Interact Through Your Data: Collective Immersive Experience Design for Indoor Exercises

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Abstract. This paper presents an explorative design for improving indoor exercising experience, through real-time data visualization and social connection in an immersive environment. A prototype was designed and implemented based on the review of related research on cognitive and mental models. Facing existing design challenges, the project aims to find potential opportunities for future indoor exercises, and explore the relationship between the immersive user experience and users' intention of exercising.

Keywords: Immersive experience · Data visualization · Social interaction · Indoor exercising

1 Introduction

1.1 Background

Regular exercising in daily life, such as running, cycling and swimming, is considered to be beneficial for people in both physical and mental health.

To increase the efficiency of exercise, large numbers of professional fitness machines have been invented to help in controlling the quality of posture and movement, improving the pertinence of individuals' fitness plans, and saving our time.

However, besides the benefits brought by the machines, there are also varieties of drawbacks, especially from the perspective of user experience, such as being stuck indoor with unchanged environment, getting abstract and confusing data as feedback, and feeling being isolated by the machines.

These disadvantages could gradually drive regular exercising in recent days into a lonely, boring and repeated process. It is hard for many to carrying on doing the exercises for a longer period of time. Boredom, loneliness and no obvious progress are common excuses for many to quit their exercises for fitness.

A better context for people to keep regular exercising is to experience an enjoyable or interesting process with their friends together at the same place, which is usually difficult to accomplish in real life. It gives opportunities for research and design practice to explore new concepts and solutions to improve current situations.

P.L.P. Rau (Ed.): CCD 2015, Part II, LNCS 9181, pp. 328–337, 2015.
DOI: 10.1007/978-3-319-20934-0_31

1.2 Related Work

A lot of studies have been done to improve the indoor exercising experience. Currently, there are two typical research directions: one is to simulate the real sports environment or create virtual immersive environment [1, 2]; the other is to combine the exercises with (online) gaming elements [3]. There are also improvements on extended service like long-term data recording and analysis.

Simulation of the real environment helps to build up an immersive experience with familiar outdoor scenes in exercising, and enriches the experience by adding natural factors onto indoor training. For example, some cycling machines provide different exercising modes to simulate outdoor contexts like climbing a mountain or riding along a road.[1] The creation of virtual immersive environment can provide people with more engaged and fresh experience that they may not have indoor in real life. However, these research directions seldom focus on creating social connection for users.

The direction to combine indoor exercising with game factors, especially online game modes, focuses more on facilitating social interaction and creating playful experience through gaming mechanics,[2] while the exercising quality is no longer a core of the sporting process.

With the maturity of sensing technology and social media, applications and services have been implemented to motivate people to do exercises through making use of psychological factors in competitions. These products and systems also provide users new approaches to record and share their achievements with others, and are becoming increasingly intelligent in giving appropriate advices based on the analysis of long-term exercising records.[3] Yet, these design concepts suit more in providing support services rather than improving the real-time experience during the exercises.

Based on observation on related work, it indicates that there is still a need to explore more possibilities for improving indoor exercising experience and evoking users' intention of exercising in places like gymnasium and sports center.

Compared with existing solutions, the design project presented here pays more attention to creating a real-time and immersive experience in digitally augmented indoor environment. It focuses on two major design problems: one is how to create an immersive but functional exercising experience, which can transform the abstract numbers from the sensors into understandable information or intuitive feelings to help users improve their exercising quality; the other is how to facilitate the sense of being accompanied through social connection and collective exercising with others.

In order to deal with the design challenges, we conducted a theoretical review to obtain a better understanding of potential methods and tools. A design framework was created and followed, aiming at bringing users a new indoor exercising experience, in order to evoke and strengthen users' intention of exercising and improve the quality of

[1] How to Ride Inside: Indoor Trainer Workouts for Cyclists, http://www.bicycling.com/training-nutrition/training-fitness/how-ride-inside-indoor-trainer-workouts-cyclists.

[2] Play It: Soccer Becomes a Virtual Sport in Barcelona, http://www.moodmedia.se/newsdetail.asp?catid=2&id=3084.

[3] Six running apps to keep you fit for 2012, http://www.phonesreview.co.uk/2012/05/24/6-running-apps-to-keep-you-fit-for-2012/.

their exercises. A prototype was implemented based on the design framework during the hackathon event in Eindhoven, called SPRINT14.[4]

2 Collective Immersive Experience

Usually, indoor places for exercising are public, except personal environment (e.g. living room or bedroom at home), and there are lots of people in exercising, which shows potentials to provide them with a collective and immersive experience. A common method is to facilitate the immersive experience in the surrounding environment by enhancing the atmosphere around with visual or multi-modal augmentation.

