Evaluation of Three Wearable Computer Pointing Devices for Selection Tasks

Joanne E. Zucco[†], Bruce H. Thomas[†], and Karen Grimmer[‡]

[†]*Wearable Computer Laboratory*
School of Computer and Information Science
University of South Australia
Mawson Lakes, SA, 5095, Australia
{jo.zucco, bruce.thomas}@unisa.edu.au

[‡]*Centre of Allied Health*
School of Health Sciences
University of South Australia
Adelaide, SA, 5000, Australia
karen.grimmer@unisa.edu.au

Abstract

This paper presents the results of an experiment comparing three commercially available pointing devices (a trackball, gyroscopic mouse and Twiddler2 mouse) performing selection tasks for use with wearable computers. The study involved 30 participants performing selection tasks with the pointing devices while wearing a wearable computer on their back and using a head-mounted display. The error rate and time to complete the selection of the circular targets was measured. When examining the results, the gyroscopic mouse showed the fastest mean time for selecting the targets, while the trackball performed with the lowest error rate.

Keywords: *Wearable computer, Pointing device, Selection tasks, Evaluation.*

1. Introduction

This paper presents a usability study which compares three commercially available pointing devices (a trackball, gyroscopic mouse and Twiddler2 mouse) performing selection tasks for use with wearable computers. Pointing devices are critical to the usability of wearable computers. Traditional workstation pointing devices such as a mouse, joystick and keyboard are not practical for users standing and moving in an indoor/outdoor environment, as these devices require a level, flat surface to operate. A new form of pointing device is therefore required. Pointing devices better suited for use with wearable computers are now emerging from research laboratories and as commercial products. To date, there are few empirical studies investigating the usability of pointing devices for wearable computers.

A wearable computer is a physical form of a portable computer. Instead of the computer being handheld, it is attached to the user by a backpack, belt, or in the user's clothing. The application areas for this form of computer range from navigation and way finding [1], touring of archaeological sites [2], entertainment and gaming [3] and assisting soldiers [4].

1.1. Motivation

The aim of our study was to determine whether there was any measurable difference to a user operating a wearable computer while standing using the different pointing devices. The study's objectives were as follows:

1. To determine whether there was a measurable difference in speed when performing selection tasks with the three different pointing devices.
2. To determine whether there was a measurable difference in accuracy when performing selection tasks with the three different pointing devices.
3. To determine whether the pointing devices could be placed in an order of effectiveness based on task completion time and error rate.
4. To determine whether users had a preference for any of the three pointing devices.

2. Commercially Available Pointing Devices

There exist a number of input devices for wearable computers, which can be grouped into the following categories: devices specifically designed for text entry purposes, devices designed for cursor control and devices capable of performing both functions. We have identified the following three commercially available devices: handheld trackball, gyroscopic mouse, and Twiddler2 mouse. All three devices provide the user with the ability to perform cursor movement and object selection, and all three devices may be used with either the left or right hand.

2.1 Trackball

The 4D Off-Table Hand Track [5] mouse referred to as the trackball device is a product of 3G Green Green Globe Co, Ltd. The device has a trackball situated on the top of the device that is manipulated with the user's thumb to perform cursor movement. The device integrates three mouse buttons: a trigger button for left clicks (index finger operation), and two buttons (thumb operation) on top of the device providing the user with the ability to right and left click. Selection of targets is performed by pressing the trigger button. Figure 1 demonstrates the position of the device in the user's hand. There are a number of other forms of this device with differing number of buttons, shape of handle, length of handle and with no trigger guard, and they all operate in a similar fashion.

Figure 1. Trackball

2.2. Gyroscopic mouse

Gyration Ultra GT cordless optical mouse referred to as the gyroscopic mouse is a product of Gyration Inc. [6]. The gyroscopic mouse has an activation trigger which enables cursor movement, two mouse buttons (left and right) and a scroll wheel. To move the cursor, users must press and hold the activation trigger with their index fingers while moving their wrist up, down or sideways. The mouse senses relative hand motion, as a result, the cursor follows the motion of the user's hand. Selection of targets is performed by pressing the left mouse button. Figure 2 demonstrates the position of the device in the user's hand, with the index finger on the activation trigger.

