Evaluating Swiftpoint as a Mobile Device for Direct Manipulation Input

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Abstract

This paper presents a promising new computer pointing device, called Swiftpoint, that is designed primarily for mobile computer (for example, laptop) users in constrained space. Swiftpoint has many advantages over current pointing devices: it is small, ergonomic, has a digital ink mode, and can be used over a flat keyboard. We present the results of a formal evaluation conducted to compare Swiftpoint to two of the most common pointing devices with today's mobile computers: the mouse, and touchpad. Two laws commonly used in evaluating pointing devices, Fitts' Law and the Steering Law, were used to evaluate Swiftpoint. Results showed that Swiftpoint was faster and more accurate than the touchpad. The performance of the mouse was however, superior to both the touchpad and Swiftpoint.

Keywords: Fitts' Law, Steering Law, ISO 9241-9 standard, pointing devices, Swiftpoint, user interface hardware, interaction techniques.

1 Introduction

The mouse is currently the most widely used pointing device. There have been many variations of the mouse since its invention in 1963 by Doug Engelbart, however, most if not all of the current pointing devices are either not as efficient as the mouse or, in the case of a mobile user (for example, laptop user in a train or plane), require space to operate. Even though the mouse has prevailed in almost all studies that compared pointing devices, such as (Card, English & Burr 1978, Douglas & Mithal 1994, MacKenzie 1991, MacKenzie, Kauppinen & Silfverberg 2001), there are many shortcomings with the mouse, such as: (1) Not practical in constrained spaces; (2) Hard to use for writing or drawing; (3) Constant hand movement between mouse and keyboard; (4) Forces the user to position his or her hands beside the keyboard rather than, the more natural position, in front of the users' body; (5) Requires cables to connect to the computer, or charging in case of a wireless mouse; and (6) Requires storage space when travelling.

To overcome such limitations, a new pointing device, called Swiftpoint, was invented by Simtrix, a company based in Christchurch, New Zealand. Swiftpoint is a small wireless pointing device that can be used on top of a keyboard. It is designed mainly for mobile users, and is expected to outperform current pointing devices such as pen, touchpad, and mouse, in terms of efficiency, speed, accuracy, and user preference.

Fitts' Law (Fitts 1954) was used to evaluate the usability of Swiftpoint in target acquisition tasks. Fitts' Law predicts participants' movement time in target acquisition tasks, and states that the movement time (MT) to acquire a target depends on the distance (D) to the target and width (W) of the target (Card et al. 1978, MacKenzie 1991, MacKenzie & Soukoreff 2003, Soukoreff & MacKenzie 2004, Zhai, Kong & Ren 2004), and is described by the following relationship,

$$MT = a + b \times ID \quad (1)$$

The values, a and b are constants, and the term (ID) is index of difficulty of the task.

The Steering Law, developed by Accot and Zhai in 1997 (Accot & Zhai 1997, Accot & Zhai 1999), was also used to evaluate the usability of Swiftpoint in dragging tasks. The Steering law predicts the time users take to steer through a constrained tunnel, such as nested menus, and could be expressed as

$$T_c = a + b \times ID_{(c)} \quad (2)$$

where, T_c represents the average time spent to steer through tunnel c, a and b are constants, while ID_c represents the index of difficulty of the task

2 Swiftpoint

Swiftpoint (Figure 1) is a computer pointing device, designed to help mobile computer users interact easily with graphical user interfaces GUIs in constrained spaces, such as on a train, or plane.

2.1 Key Features

Swiftpoint has similar properties to those of the mouse, such as pointing, clicking, and scrolling. However, the shape of Swiftpoint is completely different from that of the mouse. Unlike the mouse, Swiftpoint is very small and is not held in the palm of the hand; it rather requires the thumb to hold it and move it around, where the index and middle fingers are used to press on the primary and secondary mouse buttons respectively.

The small size of Swiftpoint allows it to be held in a similar fashion to the pen. Thus, combining the advantages of both the stylus and mouse, and enabling the user to use his or her thumb to move Swiftpoint around while typing at the same time. Swiftpoint can be used for drawing and writing, moreover it can be easily moved on any flat surface, such as a flat keyboard, or the custom designed Swiftpoint keyboard with an extended spacebar (Figure 2).

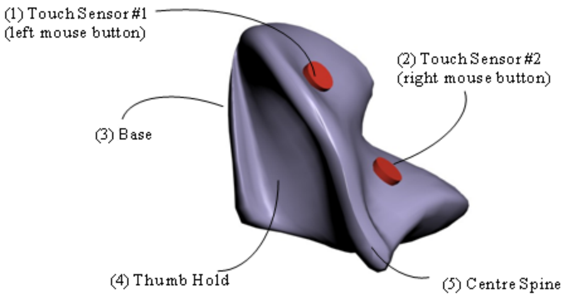


Figure 1: An aerial view of Swiftpoint.

