The Nintendo Balance Board: an added value to gesture interfaces.

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ABSTRACT
Lower body interaction has the potential to add value to gesture interfaces. With Nintendo's release of the Balance Board this means of interaction has become more accessible. But does the Balance Board improve the performance of users in applications with gesture interfaces?

The performance of subjects is tested by means of a maze game. A questionnaire is used to ask the subjects about their experience with the Balance Board. From the results we can conclude that the Balance Board does not improve the performance. However the subjects find the Balance Board more intuitive and fun to use.

Keywords
Nintendo, Balance Board, Wiimote, gesture interfaces and lower body gesture interface.

1. INTRODUCTION
Motion capturing is mostly used in the area of animation for making the movements of virtual characters look more realistic. In *gesture interfaces*, motion capture can also be used for various tasks in a home or office area, such as playing games. Cameras or suits, with sensors on them, that record and process the movement of the user are rather expensive and often need relatively large space. Smaller devices (a CyberGlove, cyber boots [ChR97] and a dance mat) were developed to tackle these problems.

Since Nintendo introduced their Wii game console, gesture interfaces made their way to homes [Nin08]. With the Wiimote controller, arm movements (and to a lesser degree upper body movement) are used to interact with the computer. In the beginning of 2008 Nintendo introduced a second device, the Balance Board, which focuses on the use of the torso and the lower body to extend the range of body motion for interacting with the Wii [WiF08].

The Wiimote has already been used for gesture interface research [SPH08], but because the Balance Board is still new, only few research initiatives have focused on the use of the Balance Board [SDK08][ScK08]. We wonder to what extend the Balance Board will be a valuable addition to gesture interfaces. To address this topic we formulate the research question: *Does the Balance Board have an added value to gesture interfaces by improving performance, like the duration to complete a task or errors made doing a task?*

In Section 2 we look into some related work on lower body interaction and some products related to the Balance Board. In Section 3 we will explain the methodology used to address our research question; the experiment results are discussed in Section 4 while Section 5 presents the conclusions based on these results. This paper ends with a discussion in Section 6 where we look critically on the experiment and possibilities for future work.

2. RELATED WORK
Interacting by shifting your centre of gravity with the Balance Board is rather new concept, although some motion capture research has been done for the lower body.

2.1 Cyber boots.
In 1997, Choi and Ricci had been working on a project called 'NCSA Boots' [ChR97]. The principle of this project was to have foot-mounted sensors strapped to the feet, which had to be unobtrusive. The wearer could even wear his shoes over it. Unlike the Balance Board the user would have complete freedom of movement and was not restricted to a single place.

This device uses four force sensors for each foot. The sensors that fitted their criteria were Force Sensing Resistors (FSRs). The sensors are placed on the four major pressure points (the heel, the inner ball, the outer ball and the tip of the toe) of the foot. The sensor would give continuous signals which would be gathered and at the end processed through fuzzy logic.

The measurements are taken directly from the pressure points of the foot, but the principle is similar to the four sensors of the Balance Board. The force on each pressure point is determined by the balance and centre of gravity of the body.

Figure 1 Joyfoots Cyber System. Right the device, left the system in action.

Barrera et al. [BTN04] came with the "Joyfoots Cyber System" (see Figure 1). The Joyfoots Cyber System uses sensors under the foot, but they added a sensor on the leg to register the angle of the ankle. Like Choi and Ricci, Barrera et al. claimed to have many positive results, but not much detail about those results were given nor was any comparison with other devices made.

2.2 The Dance Mat
One of the first devices in videogames that uses the lower body to interact with the game is the 'dance mat'. In fact these dance mats were nothing more than a gamepad moulded in a flat surface mat. People have to stand on the mat and the quadrants where their feet are, corresponds to gamepad buttons. The user moves his feet from quadrant to quadrant to interact with the videogame. Like a gamepad's buttons, more than one quadrant can be pressed at the same time.

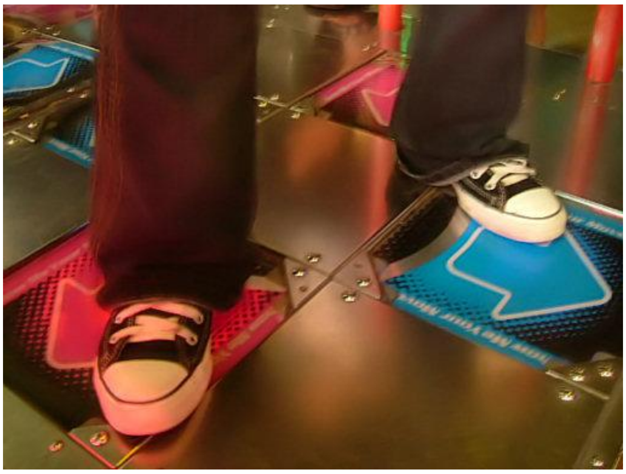

Figure 2 DDR Dance Mat (arcade version)

One of the most known games that uses the dance mat is ‘Dance Dance Revolution’ from Konami Digital Entertainment [Kon08] (see Figure 2). In these games the player has to jump from one quadrant to another (or multiple others) on the rhythm of the beat and the directions indicated on the screen.