2.1 Immersive Environment for Indoor Exercises

Immersive virtual environment (IVE) technology shows the potential in improving indoor exercising experience and enhancing the enjoyment of using. Taking advantages of virtual reality (VR), extrinsic and intrinsic motivations can be applied to evoke users' intention of exercising.

Immersion and presence are two important properties of virtual environments [4]. Since the feeling of presence is positively correlated to enjoyment [5], IVE usually emphasizes the feeling of "being there", which "requires a self-representation in the virtual environment - a virtual body" [4], according to Slater and Wilbur (1997).

While in the context of indoor exercising, users need to focus on their physical bodies, rather than the virtual body, which indicates that only digitally augmenting the environment is not enough for users who exercise regularly, as they need to pay attention to the quality of their physical exercises as well.

It is also related to users' understanding of the abstract data presented on equipment's dashboard panels. It is not so easy for people to transform the data into an intuitional feeling of how well they are doing. Even if they can understand the data after getting familiar to the functions, the reading and transforming process is still a distraction from exercising. There is a need to provide more direct or intuitive feedback to help them in real-time self-evaluation and adjustment.

Moreover, although a higher sense of presence does associate with a stronger feeling of enjoyment, it also brings possibilities in blocking social interactions and isolating users in the same indoor space.

Thus, in this context, instead of creating an immersive virtual reality environment, we tried to keep users immersed by enhancing the interplay between their exercising status and the visualization of physiological data, and to provide opportunities for social interaction. The abstract physiological data was transformed into intuitively understandable feedback through vivid and metaphorical data visualization, and projected into the physical environment, changing along with users' real-time exercising status.

[4] The website of SPRINT14, http://www.sprint14.nl/.

2.2 Related Study on Cognition and Mental Models

In order to facilitate the immersive experience through visualization of the physiological data, a design framework is created based on the literature review on related notions and models, including the model of users' intention, the cognitive hierarchy, and mental model in data visualization.

Users' intention of doing exercises. Literature review on user acceptance model showed the potential of explaining the user's intention of exercising and providing a guideline for design.

Figure 1 shows the basic model that explains the relation between users' intention and their actual behaviour. It is based on the theory of planned behaviour model (TPB) [6], which is an extension of the most widely used model called theory of reasoned action (TRA) [7]. The upper blue area shows the TRA and the entire figure shows the TPB. The main difference between two models is Perceived Behavioural Control.

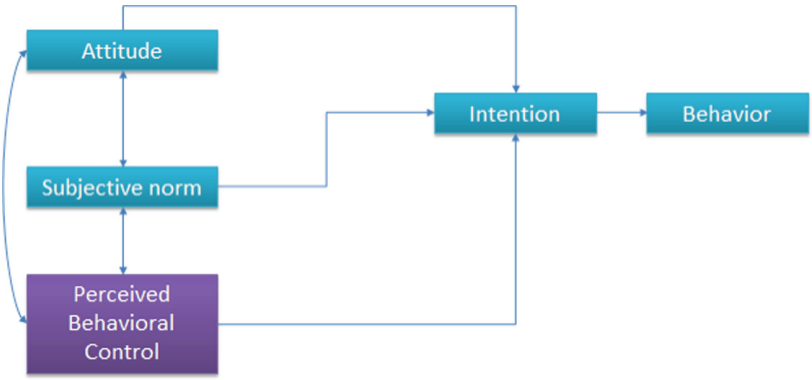

Fig. 1. Theory of reasoned action and theory of planned behaviour

Ajzen indicates that the combination of attitude towards the behaviour, subjective norms, and perception of behavioural control (Fig. 1) plays an important role in the actual behaviour execution [8]. People's subjective norms, which can be considered as "a kind of grammar of social interaction", change slowly through the social behaviour [9]. Furthermore, the easier users perceive that they can control the behaviour, the stronger their intention to perform the behaviour becomes [8].

In our context of indoor exercising, we mainly explored two design problems based on this model: (1) whether a better understanding of users' exercising status gives users a stronger perceived behaviour control, and results in stronger intention of taking the action; (2) whether the social interaction during the exercise will positively influence user's subjective norms and intention of taking the action.

Cognitive Hierarchy. Figure 2 shows the hierarchy of cognition [10], which indicates the process of knowledge generation in intelligence systems. It can be used to explain not only the process in computing system (e.g. the exercising assistance system), but also the process in human mind.