A flat keyboard, similar to that of the laptop, would be best suited for Swiftpoint, while an extended spacebar, though not necessary, would give the user more space and freedom to move Swiftpoint using his or her thumb. Swiftpoint was designed to cover three to four keys, thus, preventing any inadvertent activation of keys, while using Swiftpoint on the keyboard.

2.2 Product Description

There exist a number of models for Swiftpoint each with different features, such as scroll wheel or pen-like model. However, the standard Swiftpoint model (Figure 1) that was used in the experimental evaluations had two buttons, which resemble the primary and secondary buttons of the mouse; a sensor underneath that maps the location of Swiftpoint, and a thumb hold.

2.3 Expected Advantages Over Existing Pointing Devices

Swiftpoint is expected to:

- Eliminate the transition time (i.e. the time the user takes to move his or her hands between the keyboard and pointing device).
- Provide higher precision, with Swiftpoint the user holds it in a similar fashion to a pen, hence easier and more accurate to use for fine tasks, such as drawing or writing.
- Economical, does not require batteries or charging, and it is small (1/10 the size of the mouse) thus, requires no space.

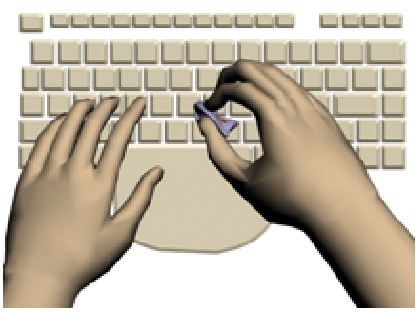


Figure 2: Swiftpoint used on top of a flat keyboard keys.

2.4 Implementation

Swiftpoint currently uses the same sensor as the Wacom Pen, hence a Wacom tablet is required to track its movement. If Swiftpoint was used with a laptop computer, a tablet would be embedded underneath the keyboard (i.e., inside the laptop) to accurately capture the movement of Swiftpoint. On the other hand, if Swiftpoint was used with a desktop computer, the user would need to use a flat keyboard with an embedded tablet, or a separate tablet next to the keyboard.

2.5 Ergonomics

Swiftpoint has the advantage of forcing the user to keep his or her hands on the keyboard, while typing or browsing. Thus eliminating hand movement between keyboard and mouse, and therefore complying with the U.S. Department of Labor occupational safety recommendations, which states that pointing device should be kept in front of the user rather than at the side of the keyboard (U.S. Department of Labour, Occupational Health and Safety Administration 2000).

3 Fitts' Law Experiment

The primary objective of this experiment is to determine if Swiftpoint is a suitable device for pointing tasks. To achieve such an objective, I applied both Fitts' Law, and the recommendations of ISO 9241-9 standard (Douglas, Kirkpatrick & MacKenzie 1999, ISO 2000) to test the speed and accuracy of Swiftpoint against common pointing devices, in a target acquisition experiment.

Since Swiftpoint was designed primarily for mobile computers, it is essential to compare it against devices of similar nature, such as the touchpad, isometric joystick, mouse, trackball, and stylus. However, due to a 40 minute time restriction before participants experience fatigue and boredom, only three pointing devices were selected for the experiment.

Device selection was based on ubiquity with mobile computers, and performance in previous research experiments. Since the mouse is the most popular and efficient pointing device (Card et al. 1978, Douglas & Mithal 1994, MacKenzie et al. 2001, Zhai 2004), it was selected as the control for the evaluation. Even though the touchpad was not the most efficient device (MacKenzie et al. 2001), it was also selected for the experiment because of its ubiquity with laptop computers. Some laptop computers come with an isometric joystick, however, previous studies have consistently shown that the isometric joystick had the lowest throughput among devices (Card et al. 1978, Douglas & Mithal 1994, MacKenzie et al. 2001). Therefore, the isometric joystick was excluded from the experiment. The trackball, and stylus were also excluded from the experiment due to time limits, and their high error rate (MacKenzie 1991, MacKenzie, Sellen & Buxton 1991).

3.1 Experimental Method

3.1.1 Participants

Fifteen computer science postgraduate students (eleven males and four females), with an average age of 23 years, participated in a one-to-one experiment. All participants were right-handed, and used the mouse extensively on a daily basis. Participants were rewarded with a $20 Warehouse voucher after finishing the two experiments.

(a) Microsoft IntelliMouse.

(b) Wacom Smart Cat touchpad.

(c) Cintiq Partner tablet.

Figure 3: Devices used for comparison against Swiftpoint.

