ShuttleKicker+: Designing Gamified Sonification to Augment the Physical Leisure Activity

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Abstract
This paper presents a design study of ShuttleKicker+, an interactive prototype that gives the sonic feedback in a specific physical leisure activity named shuttlecock-kick. This design is intended for a novel experience of collective shuttlecock-play by offering diverse gamified sound effects according to the progress of the activity. We conducted an experiment (n=12) to evaluate if our design leverages user experience in the activity. By comparing the obtained data, we find ShuttleKicker+ improved the user experience significantly in terms of the attractiveness and the novelty. Moreover, the study also suggested design implications for the future work.

Author Keywords
Shuttlecock-kick; physical leisure activity; sonification; game-like interaction; user experience.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – User-Centered Design.

Introduction
With the repaid advance of technologies, the demands for physical activity during work have been significantly reduced since the middle of 20th century [4]. However, such transitions are largely associated with sedentary behavior, which threaten people's metabolic health and

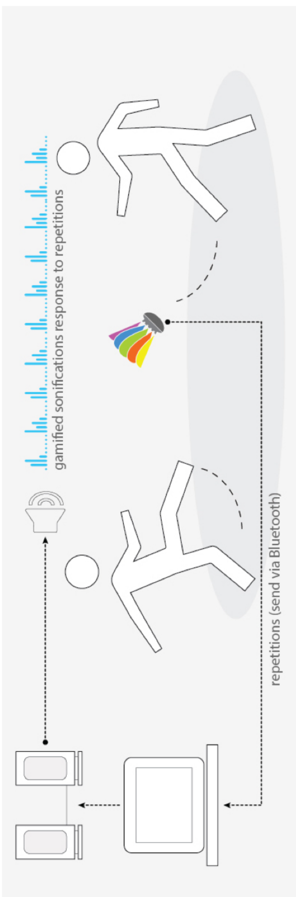

Figure 1 The concept of ShuttleKicker+.

thus later life stage [17]. To overcome this issue, one strategy among is to encourage more physical leisure activity, which is recognized to be beneficial for mental [3] and physical health [18]. Meanwhile, this topic evoked an emerging research focus in HCI to design interactions for the activity to enhance the existing experience and in turn the motivation (e.g. [6][15]). In fact, earlier studies have been exploring this field using persuasive technology [11], social support [13], visual augmentation [5–7,14], sonic feedback [1,24,25], etc.

In this paper, we approach this topic using gamified sonifications. More specifically, this paper presents a design study of ShuttleKicker+ (Figure 1), a technology designed on top of the classic shuttlecock to monitor the movement of the object using accelerometer. Correspondingly, the system provides diverse gamified sound dynamics to augment different progress of the shuttlecock-kick activity. Upon the prototype, we conducted a between-subject (6 participants for each group) test to examine the user experience about our design and to generate design insights for further study.

Background & Related Work

Shuttlecock, a simple tangible object, which contains a cork and a bunch of colorful feathers attached above, has been considered as a medium for physical activity for over 1000 years in China. Similar to hacky sack, shuttlecock-kick game is a unisex activity where players can interact with the shuttlecock using different body parts, including feed, knees, hips, and torso, etc. This activity has many benefits for physical health, such as coordination, timing, balance, perseverance, and agility, etc. [2]. Moreover, it only requires very limited space and time and can be performed either solitary or collectively. Therefore, the shuttlecock-kick game has great opportunity to be evolved as a casual physical activity for everyday life.

In an earlier exploratory study [21], we employed the social mechanisms from the persuasive systems design [16] to encourage the collective shuttlecock-kick game among office workers. Moreover, a traditional music was applied to give feedback on the progress of the activity. From the user study, we have received very positive feedback indicating the potential of sound effect to improve the activity experience. Therefore, in this paper we shift our research focus more towards the sonic interaction to augment the shuttlecock-kick experience among players.

There has been a large amount of research concerning the sonifications for different types of physical activity, such as walking [25], tennis [1], skating [24], etc. However, most of them were primarily designed for the functional feedback [23] to support exercise training. More recently, a thread of work began to discuss on how to involve sonic interaction to optimize the exercise experience. Mueller *et al.* [15] involved the physiological data that associated to the communication between joggers to balance their ability difference for a more balanced co-exercise experience. Ren *et al.* [22] designed the interactive music that responses to sitting dynamics to offer an active sitting experience for the elderly. Liljedahl *et al.* [10] correlated the MIDI-based sonic material to different actions (e.g. cue, score, alert) for immersive experience in the climbing activity. Similar to previous work, our study also aimed to explore the sonification for a more engaging experience. Inspired by [8], in this paper we employed the gamified sounds in our design, aiming to bring a novel game-like experience to the shuttlecock-kick activity.

