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Enhancing Intrinsic Motivation in Physical Activity through Quantified-self Data Sharing

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Abstract

INTRODUCTION: Quantified-self application is widely used in sports and health management; the type and amount of data that can be detected and 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.
OBJECTIVES: To design and evaluate SocialBike - a digitally augmented bicycle that aims to increase user's motivation in physical activity by showing their quantified-self data to each other.
METHODS: We conducted a within-subject experiment on a cycling simulation system with 20 participants. The on-bike display of SocialBike was compared to a control display to evaluate its impact on two dependent variables, including user's intrinsic motivation in physical activity and social relatedness with other cyclists nearby. Intrinsic Motivation Inventory (IMI) was used to measure users' self-reported intrinsic motivation and social relatedness. The user's cycling behaviour data were also recorded by the simulation system. We extracted six indicators about the two dependent variables from the behaviour data. Qualitative data were collected through semi-structured interviews. We conducted a paired sample T-test on both types of quantitative data. Qualitative data were analysed by the method of thematic analysis.
RESULTS: The results of the Intrinsic Motivation Inventory show that SocialBike's on-bike display has significant positive effects on four subscales, including intrinsic motivation, perceived competence, values/usefulness, and relatedness. The results of user cycling behaviour indicate that SocialBike increased user's social relatedness with other cyclists nearby by significantly affecting three indicators. Three themes were identified from qualitative data, including motivation, social interaction, and data visualization. The qualitative result provides supplementary evidence for the quantitative result and additional insights into the overall design of SocialBike.
CONCLUSION: SocialBike as a platform for sharing quantified-self data have positive effects in enhancing users' intrinsic motivation in physical activity and social relatedness with other cyclists nearby.

Keywords: social Interaction, human-computer interaction, quantified-self, personal informatics, intrinsic motivation, physical activity, health.

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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,

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seeking motivation or accountability from the audience, motivating or informing the sharing audience, impression management.

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] 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. The design of SocialBike was evaluated through a controlled experiment with 20 participants to investigate its impact on two dependent variables, including the user's intrinsic motivation in physical activity and social relatedness with other cyclists nearby. The work presented in this paper is an extensive study based on our previous publication [3]. In this paper, we incorporated additional data analysis and discussions from the perspective of user behaviour. New indicators of the dependent variables have been extracted from users' cycling behaviour data, providing more evidence about the impact of SocialBike. The potential impact scenarios of the concept are also discussed in this paper.

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. Hassib et al. [6] presented HeartChat as a mobile messaging application that integrates heart rate as a cue to increase the user's awareness and empathy.

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. Colley et al. [9] investigate the wearable presentation of tracked wellness data, and people's perceptions and motivations for sharing it through a wearable display.

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.

Dagan et al. [10] presented a design framework for social wearables from six perspectives, including sensing, actuating, sensing-actuating interplay, sensing-actuating interplay between wearables, personal and social requirements, and social acceptability. Dierk et al. [11] presented AlterWear as an architecture for battery-free wearable displays supporting opportunistic interactions. They demonstrated new wearables enabled through the architecture with dynamic, fashion-forward, and expressive displays across several form factors.

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, 14, 15] and wearable devices [16, 17, 18] to enrich the wearer's social expression.

Some research tried to expand the social attributes of existing personal electronics devices, such as laptops [19] and wristband [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, SocialBike's mobile app can get data from any health tracking devices that are compatible with Google Fit API (Figure 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 (Figure 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.

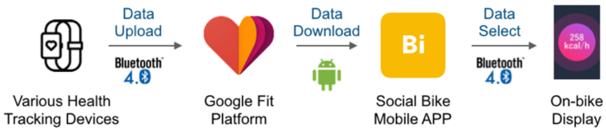

Figure. 1. Schematic of SocialBike's technical system.

Figure. 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 Figure 3.