Figure 2. Gyroscopic mouse

2.3. Twiddler2 mouse

The Twiddler2 [7] is a product of the HandyKey Corporation and is able to perform both text entry and cursor control. For the purposes of our usability study, we only made use of the cursor control and mouse button functionality of the Twiddler2. The keys on the top/back of the Twiddler2 are operated by the thumb. Moving the Trackpoint under the thumb moves the cursor. Figure 3 demonstrates the position of the device in the user's hand. Selection of targets was performed by pressing the "BS" key on the front of the device (left click). Although the "A" key is identified as the default left click, we performed a study which indicated using the "BS" key did not impede the performance of the Twiddler2, rather results indicated that the Twiddler2 performed better using the "BS" key than the "A" key for left click. Results of the study are described in section 6.4. A fabric strap wraps around the back of the hand to hold the Twiddler2 in position.

Figure 3. Twiddler2 mouse

3. Previous Work

Usability studies investigating input devices for traditional computing environments have a long rich history; however, investigating the performance of input devices for wearable computers is a relatively new field of investigation. We present an overview of these investigations into input devices for wearable computers.

Performance of traditional input devices has been measured by comparing speed and accuracy between devices to determine improvements. An example is MacKenzie et al.'s [8] experiment comparing the speed and accuracy of three input devices, a mouse, a trackball and a stylus with tablet for pointing and dragging tasks. In the case of evaluating an input device or technique, a customary task is to point and select a graphical object on a monitor. An example is the study by MacKenzie and Jusoh [9] performing a standardized comparison of two remote pointing devices, GyroPoint and RemotePoint, for selection tasks. Participants carried out a point-select task which required them to move a cursor back and forth between two targets selecting them by pressing and releasing a button on the device. The investigation employed a standard mouse as a base-line condition. The two remote pointing devices performed poorly as compared with the mouse.

To date, there are few empirical studies investigating the usability of pointing devices for wearable computers We previously examined three different text input devices for a wearable computer that was being used in a standing position: a forearm-mounted QWERTY keyboard, a five-button chording device, and an isometric mounted button with a virtual keyboard. The forearm keyboard was found to be superior [10]. We found that the isometric mouse mounted on top of the hip-placed battery container was very uncomfortable for users. We later investigated the effects of the placement of a TouchPad input device on a user's body to perform selection tasks [11]. The task was a multi-directional point and select task where participants were required to select targets placed at a given distance, equally around the center of the screen. Results indicated that the thigh front mouse position was the most appropriate for sitting, kneeling and standing, with the forearm mouse position better for the prone position.

Chamberlain and Kalawsky compared two pointing systems for use with wearable computers while mobile. They studied a touch screen stylus and an off-table mouse [12] (which appears to be the same design as the trackball used in our study). Participants did not wear a Head-mounted display (HMD) but were evaluated while stationary and moving. The authors found that while the stylus was quicker to use and had a lower workload rating than the mouse, the mouse performed with the lower error rate.

Wither and Höllerer [13] conducted a user study comparing four techniques for controlling a 3D virtual cursor from a distance. Four interaction techniques were tested: the use of a Twiddler2 Keyboard (T1), RocketMouse finger trackball (T2), head orientation with two buttons (T3), and head orientation alone with one button to switch between modes (T4). Their results showed that T2 and T3 performed similarly and were considerably faster than T1 and T4. Qualitative results showed users preferring the T2 technique. The RocketMouse is the same design as the handheld trackball used in our study.

5. Experimental Design

5.1. Participant population

Results were gathered from 30 participants who took part in the experiment. Of these, there were 28 males and 2 female, all right handed. The mean age of the participants was 26.8 years. The participants were volunteers from computer-literate students and staff at the School of Computer and Information Science. Participants were required to have no prior experience with the pointing devices, to be able to walk and to have normal corrected vision.

5.2. Wearable computer system

The experiment was conducted on a Dell Laptop Computer (Inspiron 8000) running the Microsoft Windows XP operating system. The output device used was a see-through head mounted display (HMD) produced by Sony (Glasstron with resolution 800 × 600 SVGA). Three commercial pointing devices were used for selection; trackball (Figure 1), gyroscopic mouse (Figure 2) and Twiddler2 mouse (Figure 3). The computer and power converters were stored in a small backpack. Although the display and computer could be operated with battery power, the experiment was performed using mains power due to the limited battery life.

