

Equating User Experience and Fitts' Law
in Gesture Based Input Modalities

by

Rachael A. Burno

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved July 2015 by the
Graduate Supervisory Committee:

Bing Wu, Chair
Russell Branaghan
Nancy Cooke

ARIZONA STATE UNIVERSITY

August 2015

ABSTRACT

The International Standards Organization (ISO) documentation utilizes Fitts' law to determine the usability of traditional input devices like mouse and touchscreens for one- or two-dimensional operations. To test the hypothesis that Fitts' Law can be applied to hand/air gesture based computing inputs, Fitts' multi-directional target acquisition task is applied to three gesture based input devices that utilize different technologies and two baseline devices, mouse and touchscreen. Three target distances and three target sizes were tested six times in a randomized order with a randomized order of the five input technologies. A total of 81 participants' data were collected for the within subjects design study. Participants were instructed to perform the task as quickly and accurately as possible according to traditional Fitts' testing procedures. Movement time, error rate, and throughput for each input technology were calculated.

Additionally, no standards exist for equating user experience with Fitts' measures such as movement time, throughput, and error count. To test the hypothesis that a user's experience can be predicted using Fitts' measures of movement time, throughput and error count, an ease of use rating using a 5-point scale for each input type was collected from each participant. The calculated Mean Opinion Scores (MOS) were regressed on Fitts' measures of movement time, throughput, and error count to understand the extent to which they can predict a user's subjective rating.

TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES	iii
CHAPTER	
1 INTRODUCTION	1
2 BACKGROUND LITERATURE.....	3
Fitts Linear Relationship.....	4
Subjective Assessment of Experience	9
Gesture Technology	11
3 HYPOTHESIS & STUDY OVERVIEW	13
4 METHODOLOGY	14
Subjects	14
Experimental Setup.....	15
Experimental Design & Procedures.....	16
5 DATA ANALYSIS AND RESULTS.....	18
Analyses of Behavioral Measures.....	18
Analyses of User Experience	22
Modelling User Experience with Behavioral Measures	25
6 DISCUSSION.....	27
7 CONCLUSION.....	31
REFERENCES	32

APPENDIX	Page
A FACILITATOR TEST SCRIPT	34
B PARTICIPANT CONSENT FORM	41
C ASU IRB	45
D INTEL PRIVACY PLAN	47
E SURVEY RESPONSE TEMPLATE	55
F TESTING APPARATUS SETUP	57
G USER INTERACTION WITH TESTING DEVICES.....	59

LIST OF TABLES

Table	Page
1. Study Targets Index of Difficulty.....	16
2. Fitts' Behavioral Measures Obtained by Testing Software.....	17

LIST OF FIGURES

Figure	Page
1. Fitts' One-Directional Tapping Task	4
2. Example of Multi-Directional Tapping Task.....	5
3. Software Example for Multi-Directional Task	6
4. Mean Response Time as a Function of ID.....	19
5. Average Throughputs (TP) for 5 Input Devices	20
6. Average Error Count for 5 Input Devices.....	21
7. (A) Average Error Rates as the Functions of Target Width	22
7. (B) Average Error Rates as the Functions of Target Distanc	22
8. MOS Score Across all Input Types	23
9. Device Ranking for all Input Types.....	25
10. Actual Vs. Predicted MOS Scores for Each Input Type.....	26
11. Actual Vs. Predicted Device Ranking for Each Input Type	27
12. Prediction of MOS From Throughput and Error Count.....	29

INTRODUCTION

As computing devices continue to evolve, so does our method of interacting with them. Today, we are accustomed to interacting with our devices using input methods like the Mouse, Touchpad, Touchscreen, and the Stylus. Looming on the computing horizon are more natural interaction methods, like gesture. Gesture allows users to use their hands, fingers and body to interface with the computing devices through the use of cameras. Although currently considered a novelty for gaming based applications, gesture has the potential to assist us in many more computing applications. Wachs, Kolsch, Stern, & Edan (2011) outlined four major areas of potential applicability:

- 1) Medical Systems and Assistive Technology: Instead of surgeons relying on voice commands to nurses to adjust medications, dials, technology, tools, etc., they would be able to use a touch-less gesture based system, potentially reducing time in the surgery and errors.
- 2) Crisis Management and Disaster Relief: In large disaster relief efforts, you have multiple large teams working together, passing data, via command and control systems. Gesture may be beneficial in interacting with these systems.
- 3) Entertainment: We have already seen the application of gesture in gaming systems, like the Xbox Kinect. This system has proven to be successful and the assumption is that the tolerance of errors in this environment is fairly high, given that current technology has a much higher error rate and longer latency than traditional inputs.