Initially produced for entertainment in arcades, the dance mat is even used in scientific research, like the Virtual Rap Dancer [RNP06]. The first use of the dance mat with the virtual rap dancer is to detect if a person is in position to interact. The dancer starts dancing and, by means of audio and visual cues from motion tracking, detects the beats and uses these inputs to decide which dance moves should be made next. During the dance the mat registers if the user is also dancing with his feet. The corresponding paces for the dancer are selected.

2.3 Geographic Information Systems

Schöning et al. [SDK08][ScK08] combined the Balance Board with a multi-touch surface to navigate through spatial information in a Geographic Information System (see Figure 3). Their research focuses on making navigating through extensive spatial information more intuitive and user friendly. The authors argued that current user interfaces often require an expert to operate them. The Balance Board has potential benefits “Since the feet are used to navigate in real space such a foot gesture has the additional advantage of being more intuitive in the sense that it borrows from a striking metaphor.”[SDK08]. By shifting the centre of gravity the user can perform actions like panning and tilting. Their results say that the use of the Balance Board greatly improves the interaction with a Geographic Information System.

3. THE METHODOLOGY

The research question of this research is: *Does the Balance Board have an added value to gesture interfaces by improving performance, like the duration to complete a task or errors made doing a task?* My hypothesis is that the Balance Board should improve the performance of the user doing tasks in a program. The time it takes for a user to complete a series of tasks and the accuracy of performing these tasks defines performance. We test our hypothesis by means of a maze game.

We designed an experiment to test our hypothesis. A game environment was used to perform an empirical test while subjective opinions were gathered by using a questionnaire.

3.1 The Balance Board and Wiimote

The Balance Board (see Figure 4) can take over certain tasks, like navigation, that would otherwise have to be done with the Wiimote alone. When designing a control scheme for the

Figure 3 The Balance Board and a multi-touch surface used in a Geographic Information System.

Wiimote that can perform every task of a program, one might have to result to some creative planning, especially when the number of tasks is very big. With such a very big set of tasks even an intuitive user interface might become counter intuitive. Adding the possibilities of an additional device next to the Wiimote gives more space for a user interface and might bring it back to an intuitive control.

A possible solution is the Balance Board. Although the Wiimote has the skill to be very precise as a pointer, its gesture movements might already be used for different functions. The Balance Board does have possibilities to enhance the user interface. Additionally, the Wiimote and Balance Board can be used separately so that more tasks can be performed simultaneous.

The Balance Board has four pressure sensors at the corners. The data from the Balance Board is based on these four sensors plus the total mass of the person standing on it. In this experiment the data is used to calculate the centre of gravity of the person relative to the centre of the board. Like the Wiimote, the Balance Board is a relatively cheap and easy to use device for interaction. The Wiimote contains three perpendicular accelerometers that register movement along the X-, Y- and Z-axis as well as the angle of rolling and pitching. The Wiimote does not register the angle of yawing. The Wiimote contains an infrared camera. It uses this sensor to track a number of fixed infrared lights positioned near the screen to implement pointing. The Wiimote has seven functional buttons in addition to a four-point directional pad. For this experiment only the angles for pitching and rolling are used for navigation and four of the seven buttons plus the directional pad are used. The rest of the Wiimotes capabilities are ignored.

There are two ways to control the game. The first is to only use the Wiimote. By rolling and pitching the Wiimote, the participant navigates the avatar through the hallway. By

Figure 4 Left the Nintendo Wiimote and right the Nintendo Balance Board

pitching the nose of the Wiimote up and down the avatar moves up and down. With sideways movement a bit different action is required. Pointing (yawing) the nose of the Wiimote to left and right will not accomplish anything. Therefore the participant has to roll the Wiimote. By rolling the upside of the Wiimote left and right the avatar moves left and right. The most obvious use for the lower body is moving. Therefore in the second control scheme the Balance Board is used to navigate the avatar through the hallway. In effect taking the rolling and pitching over from the Wiimote. The participant has to lean forward to move the avatar up, backwards leaning results in a downward movement. Leaning left and right makes the avatar move left and right.

3.2 The game

Our game gathers data that indicate the performance of using the Balance Board for navigation. The participants have to be able to play and understand the game without much of an explanation. This focuses the experiment more on programs with a small task set for operations. Because the participant uses his lower body, the most obvious task for the Balance Board would be movement. Therefore a game was chosen were the participant has to navigate an avatar.