3.1.2 Apparatus

The experiment was conducted on a Windows XP machine, with an AMD Athlon 64 3200+ CPU, 1GB of RAM, and a GeForce 6600 GT graphics card. The monitor was a 19 inch Compaq 9500, with a resolution of 1600×1200 pixels (111 dpi) with a viewable screen width and height of 36cm and 27cm, at a refresh rate of 75 Hz. The three pointing devices[1] used in the experiment were:

- A mouse: Microsoft IntelliMouse (Figure 3(a)).
- A touchpad: Cirque Smart Cat (Figure 3(b)).
- Swiftpoint (Figure 1), with a Wacom CintiqPartner tablet (Figure 3(c)).

Swiftpoint was used with a Wacom CintiqPartner tablet, since a laptop with an embedded tablet was not available at the time of the experiment. The tablet's dimensions were 660×243×13.9 mm, while the active area was 204.8×153.6 mm. The Wacom tablet uses the analog W8001 integrated circuit, and Penabled technolgy, which is an electromagnetic resonance technology invented by Wacom to send and receive the position of the pen on the tablet (Wacom 2001).

To ensure that all participants conducted the experiment in similar conditions, the three pointing devices were configured to use the default control-display gain values set by the Microsoft Windows XP operating system.

3.1.3 Procedure

The interface for this experiment (Figure 4) was modelled after the ISO 9241-9 recommendations. The experiment consisted of a total of six blocks of tasks for every device, where a block consists of clicking on a series of 26 targets. Every block has a different index of difficulty (3.17 – 6.98), as determined by two circle diameters (300, and 500 pixels) and four target widths (4, 8, 19, and 34 pixels). Participants would spend around four minutes with each device, and take a total of 20 minutes to complete the whole experiment (including practice tasks).

[1]Only the primary and secondary buttons were activated in each device, however, participants were only required to use the primary button for pointing and dragging tasks.

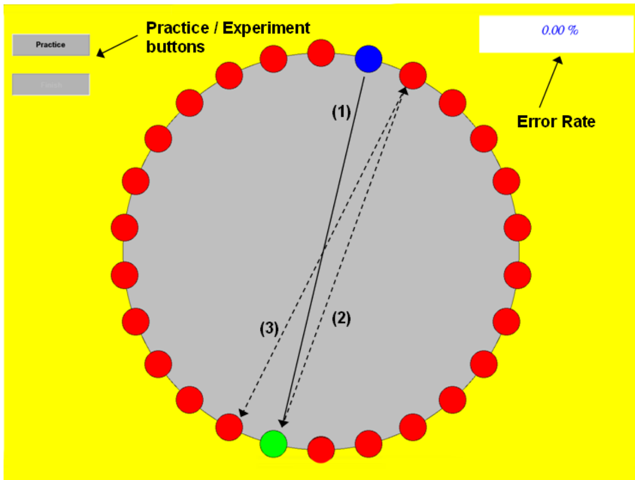


Figure 4: The interface for the first experiment.

The experimental interface (Figure 4) consisted of a circular arrangement of 26 red targets, two buttons on the top left corner (Practice or Experiment[2], and Finish), and an error rate counter on the top right corner. A task would require the participant to click on the illuminated (green) target. Once a target is clicked, the target is deactivated (turns red) and the opposite target is illuminated, thus steering the participant through each block of tasks. Participants' speed, error rate, index of difficulty, distance, and target width, were logged for further analysis.

At the beginning of the experimental session, a brief overview was given to each participant before he or she signed a consent form, and a non-disclosure agreement, followed by a demonstration of the evaluation tasks and an explanation of each device and how to use it. Participants were given the following instructions:

- Adjust the position of the screen, chair, and pointing device, to make yourself comfortable.
- Carry out the tasks as fast and as accurately as possible.
- Take a break[3] only after finishing a block of tasks (each block should be done in a continuous and constant manner).
- Only use the primary button in Swiftpoint, touchpad, and mouse, to click on a target.
- Click only once on the target as a double click or any click outside the illuminated target is counted as an error.
- Redo the task if an error is committed
- Stay as close as possible to a 4% error rate, and be slower and more accurate if the error rate exceeds 4%, and vice versa.

Pointing devices were exposed to each participant in random order. After the demonstration, a message was displayed informing the participants to plug-in the appropriate pointing device, and click on the Practice button to start the practice tasks. Another message was displayed after participants finished the practice tasks, to inform them that they had finished practising and should start the experimental tasks by clicking on the Experiment button.

[2]The Practice or Experiment button were activated depending on the nature of the task at hand.

[3]A message was displayed after every block of tasks instructing the participant to take a short break if needed.