- 4) Human-Robot Interaction: Air gesture could be used for both providing commands to a robotic system, and for operational manipulation whereby a robot mimics your movements.

There are additional usages that the authors did not mention in their article as well.

Gesture based systems could potentially be used in any environment where users cannot physically interact with or touch their systems or devices due to the demands of their environment. These can include factories, clean rooms, mines, automotive repair shops, and other environments like these.

As we move further into the field of gesture, we need to understand and be able to articulate the user experience. After all, if people find an input modality difficult to use, there will be no adoption. The novelty will wear off and the technology will be moved to the shelf in the garage that houses all other “novel technologies” that failed to excite users. Gesture based input modalities need to afford a level of usability that is acceptable by users. Designers need to understand what is considered an acceptable level of usability and how to determine the factors that contribute to user experience.

Our goal is to define and assign UX metrics to inform engineering requirements that will result in high quality user experiences with gesture-based modalities. To do this, researchers need first to understand the usability measures for traditional input methods and see if these measures can apply to gesture based inputs. Fitts’ law is traditionally used as a behavioral measurement for usability assessments by correlating a user’s response time with an index of difficulty measurement. Researchers then can attempt to predict a user’s experience by assessing these measures against a user’s Mean Opinion

Score (MOS). MOS is a subjective measurement tool that measures perceived quality, and only consists of one rating per study treatment.

BACKGROUND

Today, engineers and designers of input modalities typically refer to the International Standards Organization's (ISO) standards as the means for determining "good usability". (ISO/TS 9241-411, 2012). ISO standards establish a means for evaluating task precision with various input modalities using a target acquisition task and measures of throughput and index of difficulty established by Paul Fitts. This is now known as Fitts' Law and its effectiveness has been demonstrated in hundreds of studies from its establishment in 1954 for both one- and two- dimensional operations. Within the field of Human Factors Engineering, Fitts' law is a prominent mathematical model used to evaluate the effectiveness of pointing devices. It states that the time required to move from one target area to a second target area is a function of the size of the target and the distance to the target. Since the introduction of the computer, Fitts' law has been used primarily to test input devices for pointing and selecting. In recent literature, Fitts' law is primarily used in two ways:

- 1) To predict human movement time when moving from one target to another
and
- 2) To compare and evaluate the quality of various input devices.

For the purposes of assessing the applicability of Fitts' law to gesture based input methods, it is important to focus on the use of Fitts' law to compare and evaluate input devices.

Fitts' Law has its roots in Information Theory. In studying Shannon's Theorem which describes the effective information capacity of a communications channel (Shannon, 1948), Fitts' (1954) attempted to formulate a similar equation for human channel capacity. Generally, Fitts' law has two components: A target acquisition task and measures to assess both the number of bits of information transmitted, called Index of Difficulty (ID), and the rate of transmission, called Index of Performance. Index of performance is more recently referred to as throughput (TP) and will be referred to as such throughout this paper.

Fitts' Linear Relationship

Fitts' law's first component, the target acquisition task, started with Fitts' original study as a one-dimensional "tapping task" and is commonly referred to as Fitts' paradigm (Figure 1). In his original study, subjects used both a one ounce stylus and a one pound stylus and moved as quickly as they could between two plates and tapped their centers. Typically in one-dimensional tapping tasks, the distance and the width of the targets will vary. Measures of Movement Time, Error Rate, and Index of Throughput are then assessed. Today, this same test is used as a one-direction tapping task. It can be discrete, where the subject moves from a "home" to a "target", or serial, where the subject moves quickly between two targets, much like Fitts' original experiment.