The focus of the experiment is on the interaction of the Balance Board. A crude but simple game has been developed where the user navigates a cursor, or in this game the avatar, over a predefined course of hallways to a designated area, while at the same time she has to overcome obstacles by pressing the right key at the right time. The game is a 2D top-down view of a hallway (see Figure 5). The hallway is a number of black lines on a white background. In the game the participant has to move the avatar through a hallway towards the end. The avatar is represented by a green filled circle. In this hallway he will stand in front of doors where a key has to be pressed before it will open. Doors are represented with red bars for closed doors and cyan bars for open doors. The participant can open doors in designated areas called doormats, which are represented by a blue filled rectangle. When the participant is standing on a doormat the key to the door is shown in the top–left corner of the screen. These keys correspond with the buttons on the Wiimote (see Figure 6). Only when the key is shown, can a door be opened with the correct press of a button on the Wiimote. The participant has to work towards the finish of the area which is represented by a yellow filled rectangle.

The buttons on the Wiimote represent the keys to the doors. We explored which buttons to use and which to exclude; the buttons ‘1’ and ‘2’ are excluded because they are considered to be too far to reach and may result in dropping the Wiimote. The ‘B’ is also excluded because it is at the underside of the Wiimote. For someone who does not know the layout of the buttons on the Wiimote, that person has to turn around the Wiimote to see it. When doing the test without the Balance Board, this will lead to a forced mistake and an unfair advantage for the Balance Board.

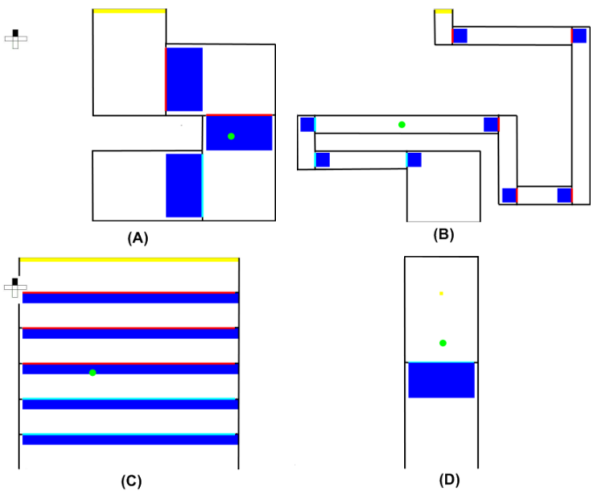

Figure 5 The four areas of the maze game.

The participant is limited to moving the avatar between the halls of the hallway and he can not cross closed doors. But that are only the limitations of the program. The participants are asked to consider more aspects of the game. The first thing they are told is to get through the game as fast as possible. The second thing is that they can not touch the walls and closed doors and it will result in penalty points. When the participant hits a wall or a closed door, he has a number of seconds to clear of it, before another hit is recorded. This prevents a low hit score if a participant continuously touches a wall. With these additional rules the program records for every play the following:

- The duration to play the entire game through,
- The number of hits against a wall,
- The number of hits against a closed door,
- The number of keys put in incorrectly,
- The durations of every time that the avatar stood on a doormat, and
- The total duration that the avatar stood on a doormat.

In total the participant had to traverse four different areas. The first area (Figure 5a) is a normal area that has wide hallways and big doormats. The second area (Figure 5b) focuses on accurately traversing a path. It has narrow hallways that makes it difficult not to touch the walls. The smaller doormats are made so the participant will be forced to stop and not to miss his turn. The third hallway (Figure 5c) focuses on opening doors very quick without slamming into them. The participant does not have to turn nor does he have to worry about touching the walls. But doormats in this area are even narrower than in the second area. In the final area (Figure 5d) the participant has to move the avatar to a single spot. The spot is rather small and therefore easy to miss.

Each participant has to do this game twice, once with the Balance Board and once without. Because of a possible learning curve of the game, two counterbalanced groups of subjects were needed to prevent such a bias. The first group will do the first test with the Balance Board and the second group will do the first test without the Balance Board.

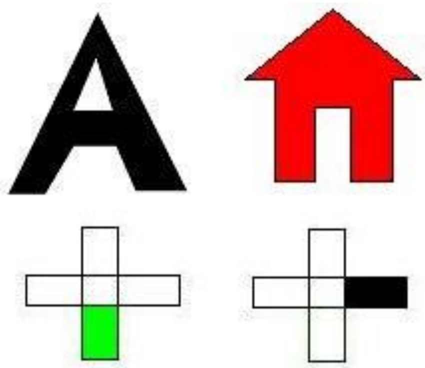

Figure 6 The keys correspond to one of the buttons on the Wiimote. A black key is with an unopened door, the red color is for an incorrect key and a green color is for an opened door.

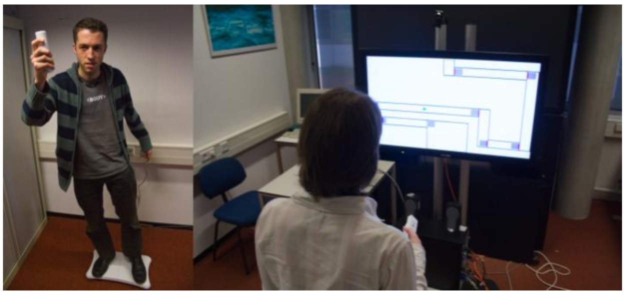

Figure 7 Subjects playing the maze game

3.3 The experiment

We can distinguish a number of stages in our experiment. In this subsection these stages will be discussed in the chronological order. When the participant enters the experiment room they are welcomed and asked if they want to fill out a questionnaire first. This questionnaire asks them some personal information, like gender, age and previous experience with the Wiimote and Balance Board. When the questionnaire is completed the experiment is explained in detail: the rules of the game, the order in which they will use the Wiimote and Balance Board and how the buttons work.

