Evaluation of Tip-activated and Push-button Infrared Pens for Interactive Whiteboards

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Abstract— **Many schools are replacing traditional whiteboards with interactive versions connected to computers and operated with a digital pen. Previous research has established that interactive whiteboards facilitate the learning activities, but there is limited research on the usability of the available digital pens. In particular, the Wiimote project is a cheap interactive whiteboard that employs an infrared pen, which is available in two versions: 1) push button and 2) tip activated. The push button is a pen which functions is similar to that of a mouse and the tip activated is a pen that acts like a "real" pen. In this article, we present an experiment that compares the usability of two infrared pens (push button and tip activated) in a target acquisition and a docking task. In addition to those typical input device tasks, we developed a more realistic drawing task, in order to assess the accuracy of each input device. We found that the tip activated pen is more usable, more accurate, and creates less fatigue.**

Keywords-usability; wiimote project; interactive whiteboard; infrared pen; push button; tip activated; target acquisition; docking

I. INTRODUCTION

There has been extensive investment by governments and individual schools in interactive whiteboard technology in developed countries premised on the assumption that their use in education will impact positively on learners achievements. Each year, a great number of schools are adopting the new technology of interactive whiteboard. Therefore the number of users (students and teachers) using this technology is increasing rapidly. There are a lot of types of interactive whiteboards depending on their sensing technology to establish interaction with the screen surface such as resistive, electromagnetic, infrared optical, laser, ultra-sonic, and camera-based (optical). A particular trend was observed in the infrared optical sensing technology of interactive whiteboards and more specifically for Wiimote project interactive whiteboards, because of their low cost and portability [1]. One of Wiimote's required accessories is the interactive infrared pen. Whiteboard interactive pen is easier than chalk to hold and write with. This can benefit persons with limited mobility in their hands, such as those affected by diseases such as arthritis or systemic lupus erythematosus. In addition, marking on an interactive whiteboard takes less time, effort, and pressure than marking on a traditional whiteboard or on a chalkboard.

Nowadays, there are two types of interactive infrared pen categorized by their use. The first type is the push button infrared pen and the second one is the tip activated infrared pen. Concerning the use of the first type of infrared pen, we should only touch the infrared led on the whiteboard surface and then push its button. The functionality of the second type of the infrared pen requires the touch of the infrared led on the whiteboard surface. Both infrared pens have the same size, weight and life duration, despite the fact that the push button infrared pen was first released. The push button infrared pen is cheaper than the tip activated infrared pen because of its simpler activation mechanism.

The pen user interface is heralded as more natural and powerful than the mouse, due to pointing, handwriting, gesturing, and drawing. [2, 3, 4] It is widely believed that the pen is mightier than the mouse. There are comparison studies of different input devices such as pen, mouse and keyboard in a variety of application areas, ranging from spreadsheet applications [5] to that of text selection and entry [6, 7]. As stated above, the previous experiments had focused primarily on the function of the "real" pen. We had hypothesized that the tip activated infrared pen is better in all the performed actions of the tasks. The actions of pointing and dragging are chosen because they are fundamental, low level operations in direct manipulation interfaces [8].

Analytically, this paper aims to report the results of an experiment designed to compare the usability of two types of infrared pens performing pointing and dragging tasks. The experiment consists of:

- Methodology that describes the design of the experiment (variables, learning effect, evaluation techniques, volunteers, equipment, procedure, measurements).
- Experiment (assignment of tasks, execution of each task)
- Results (analysis of collected data)

II. METHODOLOGY

This research was conducted in Greece. The volunteers of the experiment were six students of middle school (four boys and two girls) fifteen years old. They were all novice users of interactive whiteboards, however, they were experts in computers. The number of students was appropriate according to the setup and understanding of the experiment [9].

In order to design the experiment, we first had to identify the variables, which are: a) independent (pens, size of shapes, distance), b) dependent (time, success – failure, accuracy).

As it has already been mentioned, the experiment is based on two types of actions: pointing and dragging. Three types of tasks were designed, to perform these actions; specifically, the first part is based on two pointing tasks (targets), the second part is based on a dragging task and the last one (called drawing task) is based on a combination of the two actions.