3.1.4 Design

The experiment was a 3×3×2 within-subjects design with repeated measures ANOVA. The factors were as follows:

- Input Device: mouse, touchpad, and Swiftpoint.
- Width of target W: 4, 8, 19, and 34 pixels.
- Distance to target D: 300 and 500 pixels.

These factor levels produced six different indices of difficulty (3.17, 3.91, 4.75, 5.25, 6.25, 6.98), using Fitts' formula for index of difficulty (Equation 3). Dependent variables were movement time MT, error rate, and throughput TP, while independent variables were W and D, determined by the width and amplitude[4] of targets. For every task, movement time was calculated by measuring the elapsed time between clicking on two opposite targets.

$$ID = \log_2\left(\frac{D}{W} + 1\right) \tag{3}$$

Fifteen participants were recruited for the experiment, however data for one of the participants was not included in experimental analysis due to a system crash, which caused an error in recording the participant's data. With 14 participants, 26 tasks per block, three devices, and six different indices of difficulties, the total number of tasks in this experiment was 14×26×3×3×2 = 6552 tasks.

Instances where a participant spent an unexpectedly long amount of time (greater than 3 standard deviations from the mean) to select a target were considered as outliers, and consequently excluded from further analysis. Time to acquire the first target was also excluded form analysis, since participants spent time to click on the Experiment button before starting the experimental tasks.

3.1.5 Experimental Results

Analysis of variance ANOVA produced a grand mean of 1.70s and a standard deviation of 0.68. Of the data collected 6.2% of the touchpad's data, and 0.49% of Swiftpoint's data were outliers and hence excluded from further analysis. There were no outliers for the mouse.

The results show that participants were fastest, and more accurate using the mouse (Table 1) with a mean movement time and standard deviation of (1.24s, 0.37), followed by Swiftpoint (1.61s, 0.51), and touchpad (2.23s, 0.69) giving a significant main effect for the factor pointing device, with (F (2, 26) = 74.12, $\rho < 0.001$).

There was a significant difference between the different levels of ID with (F (5, 65) = 317.74, $\rho < 0.001$). Significant interaction was also observed between pointing devices and indices of difficulty with (F (10, 130) = 12.123, $\rho < 0.001$).

Pointing Device	Mean Time	SD	SE
Mouse	1.24	0.37	0.04
Touchpad	2.23	0.69	0.07
Swiftpoint	1.61	0.51	0.05

Table 1: Mean acquisition time, standard deviation, and standard error for the three pointing devices tested during the first experiment.

Table 2 shows the line of best fit equations, correlation (r^2), and throughput TP for the three devices

[4]Distance to target is sometimes referred to as amplitude

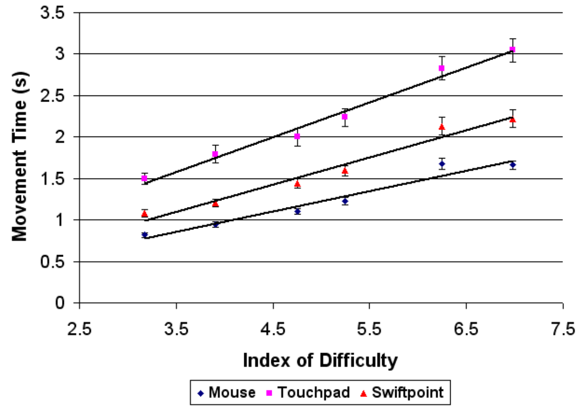


Figure 5: Fitts' Law results.

Pointing Device	Movement Time	(R^2)	TP
Mouse	MT = 0.25×ID - 0.01	0.95	4.05
Touchpad	MT = 0.42×ID + 0.11	0.98	2.38
Swiftpoint	MT = 0.33×ID - 0.04	0.97	3.05

Table 2: Movement time equation, correlation, and throughput for the three pointing devices tested in the first experiment.

tested. All devices had an accurate correlation thus indicating a strong relationship between time and index of difficulty for the device.

The examination of the error rates for the three pointing devices showed a linear relationship between the index of difficulty and error rate (Figure 6), meaning that as the index of difficulty increases the error rate increases. Figure 6 also shows that Swiftpoint had the lowest error rate for targets with a low index of difficulty, followed closely by the mouse, and touchpad. However, as the index of difficulty increases, Swiftpoints' error rate increases to exceed that of the mouse, and the touchpad.