In the second stage the participant will perform his first empirical test (see Figure 7). First they are allowed to practice controlling the avatar with the control scheme that they are currently using. After they understand how to move the avatar, which they indicate explicitly, the game will be started. As the game is completed, the logged data (see section 3.2) is stored in a plain text file. The participant is then asked to fill in another questionnaire that focuses on questions such as, how easy it is to learn to move the avatar, how intuitive the controls were, how easy it was to open doors, how accurate the controls were and more. For each question the participant has to give a score ranging from 1 (very bad) to 5 (very good). This score range was determined to be the best, because it gave enough distinguish between scores without getting a detailed score. The Balance Board is still a relatively unknown device and it is hard to judge a device after just using it one time.

The third stage is exact the same as the second stage. The participant learns how to move the avatar, followed by playing the same game and finally taking a questionnaire with exact the same questions. The third stage is a repeat of the second stage, but the participant uses the other control scheme.

In the final stage the participant is asked to fill in another questionnaire. The questionnaire exists of two parts: 1) A comparison between the empirical tests, and 2) to ask the participant if they can see a use for the Balance Board with various applications. In the comparison the participants are asked similar questions to the questionnaires in the second and third stages. Instead of having to give a score ranging from 1 to 5, they are asked which of the two interfaces they like the best or if there was no noticeable difference. In the second part of this questionnaire the participant is asked a number of questions with a focus on a possible future use. To prevent that the participants limit their thoughts to just videogames, as the Balance Board might suggest, a number of different applications are given where they have to answer if they see a way of using the Balance Board. These questions are semi multiple choice questions. The participants can choose between 'yes' and 'no'. In case of a 'yes' they are asked to describe the interaction of the Balance Board.

3.4 Analysing the results

To analyse the results of the questionnaire and the empirical test two methods are used. For the results of both empirical test and their belonging questionnaires, a Student's t test is done with the help of SPSS 16. The sample size is rather small and therefore the t test is the most appropriate statistical formula to use. For the questionnaire that covered the comparison and the participants future vision of the balance board the numbers are simply counted.

The Student's t test that is used is a paired t test. The participants are divided into two groups, one group starting with the Balance Board and the other without. The participants are assigned into groups in alternating order. Both groups do both tests and only the order of the tests is changed to prevent a learning effect. The groups for the t test are based on the fact that one test is done with the help of the Balance Board and the other test is done without this help. Because both tests record the same data and have the same questions in the questionnaire, this division can be used for the two datasets, which allows for a paired t test.

By default, the null hypothesis of a standard t test states that the two groups do not differ for the tested pair of variables and the t test checks if it is correct. Our hypothesis is that the performance with the use of the Balance Board is better than without. When in the results the value for 'Significance (2-tailed)' is below 0.05 and the mean(s) favours the use of the Balance Board, then the hypothesis of the research holds. Is the value for 'Significance (2-tailed)' below 0.05 and the mean(s) favours the use without the Balance Board, then the hypothesis of this research is rejected for the following: *The Balance Board does not improve the performance.* Not all the results are put through a t test. For the results from the questionnaire at the end of the experiment the numbers are only counted, because no variable has to be compared to any other variable or any group to another.

4. THE RESULTS

A total of 18 people have participated in the test, 9 started with the Balance Board first and 9 started with the Wiimote only. We will first discuss some aspects of the sample group. Secondly, we present the results from the t test. Finally, the result of the comparison and future vision is presented.

4.1 The participants

A total of 18 people participate in the test. These subjects are assigned to our two groups in alternating order, starting with the Balance Board or without the Balance Board. Of those 18 people 4 of them are women. The age of the subjects ranges from 18 to 56 years with a mean μ of 29 years and a variance σ

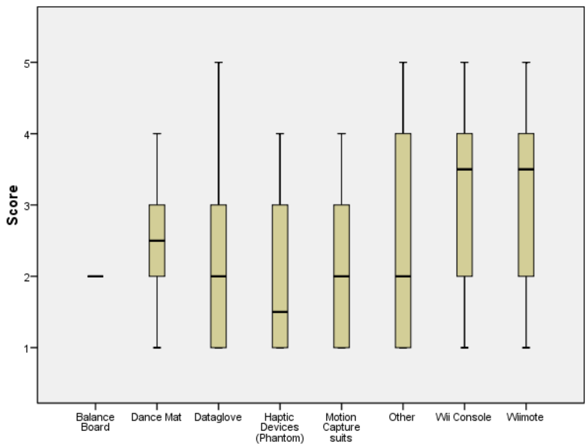

Figure 8 The experience of the users with various devices. The score on the left represents: 1) Never heard of it, 2) only heard of it, 3) seen the device, 4) used the device, and 5) own one or more copies.

of 11 years. In education, 6 subjects have a Bachelors degree, 9 have completed their Masters and 3 had no or another kind of degree.

