption. "I need to know what is the meaning of that number, if I know that, it will be more motivating for me" (P7). "I do not know what 200 calories mean. If it can be converted into the corresponding food, I will have stronger motivation." (P2). We also asked each participant if SocialBike could display other data types, what they wanted to show on their own bike. "Speed" was mentioned by 8 participants, "heart rate" and "total distance" was mentioned by 3 participants, "cycling route" was mentioned by 2 participants. Other options such as "slope", "achievement", "badge", "emoji" were also mentioned.

6 Discussion

6.1 The Data Type and Display Form

In this experiment, the quantified-self data we used is calorie consumption per hour. Since SocialBike can collect and display various types of data, other data types could also be implemented and evaluated in a future iteration. The result of the interview shows that users prefer to display real-time quantified self-data during the ride. Compared to historical data over time, real-time data will change dynamically in a short period. Therefore, participants have less concern about privacy issues when showing their real-time data. In future iterations, we will prioritize the use of real-time data in the design process. In addition, when displaying quantified-self data during cycling, the strategy of data visualization should be simple and intuitive. It is not necessary to excessively pursue the accuracy of the data presented.

6.2 The Influence of Mutual Data Display

In this study, we focus on the influence of other people's quantified-self data on participants' behavior and mental state. However, in the full concept of SocailBike, the data display between cyclists is mutual. If participants have a clear awareness of the data they are presenting to others, then SocialBike may have a different impact on them. In order to evaluate this impact in future studies, a front interface could be provided to the user to let them compare their data with other cyclists' data. Considering the riding safety, the information displayed on the front interface should be simple, conspicuous, and does not take too much attention from the cyclist.

6.3 The Simulated Cycling Experience

The cycling simulation system allows us to perform rigorous control experiments in the laboratory. In the design of the cycling simulation system, we have considered the inertia, friction, light, and many other environmental factors. Although there are always some inevitable differences between the simulated scene and the real environment, we still find some space for improvement through this study. During the interview, many participants expressed satisfaction with the visual experience of the simulator. However, one participant stated that there was a lack of auditory experience during the ride. In order to make the user's riding experience more realistic in future iterations, the auditory experience can be introduced by adding ambient sound effects to the program.

7 Conclusion

In this study, we explored the opportunity of incorporating a digital communication channel into the context of social cycling. SocialBike was presented as a digitally augmented bicycle that aims to increase cyclists' motivation and social relatedness in physical activity. An experiment was conducted with a cycling simulation system. Both quantitative results and qualitative results show that SocialBike increased cyclists' intrinsic motivation, perceived competence, and social relatedness in physical activity.

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