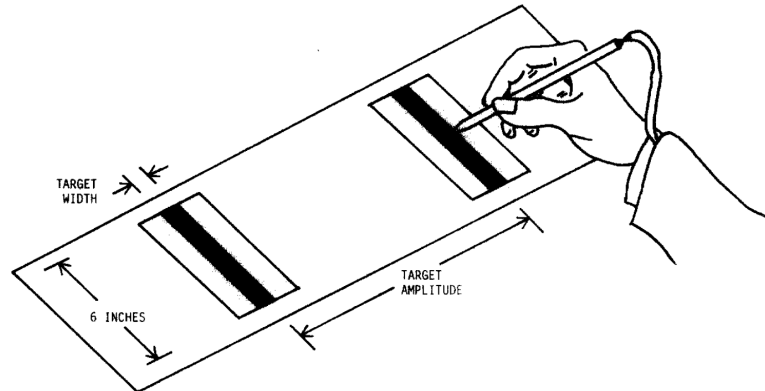


Figure 1: Fitts' one-directional tapping task

The target acquisition task was first applied to two-dimensional computer interfaces in 1978 to assess four different pointing devices: Mouse, Isometric Joystick, text keys, and step keys. (Card, English, & Burr, 1978). In this experiment, Card et al. noted that the angle at which a user approaches the target (approach angle) has a significant effect on movement time, and therefore, throughput. Because of this, most researchers use some form of a multi-direction tapping task (Figures 2 & 3). This controls for the effect of direction that is now a factor in two-dimensional devices. Targets can be circular or rectangular, however, circular targets allow for a consistent width regardless of direction of approach to target. Square and rectangular targets produce varying widths. The one- and two-directional target acquisition tasks has since been used to assess various pointing devices and is considered the standard for evaluating performance of input modalities for computing devices.

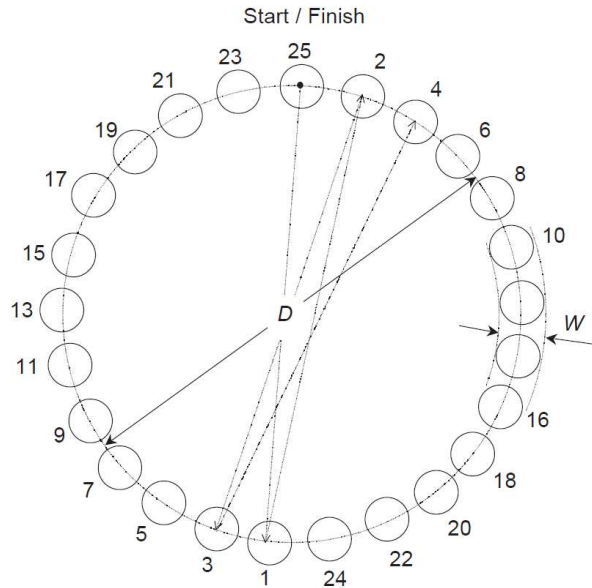


Figure 2: Example of Multi-directional tapping task (Soukoreff & MacKenzie, 2004)

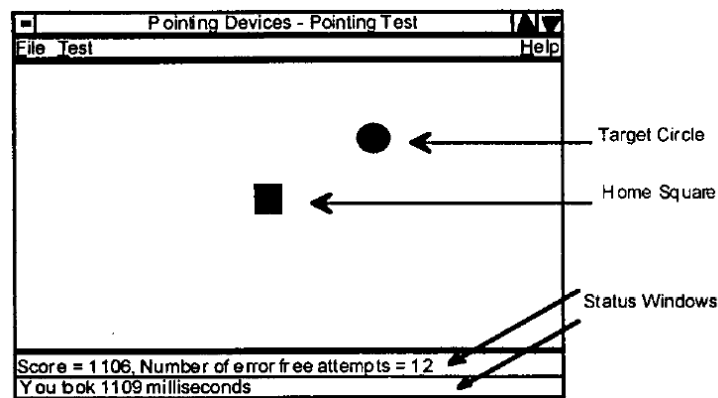


Figure 3: Software Example for Multi-directional task (Douglas, Kirkpatrick, & MacKenzie, 1999)

The second major contribution of Fitts' law are the measures to assess Index of Difficulty, Throughput, and predicted Movement Time. As mentioned earlier, Index of Difficulty describes the number of bits of information transmitted within the context of human motor system. Fitts' original formula was based on Shannon's theorem (Shannon, 1948), $C = W' \log_2 \frac{signal + noise}{noise}$, where C = the channel capacity and W' = bandwidth of the communication channel. In this theorem, Shannon described "...the information

capacity of a continuous channel in the presence of noise” (Soukoreff & MacKenzie, 2004). Fitts’ original formula, $I_D = \log_2\left(\frac{2d}{w}\right)$, was similar, where d = distance to the target = signal and w = width of target = noise. This measure was useful in that the effects of distance and width, two physical properties of movement tasks, were combined into a single measure (MacKenzie, 1992). However, in 1989, Mackenzie proposed moving back to Shannon’s original theorem, $I_D = \log_2 \frac{distance+width}{width}$, for several reasons:

- 1) Research had found that target width was a stronger contributor to movement time and error count than was target distance.
- 2) Fitts’ original formula could result in negative ID numbers, which is unrealistic in practice.

