A Comparative Analysis Between the Mouse, Trackpad and the Leap Motion

Ashley General
McMaster University
Hamilton, Ontario
generaaa@mcmaster.ca

Brandon Da Silva
McMaster University
Hamilton, Ontario
dasilvbc@mcmaster.ca

Daniel Esteves
McMaster University
Hamilton, Ontario
fusillded@mcmaster.ca

Matthew Halleran
McMaster University
Hamilton, Ontario
hallermj@mcmaster.ca

Michael Liut
McMaster University
Hamilton, Ontario
liutm@mcmaster.ca

Author Keywords
Mouse, Trackpad, Leap Motion, Literature Review, Input Device Comparison.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g. HCI): User Interfaces Input devices and strategies (e.g., mouse, touchscreen)

INTRODUCTION

When it comes to interacting with a cursor on a computer interface there are various input devices that can accomplish the task at hand. However, not all devices offer the same level of speed, precision or comfort. This study's primary goal is to identify which input device is best for human performance in terms of speed and precision. Specifically, this in-depth examination will compare the mouse, the trackpad, and the Leap Motion, looking at the average completion time for target acquisition as well as the average number of errors made when doing this task.

This is an important topic of research considering that pointing devices are one of the most common input devices used by the general public. The mouse has been the most common device for a great deal of time. With the popularity of portable computers, the trackpad is trending with newer generations and becoming the norm. The Leap Motion is the least commonly used device among the three, and therefore it will be compared against these other two successful devices to gauge its potential in accurate and fast target acquisition. Testing will be done to determine the mean speed it takes users to select a target using all three devices, as well as the average number of errors that are made during each test.

After gathering the information from the various research studies outlined in the literary review, we expect the mouse and trackpad to offer better performance when completing target acquisition tasks in comparison to the Leap Motion. The Leap Motion is predicted to perform poorly for various reasons such as fatigue [6] and the average 0.29% error that arises in participants using the technology [2]. However when comparing between the trackpad and the mouse, it is predicted that the mouse will perform better in our study, due to the long-standing popularity of the mouse as an input device for selecting targets.

LITERATURE REVIEW

Multiple researchers have studied input devices and their performance based on accuracy and comfort. Eight articles have been chosen to ensure uniqueness in our procedure, but more so to ensure accuracy of our results without making the same mistakes our predecessors have.

Apostolellis et al. in [2] speaks to the Leap Motions potential to revolutionize the way humans can interact with computers. By selecting 23 conventional computer users, they were able to investigate the effects of spatial, positional, rotational, intensity error and completion time on the mouse in comparison to the Leap Motion. This study identified that the use of the Leap introduces an additional 0.29% error, while the completion time model determined an estimated mean time increase of 1.08s to complete any task and position/rotation tasks increase by 1.13s in comparison to the mouse. Thus concluding that the Leap Motion can be problematic in manipulating 3D objects when performing realistic tasks in optimal environment settings.

Similarly, Brown et al. [4] explored the benefits and compromises of in-air pointing as an interaction modality. By completing two unique user studies, they first defined the best operational methods for un-instrumented pointing and then discussing the in-air interaction with a mouse. Alongside selecting 16 different participants for each study and conducting standardized Fitts law studies, they determined that the Leap Motion's throughput to be approximately 3.1bps while the performance level of a mouse is approximately 4bps, not to mention the physical discomfort of using an in-air system. Brown et al. were unable to recommend an un-instrumented in-air hand tracking for user interfaces, which can directly compete with a mouse or touch screen device.

Furthermore, Codd-Downey and Stuerzlinger [6] conducted a study that demonstrated gestures that can be mapped to different controls of a Leap Motion controller in order to maneuver in a FPS video game. By using different gestures above the controller, the user is able to navigate forward, reverse, side-to-side and come to a stop (combination of forward and reverse). This was previously handled by either mouse and keyboard or a joystick input device. With alterations of certain gestures, more features can be mapped but may have limitations. This can be taken into account when judging the pointer performance with the Leap Motion in comparison to the mouse and trackpad.

Johnson et al. [7] analyzed if muscle fatigue could be measured in the fingers during extended periods of mouse use. A test was performed on a experienced mouse users, having them play solitaire for six hours each on two separate days. The mouse had two modes of operation, a standard mode and a drag-lock mode. After the six hour simulation the users were tested positive for muscle fatigue on their fingers which lasted up to 40 minutes after the experiment ended. They manually counted as well the errors and the participants were also tested on side force, button force, time pointing, time dragging, time clicking and button accuracy. Over the six hours there was only a difference in the muscle fatigued noticed in the index finger. With this, there is no change in any of the stats measuring performance.