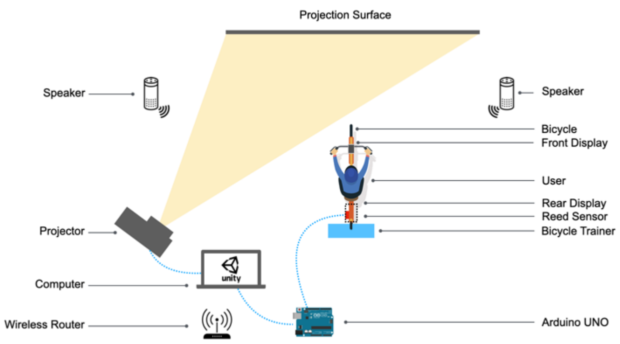

Figure. 3. Schematic of the Cycling Simulation System (Top View).

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 (Figure 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.

Figure. 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).

Figure. 5. The cycling simulation system under development.

When the system is running, this speed value is continuously transmitted to the computer through a serial port.

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 (Figure 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 (Figure 6).

Figure. 6. Screenshots of different scenes in 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 (Figure 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 behaviour in the experiment, such as position, speed, and distance to the virtual cyclist [24].

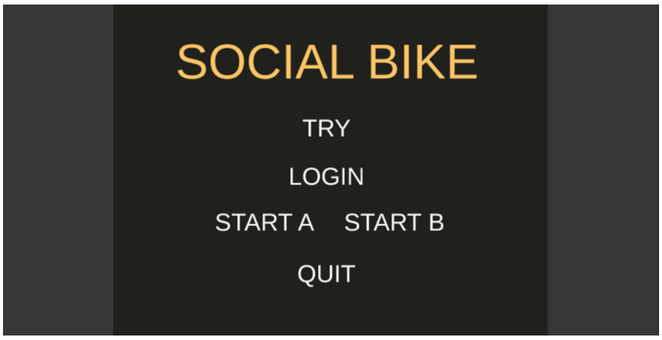

Figure. 7. Start menu of the simulation program.

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.

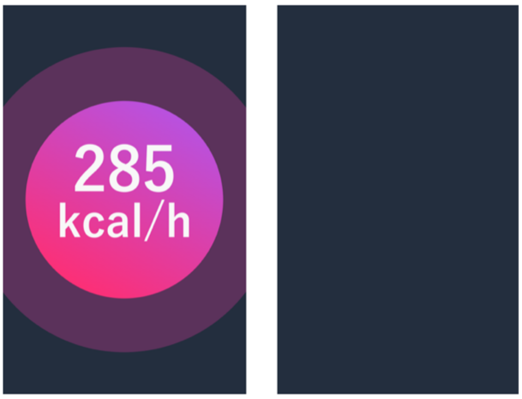

Figure. 8. The status of the independent variable in the experiment scenario (left) and control scenario (right).

4.2 Independent Variable

In this experiment, we evaluated the influence of other people's quantified-self data on participants' behaviour 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 (Figure 8).

4.3 Measurements

The Intrinsic Motivation Inventory (IMI) [25, 26] was used to evaluate the effect of the independent variable on participants' intrinsic motivation in 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 behaviour data was automatically recorded by the simulation system. Six variables related to user's cycling behaviour were extracted.

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 a cycling simulation system (Figure 3). The simulated scenario was projected on a large surface in front of the bicycle. The size of the projected area is 291cm wide and 188cm high. The distance from the bicycle's front wheel to the projection surface is 160cm (Figure 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.

Figure. 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 minutes 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 minutes. 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 minutes 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-minutes 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 Results of the Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) has seven subscales， including Interest/Enjoyment, Perceived Competence, Effort/Importance, Pressure/Tension, Perceived Choice, Value/Usefulness, and Relatedness. The first subscale (Interests/ Enjoyment) is considered to be the measure of intrinsic motivation [25], which is the primary measure of this experiment. A paired sample t-test was conducted on each subscale to evaluate the effect of SocialBike.

Interest/ Enjoyment

This subscale is considered the self-report measure of intrinsic motivation [25]. Base on the paired sample t-test, participants' intrinsic motivation 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 (Figure 10).