Table I, presents the design of all the combinations of pens that took place to different tasks and users (volunteers), to avoid the undesired influence of learning.

TABLE I.   LEARNING EFFECT [10, 11]

Volunteers	Pointing Task 1	Pointing Task 2	Dragging Task	Drawing Task
User 1	push button	push button	tip activated	tip activated
User 2	tip activated	tip activated	push button	push button
User 3	tip activated	tip activated	tip activated	tip activated
User 4	push button	push button	push button	push button
User 5	tip activated	push button	tip activated	push button
User 6	push button	tip activated	push button	tip activated

The evaluation techniques that took place were: a) observing users by using logging files, b) interviewing the users. The equipment that was used consisted of: a) a PC that is connected to a Video Projector and to a Nintendo Wii Remote as shown in Fig. 1 situated on the right side of the laboratory (in a distance equal to the double height of the screen), b) the infrared pens (push button and tip activated, as shown in Fig. 2). The Video Projector is 2.5 meters away from the viewing point ("normal" whiteboard). The software that has been used is: a) Windows XP with service pack 3 for the PC, b) smoothboard v.1.6 (interactive whiteboard software), c) logging software that has been created using Visual Basic.

Figure 1. Nintendo Wii Remote.

Figure 2. Infrared pens.

The overall procedure consists of a demonstration, a thirty minute testing for each participant and a final interview. According to this procedure, the desired measurements were: a) the size of the objects, b) the completion time, c) the success and failure of the task, d) the accuracy.

III. EXPERIMENT

Initially, the experiment was performed in a laboratory setting using two adults as control subjects. This was done to ensure the validity of the data and to work out any kinks in the experimental design. Fig. 3 shows the specifications of the laboratory that was designed for the volunteer group (fifteen years old students) based on their biometric data, such as height, distance, and size. The diagonal of the projected computer screen is 74 inches and the upper limit is 1.99 meters (measured from the laboratory floor).
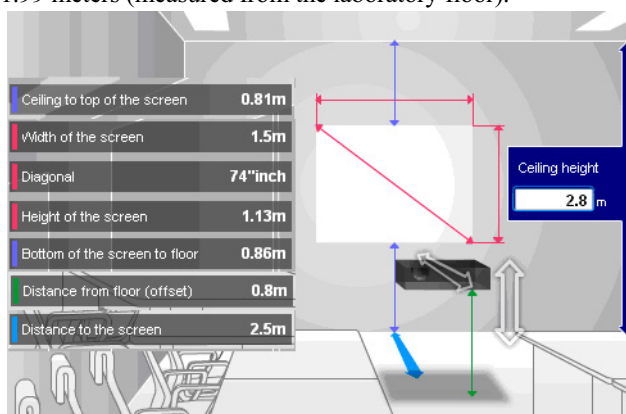

Figure 3. Specifications of the laboratory [12].

The following procedure was followed: 1) the procedure was demonstrated to all the volunteers, 2) testing began and each user was given a pen as described in Table I, 3) the volunteers performed the tasks depending on the experiment (two pointing tasks, one dragging and one combination of the two). Fig. 4, shows the initial form of the experiment. Data from the form was held in a log file that was automatically given a name, based on the date and time that the test occurred.
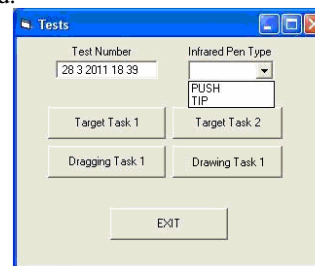

Figure 4. The initial form of the experiment.

During the first pointing task, the user has to hit (click) the target with the corresponding pen, for six minutes. When the hit is successful, the target changes randomly its position. Every one and a half minute the target becomes smaller

(changes its size to half, initial size is 7.95x7.95 cm). Fig. 5 shows the first pointing task.
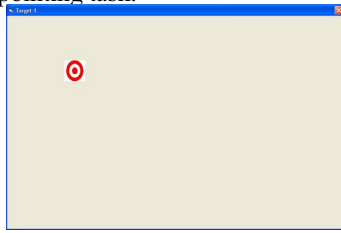

Figure 5.   The first pointing task.