This brings us to Cakir et al. [5], who did a study on users performance and comfort using the trackpad, a touch input device. The experiment was done by participants with experience using Macintosh computers, and consisted of tests and tasks resembling common office tasks. Both performance and postural comfort were measured, using eight Fitts' tests and EMG postural analysis, respectively. Their results indicate that using a trackpad as an input device causes no muscle fatigue or postural discomfort. As well, users preferred the trackpad over the mouse if they could achieve the same level of performance with it by direct comparison.

Accot and Zhai [1] did a study on trajectory-based tasks with multiple pointing devices to test the Steering law, which is a law similar to Fitts' law. Instead of measuring based on target acquisition the Steering law can be used to measure device efficiency from trajectory-based tasks. A steering task is described as moving the cursor through narrow tunnels, and the Steering law predicts completion time based on the tunnel's parameters. Five devices were used and with these devices users were asked to complete two trajectory tasks; one linear and one circular. Using the steering law for analysis their results ranked the devices in the following order: 1. tablet and mouse 2. trackpoint 3. touch ball and trackpoint.

Similar to how Accot and Zhai [1], used Fitts' law to derive Steering law, MacKenzie et al. used Fitts Law to help predict dragging task times. MacKenzie et al. [9] did a study comparing pointing tasks and dragging tasks, showing that dragging is simply a derivative of pointing. The study compared a mouse, trackball and a stylus with a tablet. The study had participants perform both a target acquisition task and a task involving dragging objects to a target. For pointing, the tablet performed the best (665ms), followed by the mouse (674ms) and then the trackball (1101ms). For dragging the the tablet again performed best (802ms), followed by the mouse and then the trackball, and therefore Fitts' Law can be applied to dragging tasks.

Lastly, Benko and Feiner [3], did a study on a new mouse system (M_3 which is the name of the product they were proposing), an attempt to verify improvements on target acquisition performance in multi-monitor systems. Participants were chosen based on their unique unfamiliarity with the techniques being used in the study. The setup consisted of four corresponding screens all with an inactive spreadsheet image, and noise to simulate a working environment. The time to traverse screens and acquire target were recorded and user errors (target misses) were also counted. Therefore, Benko and Feiner deduced that all the time saved was a result of traversing across multiple screen, showing a 17% increase in time to perform the task compared to traversing screens without the mouse system.

METHODOLOGY

Participants

Ten right-handed participants (aged 19 to 22) will be recruited to participate in the study. Half the participants will be male, and half will be female. The participants will be computer literate students at McMaster University, from a wide range of programs. Participants will not be provided compensation for participating in the study, which will take approximately 30 minutes. Prior to the experiment, participants will be asked to wear comfortable clothing, to not wear wrist or hand jewelry, and to not have consumed any coffee, alcohol, or drugs on the day of the experiment.