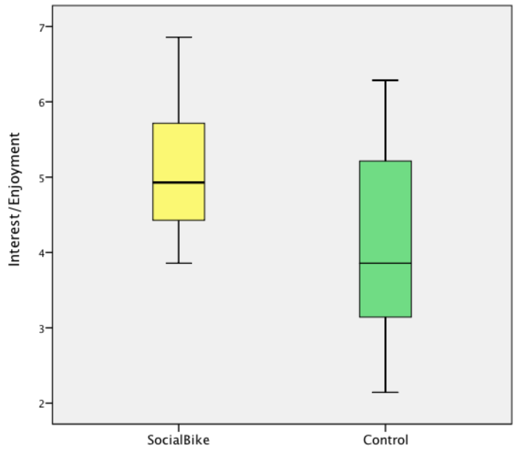

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Figure. 10. The result of Interest/Enjoyment (ranges from 1-7).

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 (Figure 11).

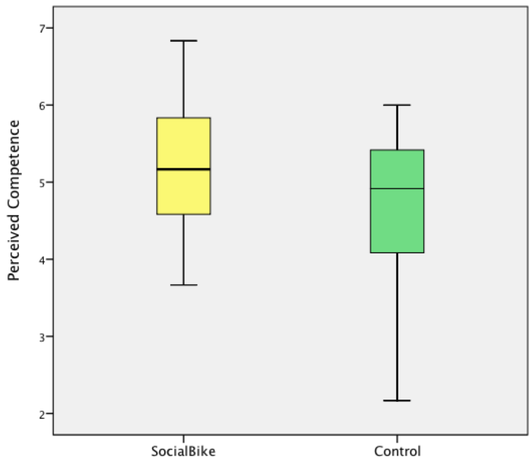

Figure. 11. The result of Perceived Competence (ranges from 1-7).

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 (Figure 12).

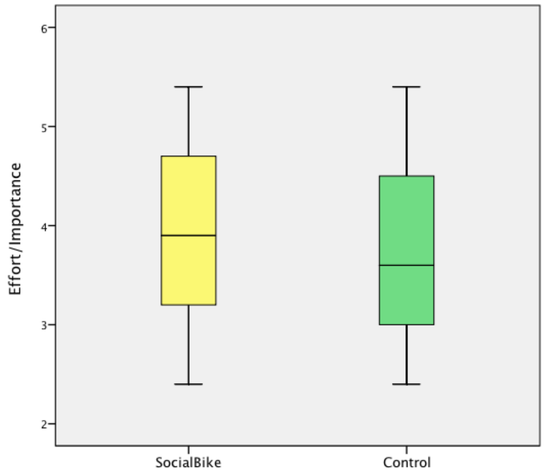

Figure. 12. The result of Effort/Importance (ranges from 1-7).

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 (Figure 13).

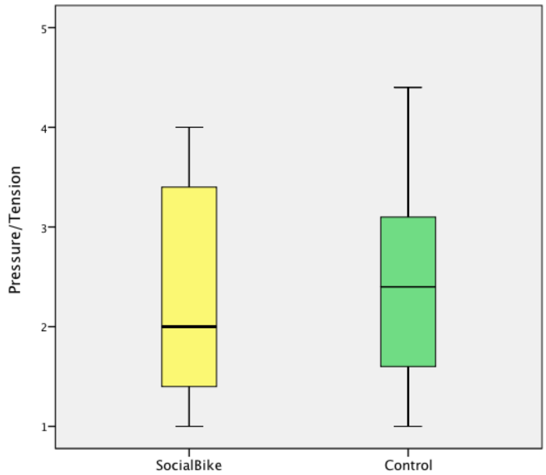

Figure. 13. The result of Pressure/Tension (ranges from 1-7).

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 (Figure 14).

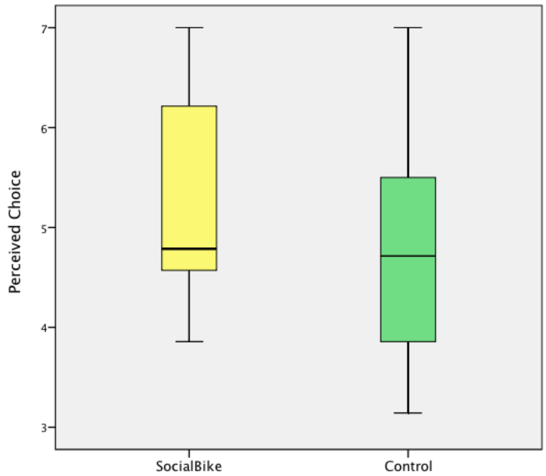

Figure. 14. The result of Perceived Choice (ranges from 1-7).