The logging file (which is saved by the combination of the test number plus the name of the task plus the type of pen) holds data like starting time, width and height of the target, successful and unsuccessful hits of the target and the time that the hit occurred. Table II, shows the logging file of the first pointing task.

During the second pointing task, the user has to hit (click) a number of targets. This is done four times each lasting a minute and a half, with the corresponding pen, in order to view a picture. Every one and a half minute the targets become smaller (changes its size to half, initial size is 11.15x11.15 cm). The total time of the task is six minutes. Fig. 6 shows the second pointing task.
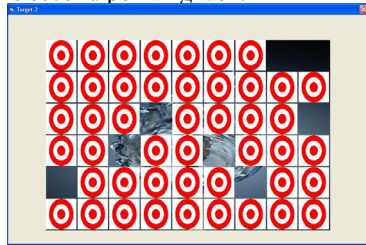

Figure 6.   The second pointing task.

TABLE II.   THE LOGGING FILE OF THE FIRST POINTING TASK.

Staring time of the task	Height of the target (cm) * 100	Width of the target (cm) * 100	Seconds of the task, when the user hits successfully or not the target	Successful hit=1 or Unsuccessful hit=0
6:54:22 pm	795	795	5	1
6:54:22 pm	795	795	4	1
6:54:22 pm	795	795	4	0
6:54:22 pm	795	795	3	1

The logging file (which is saved by the combination of the test number plus the name of the task plus the type of pen) holds the same data as the first pointing task. Table III, shows the logging file of the second pointing task.

TABLE III.   THE LOGGING FILE OF THE SECOND POINTING TASK.

Staring time of the task	Height of the target (cm) * 100	Width of the target (cm) * 100	Seconds of the task, when the user hits successfully or not the target	Successful hit=1 or Unsuccessful hit=0
7:50:21 pm	1115	1115	6	1
7:50:21 pm	1115	1115	5	0
7:50:21 pm	1115	1115	5	1
7:50:21 pm	1115	1115	3	1

During the dragging task, the user has to drag the picture, with the corresponding pen on the target. When the drag and drop has successfully completed, the color of the target changes. The overall time of the task is nine minutes. The first four and a half minutes has three terms of one and a half minute. In all the terms of the four and a half minutes, the distance between the picture and the target does not alter but it remains on the standard basis (24.45 cm). The only parameter that varies over time (every one and a half minute) is the picture which changes its size to half although its initial size was 7.95x7.95 cm. The previous procedure is repeated for another four and a half minutes with a bigger distance (previous distance multiplied by two). Fig. 7 represents the dragging task.
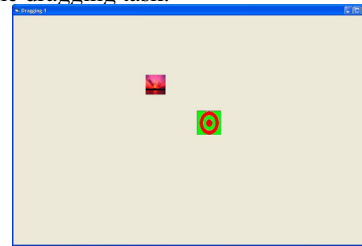

Figure 7.   The dragging task.

The logging file (which is saved by the combination of the test number plus the name of the task plus the type of pen) holds the same data as the first and second pointing tasks. Table IV, shows the logging file of the dragging task.

TABLE IV.   THE LOGGING FILE OF THE DRAGGING TASK.

Staring time of the task	Height of the target (cm) * 100	Width of the target (cm) * 100	Seconds of the task, when the user hits successfully or not the target	Successful hit=1 or Unsuccessful hit=0
8:34:02 pm	795	795	5	0
8:34:02 pm	795	795	4	1
8:34:02 pm	795	795	3	0
8:34:02 pm	795	795	3	1

During the drawing task, which is a combination of the pointing and dragging actions, the user has to draw a given picture (in this experiment a colored house). The screen of the task has two sides. On the left side, there is a Microsoft Paint Template and on the right is a sample picture that has to be drawn, with the corresponding pen. Fig. 8 shows the Template that was used. The logging file holds the overall time that the user spent to finish the task.
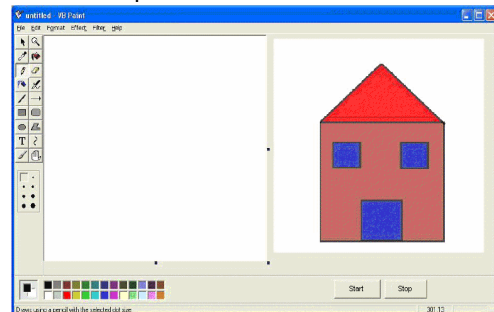

Figure 8.   The drawing task.

