The Fwobble

Continuous audio-haptic feedback for balance control

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Poster: The Fwobble: continuous audio-haptic feedback for balance control

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ABSTRACT

In this paper we present a novel interface called the Fwobble, designed to investigate the role of multimodal feedback in balance control. The interface is designed as a traditional wobble board enhanced with actuators that provide haptic feedback and an accelerometer that tracks the acceleration of the board converted to tilt angle. Using this board, an experiment was conducted in order to assess the role of auditory and haptic feedback in facilitating balance control. For this purpose, a casual balance game was designed, where players were asked to balance a penguin standing on a rotating ice floe. Results of the experiment show that feedback does not significantly facilitates balance control. Moreover, although all players enjoyed interactive with the game using the board, they were quite divided when evaluating the role of the audio-haptic feedback. Indeed, some players found it enjoyable and usable, while others found it distracting.

Index Terms: H.5.5 [Information Systems]: Information Interfaces and Presentation—Sound and Music Computing; H.5.2 [Information Systems]: Information Interfaces and Presentation—User Interfaces

1 INTRODUCTION

A wobble board is an exercise device primarily intended to strengthen one's ankles, to train the sense of balance, and to help in certain rehabilitation techniques [2]. Individuals in need of ankle training frequently lack the motivation necessary in order to successfully complete the training or rehabilitation process.

Figure 1: Actuated and instrumented wobble board.

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One possible way of alleviating the problem of lacking motivation is to leverage games potential as a source of motivation. To be more exact, it seems possible to provide the necessary motivation by combining training or exercising with the act of playing a game. This motivated us to add sensors and actuators to the wobble board in such a way that it could be programmed to respond to its movements in a great variety of ways, beyond and above its basic mechanics. This way, the board can be programmed to respond visually, acoustically and mechanically in variety of ways that may or may not be physically lawful, providing it with hyper realistic capabilities. During exercises, users can watch a screen, listen to sounds and feel high-fidelity vibrotactile stimuli which are all under computer control, while the kinesthetic and vestibular inputs are produced naturally. This way, a hyper-reality wobble board could be constructed at low cost, and provide a possibility to build exercises which are less tedious, while exploiting the possibilities offered by different kinds of feedback. The wobble board augmented with sensors and actuators is shown in Figure 1. In this paper, we first describe the interface built, and we then introduce an experiment designed to investigate whether multimodal feedback facilitates the task of balancing on the Fwobble.

2 DESCRIPTION OF THE INTERFACE

As shown in Figure 1, we enhanced a traditional wobble board with sensors and actuators. Specifically, two vibrotactile actuators (Haptuator, Tactile Labs Inc., Deux-Montagnes, Qc, Canada) were accomodated between the two wooden circular layers of the board. The board on which one stands was replaced by two boards connected by specially designed structural elements that provide optimal compliance in the lateral direction independently from the load that they support, see Fig 1. The system also included a 2-axis accelerometer (from Phidgets Inc.) located between the two boards and which provides tilt information. This information can be used to drive the audio, visual and haptic synthesis algorithms. Users can wear headphones or listen to strategically placed loudspeakers. Every sound configuration is properly spatialized to enhance the game. The auditory feedback was delivered through a pair of Beyerdynamic DT 770 closed headphones.

3 THE PENGUIN GAME

The goal of the game is to control the movement of an ice floe by means of the wobble board. The tilting angle of the board is directly mapped to the tilt of the ice floe. A penguin is located on the surface of the ice floe and the objective of the game is simply to prevent the penguin from falling off the ice floe and into the water for as long as possible.

The game was created in the multiplatform development environment Unity 3d[1]. The movement of the penguin in response to the tilt of the ice floe is governed by the NVIDIA PhysX physics engine built in to Unity 3d. When the penguin is sliding, the velocity of penguins movement is sent from Unity to the realtime synthesis platform Max/MSP[2], that is used to simulate the auditory and hap-

[1]http://www. unity3d.com
[2]http://www. cycling74.com

tic feedback. When sliding on the ice floe, the penguin creates friction which can be both heard and felt at the feet. The audio-haptic synthesis engine is based on a physically-based simulation of sliding on a solid surface, initially developed as part of the Sounding Objects (SOb) EU project [1].