Subjects are asked for their experience with gesture interfaces and other motion capture systems. This is shown in Figure 8. They give a score ranging from 1 (never heard of it) to 5 (I own one). Figure 8 shows that the average of participants has seen a Wii and Wiimote before participating in the test ($\mu = 3.4$, $\sigma = 1.2$). The Balance Board ($\mu = 2.3$, $\sigma = 0.9$) however, most of the subjects give the score of two, meaning the subjects have only heard of it but not seen a Balance Board, prior to the test. The other motion capture devices have a similar score ($\mu = 2.0$, $\sigma = 0.8$), although the dance mat scores higher than the Balance Board.

4.2 Experiment Results

The variables are paired by the data gathered from the empirical test and their respective questionnaires and put through the t test. The meaning of performance is the time it takes to do a task and the number of errors made doing it. From the questionnaire only the results that have any significance will be discussed. The detailed results of the t test are shown in tables 1 and 2 in the appendix at the end of this paper. A note on the side with the results from the empirical test the lower value is the better one, while for the questionnaires the higher values are better.

It is interesting to see that of the 15 pairs of variables 6 favour the use of the Balance Board, 8 favour the use of the Wiimote only and 1 says that there is no difference. But most of results from the pairs are pretty much insignificant, which means that the null hypothesis still might hold up.

From the seven pairs of variables logged during the experiment, the analyses shows that four favour the use of the Wiimote only:

- The total duration of the game (df mean = 17.467 seconds, Sig = 0.041, t = 2.208),
- The number of hits against a closed door (df mean = 0.722, Sig = 0.864, t = 0.174),
- The number of keys entered incorrect (df mean = 6.444, Sig = 0.424, t = 0.82),
- The number of doormats crossed (df mean = 4.278, Sig = 0.002, t = 3.725).

Although 4 of the 7 pairs favour the use of only the Wiimote, only two, *the total duration of the game* and *the number of doormats crossed*, differs significantly. In this case the Wiimote alone has a better performance. The pairs that favour the use of the Balance Board are:

- The number of hits against the wall (df mean = -3.333, Sig = 0.399, t = -0.865),
- Average duration spend on a doormat (df mean = -0.465 seconds, Sig = 0.043, t = -2.19),
- The total duration spend on a doormat (df mean = -3.286 seconds, Sig = 0.483, t = -0.717).

The Balance Board has a significant better performance for the pair *Average duration spend on a doormat*.

From the questionnaire the results for 'Accurate movement of the avatar' (Sig = 0.005, t = -3.198) and 'Getting fatigued in the arm' (Sig = 0.015, t = 2.715) have significant results. The movements of the avatar are more accurate when only the Wiimote is used and thus the Balance Board performs poorer in this case. But the subjects got less fatigued in the arms with the use of the Balance Board. For the variable pair *getting fatigued in the arm* a higher score was given to the use with the Balance Board, meaning that the research hypothesis holds.

Although the results for the variables 'Intuitive in moving the avatar' (Sig = 0.108, t = 1.699) and 'Fatigued from standing up' (Sig = 0.11, t = -1.686) are not significant in the case of Sig < 0.05, but still the results show some promise if our sample size would have been bigger. The subjects find controlling the avatar by means of the Balance Board the most intuitive for navigation. The control with the Wiimote is mentioned by some to be counter intuitive. However the use of only the Wiimote results in less fatigue from standing up.

One more case has an exceptional value for significance. This is the pair for the 'Smooth movements of the avatar'. The significance value is exact 1, which results in a t value of exact 0. This means that the null hypothesis pretty much holds up and that there is no difference in the smoothness of the avatars movements between the use with or without the Balance Board.

During the test some additional things concerning the Wiimote and the Balance Board are perceived. A number of participants remarked that the control with the Wiimote is actually counter intuitive. They prefer the avatar going up with a negative pitch of the Wiimote (pointing the nose down) and vice versa. Many participants have trouble to keep the avatar still when using the Balance Board, which is the result of the participant's centre of gravity at a resting stance is being unequal with the centre of the board. The participant gets cornered next to the door and is off the doormat. This only shows that the participants do not have complete control over the avatar navigation when using the Balance Board. With the Wiimote the subjects move the avatar in a straight horizontal or vertical line, but not diagonally. The path is more fluid and natural when the subjects use the Balance Board.