5.3. Custom-built application

A custom-built application to present the experimental conditions to the participants was written in Java. The custom built application coordinated sets of tasks, and each task presented 40 circle targets, one at a time, to the participant who was to select each target as quickly and accurately as possible. To begin the task, participants select a target positioned in the center of the screen as seen in Figure 4. Once the target had been selected, that target was removed from the screen and a second target was placed on the screen with an offset of 180 pixels in one of the eight directions (N, S, E, W, NE, SE, NW, SW) selected randomly and so on. The eight target directions were each presented five times. The targets were circles of 40 pixels in diameter.

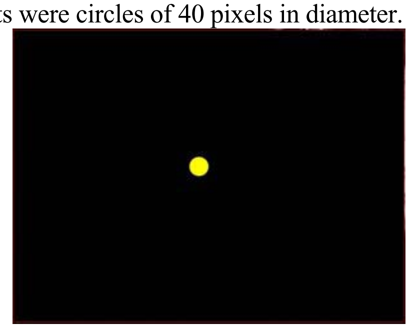

Figure 4. Custom-built application

The application prompted the user to change pointing devices in one of the two following methods: 1) for training sessions, the name of the pointing device to use appeared on the computer display and 2) for experimental sessions, the number of a paper poster for the participant to walk to appeared on the computer display. The data recorded for each trial included the times in nanoseconds at which the user selected or missed the start target and every selection, until and including the final target. Also recorded was the total number of errors (missed selections) and the total time between the first selection and the final selection of each task (40 trials).

5.4. Training session (Session 1)

The participants were required to undertake an initial training session, during which they were asked to read an information sheet, fill out a consent form, and undergo training using the three pointing devices. The supervisor demonstrated how each pointing device operated prior to the training. Participants were instructed to use the devices with their dominant hand. The participants were then asked to start the session, and the supervisor started the custom-built application. The application provided prompts that instructed the participant which pointing device to use in order to complete each task (40 trials). As the purpose of the session was to familiarize participants with the pointing devices, the participants did not wear the computer in a backpack and did not wear the HMD, but rather sat in a chair using the laptop computer on a desk to perform the training. The total duration of the training session was ~30 minutes.

5.5. Experimental session (Session 2)

Having completed the training session, participants undertook a second experimental session lasting approximately one hour. A minimum of 24 hours was allowed between the training session and the second experimental session. Reading from a script, the supervisor explained to each participant what was expected of them during the session and reminded them how each pointing device worked. The participants were then asked to start the session, and the supervisor started the custom-built application.

Nine stations were positioned around a large room (signaled by paper posters on the wall indicating the station number and the pointing device to use). The application provided prompts which instructed the participant to move to the next indicated station. Once the participant reached a station, the poster provided instructions regarding which pointing device to use in order to complete the task. This was implemented in order to have the participant interact with the environment and in turn perform a task using a wearable computer. The tasks were completed while standing and wearing the wearable computer and HMD as we believe that most interaction with a wearable computer occurs while standing still, focusing on the task at hand. The stations were addressed more than once, thus the need for only nine stations instead of 18.

5.6. Design

The experiment was a 3 × 6 x 40 repeated-measures design, meaning all participants were tested on all levels. All factors were repeated measures. The factors and levels are outlined in Table 1. To reduce learning effect, each participant performed six blocks of trials presented in random order. Each block consisted of three tasks in random order with each of the three devices. Participants were asked to rest for at least one minute after completing two blocks.

As outlined in Table 2, one task is defined as forty selections of a target with one pointing device. The 40 trials in random order were made up of eight target direction positions presented five separate times (8 × 5 = 40 trials). One block is made up of three tasks, and each task within a block used a different pointing device in a random order. One group is made up of six blocks in a random order. A group represents an entire training or experimental session for a participant, with the constraint that there is an equal number of participants who operate each pointing device as the first device of a session. This task was modeled on the previously mentioned point and select studies [9, 11]. However, we modified the position of the targets to appear randomly around the entire screen. The design of the participant's task was to emulate a user selecting an icon or graphical object.