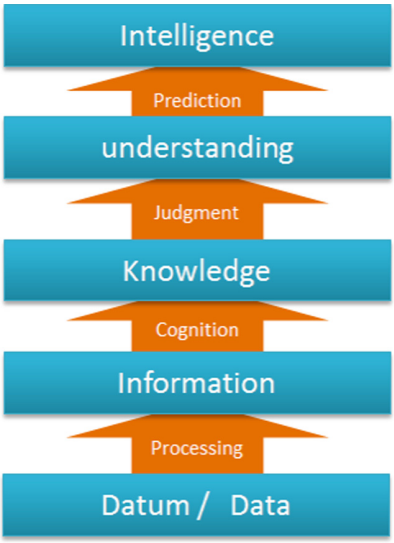

Fig. 2. The cognitive hierarchy [10]

At the bottom of Fig. 2, in the context of indoor exercising, the internal exercising data (e.g. users' physiological data) and external data (e.g. the environment data) basically present the facts, and are processed into information in the next step.

To gain knowledge from information, users' cognition works as an interpreter, translating information into knowledge, with which users can recognize the situation in a general context. When there is enough knowledge about the exercise, users can achieve an understanding of the exercising status by judging the knowledge. The final step is intelligence, which is used to support decision-making. An appropriate understanding gained from former steps will help users predict their exercising status and adjust their performance.

The cognitive hierarchy shows the process of how the external and internal data being transformed into knowledge that can help users to evaluate and adjust their performance in exercising process. And it indicates that the step of transforming information into knowledge through cognition plays an important role in obtaining good understanding to influence users' intention of exercising.

Mental models for data visualization. Considering the cognitive hierarchy mentioned above, current information presentation applied by many existing indoor exercising systems leaves a gap between information and knowledge. Most data cannot be made full use of in a smooth and continuous process. While it is suggested in many related studies that mental models can work as a joint in between [11, 12].

Mental models have been defined as an internal representation of concepts, which is considered to be critical for cognition theories. Since they are mental structures, they are used to infer novel knowledge, which is the deeper understanding of presented information [13], and have strong influences on users' knowledge construction. In visual analytics process [11], abstract knowledge is generated from information by

users' mental models. In the case of indoor exercising system design, mental models will be engaged for ensuring that understandable knowledge is provided to users.

2.3 Design Framework

Based on the combination of mentioned models, we propose a design framework for indoor exercising (Fig. 3). In this framework, data has been divided into two categories, and information will be processed into different potential knowledge.

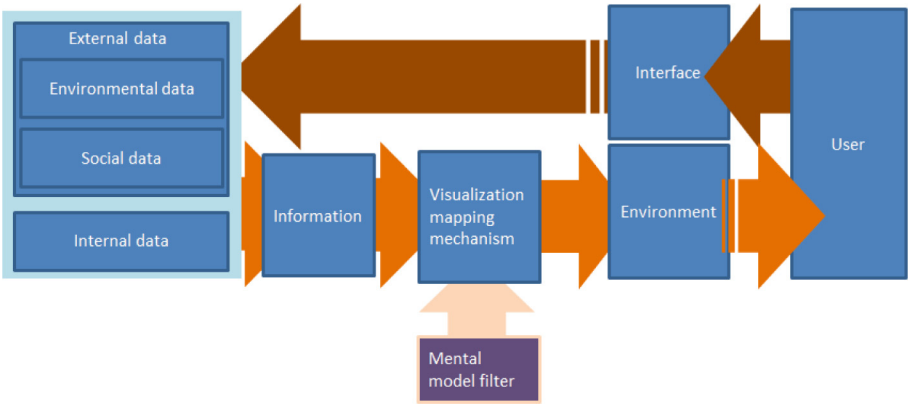

Fig. 3. Design framework for indoor exercises

Internal data will be collected to present the exercising status, such as users' heart rate and the calories burned during the exercises. External data, including both the indoor environmental data and users' social data, will also be collected to help project visualized information into the physical space and create potential social connection between users.

Users' mental models are used to create a mental model filter, and a visualization mapping mechanism is designed for more appropriate data transformation and knowledge generation based on this filter. The generated knowledge will be projected into the physical environment to create an immersive experience. Since the knowledge is generated by the mapping mechanism, based on users' mental models, the understanding should be more suitable and accurate. After obtaining a better understanding of the exercising status, users can better adjust their performance and interact with others though the visualization in the environment.