4.3 Subjective Device Comparison

Unlike the results from the empirical experiment the results from the comparison questions are not analysed with statistical formulas. Figure 9 shows that 10 of 18 subjects choose the Balance Board as the favourite for "learning of how to move the avatar the easiest". Six people choose the Wiimote as the easiest and two find no difference. Thirteen subjects find the Balance Board the most intuitive means to control the avatar, while two choose for the Wiimote and three consider them to be equally intuitive. Although the choice is made to move the avatar up by pointing the nose of the Wiimote up and to move the avatar down by pointing the nose down, some remarks are noted that this is considered to be counter intuitive.

Most of the subjects consider the Wiimote to be the best for the smoothest and most accurate movements of the avatar, while some choose the Balance Board to be the best. A few think

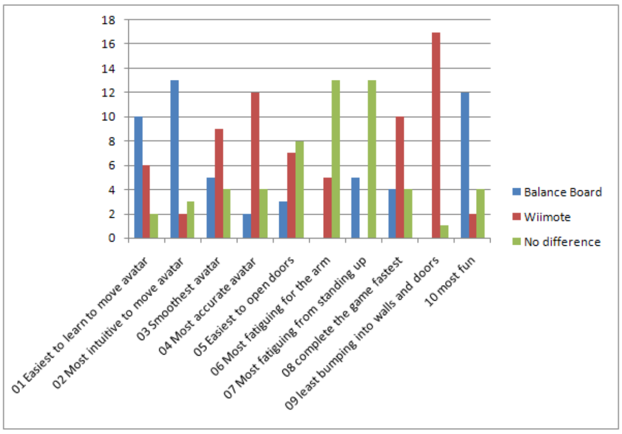

Figure 9 The results from comparing the two tests by the participants. A total of 18 subjects participated.

there is no difference in smoothness and accuracy of the avatar. When asking with which test they bumped into the closed doors and walls the least every subject except one choose the use of the Wiimote. This one subject considers that there is no difference. In the results of the empirical test one person actually has an equal amount of bumps into walls and closed doors for both test, but this subject chooses the Wiimote to have the least. Users indicated they completed the game the fastest with the Wiimote (10) However some subjects consider completing the game with the Balance Board (4) the fastest and four subjects think both are equally fast. In these cases the Balance Board is considered by the subjects to have a poorer performance than the Wiimote.

Opening the doors in the game is done by pressing a button on the Wiimote, but keeping the avatar on the doormat depends on the navigation by means of the Wiimote or Balance Board. The participants are asked which of the cases they find it easier to open doors. Eight of 18 subjects experience no difference, followed by seven votes for the use of only the Wiimote and three for the use with the Balance Board. Meaning that in overall the Wiimote performs better then the Balance Board for opening doors. Most of the subjects consider that there is no difference between the tests in getting fatigued, although some choose the Wiimote for getting fatigued in the arm during the test and some subjects choose the Balance Board for getting fatigued from standing up during the test. Most of the subjects have more fun using the Balance Board. The subjects comment on how enjoyable the Balance Board is to play with.

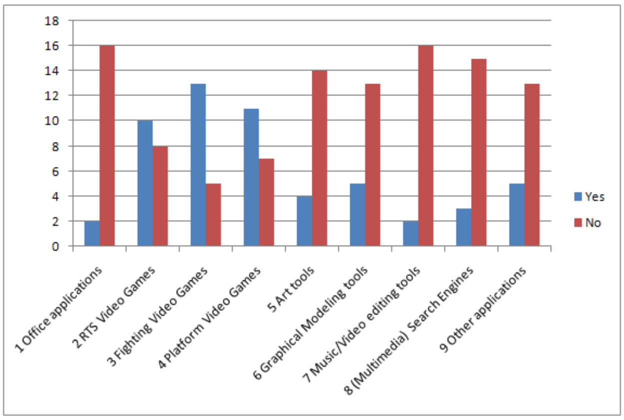

Figure 10 The results of how the participants see the use of the Balance Board with various applications.

Figure 10 shows the result of the subjects' ideas on the use of the Balance Board with various applications. Every category has at least two of the 18 subjects answering 'yes'. The most accepted use of the Balance Board is in entertainment.

The comments given with the 'yes' answers focuses mostly on navigational tasks, such as moving a virtual character, navigating the screen or the results in search engines. In graphical modelling tools comments are given to use the Balance Board to rotate the model. Some other suggestions of the subjects are; Using the Balance Board to create art, indicating the beat in music editors or to use the Balance Board for simple selection tasks. The most remarkable comment is to use the Balance Board as a preventive against RSI with office applications. This comment can apply to all the applications.

5. CONCLUSION

The research question is: *Does the Balance Board have an added value to gesture interfaces by improving performance, like the duration to complete a task or errors made doing a task?* Our hypothesis is that the use of the Balance Board with the Wiimote has a better performance than the use of the Wiimote alone.

The Wiimote has a significant better performance than the Balance Board. Using the Wiimote to control the avatar results in less going on and off the doormats. This shows the subjects to have more control over the avatar and keeping it still. With the use of the Balance Board the subjects start to wander when pressing a key. The results show that the Balance Board performs significantly better in the average time spend by the subjects on a doormat, which is the result from the subjects having less control over the avatar. Navigating the avatar with the Wiimote completes the game significantly faster than using the Balance Board.