Table 1. Experimental factors

Factor	Levels
Device	trackball, gyroscopic mouse, Twiddler2 mouse
Block	1, 2, 3, 4, 5, 6
Task	1, 2, 3 … 40

Table 2. Explanation of terms

Group	Six blocks (presented in random order).
Block	Three tasks (one per pointing device assigned in random order).
Task	40 trials (in random order – eight directions presented five times).
Trial	Target position.

6. Quantitative Results

6.1. Errors

Across all participants and devices there were 2.6 errors (SD 2.8) per task, with a range 0 – 18 errors per task. Overall the number of errors correlated poorly with the total time per task ($r2 = 0.0004$) or 0.04%.

We used a single factor ANOVA (analysis of variance) in order to determine whether the difference reported was significant. We tested for an ordering effect based on the first pointing device the participant operated in the experiment. Group 1's first device in the experiment was the trackball, group 2's was the gyroscopic mouse, and group 3's was the Twiddler2. In a single factor ANOVA model which tested the effect of ordering on errors, there is no effect of group on errors ($p>0.05$).

We tested for a learning effect across all devices and participants by block number; block 1 being the first block. We found there is no effect of block number on errors ($p>0.05$) from a single factor ANOVA model.

We found there was a significant individual participant effect on errors ($p<0.01$). Across all groups, blocks, and participants, there is a significant device effect on errors ($p<0.01$). Post hoc testing between the gyroscopic mouse and Twiddler2 indicated no significant differences, and indicated that the trackball significantly performed with a lower error rate. Table 3

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lists the mean error by pointing device. The trackball pointing device had a lower mean error rate and a lower maximum error rate per task. The Twiddler2 ranked second, with the gyroscopic mouse having the highest error rate.

In a multivariate ANOVA model (taking account of random participant effects, block, group and device effects) the pattern of effect remains (significant effect of device and individual participant), and not of block or group.

Table 3. Mean error by pointing device

Device	Mean errors per task	Std Dev	Max
Trackball	1.4	1.6	9
Gyroscopic mouse	3.4	2.9	16
Twiddler2 mouse	3.1	2.4	18

6.2. Time

Across all devices and participants the mean total time for one task was 64.558 seconds (SD 17.071). In univariate ANOVA models, we determined the following:

1) There is a significant effect of group number on mean total time per task ($p<0.05$).
2) There is a significant effect of block number on mean total time per task ($p<0.01$).
3) There is a significant effect of participant on mean total time per task ($p<0.01$).
4) There is a significant effect of device on mean total time per task ($p<0.01$).

With a significant effect of group number, which implies an ordering effect regarding the device the participants operated first. Table 4 lists the mean times per task over all participants for each group. A training effect was observed with the significant effect on block number. Table 5 shows the mean times per task over all participants for each block.

Of importance to this study, there was a significant effect of device on mean total time per task. Table 6 lists the mean times per task over all participants for each device. The order of fastest devices was (1) Gyroscopic mouse, (2) trackball, and (3) Twiddler2. In a multivariate ANOVA model (taking account of random participant effects, block, group and device effects) the pattern of effect remains (significant effects of all independent predictors).

To better understand this learning effect, Figure 5 depicts a graph illustrating the mean time of a task for each device by group number over the six blocks. The legend codes each data series by a two digit number (group number, device number). The group and device number coding scheme is (1) trackball, (2) gyroscopic mouse, and (3) Twiddler2. Viewing the graph, data series 13, 23, and 33 tend to remain the top three or slowest device (Twiddler2). Where data series 12, 22, and 32 tend to be the fastest device (gyroscopic mouse), and the data series 11, 21, and 31 all tend to be in the middle. While there is a statistically significant effect depending on which device was operated first in the first task of the experiment, there is also a statistically significant effect due to device type.