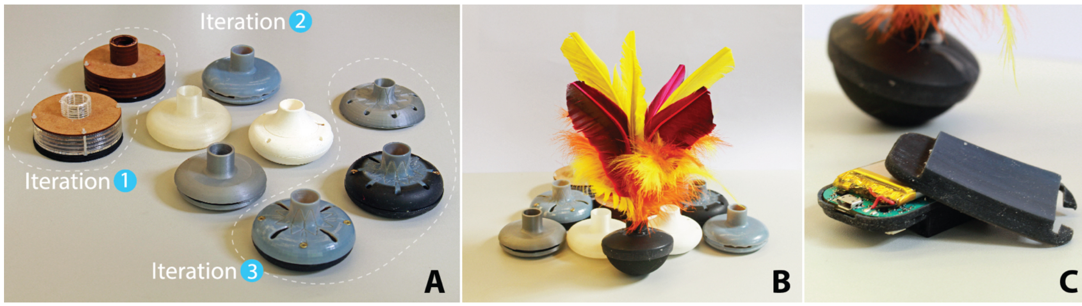

Figure 2 (A) the formal exploration; (B) the final prototype; (C) the case to protect the sensor board.

protocol	icon
Background sound	
Continuous	ground theme
Repetition feedback	
once every rep	jump
once every 3 reps	get coin
Complimentary sound	
once every 5 reps	power up
once every 15 reps	stage clear
Game over feedback	
Reps <= 6	none
12 => Reps >= 6	Mario dies
Reps >= 12	game over

Table 1 The protocol of the sonification for each set. Different effects are given according to the number of Reps. Rep stands for repetition. See a full list of the sound clips of Super Mario Bros from [26].

ShuttleKicker+

ShuttleKicker+ consists of two parts: a tangible prototype of shuttlecock for physical interaction and motion measurement; a program on the computer to collect the data and to give different sonic responses.

Hardware

Specifically, our physical prototype (see Figure 2) was equipped with a LightBlue Bean+ [19], an Arduino-based microcontroller embedded with a 3-axis accelerometer to track if the shuttlecock is being kicked or falling on the ground; a 600mAh Lithium polymer battery to offer power supply for the sensor board; and a Bluetooth module to enable the communication with the program on the computer. To place the sensor board into the prototype, we redesigned the bottom part of the shuttlecock as a casing for the electronics. After several explorations, we decided to use a 3D-printed flexible silicone case to protect the sensor board, which fitted tightly into a customized coaster. The upper part of the coaster was 3D-printed using semi-flexible silicone, which stabilizes the form of the prototype and provides the connection to the feathers above. The lower part of the coaster was an upholstered hemisphere, which offers extra protection for the sensor board and reduces the negative influence from the weight of the prototype.

Software

Since the trajectory of the shuttlecock basically follows the parabola, we applied an algorithm adapted from the acceleration fall-detection [20] to estimate the movement of the prototype. A timer was also settled to determine when one single set ends. Therefore, the relevant data is then sent periodically (once every 200 millisecond) over Bluetooth to the processing-based program on the laptop. Based on received different values, the program provides diverse acoustic effects to the players in real time. In this study, we have exclusively used the sound clips from one of the most popular video games of "Super Mario Bros" [12] as the assets for the sonification. The protocol of the sounds for each feedback is organized in Table 1.

User Test

To understand if the sonic dynamics could improve the user experience in the collective shuttlecock-play among office workers, a between-subject experiment was conducted in the office environment.

Participants

12 Chinese participants (6 females, age: M=27.9, SD=1.6) were recruited in our experiment. Through a pre-questionnaire, we learned all of them had the experience of playing shuttlecock with friends. They also rated their skills about shuttlecock-play from beginner to intermediate level. We assigned our participants to experimental group and control group randomly in this study.