The user's drawing (on the left side) is compared with the sample picture on the right and analyzed using specific software called "ImageDiff". The ImageDiff software gives the percentage of similarity of both pictures. Fig. 9 shows the imageDiff software with its results.
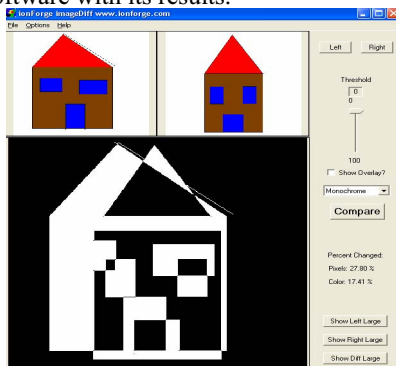

Figure 9.   The "ImageDiff" software with its results.

The last step of the procedure was the interview of each participant. The volunteers stated with the same percentage that a) the tip activated infrared pen is better than the push button and there is no comparison between them, b) there is no better pen, everything depends on the tasks.

IV.   RESULTS

The hypothesis of the experiment was that the tip activated infrared pen is better in all the performed actions of the tasks. The results showed that the tip activated infrared pen is better in three of the four tasks performed.

The results from the first pointing task (Fig. 10) showed that the tip activated infrared pen recorded less unsuccessful hits compared to that of the push button. Specifically, the tip activated pen resulted in 99% successful hits vs. 1% unsuccessful hits. Unlike the push button infrared pen which had 10% unsuccessful hits and 90% successful.
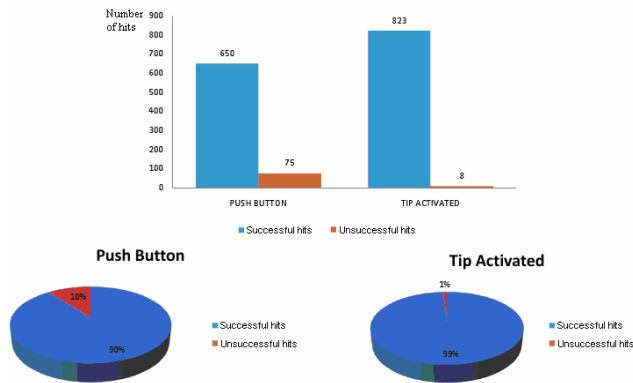

Figure 10.   The results of the first pointing task

The results of the second pointing task (Fig. 11) showed that the tip activated infrared pen had more unsuccessful hits than the push button (7% vs. 2%, respectively). Specifically, the tip activated had 93% successful hits while the push button had 98%.
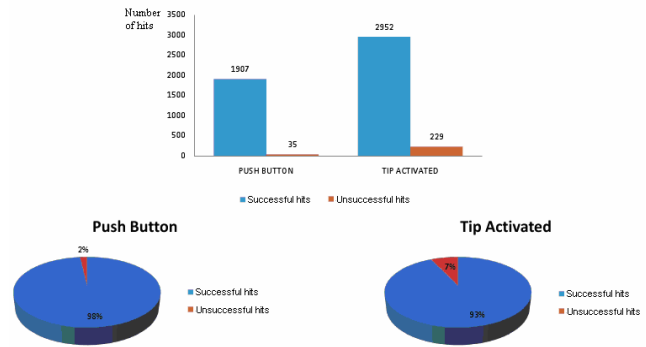

Figure 11.   The results of the second pointing task

The results of the dragging task (Fig. 12) showed that the tip activated infrared pen has less unsuccessful hits than the push button. Specifically, the tip activated had 99% successful hits compared to the push button which had 97%.
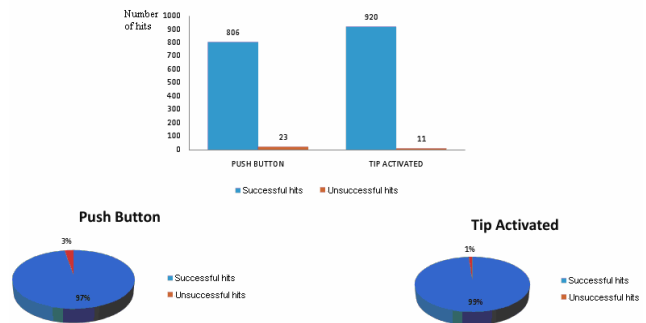