Table 4. Mean time in seconds by group

Group	Mean (sec)	Std Dev	Min	Max
1	64.8303	19.1411	33.6979	134.1460
2	67.1144	18.0652	41.1451	158.3658
3	61.7290	13.0437	38.8255	112.4675

Table 5. Mean time in seconds by block

Block	Mean	Std Dev	Min	Max
1	69.5833	18.9957	40.4173	145.0539
2	67.5846	19.6342	34.8987	141.7438
3	64.9879	17.0518	38.8015	134.1460
4	62.3973	13.8823	33.6979	108.0345
5	62.5023	17.4304	34.6181	158.3658
6	60.2918	12.9987	37.4417	98.0797

Table 6. Mean time in seconds by device

Device	Mean	Std Dev	Min	Max
Trackball	64.5013	13.0373	45.9444	158.3658
Gyroscopic	56.3383	17.0660	33.6979	141.7438
Twiddler2	72.8340	16.7191	45.5185	145.0539

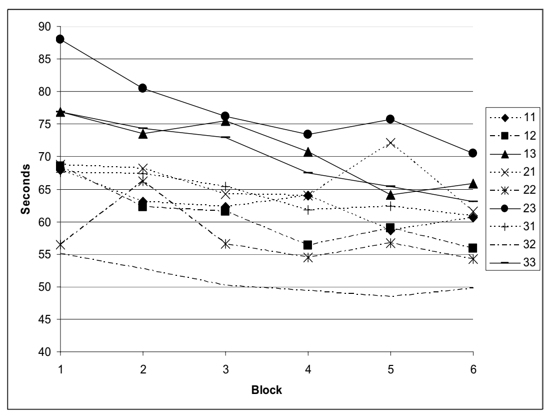

Figure 5. Mean time per task by group and device

6.3. Survey

Participants completed an exit questionnaire for pointing device satisfaction. They were asked to rate the devices on a 7 point scale in terms of "overall reaction" to the device and "describe your experience" using the device. Table 7 lists the attributes the participants were asked to rate and scale. The mean rating across all participants and attributes for each of the devices is as follows: gyroscopic mouse 2.67 (1.34 SD), trackball 2.87 (1.43 SD) and Twiddler2 4.63 (1.57 SD). Figure 6 graphs the mean across all participants for each attribute for each device. The graph clearly shows a preference for the trackball and gyroscopic mouse across all attributes. The graph depicts ease of use, speed of use, accuracy, intuitive, comfort and button press as being comparable for the trackball and gyroscopic mouse. It is interesting to note that while most of the rating factors are comparable between the two devices, a variation occurs with cursor movement. The participants were asked to explicitly rank the three devices in order of 1st, 2nd, and 3rd, as shown in Table 8. The rankings support the survey findings in Figure 6.

Table 7. Rating factors for devices

Ease of use	(1) very easy	(7) very difficult
Speed of use	(1) too fast	(7) too slow
Accuracy	(1) very precise	(7) very imprecise
Intuitive	(1) very intuitive	(7) very confusing
Comfort	(1) very comfort.	(7) very uncomfort.
Cursor Move.	(1) very easy	(7) very difficult
Button Press	(1) very easy	(7) very difficult

6.4. Twiddler2 key press study

A small study was carried out to determine whether the use of the "BS" key instead of the "A" key to select targets affected the performance of the Twiddler2. We performed a study with six participants similar to that outlined in section 5.4. Results of the study show the "BS" key performed with a lower error rate and a faster completion time than with selection using the "A" key. We found a significant effect of key on mean total time to complete one task ($p<0.05$). It is interesting to note that there was no significant effect of key on the mean number of errors per task ($p>0.05$). An exit questionnaire filled out by participants showed that 5 out of 6 participants preferred the "BS" key over the "A" key. As indicated by the results, using the "BS" key did not impede the performance of the Twiddler2, rather results indicated that the Twiddler2 performed better using the "BS" key than the "A" key for left click.

7. Qualitative Results

Written responses obtained from the survey relating to likes and dislikes of the pointing devices, along with cursor movement and selection difficulties, are discussed in this section. Although the number of comments does not reflect the usability of each device, it does however provide an insight into the possible methods for improving these devices. The comments were categorized to provide a means of determining overall concerns and positive features. In some instances, participants provided multiple comments when answering a particular question.