Q1	What did you like the most about shuttlekicker+?
Q2	What did you like the least about shuttlekicker+?
Q3	How does the experience with shuttlekicker+ differ from regular shuttlecock?
Q4	How does watching someone play differ from regular shuttlecock?
Q5	Would this help you to keep doing this in a long run?
Q6	Other comments?

Table 2 Questions for interviews.

	Experiment group		**Control group**	
	T1	T2	T3	T4
total reps	188	299	279	231
total sets	108	84	98	101
highest reps	5	17	11	6
average reps	243.5		255	

Table 3 the prototype recorded data for all the experiments. T1, T2, T3, T4 refer to team one, two, three, four respectively. Reps stands for repetitions.

Experiment design

All the experiments were carried out in the afternoon between 5:00 PM and 6:00 PM, the time when the participants just finished their work. Our study was settled in the lobby of an office building. We conducted our experiment with three participants per time. Each experiment consisted out of two sessions:

1. We invited three participants to play shuttlecock-kick game together for 10-min. The goal of the game was to kick shuttlecock together as many times as possible. For the experimental group, we applied the acoustic feedback in the game, where a Bluetooth speaker was deployed. Before the game, we explained and demonstrated the protocol of the interactions. For the control group, we muted the sound during the activity and no introduction beforehand. We hided the computer to our participants in all the experiment.
2. After the game, we immediately asked them to fill in the post-questionnaire per individual. We also conducted the post-interview with the experimental group about how they think of our design.

Data collection

During the experiment, we video-recorded the whole game process. Moreover, our prototype gathered how many repetitions the group have made per set and how many sets the group have played in total. Here we aimed to explore if there was any different performance between groups. During the post-experiment session, every participant was given the User Experience Questionnaire (UEQ) [9], which uses semantic differential associations to evaluate six aspect of user experience, including attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. The goal of using UEQ was to examine if our interaction could improve the user experience of the collective shuttlecock-play. For the experimental group, we interviewed them with the open-ended questions (see Table 2) adapted from [7] to learn users' opinions about our design qualitatively. All the interviews were audio-recorded and transcribed for further analysis.

Results

The results from the evaluation is organized into two parts: 1) the analysis of the participants' performance during the game, 2) the feedback on the experience with our prototype from UEQ and the post-interview.

Performance

From the prototype-recorded data (Table 3), we observed that the teams from experimental group made the worst and best performance respectively, yet the general scores between two groups were more or less similar. Which suggested the skills of shuttlecock-kick were fairly equal between groups. Moreover, from the recorded video we found all the players have been talked to each other a lot along with the game progress. For the control group, most of the topics revolved around the activity itself, while some discussions about the sounds appeared in the experimental group. In particular, the team who made the lowest scores have been tried for more sound effects. However, they did not really improve their repetitions. This suggested our design could encourage our participants to make more effort in the activity, yet it could not support to improve the skills in a short period.

User experience

Although the sample size in this study was small, we still decided to use the statistics about UEQ to show an

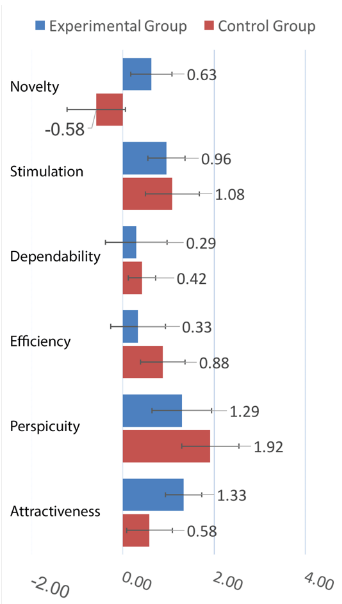

Figure 3 The results from UEQ.

approximation of the user experience about our design. Moreover, we use the interview findings here as well to explain the result from the UEQ.

As is shown in Figure 3, the t-test shows that our participants in the experimental group have went through a more attractive (p=.046) and novel (p=.015) user experience. From the post-interview, we learned this result can be attributed to the following reasons:

- **Attractiveness:** Our interaction design was featured to be attractive several times during the interviews. As the first-time users, they thought it was much easier to get involved in the activity with the sonic feedback. Furthermore, our participants highlighted that *"The interactive sound could have the magic to invite the others (people who passed by) to join in."*
- **Novelty:** All the participants were impressed by the gamified sonification. They felt the combination between the physical activity and the digital game have provided a unique activity experience. As they said, *"It make me feel like childhood." "I have been enjoyed the activity, as I see it as another Super Mario game in the real world."* One participant even believed: *"I can play it for 30-min alone, as I would like to consider it as a [digital] game."*

In contrast, the control group gave more positive feedback on the aspects of stimulation (p=.74), perspicuity (p=.21), efficiency (p=.20), and dependability (p=.75). However, there were no statistical difference among these aspects. From the interview, we learned a few reasons that could be contributed to the negative user experience.