3.1.6 Discussion

In an effort to make participants adjust their speed vs. accuracy movement (i.e., be slow and accurate vs. fast and less accurate), an error rate indicator was displayed on the top right–hand corner of the interface. This turned red once the participant ex-

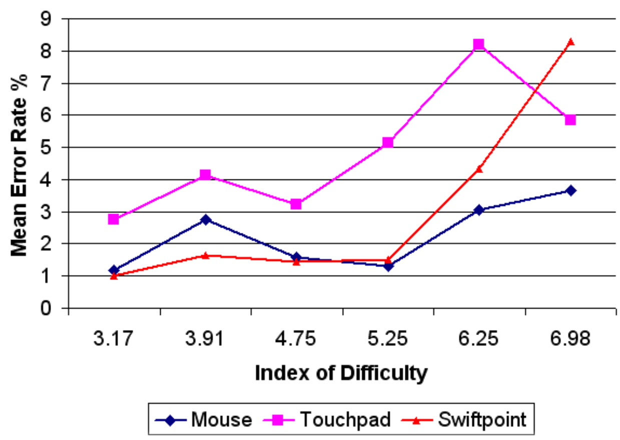


Figure 6: Mean Error Rate for the three pointing devices.

ceeded the 4% error rate recommended by ISO 9241-9 (Soukoreff & MacKenzie 2004), allowing participants to adjust their movement behaviour accordingly.

Results of the experimental evaluation showed that both the mouse and Swiftpoint were faster and more accurate than the touchpad. The mouse did also outperform Swiftpoint in terms of user preference and speed, but this may be due to two factors: (a) participants' daily use of the mouse as their primary pointing device; and (b) the use of a tablet with Swiftpoint caused clutching (i.e., participants had to lift Swiftpoint and reposition it, once Swiftpoint reaches the edges of the tablet), which inevitably slowed down participants.

Participants were more accurate with Swiftpoint than with the mouse for targets with a low index of difficulty, with an average error rate lower than the 4% recommended by ISO 9241-9 standard. However, as the index of difficulty increased, Swiftpoint's error rate increased beyond 4% to exceed that of the mouse and touchpad. The high error rate for both the touchpad and Swiftpoint, at high indices of difficulty, is due to participant's focus on speed rather than both speed and accuracy (i.e., completing the task as fast as possible vs. as fast and as accurately as possible) which ultimately caused more errors and hence, more time in completing the task. This trend was not observed with the mouse, since participants used it regularly on a daily basis.

The high correlation ($r^2 > 0.9$) proved that Fitts' Law does apply to Swiftpoint. The lower movement time and error rate, and the higher throughput of Swiftpoint than those of the touchpad, proves that Swiftpoint is significantly better than one of the most common devices with mobile computers, the touchpad. The mouse, however did outperform Swiftpoint, thus proving its superiority over current computer pointing devices.

4 Steering Law Experiment

The Steering Law (Accot & Zhai 1997, Accot & Zhai 1999, Accot & Zhai 2001) models actions such as navigation through nested menus, dragging, drawing, and writing, most of which are performed regularly by computer users while interacting with graphical user interfaces. The primary objective of this experiment is to examine how participants would perform such interaction tasks using Swiftpoint, by applying the linear tunnel version of the Steering Law (Equation 4) to test the speed and accuracy of Swiftpoint against two pointing devices, Microsoft IntelliMouse and a Cirque Smart Cat touchpad. Reasons for selecting these pointing devices were discussed in Section 3.

4.1 Experimental Method

The same participants conducted both experiments in the same session. Information about participants, and the experimental apparatus are identical to that discussed in sections 3.1.1 and 3.1.2 respectively.

4.1.1 Procedure

The experiment consisted of a total of seven blocks of tasks for every device, where a block consists of using the pointing device to drag the cursor (i.e., highlight) through a series of eight pieces of text located at random positions. Every task has a constant tunnel width of 18 pixels, but different index of difficulty (20 – 60), as determined by the tunnel height and seven tunnel lengths (360–1080 pixels). Participants would

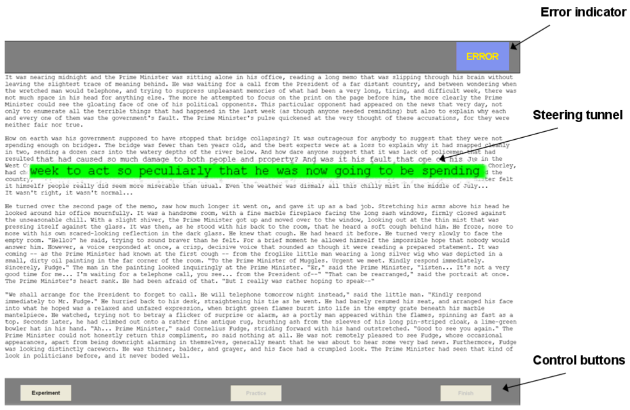


Figure 7: The interface for the second experiment, where participants were required to drag the cursor through the highlighted tunnel. The tunnel is represented by a green rectangle that covers a number of words, depending on the tunnel length.

spend around five minutes with each device and a total of 20 minutes to complete the whole experiment (including practice tasks).