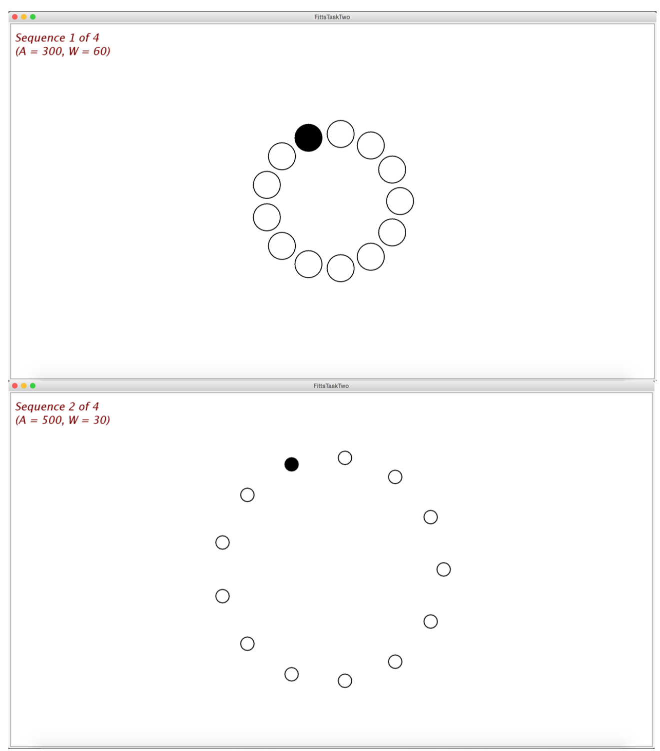

Figure 1. FittsTasktwo selection application used

Apparatus

The experiment took place on a 13” MacBook Pro (Apple laptop) with a 2.4 GHz Intel Core i5 CPU containing 4GB of RAM and an Intel Iris 1536MB GPU. The first device used in the experiment was a Leap Motion, a computer hardware sensor device that supports hand and finger motion as input. This device was compared against a generic wired mouse (Microsoft brand), and also against Apples multi-touch Magic Trackpad.

The software used in the experiment was MacKenzie's FittsTaskTwo software, available on his website and shown in Figure 1. This implements the standard ISO 9241-9 2D reciprocal selection task which is implemented in the FittsTaskTwo software. Each test condition runs through four randomly ordered trials of Fitts selection tasks, each with a different ID (index of difficulty). The values of the amplitude and width of the four trials varied as follows (respectively): 300 and 60, 300 and 30, 500 and 60, 500 and 30. The targets were set to black and the background was white.

Procedure

A one page written sheet of instructions will be given to the participants prior to their participation in the experiment. These instructions will outline the experiment, so that each participant receives the same information prior to the experiment. The participant will be asked to read the instructions before signing a consent form.

After the participant has signed a consent form they will be asked to sit down in the experiment room in front of the computer display. The experiment room will be quiet with no distractions. Before beginning, the participant will complete a practice trial for each of the three devices being used in the experiment. The practice trials will give the participant a chance to get familiar with the input devices.

At this point in the procedure, the experiment trials will begin. Depending on what trial the participant is currently doing, the participant will be asked to click on targets using one of the input devices focusing on either speed or accuracy. Prior to each trial an information screen will be shown on the display informing the participant of what device they will use and it will tell them whether they will be focusing on speed or accuracy during that trial. There will be a start button on this information screen and once clicked the trial and timer will start. When the trial starts the participant is shown a blank white screen and small circular black targets will show up randomly on the screen. Participants will click these targets using the specified input device and focus for that trial.

After the participant completes all of the experiment trials they will be asked to fill in a questionnaire. The questionnaire will ask questions about the participant's demographics and the participant's previous experience using each of the devices. The questionnaire will also include questions asking the participant about their preference and opinions on each of the input devices used in the experiment.

Design

As similar to MacKenzie and Isokoski's study of throughput and the speed-accuracy tradeoff discussed in his 2008 paper [8], we gathered the movement time and error rate. However, we did not determine the throughput of the participants as in MacKenzie and Isokoskis study. The setup is similar in terms of having participants execute point-selection tasks however we were not comparing speed and accuracy to throughput as MacKenzie did.

This performance-based study has two independent variables, input modality, and participant focus. Input modality has three levels: Microsoft wired mouse, Apple Magic trackpad, and Leap Motion. Participant focus has two levels: focus on speed and focus on accuracy.

There will be six trials (3 input modalities $\times$ 2 participant focuses) because each input device will be tested once while asking the participant to focus on selecting targets quickly and again asking them to focus on selecting targets accurately. The ordering of input device and participant focus trials will be counterbalanced by ordering via a Latin Square. For each of the six trials the participant was required to perform four different point selection tasks of the targets. These tasks had the targets vary in width as well as the amplitude between the targets was different between tasks. This allowed for various indices of difficulty to gauge a better set of results.

The dependent variables in this study are the completion time of each trial (each trial consists of the same number of selections) and the number of errors that the user makes during a trial. A confounding variable in our study was the gain settings for the devices. To account for this, each of the devices was set to their default gain settings.

RESULTS

The grand mean for movement time (MT) was 1805.15 milliseconds. The mouse when participants were focusing on speed was the fastest at 835.89 milliseconds, while the Leap Motion when participants were focusing on accuracy was the slowest at 3696.08 milliseconds. The effect of device on MT was statistically significant ($F_{2,20} = 360.92$, $p < .005$). The effect of task type on MT was statistically significant ($F_{1,10} = 9.671$, $p < .005$). However, the effect of device x (cross) task type was not statistically significant ($F_{2,20} = 3.864$, $p < .05$). The results by device and task type are shown in Figure 2. The error rate (percent of selection errors) by device and task type are shown in Figure 3. Table 1 shows each participant's mean movement time in milliseconds when using each device and completing each task type.