3 Project RIPPLE

3.1 Concept Implementation

Concept for prototype. The concept "RIPPLE" entails an interactive immersive environment for cycling exercises. The goal of the project is to offer a better user

experience by creating an immersive environment and an interactive visualization. The prototype was initially constructed during a two-day hackathon event, called SPRINT14 in Eindhoven, and became one of the winning concepts to be further developed, due to the novel immersive experience and the delighting social connection it might bring to users.

The metaphorical data visualization is employed to present users' exercising status and exercise-related physiological data (e.g. heart rate and calories). Compared to the traditional graphic or numeric display, the interactive visualization is assumed to feedback the sport and bodily information to the users in a more intuitional and understandable way. In multi-user contexts, a social connection is built up between users in the same space through the dynamic changes of the elements in the visualization.

Visualization Design. As shown in Fig. 4, we selected the 'sea' as the background of the visualization; it renders a nature scene in an indoor space. The size and amount of waves under the cycling machine are mapped from the cycling speed, which creates a dramatic effect, as if the user is riding across the surface of the water. The ripples are triggered by the user's heartbeats. The idea here is to present a sweat-breaking process of cycling exercises. As the intensity and the duration of the exercise increasing, increased heart rate will generate more ripples in the water.

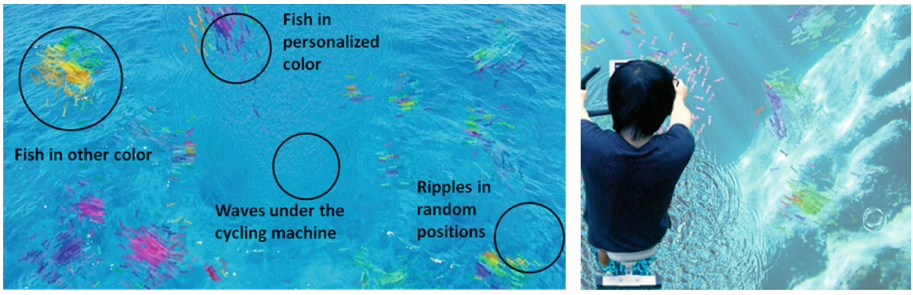

Fig. 4. Visualization design in the project

To promote social bonding or connections in a 'light-weight' way with little extra operation and distraction from exercising, we use the "abstract fish" as the symbol of users; the amount of the fish of one user will be mapped to the calories she burnt in the exercise. The fish appear around the user initially, and as the exercising time passes by, the fish will swim outside to 'communicate' with the fish of other users. This process is designed to create a social bonding and a collective exercising experience, breaking the individuals' isolated status and providing users with more fun and motivation.

Data collection. In this prototype, a phytoplethysmograph (PPG) sensor is used to measure pulse signals from the participant's index finger. Compared to ECG electrode, the biggest advantage of the optimal PPG is being easy to use. Participants do not need to attach gel-coated electrodes on their chest. Heart rate data is calculated from pulse signal and used in in real-time. The calories burned during the exercise session are

estimated by using the following formula: $C = (0.4472 \times H - 0.05741 \times W + 0.074 \times A - 20.4022) \times T/4.184$ [14]. C is the number of calories burned, H is the average heart rate, W is the weight, A is the user' age and T is the length of the exercise session in minutes.

Set-up. In order not to interrupt the exercise process, the visualization is projected on the floor, under the cycling machine (Fig. 5). A projector is fixed on a frame above and in front of the cycling machine. A cycling machine is placed on a white curtain tiled on the ground. The visualization program is developed in Processing.

Fig. 5. The set-up of the 'Ripple'

3.2 Social Interaction Through Exercising Data

Besides the real-time interplay between users and the visualized data, the potential social connection between users is also explored, in order to create a collective exercising experience, breaking the individuals' isolated status and providing users with more fun and motivation.

Since the context of doing regular exercises with friends together is hard to realize for many in daily life, design concepts are explored, for example, facilitating interaction between people who are doing exercise at the same place.

The indoor exercising space holds the potential to provide users with a social environment, while it is usually hard for strangers to break the ice and socially interact with each other. There is a need to help them create the connection that will neither make them feel embarrassed nor interrupt their exercises.

Compared with the solutions that connect friends online for gaming or communication, we prefer to enhance the connection at same indoor places, based on the physiological data visualization.

The social interaction in this context is to connect users by facilitating cooperation through the visualization, raising social awareness between people via its lively movements and changes [15], and providing a collective feeling of being accompanied or appreciated in exercising. When people are connected, the interaction between their data and the impact brought towards the whole augmented environment will change along with the cooperation. For example, if all the users are exercising in a standard or high-quality status, the collective visualization may transform into a more harmonic presentation as a reward or general feedback for their efforts.