As expected, controlling the avatar with the Balance is significantly more intuitive than the Wiimote, where the subjects often consider the Wiimote to be counterintuitive. The subjects are more active with the arm when using the Wiimote to navigate the avatar than the Balance Board. The results show the Balance Board to have a significant less fatiguing effect in the arm. The sugestion from a subject to use the Balance Board as a preventive measure against RSI seems to have merit. However the subjects get quicker fatigued from standing up, with the Balance Board.

In our hypothesis we consider the Balance Board to have a better performance over the Wiimote. But asking the subjects to compare the two devices, has given some unexpected and interesting results. The Balance Board is considered to be the easiest to learn and more intuitive to use. And the Balance Board is the most fun to use. The subjects vote the Wiimote to have a better performance in accuracy and smoothness of the avatars movements. But this is expected, because the subjects are not as familiar with the Balance Board as they are with the Wiimote. The Wiimote is also considered to complete the task the fastest and making the least number of mistakes which contradicts our hypothesis.

We find unexpected are the results for opening doors. We think it easier to open doors with the use of the Balance Board. The orientation of the Wiimote has no effect on the game, with the Balance Board, and can be held in the line of sight with the screen. This will also result in getting more fatigued in the arm. Instead the subjects keep the arm in a resting position and only raise the arm or look down when they have to press a button.

Although everyone is not familiar with every application the suggestions of those who are familiar show some promising results. It is expected that most of the suggestions concern with movement and navigating. The suggestion 'indicating beats' in a music editor, shows that not all uses involve standing on the board. The Balance Board can also be used while sitting on a chair. The most remarkable suggestion is using the Balance Board to prevent RSI.

Returning to the research question, the results show that the Balance Board does not improve the performance in completing tasks faster or making fewer errors. The Balance Board has a poorer performance than the Wiimote. This might be due to the fact that the subjects are less familiar with the Balance Board. The subjects do find navigating with the Balance Board intuitive and easy to learn. Schöning et al. claim that for their experiment the Balance Board did improve the performance. The difference between their test and ours is that theirs has a more complicated task set than ours.

For a complicated task set the Balance Board might have an added value to gesture interfaces by improving performance, but with a simple set of tasks the Balance has no added value. But most of our subjects enjoy using the Balance Board more than just the Wiimote. Meaning that the Balance Board has an added value to gesture interfaces in making interacting with the computer more enjoyable. Making the focus of using the Balance Board on digital entertainment, such as videogames.

6. DISCUSSION AND FUTURE WORK

This research has delivered some interesting expected and unexpected results. The program of the empirical test is not optimal. The graphics of the game show a blinking effect, which can be solved by using double buffering. The collision detection with the walls is done with a simple and crude algorithm. When the radius of avatar is equal or smaller to the distance to a door, the avatar can close in on the walls next to the door. In other cases the centre of the avatar would remain at a distance of the radius. These programming errors can affect the results. The effects can be neglected because everyone is troubled by them.

The time span of our tests is too short to notice any real fatiguing. These data are not the biggest focus of the research do not effect the results on the research question.

The questionnaire asks the subjects about possible use of the Balance Board with a number of applications to prevent the focus to be on videogames, as the Nintendo Balance Board will suggest. This is something that definitely has an effect on the results and it also has a danger. Applications like videogames and Office are known to everyone (with maybe the exception of a single person), while the other applications and their functions are not known to everyone. This leads to an unfair advantage for videogames and Office. The results of these questions are not very reliable. The main focus of these questions, however, is to get ideas of possibilities for using the Balance Board with these applications. The Balance Board is still relatively new and it is therefore hard to imagine how to use it, when you do not know how it works and people will default to what is known and done.

Many of the empirical results are insignificant, due to a small sample size. With more resources, volunteers and (above all) time the sample size can be bigger but it does not guarantee the significance becoming better.

Someone suggests to use the Balance Board as a prevention method against RSI. It is interesting to see if it does really help against RSI or that it produces a new kind of aching. Additionally the time span of the test was too short to measure fatiguing. To measure fatiguing it is better to make the game a lot longer and to truly focus on this aspect.

The lack of experience from the users can be an explanation of the results. To test this aspect the subjects should first be given a chance to work with and explore the Balance Board and Wiimote for a longer period, by playing Wii Fit or another game for example.

Finally work can be done to find the size of the task set and types of tasks, where the use of the Balance Board does give a better performance.

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Table 1 T test paired sample statistics (N = 18), BW is the test with the Balance Board and Wiimote and WM is the test with only the Wiimote. Results from the empirical test.