Table 8. Participant rankings

Rank	Trackball	Gyroscopic	Twiddler2
1	12	17	1
2	14	10	6
3	4	3	23

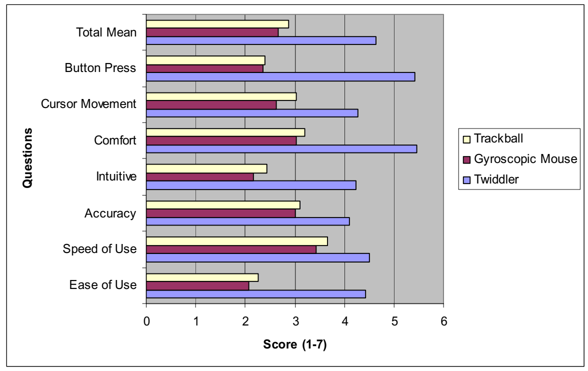

Figure 6. Mean values of rating factors

7.1. Trackball

The comments relating to the question "Trackball cursor movement and selecting difficulties" fell into the following three categories; eight comments about the form factor, one comment about the non-intuitiveness and eleven comments about the precision of selection. Having to use the thumb to move the cursor was the major concern. A typical comment being: "*Starting with the thumb in a central position on the ball, most movements seemed to require slightly more than one roll sideways, requiring the thumb to return to the initial position and repeat the movement; this is somewhat tiring for the thumb. Diagonal movement seems somewhat hard to perform compared to horizontal or vertical movement*." The form factor of the device was a concern. A comment representative of this was: "*You cannot adjust the device to suit your hand. For me, the trackball hole for the pointer finger was too big*."

The comments concerning the "Like about trackball?" fell into the following four categories: fourteen comments about the form factor, seventeen comments about the intuitiveness, two comments about the low level of fatigue, and fourteen comments about the precision of a selection. Participants liked the fact that it appeared to operate similar to a traditional mouse, with comments like: "*Usage similar to a normal mouse and therefore very intuitive, fast to move, relaxing usage - the hand could even hang down.*" The design of the device was found to be pleasing, with the following example comment: "*Simple design, easy to hold and use.*"

The comments concerning the "Dislike about trackball?" fell into the following three categories: eleven comments about the form factor, two comments about the fatigue using the device and eleven comments about the precision of a selection. A number of comments centred on the difficulty of using the thumb for fine control and the device being hard to hard hold. The following comments were typical of those stated: "*Very sensitive, hard to position accurately.*

Uncomfortable.", and "*Using my thumb alone made it difficult to move the cursor.*"

7.2. Gyroscopic mouse

The comments concerning the "Gyroscopic mouse cursor movement and selecting difficulties" fell into the following four categories: thirteen comments about the device effecting selection, four comments about the form factor, seven comments about the non-intuitiveness and three comments about the precision of a selection. Reported fatigue to the hand and arm produced involuntary hand movements. An example comment being, "*Expected cursor to point where I was aiming, intuitively. Hand started shaking after prolonged use. Hand moves on trigger press.*" This is a typical comment about the form factor of the device. "*Always pressing the movement button makes it sometimes complicated if the starting position wasn't the centre. Mouse click with thumb quite uncomfortable.*" The precision of the device produced comments like the following: "*Very sensitive and required too much high precision to move cursor to exact spot.*"

The comments concerning the "Like about gyroscopic mouse?" fell into the following three categories: thirteen comments about the form factor, nineteen comments about the intuitiveness, and three comments about the precision of a selection. The positive comments centred on the following: easy to use, intuitiveness, the wireless nature, and good form factors. The following comment was representative: "*Easy to hold, no cord, felt very intuitive and easy to click the button without moving it while the gyro on button was still pressed.*"

The comments concerning the "Dislike about gyroscopic mouse?" fell into the following four categories: thirteen comments about holding the device effecting selection, four comments about the form factor, seven comments about the non-intuitiveness and three comments about the precision of a selection. Once again the participants noted fatigue to hand and arm, with comments like: "*Take a while to get used to it. Hand is hurting after use.*" The participants reported cursor positioning problems, "*Unsteady cursor movement.*" There were a few participants having problems with button configurations, with comments such as: "*Having to remember to hold the "trigger" button to move the cursor, but this stopped being an issue when I got used to it after a while.*"