3.3 Next Steps

The design concept introduced in this paper tries to transform the indoor space into an immersive environment for exercising people through ambient projection. The whole design aims to help users concentrate on their exercising while being aware of their exercising status (e.g. standard or not).

In addition, instead of connecting with friends online to socially interact through avatars or images, we explore the possibilities to highlight or create social connection between the people who are doing co-located exercising. The social interaction between users and the immersive environment provide users intensive enjoyment, which can be considered as an intrinsic motivation for taking regular exercises.

For the next steps, iterations of the design framework and the prototype will be conducted, in order to deploy further design research on the relation between the immersive experience and users' engagement and motivation towards indoor exercising.

The mechanism of mental models needs to be further developed and tested, in order to work as an instrument for knowledge selection and visualization mapping in a certain context.

The long-term data recording may be added into the system for a better self-evaluation and real-time analysis of users' exercising status. The recording can also be used for socially motivating users by combining it with current social service.

4 Conclusion

In the presented project, we focus on creating an immersive experience through data visualization, creating and enhancing social interactions between co-located exercising people.

To evoke and strengthen users' intention of exercising, literature study on cognitive psychology, immersive virtual reality, and user acceptance was conducted. A design framework was used to guide the visualization design process for indoor exercising context, such as gymnasium and sport center. A prototype was implemented based on the design framework, using the sea and fish as metaphor to create an interactive immersive environment for indoor cycling context.

Through this design, we hope to create an interesting, motivating and unique experience for indoor exercising through data visualization and ambient projection in physical space.

Acknowledgments. We would like to thank China Scholarship Council for the support on the design research. We also thank MADspace Eindhoven and InnoSportLab Sport en Beweeg and all the sponsors of SPRINT14 for the support on the event.

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Proceedings, Part II

Springer

Editor
P.L. Patrick Rau
Department of Industrial Engineering
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ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-20933-3 ISBN 978-3-319-20934-0 (eBook)
DOI 10.1007/978-3-319-20934-0

Library of Congress Control Number: 2015943044

LNCS Sublibrary: SL3 – Information Systems and Applications, incl. Internet/Web, and HCI

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Printed on acid-free paper

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Foreword

The 17th International Conference on Human-Computer Interaction, HCI International 2015, was held in Los Angeles, CA, USA, during 2–7 August 2015. The event incorporated the 15 conferences/thematic areas listed on the following page.

A total of 4843 individuals from academia, research institutes, industry, and governmental agencies from 73 countries submitted contributions, and 1462 papers and 246 posters have been included in the proceedings. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The papers thoroughly cover the entire field of Human-Computer Interaction, addressing major advances in knowledge and effective use of computers in a variety of application areas. The volumes constituting the full 28-volume set of the conference proceedings are listed on pages VII and VIII.

I would like to thank the Program Board Chairs and the members of the Program Boards of all thematic areas and affiliated conferences for their contribution to the highest scientific quality and the overall success of the HCI International 2015 conference.

This conference could not have been possible without the continuous and unwavering support and advice of the founder, Conference General Chair Emeritus and Conference Scientific Advisor, Prof. Gavriel Salvendy. For their outstanding efforts, I would like to express my appreciation to the Communications Chair and Editor of HCI International News, Dr. Abbas Moallem, and the Student Volunteer Chair, Prof. Kim-Phuong L. Vu. Finally, for their dedicated contribution towards the smooth organization of HCI International 2015, I would like to express my gratitude to Maria Pitsoulaki and George Paparoulis, General Chair Assistants.

May 2015

Constantine Stephanidis
General Chair, HCI International 2015

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- Human-Computer Interaction (HCI 2015)
- Human Interface and the Management of Information (HIMI 2015)

Affiliated conferences:

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- 9th International Conference on Universal Access in Human-Computer Interaction (UAHCI 2015)
- 7th International Conference on Virtual, Augmented and Mixed Reality (VAMR 2015)
- 7th International Conference on Cross-Cultural Design (CCD 2015)
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- 6th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management (DHM 2015)
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HCI International 2016

The 18th International Conference on Human-Computer Interaction, HCI International 2016, will be held jointly with the affiliated conferences in Toronto, Canada, at the Westin Harbour Castle Hotel, 17–22 July 2016. It will cover a broad spectrum of themes related to Human-Computer Interaction, including theoretical issues, methods, tools, processes, and case studies in HCI design, as well as novel interaction techniques, interfaces, and applications. The proceedings will be published by Springer. More information will be available on the conference website: http://2016.hci.international/.

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