DISCUSSION

Prior to conducting our experiment, it was hypothesized that the mouse and trackpad would outperform the Leap Motion when performing target acquisition tasks. Through our testing we were able to verify that the performance of the Leap Motion fell far behind the mouse and trackpad. This outcome was originally anticipated due to the lack of prior experience users have with the Leap Motion. We had also determined that the mouse and trackpad would come the closest in movement time due to the large popularity of trackpad and mouse

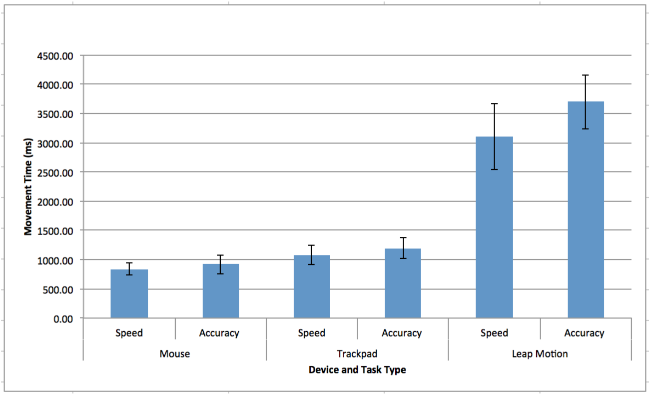

Figure 2. The Effect of Device and Task Type on Movement Time

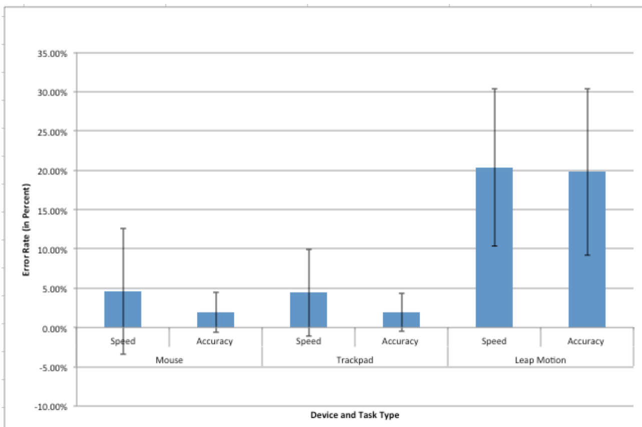

Figure 3. The Effect of Device and Task Type on Error Rate

Participants	Mouse		Trackpad		Leap Motion	
	Accuracy	Speed	Accuracy	Speed	Accuracy	Speed
1	0.00%	1.92%	0.00%	0.00%	23.08%	28.85%
2	3.85%	0.00%	3.85%	3.85%	23.08%	23.08%
3	1.92%	3.85%	0.00%	1.92%	26.92%	28.85%
4	7.69%	26.92%	5.77%	19.23%	30.77%	28.85%
5	3.85%	0.00%	1.92%	3.85%	9.62%	7.69%
6	0.00%	3.85%	0.00%	3.85%	11.54%	28.85%
7	0.00%	3.85%	0.00%	0.00%	19.23%	7.69%
8	1.92%	0.00%	5.77%	3.85%	9.62%	23.08%
9	0.00%	1.92%	1.92%	5.77%	5.77%	23.08%
10	0.00%	3.85%	0.00%	1.92%	38.46%	3.85%
Mean	1.92%	4.62%	1.92%	4.42%	19.81%	20.39%
Standard Deviation	2.56%	8.02%	2.40%	5.52%	10.61%	10.02%

Figure 4. Participant results: Movement time in milliseconds

usage over recent years. However, it was further narrowed down that the mouse would outperform all input devices.

To conduct a procedure resulting in acquiring the utmost precise data, it was established that our dependent variable is movement time (the time taken for the user to select the target), and our independent variables are input device (Leap Motion or Mouse or Trackpad) and task focus (accuracy or speed). From this study, it was quite clear that the mouse showed the fastest movement times followed by the trackpad and finally the Leap Motion. Thus, we were able to confirm our hypothesis as the results of the experiment verify and support our initial supposition.