	Mean	Std. Deviation	Std. Error Mean
Total duration of the game (BW, hh:mm:ss)	00:02:16,386	00:00:26,798	00:00:06,316
Total duration of the game (WM, hh:mm:ss)	00:01:58,919	00:00:25,971	00:00:06,122
Total number of hits against a wall (BW)	47,61	7,047	1,661
Total number of hits against a wall (WM)	50,94	15,360	3,620
Total number of hits against a closed door (BW)	13,22	6,198	1,461
Total number of hits against a closed door (WM)	12,50	17,099	4,030
Total number of keys entered incorrect (BW)	33,28	44,720	10,541
Total number of keys entered incorrect (WM)	26,83	23,593	5,561
Total number of doormats gone on and off (BW)	25,61	5,532	1,304
Total number of doormats gone on and off (WM)	21,33	3,597	,848
Average duration spend on a doormat (BW, hh:mm:ss)	00:00:01,782	00:00:00,582	00:00:00,137
Average duration spend on a doormat (WM, hh:mm:ss)	00:00:02,247	00:00:00,614	00:00:00,145
Total duration spend on a doormat (BW, hh:mm:ss)	00:00:43,960	00:00:14,153	00:00:03,336
Total duration spend on a doormat (WM, hh:mm:ss)	00:00:47,247	00:00:13,324	00:00:03,141
How easy it is to learn moving the avatar (BW, score 1-5)	3,89	1,183	,279
How easy it is to learn moving the avatar (WM, score 1-5)	4,11	,900	,212
How intuitive the movement of the avatar is (BW, score 1-5)	3,89	,963	,227
How intuitive the movement of the avatar is (WM, score 1-5)	3,39	,979	,231
How smooth the movement of the avatar is (BW, score 1-5)	3,50	,924	,218
How smooth the movement of the avatar is (WM, score 1-5)	3,50	,985	,232
How accurate the movement of the avatar is (BW, score 1-5)	3,17	,707	,167
How accurate the movement of the avatar is (WM, score 1-5)	3,89	,832	,196
How easy it is to open doors (BW, score 1-5)	3,28	1,074	,253
How easy it is to open doors (WM, score 1-5)	3,56	,922	,217
How fatigued the subject gets in the arm (BW, score 1-5)	4,89	,323	,076
How fatigued the subject gets in the arm (WM, score 1-5)	4,50	,618	,146
How fatigued the subject gets from standing up (BW, score 1-5)	4,44	1,042	,246
How fatigued the subject gets from standing up (WM, score 1-5)	4,83	,383	,090
How much the subject enjoys the game (BW, score 1-5)	3,50	1,098	,259
How much the subject enjoys the game (WM, score 1-5)	3,28	1,364	,321

Table 2 T test paired differences (df = 17), BW is the test with the Balance Board and Wiimote and WM is the test with only the Wiimote. Results of the empirical test

	Df Mean	Std. Deviation	Std. Error Mean	t	Sig. (2-tailed)
Total duration of the game (BW, hh:mm:ss) - Total duration of the game (WM, hh:mm:ss)	00:00:17,467	00:00:33,555	00:00:07,909	2,208	,041
Total number of hits against a wall (BW) - Total number of hits against a wall (WM)	-3,333	16,356	3,855	-,865	,399
Total number of hits against a closed door (BW) - Total number of hits against a closed door (WM)	,722	17,623	4,154	,174	,864
Total number of keys entered incorrect (BW) - Total number of keys entered incorrect (WM)	6,444	33,347	7,860	,820	,424
Total number of doormats gone on and off (BW) - Total number of doormats gone on and off (WM)	4,278	4,873	1,148	3,725	,002
Average duration spend on a doormat (BW, hh:mm:ss) - Average duration spend on a doormat (WM, hh:mm:ss)	-0:00:00.465	00:00:00,901	00:00:00,212	-2,190	,043
Total duration spend on a doormat (BW, hh:mm:ss) - Total duration spend on a doormat (WM, hh:mm:ss)	-0:00:03.286	00:00:19,451	00:00:04,585	-,717	,483
How easy it is to learn moving the avatar (BW, score 1-5) - How easy it is to learn moving the avatar (WM, score 1-5)	-,222	1,263	,298	-,747	,466
How intuitive the movement of the avatar is (BW, score 1-5) - How intuitive the movement of the avatar is (WM, score 1-5)	,500	1,249	,294	1,699	,108
How smooth the movement of the avatar is (BW, score 1-5) - How smooth the movement of the avatar is (WM, score 1-5)	,000	1,085	,256	,000	1,000
How accurate the movement of the avatar is (BW, score 1-5) - How accurate the movement of the avatar is (WM, score 1-5)	-,722	,958	,226	-3,198	,005
How easy it is to open doors (BW, score 1-5) - How easy it is to open doors (WM, score 1-5)	-,278	,895	,211	-1,317	,205
How fatigued the subject gets in the arm (BW, score 1-5) - How fatigued the subject gets in the arm (WM, score 1-5)	,389	,608	,143	2,715	,015
How fatigued the subject gets from standing up (BW, score 1-5) - How fatigued the subject gets from standing up (WM, score 1-5)	-,389	,979	,231	-1,686	,110
How much the subject enjoys the game (BW, score 1-5) - How much the subject enjoys the game (WM, score 1-5)	,222	1,166	,275	,809	,430