Figure 12. The results of the dragging task

Small differences in rates between the examined infrared pens are in fact major differences in the number of hits. Therefore tip activated infrared pen has more hits compared with push button infrared pen.

The results of the drawing task (Fig. 13) showed that the user was able to draw the picture quicker using the tip activated infrared pen rather than the push button. Specifically, with the tip activated infrared pen, the picture is drawn in 91 seconds. Unlike the push button infrared pen which took 107.33 seconds for the picture to be drawn.
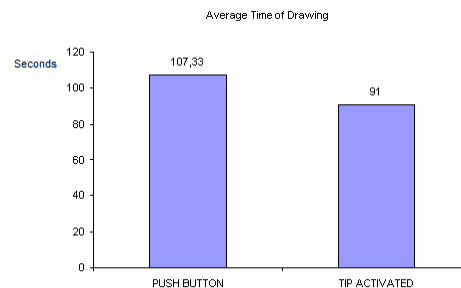

Figure 13. The results of the drawing task according to time.

Also, the results of the drawing task (Fig. 14) shows that the user's picture is drawn more accurately with the tip

activated infrared pen rather than the push button (78.87% vs. 75.19%, respectively).
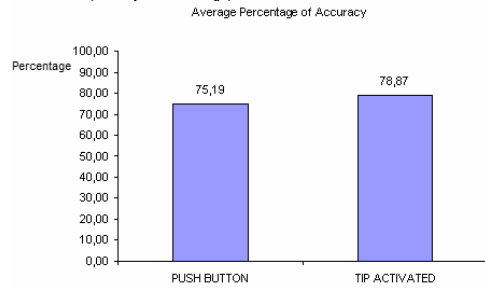

Figure 14. The results of the drawing task according to accuracy.

V. CONCLUSIONS

There is no previous work on the Wiimote project that examines its infrared pen. The experiments presented in this paper are an initial effort in evaluating infrared pens for interactive whiteboards based on pointing and dragging actions.

This experiment confirms the hypothesis of superb performance of the tip activated infrared pen for the major part of the tasks compared to the performance of the push button infrared pen.

Some volunteers complained about the fact that, while holding the push button infrared pen, they felt slightly uncomfortable as their hand became tired during the procedure of the tasks. Nevertheless, the tip activated infrared pen has several benefits. In three of the four tasks (the first pointing task, the dragging task and the drawing task) the tip activated infrared pen is more accurate and the experienced users save time and hits and they avoid hand fatigue. The push button infrared pen is better than the tip activated infrared pen only in the second pointing task. According to our observation, this happened because the participants made fewer hand movements (forward and backward to the whiteboard). Analytically, when the pen touched the whiteboard their hand followed the flow of the targets, minimizing the effort of completing the specific task. Unlike, using the tip activated infrared pen more movements have been made (forward and backward to the whiteboard) by their participant's hand which followed the flow of the targets. Based on the participant's interviews this task (compared to the other tasks) was more restful using the push button infrared pen rather than the tip activated infrared pen.

In the tasks where the number of infrared pen's hits were measured (first pointing task, second pointing task and dragging task) the tip activated infrared pen has been superior to the push button infrared pen. This happens because the push button infrared pen needs slightly more time for its button to be pressed.

In conclusion, the tip activated infrared pen has better usability. Using this pen takes advantage of natural co ordination between hand and eye and as it provides the illusion of using a pen or a chalk on a traditional whiteboard it, also, offers all the benefits of a completely digital workflow. Its ergonomic design provides intuitive grip, perfect on your desk, in your lap, or angled any way you want with the dynamic, free-moving stand. Therefore, the users should choose to use tip activated infrared pen not only for the Wiimote project interactive whiteboard but for all interactive whiteboards.

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