7.3. Twiddler2

The comments concerning the "Twiddler2 cursor movement and selecting difficulties" fell into the following three categories: twenty three comments about the form factor, one comment about the non-intuitiveness and nine comments about precision of a selection. The comments manly focused on the positions of the buttons for mouse button presses, difficulty positioning the cursor precisely, and the device (for some) was awkward to hold. The following comments were characteristic: "*Hard to handle because of the position of the fingers and thumb at the back. Hard to reach the button on the front. You have to learn how to handle it.*", "*Unable to comfortably hold as it was not flexible to hand size.*"

The comments concerning the "Like about Twiddler2 mouse?" fell into the following three categories: seven comments about the form factor, six comments about the intuitiveness, and nine comments about the precision of a selection. Precision of cursor movement and the fact the device is both a cursor control device and keyboard were listed in the positive comments about the Twiddler2 mouse. With the following example comments: "*Cursor movement is extremely easy, even for tiny adjustments. It is the least tiring of the devices for the thumb.*" and "*Possibility of a whole keyboard.*"

The comments relate to the question "Dislike about Twiddler2 mouse?" fell into the following three categories: twenty five comments about the form factor, two comments about the non-intuitiveness and one comment about precision of a selection. Once again the main concern about the device was the shape, placement of buttons, and the method of mouse button presses combined with cursor movement. The following is an example of comments: "*Cursor button is too small. Moving the cursor and pressing the buttons is uncomfortable.*"

8. Discussion

We wanted to determine if there was a difference in time taken and accuracy to complete the task between different pointing devices. If there was a difference, we wanted to rank the devices in regards to error rate and completion time. Results from the study clearly demonstrate that there is a measurable difference in speed and accuracy when performing selection tasks. There is a significant effect of device on mean total time per task ($p<0.01$). There is a significant device effect on errors ($p<0.01$) across all groups, blocks, and participants.

Although the trackball performed with the lowest error rate and participants found it to be quite comfortable, it was noted that some participants found that the thumb did not offer enough fine grain motor skills. However, leveraging previous skills with a traditional mouse made for a more intuitive device, perhaps being the device of choice for infrequent/novice users of wearable computers.

Participants found the Twiddler2 the least comfortable to use. Although ranking third for mean time and second for error rate, participants noted that cursor movement seemed to be easier than the other devices. The Twiddler2 is the only one of these devices that is a combination text entry and cursor control device interface, thus providing a greater level of functionality.

The wireless nature of gyroscopic mouse was favourably commented on, but this feature required it to be self powered and use a bulky base station. Although the gyroscopic mouse performed with the fastest mean time, it performed with the highest error rate. Fatigue was a problem reported by participants, perhaps providing an insight as to its high error rate. Forcing users to hold their hands and arms in a fixed position and orientation for extended periods of time caused fatigue and produced involuntary hand movements that affected the cursor position and selection. Perhaps the gyroscopic mouse may therefore only be used for small short tasks, or where the user is able to rest between tasks.

9. Conclusion

We have presented a usability study which compares three commercially available pointing devices (a trackball, a gyroscopic mouse and Twiddler2) performing cursor movement and selection tasks for use with wearable computers. The gyroscopic mouse performed with the fastest mean time. The trackball ranked second, with the Twiddler2 having the slowest mean time performing selection tasks. Testing indicated that the trackball significantly performed with a lower error rate. Post hoc testing between gyroscopic mouse and Twiddler2 indicated no significant differences. The Twiddler2 ranked second, with the gyroscopic mouse having the highest error rate. The qualitative results obtained by means of a survey, support the ranking based on time and clearly show a preference for the gyroscopic mouse and trackball across all attributes over the Twiddler2 mouse. Participants ranked the gyroscopic mouse first, the trackball second and the Twiddler2 third. The majority of comments made by the participants indicated that a number of attributes influenced their use of a handheld pointing device. The form factor of the device in terms of accommodating hands of differing sizes and comfort was noted. The placement of mouse buttons was identified as an important consideration.

9.1. Future work

We will continue to evaluate the usability of pointing devices for wearable computers as we see this as an important area for wearable computer development. Future work will aim to extend this study in order to contrast results obtained while users are walking to that obtained while users are stationary. We also aim to evaluate the effectiveness of the pointing devices when performing tasks other than selection, for example, drag and drop and drop down menu selection and operation. We are interested in determining whether certain devices are better suited to certain tasks or whether there is an optimal pointing device in terms of operator performance over a suite of tasks.

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