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 (Figure. 15).

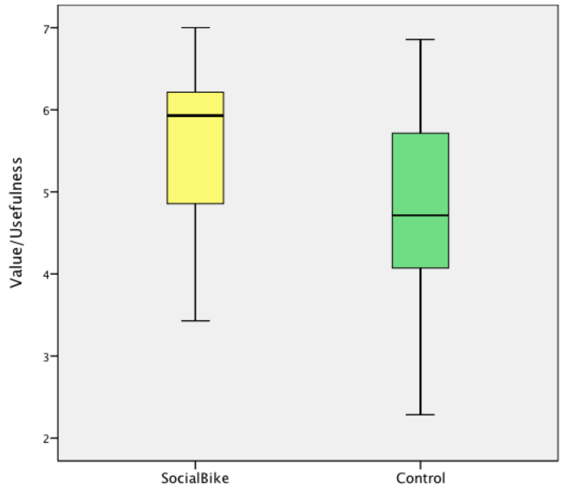

Figure. 15. The result of Value/Usefulness (ranges from 1-7).

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 (Figure 16).

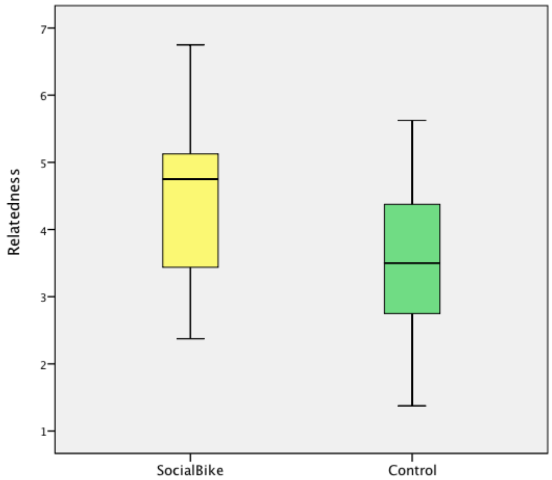

Figure. 16. The result of Relatedness (ranges from 1-7).

Conclusion

Results of the Intrinsic Motivation Inventory show that SocialBike's on-bike display has a significant positive effect on four subscales of the inventory, including "Interest/Enjoyment (Intrinsic Motivation)", "Perceived Competence", "Value/ Usefulness" and "Relatedness". On other three subscales, the differences between the experimental group and the control group are not significant (Table. 1).

Table 1. Results of the Intrinsic Motivation Inventory

Subscales	Mean Diff.	SD Diff.	P-value
Interest/Enjoyment	0.914	1.285	**0.005**
Perceived Competence	0.450	0.703	**0.010**
Effort/ Importance	0.170	0.824	0.368
Pressure/ Tension	-0.170	0.681	0.278
Perceived Choice	0.428	0.983	0.066
Value/ Usefulness	0.900	1.042	**0.001**
Relatedness	0.963	1.382	**0.006**

5.2 Results of the user behaviour

Define indicators

From the user's riding behaviour data, we extracted six data types of data as indicators of intrinsic motivation and social relatedness, including "Average Speed", "Total Time within 5 meters", "Total Time Behind", "Total Time Ahead", "Average Distance Behind" and "Average Distance Ahead". "Average Speed" is defined as the average cycling speed of the participants throughout each test. "Total Time within 5 meters" is defined as the total time that the participant spent riding within 5 meters of the virtual cyclist. "Total Time Behind/ Ahead" is defined as the total time that the participant spent riding behind/ in front of the virtual cyclist. "Average Distance Behind/ Ahead" is defined as the average distance between the participant and the virtual cyclist when the participant is riding behind / in front of the virtual cyclist.

In the above six data types, "Average Speed" is an indicator of motivation in physical activity, and the others five data types are indicators of social relatedness. Because SocialBike's on-bike display is located at the rear of the bicycle, users can only see the data shared by other cyclists when riding behind them. If users ride far away in front of other cyclists, they can no longer see the data of other cyclists and lose the possibility of interacting with them. Therefore, we define four indicators about total time and average distance according to the positional relationship (Behind/ Ahead) between the user and the virtual cyclist.