4 EXPERIMENT DESIGN

We designed an experiment in order to determine how the addition of haptic and audio-haptic feedback affected subjects' performance while playing the simple game described in the previous section.

The experiment was performed using a within-subjects design, where subjects were exposed to the following kinds of feedback: visual feedback only, visual and auditory feedback, and visual and audio-haptic feedback. The influence of the added feedback on the participants was assessed by means of two metrics, namely, a performance metric and self-reports. Since the objective of the game is to keep the penguin on the ice floe for as long as possible, the participants proficiency at playing the game was determined based on how long time they were able to do so. These times were recorded for all nine trials. However, only the data obtained from the final six trials was used for the subsequent comparison of the participants performance across the three conditions. After the final exposure to the game a questionnaire was administered. This questionnaire contained items pertaining to the perceived difficulty of the game, their preference in regards to the provided feedback and the gameplays ability to serve as a source of intrinsic motivation.

4.1 Participants and procedure

A total of 20 participants took part in the experiment (15 men and 5 women) aged between 20 and 30 years (mean = 23.3, standard deviation = 2.5). All participants were exposed to each of the three conditions three times and thus played the game a total of nine time.

4.2 Results

Since the participants performance was measured on a ratio scale the central tendencies are presented as the mean time spent playing the game and the variability presented as the corresponding standard deviations (Table 1). The participants did in average perform the best while exposed to the auditory condition and performed the worst when the visuals were accompanied by audio-haptic feedback. However, the performed single factor ANOVA did not reveal any significant difference across the three feedback combinations, F (2, 117) = 1.09, p = 0.34. It is worth noting that a comparison of the data obtained from all 9 trials revealed that there was a positive correlation between trial number and the amount of time spent playing the game, Pearson r = 0.63.

Visual	Auditory	Audio-haptic
18.05 ± 14.37	19.88 ±10.97	15.92 ± 10.30

Table 1: Mean time spent playing across the three conditions ± one standard deviation

The data pertaining to the participants preference of the different conditions is treated as ordinal data and the results are presented as the frequency of responses (Table 2). Note that one participant failed to perform the ranking correctly and this data has therefore been omitted from the table.

Ranking	V	A	AH
1st	6	4	9
2nd	5	12	2
3rd	8	3	8

Table 2: Subjects' rankings of the different conditions.

The data related to the perceived difficulty is similarly treated as ordinal data and the results presented as the frequency of responses (Table 3). It should be mentioned that one of the participants did not believe the difficulty to differ across the three conditions, entailing that results are based on the rankings provided by the remaining 19 participants.

Ranking	V	A	AH
Easiest	9	5	5
Intermediate	1	11	7
Hardest	9	3	7

Table 3: Frequency of rankings related to perceived difficulty

The data obtained from the IMI is treated as interval data. The central tendencies are summarized as the mean ratings, and the variance presented as the associated standard deviations. Table 4.2 details the means and standard deviations corresponding to each of the five questions as well as the aggregate subscale score (the grand mean) representing average level of experienced intrinsic motivation. Note that one questionnaire item (Q4) was negatively worded and were thus rescaled prior to the data analysis.

Q1: I enjoyed the game very much	5.4 ± 1.2
Q2: Playing the game was fun	5.6 ± 1.2
Q3: I would describe the game as very interesting	4.7 ± 1.2
Q4: This game did not hold my attention (Reversed)	5.8 ± 1.7
Q5: While I was playing the game, I was thinking about how much I enjoyed it	3.9 ± 1.4
Subscale score:	**5.1 ± 1.3**

Table 4: Means ± one standard deviation corresponding to the IMI items and the subscale score

5 DISCUSSION

The data obtained from the performance measure did as suggested indicate that the there was a difference in how well the participants performed across the three condition, albeit a statistically insignificant one. In average the performance was best when the visuals were accompanied by auditory feedback while it was worst during exposure to the audio-haptic feedback.

Finally it is worth noting that, a single factor ANOVA was used to compare the mean time spent playing by each of the 20 participants. This comparison yielded a significant difference (F (19, 158) = 6.66, $p > 0.05$), which suggests that there is a difference across the participants in terms of how proficient they were at controlling the game by means of the board.

Finally the data pertaining to the IMI items yielded relatively positive results across the board and the subscale suggests that the participants generally had experienced the activity as intrinsically motivated, albeit to varying extents.

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