During the experiment participants were observed and their behaviour was recorded. We found that participants grew particularly frustrated with the Leap Motion as they used it saying things like "I hate this" and "why would anyone use this for anything". Furthermore, many of the participants also showed signs of fatigue while using the Leap Motion by taking frequent breaks, switching their controlling hand and verbally stating that the Leap Motion was debilitating. Based on our observations we can see that the Leap Motion has a learning curve and that it can cause the user's arm to fatigue within minutes. The trackpad trials went much quicker than the Leap Motion trials, and participants were observed to be much more focused during these trials. Moreover, the mouse trials were observed to be natural with no learning curve. During the mouse and trackpad trials, there were no signs of fatigue or verbal protest. While using the trackpad participants had the option to fully press the trackpad down (receiving tactile feedback) to make a selection, or to lightly tap the trackpad without fully pressing it in. The majority of users used the tap-to-click method, not fully depressing the trackpad every time they tried to make a selection.

The use of questionnaires allowed us to obtain the user's thoughts and feedback immediately after concluding the experiment. Specifically, the questionnaire revealed that none of the participants had any experience using the Leap Motion and all identified the device to be the most difficult of the three to use. Moreover, the mouse was favoured over the trackpad by 7 of the 10 participants selecting the mouse as their preferred pointing device. Participants rated the mouse as easiest to use when compared to the other two pointing devices.

It can be hypothesized that the Leap Motion could outperform the mouse and trackpad if a longitudinal study was completed as there is a cultural bias towards the mouse and trackpad.

CONCLUSION

Overall, the research gathered from prior experiments continuously identified the mouse and trackpad to be the optimal devices for pointing tasks. Through this experiment that is what was set out to be shown by comparing the results of the mouse and trackpad to the Leap Motion. According to the results of previous research studies, it was hypothesized that the mouse and trackpad would be superior to the Leap Motion in point-selection tasks. Once experiments were conducted, it was established quickly that the Leap Motion was the poorest choice for point-selection tasks and the mouse performed the best of the input devices tested.

When looking more closely at their results and evaluating them through ANOVA software analysis, it was determined that these observations are consistent. Comparing input devices among users indicates that the mouse performs better in terms of speed and accuracy compared to the trackpad and Leap Motion. These conclusions are solely based off of the results of the experiments and the participants reactions to using the input devices. Overall, after concluding this experiment and evaluating the results, it was concluded that of the three input devices the mouse was the overall top performer.

REFERENCES

1. Accot, J. and Zhai, S. Performance Evaluation of Input Devices in Trajectory-based Tasks: An Application of The Steering Law. *Proceedings of ACM CHI 99 Conference on Human Factors in Computing Systems*, 1999. 466-472.

2. Apostolellis, P., Bortz, B., Peng, M., Polys, N., and Hoegh, A. Poster: Exploring the Integrality and Separability of the Leap Motion Controller for Direct Manipulation 3D Interaction. *2014 IEEE Symposium on 3D User Interfaces (3DUI)*, IEEE, Minneapolous. 2014. 153-154.

3. Benko, H., and Feiner, S., Multi-Monitor Mouse. *CHI EA '05 CHI '05 Extended Abstracts on Human Factors in Computing Systems*. ACM, New York. 2005. 1208-1211.

4. Brown, M.A., Stuerzlinger, W., and Mondona Filho, E.J., The Performance of Un-Instrumented In-Air Pointing. *Graphics Interface Conference*, ACM, Montreal. 2014. 59-66.

5. Cakir, A., Cakir, G., Muller, T. and Unema, P. Trackpad - A Study on User Comfort and Performance. *CHI 95 Conference Companion*, 1995. 97-98.

6. Codd-Downey, R. and Stuerzlinger, W. LeapLook: A Free-Hand Gestural Travel Technique using the Leap Motion. *SUI '14 Proceedings of the 2nd ACM symposium on Spatial user interaction*, ACM, New York. 2014. 153.

7. Johnson, P.W., Measuring Muscles Fatigue During Computer Mouse Use. *Ergonomics Lab*. California University. (1996). 1454-1455.

8. MacKenzie, I. S., and Isokoski, P. (2008). Fitts' throughput and the speed-accuracy tradeoff. *Proceedings of the ACM Conference on Human Factors in Computing Systems CHI 2008*, pp. 1633-1636. New York: ACM.

9. MacKenzie, S., Sellen, A., and Buxton, W., Comparison of Input Devices in Elemental Pointing and Dragging Tasks. *CHI 91 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. IEEE, New York. 1991. 161-166.