- **Stimulation:** Although we did not receive very remarkable ratings on the motivational aspect, most of the participants still agreed that the music could motivate them to do this activity. For instance, one thought was: *"The sound told me perhaps I can do better."* However, they also showed the concerns over the long-term usage. As one participant from T1 stated: *"The current sounds were very simple, people may easily feel the feedback was tedious and get bored."* They also mentioned: *"[The music from] Super-Mario may suit for us, but not for everyone, especially people who don't know the game."*
- **Perspicuity:** We also got a lower score about the perspicuity of our design. One participant gave explanation that: *"You told us the rule of the sound in advance. But we still have to explore the real feeling in the activity. It did not really in consistent with the rhythm of Super Mario."* While another participant thought that: *"After using the prototype for longer time, we will know it better."*
- **Efficiency:** We changed the shuttlecock from a flat bottom into a round shape, yet we did not expect it would disturb the activity a lot. However, during the interview all the participants stated that it was very hard to control the movement of our prototype. *"I don't know how much effort I have to use for each repetition, too much or too little."* One participant's concern.
- **Dependability:** As we discussed earlier, the interaction we employed in this study was relatively simple. It on the one hand was not supportive to sustain participant's motivation. On the other hand, it did not offer sufficient information for participants to know their exact progress in the activity. As one participant said: *"After two minutes, I could not feel the strong connection between the sound and my performance."*

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Discussion
In this study, we designed ShuttleKicker+ and tested if the gamified sonification could improve the experience in the activity. Our results suggested the novelty and attractiveness of our design could support people to engage in the activity. More importantly, our study enlightens a few directions should be considered more carefully for the future design. In what follows, we unfold these directions in detail.

GAMIFIED EXPERIENCE
Our study has exemplified involving the gamified sonification to create the novel experience in the physical activity. Yet in this study we only designed the feedback protocol based on repetitions within one set of the activity. Our findings revealed that the current mechanism was not enough for the target users. To address this gap, previous study suggested the sounds should closely integrated into the overall exercise experience [10]. Thus, we propose to use more sound dynamics to provide the progressive effects along with the progress of the entire activity. For example, one of our participants suggested: *"Similar to the game like Super Mario, if in this design more game elements, such as checkpoint and different game levels, could be added and could be presented through diverse layer of the sounds, we would be more likely to involve into the activity."* As such, it will enhance the bonding between the users and the system and thus sustain users' engagement in the activity.

SOCIAL ENGAGEMENT
From this study, we also learned an impact of our design to encourage more social engagement into the activity. This can be interpreted into two aspects. First, the audience of the activity could be attracted to join in the activity. To improve this effect, we propose to employ more sensing technology to track if audience may have interests on the activity. Therefore, corresponding interaction can be performed to invite participations. Second, similar to [15], we found the system should be customized to balance the experience between different types of users in different scenarios. Moreover, new parameters (e.g., physiological data) could also be included to leverage the sound effects.

TANGIBLE IMPROVEMENT
Another lesson from the study was that the current physical implementation was not very efficient. The size, the weight, and the form of our prototype need to be improved. To optimal our design, for example, instead of using a commercial sensor board, we could customize the board to make it smaller, lighter, more stable, and more embedded into the prototype. Moreover, the study also implies that the bottom of the shuttlecock should be replaced to the ordinary flat one. Otherwise the difficulty of the activity will be increased.

Conclusion & Future Work
This paper explains how we explored and evaluated the design of the gamified sonification for the shuttlecock-kick activity. The results from the user test confirmed our design concept. Moreover, design implications were generated to improve the future practice. We believe this work can inform the related explorations in HCI.

For future work, we firstly plan to update our prototype according to the insights from this study. We then plan to conduct a study for a longer period to verify if our design could engage the office workers in the physical activity in the repeated sessions.

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