We also set a relatively low average speed (7 mph) for the virtual cyclist in the experiment, which means that all users can choose to overtake or follow him. This setting ensures that users' positional relationship with the virtual rider reflects their true intentions, and users will not be limited by their maximum speed.

In addition to following and overtaking, users have another riding behaviour in the experiment. Some users continuously ride in parallel with other cyclists. They may accelerate or decelerate within a small range, but they will not ride far away from the virtual cyclist. Based on this riding behaviour, we extracted "Total Time in 5 meters" as another indicator of Social Relatedness.

A Paired sample t-test was conducted on each indicator to evaluate the effect of SocialBike.

Average Speed (mph)

Participants' average speed had no significant difference in experiment scenario (Mean=8.213, SD=1.613) and in control scenario (Mean=8.946, SD=1.834), t(19)=-1.607, p=0.124 (Figure. 17).

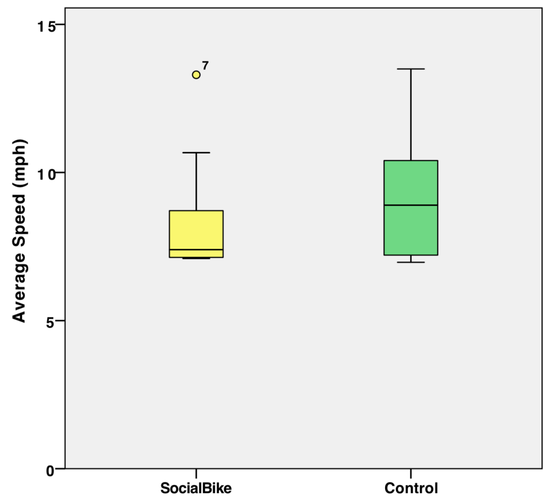

Figure. 17. The result of Average Speed (mph)

Total Time within 5 Meters (second)

The total time that participants keep within 5 meters 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 (Figure 18).

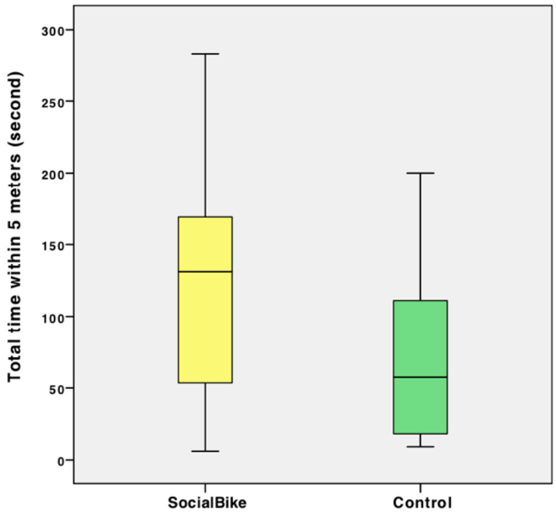

Figure. 18. The result of Total time within 5 meters (second)

Total Time Behind (second)

The total time that participants riding behind the virtual cyclist in experiment scenario (Mean=175.700, SD=107.685) is significantly shorter than in control scenario (Mean=184.90, SD=87.406), t(19)=2.187, p=0.041 (Figure. 19).

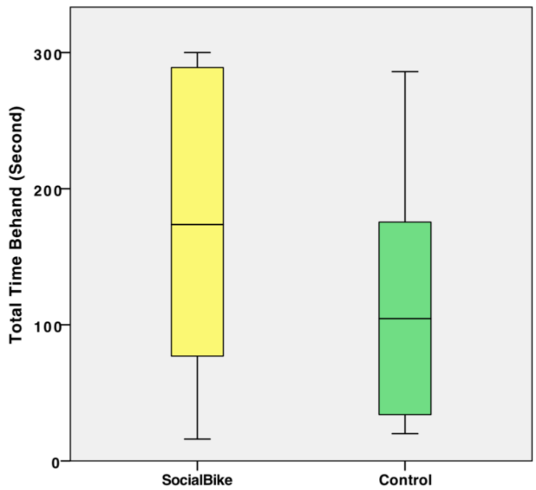

Figure. 19. The result of Total Time Behind (second)

Total Time Ahead (second)

The total time that participants riding in front of the virtual cyclist in experiment scenario (Mean=123.55, SD=107.685) is significantly longer than in control scenario (Mean=184.90, SD=87.406), t(19)=-2.216, p=0.039 (Figure. 20).