The experimental interface (Figure 7) consisted of a one page text document, three control buttons (Practice, Experiment, and Finish)[5] at the bottom of the interface, and an error indicator on the top right-hand corner. A task would require the participant to click and drag the cursor (i.e., highlight) through the illuminated (green) tunnel. Once a tunnel is highlighted and the participant releases the mouse button, the tunnel is deactivated, and another tunnel is illuminated. Participants' speed, error rate, out of path movement, index of difficulty, distance, and tunnel width, were logged for further analysis.

Participants were given identical instructions to those in section 3.1.3, however due to the different nature of this experiment, they were given the following instructions:

- Press the pointing device's primary button, steer through the tunnel, and release the button.
- A double click, a click or a release at the wrong position inside the tunnel boundaries, or a release outside the horizontal tunnel boundaries, counts as an error.
- If an error is committed, a gentle sound is produced, and an error indicator on the top right corner flashes in a red colour.
- Redo the task if an error is committed.
- Stay within the tunnel boundaries, if possible. However, if you inadvertently steered outside the tunnel boundaries but completed the task successfully, a warning indicator will flash in a yellow colour, at the top right corner of the interface.

Pointing devices were exposed to each participant in random order. After finishing both experiments, participants were asked to complete a NASA-TLX questionnaire to rate their experience with Swiftpoint. Another NASA-TLX questionnaire required participants to rate their experience with the three pointing devices. Results of the two questionnaires are shown in Section 5.

[5]The Practice button started a series of practice tasks, while the Experiment button started experimental tasks, and the Finish button ended the experiment.

4.1.2 Design

The experiment was a 3×7 within-subjects design with repeated measures ANOVA. The factors were as follows:

- Input Device: mouse, touchpad, and Swiftpoint.
- Distance to target D: 360, 480, 600, 720, 840, 960, and 1080 pixels.

With tunnel width fixed at 18 pixels, these factors produced seven different indices of difficulties (20, 26.64, 33.36, 40, 46.64, 53.36, and 60) by using the reduced Steering Law formula for index of difficulty (Equation 4). Dependent variables were movement time MT, error rate, and throughput TP. The independent variable was ID, determined by the width and amplitude of targets. For every task, time was calculated by measuring the dragging time (i.e., the time the participant takes to click-drag-release) through the tunnel.

$$ID_c = \frac{D}{W} \tag{4}$$

The experiment had eight tasks per block, three devices, and seven different indices of difficulties, the total number of tasks in this experiment was 14×8×3×7 = 2,352 tasks.

Instances where a participant spent an unexpectedly long amount of time (greater than 3 standard deviations of the mean) to select a target were considered as outliers, and consequently excluded from further analysis.

4.2 Experimental Results

Analysis of variance (ANOVA) produced a grand mean of 3.00s and a standard deviation of 1.44. Of the data collected (i.e., steering times) 7.59% of the touchpad's data, 1.38% of the Swiftpoint data, and 0.48% of the mouse data were outliers and hence excluded from further analysis.

The results show that participants were fastest using the mouse (Table 3) with mean movement time and standard deviation of (2.53s, 1.39), followed by Swiftpoint (2.81s, 1.25), and touchpad (3.65s, 1.44) giving a significant main effect for the factor of pointing device, with (F (2, 26) = 15.64, $\rho < 0.001$).

There was a significant difference between the different levels of ID (F (6, 78) = 12.58, $\rho < 0.001$). However, interaction between pointing devices and indices of difficulty was not significant (F (12, 156) = 1.11, $\rho = 0.35$). Figure 8 shows the mean steering time against index of difficulty (ID) for the three pointing devices, where the performance of both Swiftpoint and the mouse converges as the index of difficulty increases.

Table 4 shows the line of best fit equations, correlation (r^2), and throughput TP for the three devices. All devices had an accurate correlation thus indicating a strong relationship between time and index of difficulty for the device.

The examination of the error rates for the three pointing devices showed that the mouse had the least error rate followed by Swiftpoint and the touchpad.

4.2.1 Discussion

This experiment showed that for all devices, the steering time increases as the index of difficulty increases. As expected, both the mouse and Swiftpoint were faster than the touchpad, with the mouse having the least mean steering time.

Pointing Device	Mean Time	SD	SE
Mouse	2.53	1.39	0.14
Touchpad	3.65	1.44	0.15
Swiftpoint	2.81	1.25	0.13

Table 3: Mean steering time, standard deviation, and standard error for the three pointing devices tested during the second experiment.

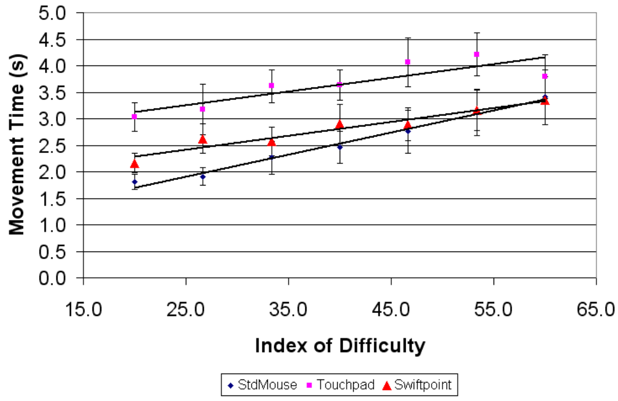


Figure 8: Steering Law mean movement time for the three pointing devices.

The touchpad had the highest correlation and least intercept among the pointing devices, followed by the mouse and Swiftpoint. However, the intercepts for the three devices were excessively high, with the touchpad having the lowest intercept followed by the mouse and Swiftpoint. This higher than usual intercept could be explained by the high frequency of out of path movement (OPM) committed by participants with each device.

Participants were observed steering outside the tunnel boundaries (i.e., out of path movement) to complete the task. This in some cases caused participants to finish a task faster than usual, or in other cases take longer to finish a task, as participants would try to get back in the tunnel if OPM occurred. OPM was observed in 73.86% of the tasks with the mouse, 76.02% with the touchpad, and 75.29% with Swiftpoint. Kulikov et. al experienced similiar results in their experiment, where 77% of the tasks were committed with OPM (Kulikov, MacKenzie & Stuerzlinger 2005). Their solution was to include these data into analysis rather than execluding them as errors. Hence, the author followed Kulikov et al.'s approach in dealing with out of path movement.

Swiftpoint's performance in general was better than the touchpad, with faster steering times, higher throughput, and lower error rates. Even though the mouse was faster and had a higher correlation than Swiftpoint, its throughput was slightly lower than that of the mouse.

Pointing Device	Movement Time	(R^2)	TP
Mouse	MT = 0.21×ID + 1.75	0.93	4.73
Touchpad	MT = 0.33×ID + 0.88	0.99	3.02
Swiftpoint	MT = 0.21×ID + 2.61	0.74	4.84

Table 4: Movement time, correlation, and throughput for the three pointing devices tested in the second experiment.

5 Questionnaire Analysis

After finishing the experiments participants were given a a pointing devices questionnaire (Figure 9) to compare and rate Swiftpoint's performance against the mouse and touchpad, and a Swiftpoint questionnaire (Table 5) to evaluate their experience with Swiftpoint.

Participant's preference for the pointing device of choice differed significantly (Chi-square test df = 2, $\chi^2 = 12.4$, $\rho < 0.01$), with 73% of participants choosing the mouse as their device of choice, and 26% choosing Swiftpoint. None of the participants indicated that they would use the touchpad. Results of the Pointing Devices questionnaire (Figure 9) supported the participants' preference, with the mouse having the highest mean, followed by Swiftpoint and touchpad. Friedman test showed significant difference between the Likert-scale ratings for the three pointing devices with $\rho < 0.001$.

Some of the participant's comments on the design, size, efficiency, and prolonged use of Swiftpoint were as follows:

- Design: Swiftpoint is more ergonomic than the mouse, quiet (i.e., no clicking sound), but it would be better if Swiftpoint was bigger, made out of plastic and had flat buttons. The protruding buttons are painful if Swiftpoint was used for a long period of time.
- Size: Swiftpoint is small, compact, and easy to carry.
- Efficiency: Swiftpoint is better, and faster in clicking and dragging than the touchpad. However, it would be hard to play games using Swiftpoint.
- Prolonged use: Swiftpoint would be better than the mouse, if used for a long period of time.

In selecting their preferred pointing device, some participants selected the mouse, and commented that their choice was based on their familiarity and experience of using the mouse. They also indicated that Swiftpoint would be easier to use than the mouse if they used it for a long period of time.

6 Discussion and Conclusions

In this paper I introduced the evaluation results of a new pointing device, Swiftpoint, which combines the advantages of both the mouse and the stylus. A brief overview of Fitts' Law and Steering Law was given before giving an overview of Swiftpoint.

The primary aim of this study was to evaluate Swiftpoint and determine if it is a suitable pointing device for pointing and dragging tasks. Two experiments were conducted to evaluate Swiftpoint. In the Fitts' law experiment, participant's speed and accuracy were tested in target acquisition tasks. Participants completed the tasks significantly faster with less error rate with Swiftpoint than with the touchpad. The mouse, on the other hand, had the highest throughput and least acquisition time than both Swiftpoint and touchpad. However, the mouse did have a higher error rate than Swiftpoint for targets with a low index of difficulty.