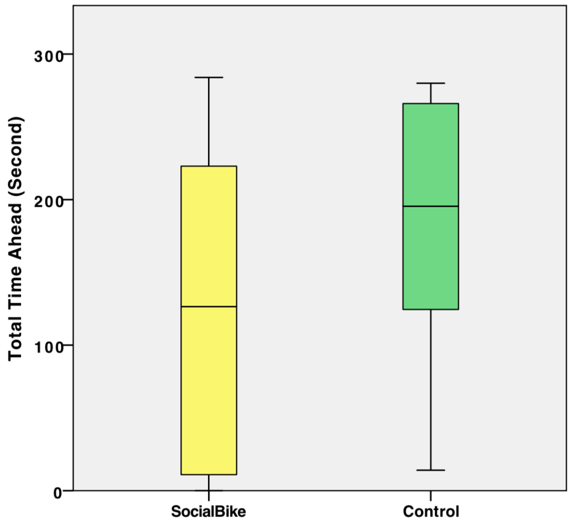

Figure. 20. The result of Total Time Ahead (second)

Average Distance Behind (meter)

Participants' average distance to the virtual when riding behind in experiment scenario (Mean=7.024, SD=3.053) is shorter than in control scenario (Mean=9.577, SD=5.810). However, the difference is not significant t(19)=-2.083, p=0.051 (Figure. 21).

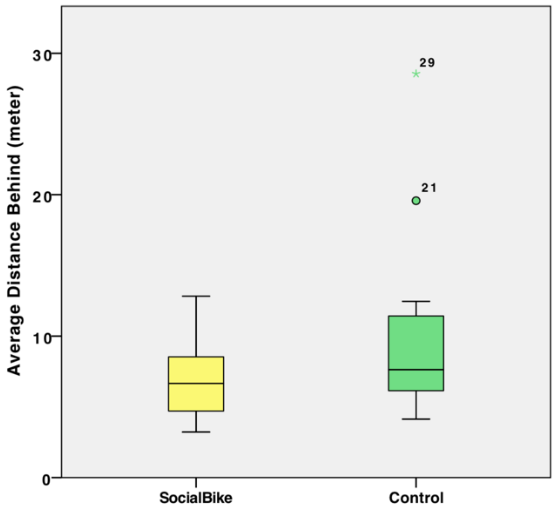

Figure. 21. The result of Average Distance Behind (meter)

Average Distance Ahead (meter)

Participants' average distance to the virtual when riding in front of the virtual cyclist had no significant difference in experiment scenario (Mean=57.917, SD=70.364) and in control scenario (Mean=79.405, SD=70.887, t(19)=-1.031, p=0.319 (Figure. 22).

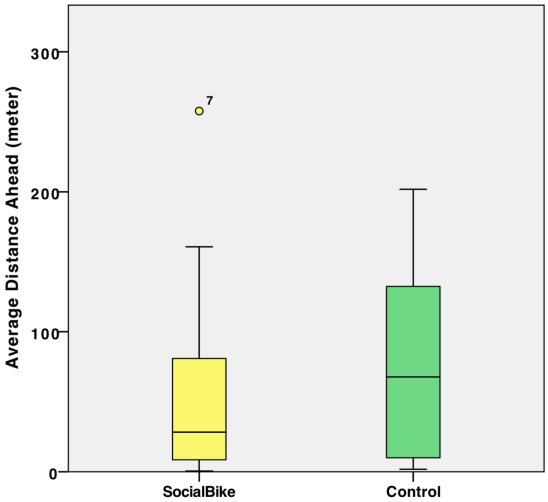

Figure. 22. The result of Average Distance Ahead (meter)

Conclusion

Results of the Intrinsic Motivation Inventory show that SocialBike's on-bike display has a significant positive effect on four subscales of the inventory, including "Interest/Enjoyment (Intrinsic Motivation)," "Perceived Competence," "Value/ Usefulness" and "Relatedness." On the other three subscales, the differences between the experimental group and the control group are not significant (Table. 1).