The Steering law experiment exhibited similar results, with the mouse having the least steering time and error rate, followed by Swiftpoint and the touchpad. However, three trends were observed:

1. The steering time for the mouse and Swiftpoint converges as the index of difficulty increases.

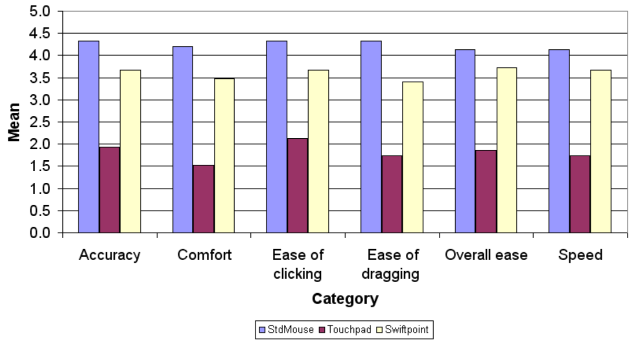


Figure 9: Mean results of the NASA-TLX ratings for the three pointing devices.

Category	Mean	SD
Force	2.80	0.68
Smoothness	3.73	1.03
Accuracy	3.27	1.28
Mental effort	3.20	0.86
Physical effort	2.60	0.98
Frustration level	2.93	0.96
Overall performance	3.80	0.94
Operation speed	2.80	1.01
Finger fatigue	3.00	1.13
Arm fatigue	2.73	0.96
Wrist fatigue	3.27	1.16
Shoulder fatigue	3.53	1.27
Neck fatigue	3.53	1.12
General comfort	3.20	0.86
Comfort (clicking)	3.20	1.15
Comfort (dragging)	3.27	0.96
Comfort (moving pointer)	3.45	1.19
Comfort (over long period of time)	2.93	0.96

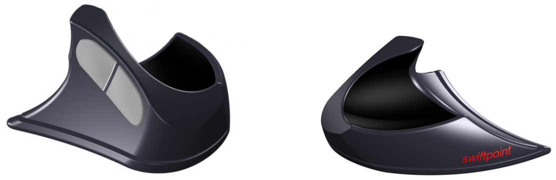
Table 5: Results of the Swiftpoint questionnaire.

2. Swiftpoint's error rate decreases as the index of difficulty increases. These two trends indicate that for higher indices of difficulty, participants would perform tasks faster with less error rate with Swiftpoint than the mouse
3. Swiftpoint had the least correlation, the highest throughput and intercept. This was due to the large amount of out of path movement (*OPM*) committed by participants, hence *OPM* was not considered as an error even though participants stepped outside the boundaries of the tunnel.

Swiftpoint's design was new to participants, the design is different from any available pointing device in the market. This was reflected by the progress of one participant's comments as he was conducting the experiment *"weird, not bad, as good as the mouse"*.

The ubiquity of the mouse, with computers, had an effect on participants choice for their preferred pointing device as several participants indicated that their choice was based on their familiarity with the mouse.

Participants also expressed their preference for a bigger device with flat buttons. However, Swiftpoint's design was aimed at users in constrained space, where the use of a mouse would be inconvenient and the touchpad would be prone to error, as one participant commented *"the touchpad is terrible to use"*. Material and button design, on the other hand, were changed due to participants comments, the new design (Figure 10) is made out of plastic, and has flat buttons, such that users do not experience any discomfort while clicking on the button.



(a) A right view of the new Swiftpoint model.

(b) A left view of the new Swiftpoint model.

Figure 10: The new Swiftpoint model.

Results have shown that Swiftpoint is a promising new pointing device that outperformed the mouse in some aspects, and suitable for pointing and dragging tasks, to such an extent that it outperformed the touchpad. It is expected that, after the new modifications to the design of Swiftpoint, future studies would find participants perform tasks faster and more accurately, and would prefer to use Swiftpoint as their primary pointing device with mobile computers.

7 Future Work

Swiftpoint is being marketed in Japan. If successful, Swiftpoint is expected to be popular with mobile computer users. The experimental evaluation of Swiftpoint was conducted with the standard model (Figure 1), which was criticised by some participants. It would be valuable to evaluate the new Swiftpoint model (Figure 10).

Currently Swiftpoint requires a tablet to capture its movement, future models are expected to use laser technology to more accurately track its movement.

Future experiments could test Swiftpoint's digital ink mode against the Stylus, in writing, dragging, and selecting targets, on a tablet PC. A deployment study would prove fruitful in gathering users' reaction after using Swiftpoint for a long period of time, typically two or more weeks.

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