Table 2. Results of user behaviour

Variables	Mean Diff.	SD Diff.	P-value
Average Speed	-0.73	2.04	0.124
Total Time within 5m	51.45	75.08	**0.004**
Total Time Behind	60.60	123.89	**0.041**
Total Time Ahead	-61.35	123.83	**0.039**
Average Distance Behind	-2.55	5.48	0.051
Average Distance Ahead	-21.49	83.38	0.319

5.3 Results of the 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. Ten 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" and "emoji" were also mentioned.

6. Discussion

6.1 Data type and visualization

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 Influence of mutual data display

In this study, we focus on the influence of other people's quantified-self data on participants' intrinsic motivation in physical activity and social relatedness with other cyclists nearby. However, in the full concept of SocialBike, 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 Influence of competitor’s performance

Since the average riding speed of different participants is diverse, in this experiment, we set a relatively low average speed for the virtual cyclist. Under this setting, all participants have the opportunity to approach and overtake the virtual cyclist. However, this speed limit also affected the average riding speed of the participants. The results of user behaviour show that participants spent a lot of time following other cyclists in the experiment scenario, which means they must ride at a speed close to 7 mph. This resulted in the mean of users’ average speed is lower in the experimental group than in the control group. In this case, the users’ average speed as an indicator of motivation is affected by other factors because of the user’s desire to accelerate conflicts with their purpose of following other cyclists.

In future iterations, other virtual cyclists riding in different speed ranges can be added to the experiment.

With competitors of different performance levels, users can meet other SocialBike users when riding at different speeds. When users’ desire for acceleration is not restricted by other purposes, we can extract more variables related to speed and obtain more evidence about the impact of SocialBike on the user’s motivation.

6.4 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.

6.5 Potential Impact Scenarios

Today, bicycles play two primary roles in people’s daily lives. They can be used as exercise or relaxation equipment, or as commuting tools. As the results of this article show, SocialBike as a digitally enhanced bicycle can enhance user’s intrinsic motivation in physical activity and social relatedness with other cyclists nearby. Therefore, the main impact scenarios of SocialBike will be cycling activities for the purpose of exercise or relaxation, especially when these activities are carried out in groups. When a user has an urgent commuting purpose, other people’s data may not attract their attention. As a result, SocialBike will have less impact in a pure commuting scenario. However, in some scenarios, the boundary between exercise and commute is blurred. When users use bicycles as commuting tools in non-emergency situations, they can also maintain the purpose of exercising at the same time. Therefore, SocialBike can also have a certain impact on users in these scenarios.

When implementing the design of SocialBike in actual scenarios, the current experiment-oriented simulation system needs to be replaced by a mobile technology solution. We have developed a mobile working prototype based on Google Fit and Android platform (Figure. 1). In this solution, the data storage and display are operated by two separate devices connected through Bluetooth. In other words, the on-bike display act as an external screen of SocialBike mobile application and will only be activated when connected to the mobile app through Bluetooth. This solution can reduce the implementation cost of SocialBike and improves the security of user’s data.

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 with 20 participants. Intrinsic Motivation Inventory was used to measure users' self-reported intrinsic motivation and social relatedness. Six indicators about the dependent variables were extracted from users' cycling behaviour data. Qualitative data were collected through semi-structured interviews. The results of the Intrinsic Motivation Inventory show that SocialBike's on-bike display has significant positive effects on four subscales, including intrinsic motivation, perceived competence, values/usefulness, and relatedness. The results of user cycling behaviour indicate that SocialBike increased user's social relatedness with other cyclists nearby by significantly affecting three indicators, including "Total Time within 5 meters", "Total Time Behind", and "Total Time Ahead". Three themes were identified from qualitative data, including motivation, social interaction, and data visualization, providing supplementary evidence for the quantitative result and additional insights into the overall design of SocialBike. We discussed the insights obtained in the process of design, implementation, and data analysis, as well as opportunities for future development.

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