This new measure of Index of difficulty (ID) with the corrected weighting for distance and width solves both of the issues listed above.

The second measurement, the rate of information transmission known as throughput, can now be calculated. Throughput is calculated as $TP = \frac{I_D}{MT}$. Where I_D = Index of Difficulty and MT = Movement Time. The Fitts’ model predicts movement time as a function of a task’s Index of difficulty. Once each subject’s movement time is calculated, predicted movement time is $MT = a + b \cdot \log_2\left(\frac{distance+width}{width}\right)$, where a = intercept, or the constant, and b = slope.

Current ISO documentation now consistently uses Fitts’ law as a method for evaluating performance of input methods. Specifically, ISO standard 9241-411 (ISO/TS 9241-411, 2012) establishes a means for highlighting how to evaluate task precision with

various input modalities using the Fitts' components of the target acquisition task and measures of index of difficulty, throughput, and predicted movement time. The standard for evaluating input devices includes two themes that are the focus of this study; the assessment of task precision and the measures of usability.

The first theme, task precision, is a measure of the accuracy required for a pointing, selecting or dragging tasks, quantified by the index of difficulty (using Shannon's formula). The standard defines 4 classes for devices (ISO/TS 9241-411, 2012):

- C1, High (degree of precision required for) $I_D > 6$.
- C2, Medium (degree of precision required for) $= 4 < I_D \leq 6$
- C3, Low (degree of precision required for) $= 3 < I_D \leq 4$
- C4, Very low (degree of precision required for) $I_D \leq 3$

There are multiple target acquisition tests that can be used to establish the input modality's task precision. The most commonly used target acquisition test used (in various forms) in Fitts' HCI based research is the multi-directional target acquisition task that was described earlier and the one that is most applicable for the current research.

The second theme is related to input device usability. The ISO standard defines two attributes related to usability. The first is that the device must be usable for its designated purpose as measured by conformance with the design requirements. The second is satisfactory level of performance as determined by measuring and demonstrating comfort. This is assessed using the comfort-rating scale and subjects can rate the input devices either independently or comparatively, if the intent of the research

is to compare two different input modalities. The survey is given to subjects after they complete a series of target acquisition tasks with an input device.

In reviewing the ISO standards and all of the previous research using Fitts' Law to assess the "usability" of an input device, a few things become increasingly apparent. The first is that the ISO standards do not attempt to assess the perception of positive experience as rated by the user, given the measures of precision, accuracy, movement time, or throughput. Does a user's level of satisfaction of a device correlate with any of these measures, and if so, are any measures more influential than others? Also, while ISO documentation uses effective width and effective index of difficulty to attempt to take into consideration user accuracy, it does not account for error rate in their task precision analysis. This is of particular interest in newer technologies where the user is unfamiliar with the input modality and this may produce an increased chance of producing errors. The level of user tolerance for errors in any of the input modalities should also be understood as error count may influence a user's level of satisfaction with a device as well.

Subjective Assessment of Experience

A few studies have attempted to establish both a quantitative and qualitative evaluation, specifically for gesture based modalities, and correlate them to get an overall view of user experience. The first was conducted by Ryu, Koh, Ryu, & Um (2011). The group had developed a Touchless mouse that used both finger gesture and palm gestures to manipulate the cursor on the screen. They were looking for something that can be used in alternative settings, like clean rooms and hospitals, and not in your typical everyday office environment. Using ISO 9241-9 (evaluation methods for pointing devices) as their

guideline, the quantitative metric for this study was throughput in bits per second (bits/s). The experiment found that throughput for the “Touchless Mouse” was significantly lower than the conventional mouse and only 2 out of 18 subjects preferred this method (mostly due to speed issues, not errors). However, more than three quarters of the subjects stated that this may be a useful alternative in alternate settings (Ryu, Koh, Ryu, & Um, 2011). Although this test was a great baseline to work from, the user’s level of tolerance for errors and latency with this device was not understood. There are no data to say that at any specific level of performance, the user experience degrades. Also, because there was no baseline for conventional mice for user tolerance of errors, there was nothing to compare to the “user experience” of the Touchless Mouse. If there had been a baseline, a useful experiment would be to test the throughput using Fitts’ Index of Performance and determine at exactly what level of performance the user decides to abandon the device as an input modality. That data could then be compared with that of the conventional mouse.

Whereas the first study may not have been able to tell us user tolerance of errors and latency, the second study comes as close as any seen to date. The study, conducted by Karam and Schraefel did, in fact, provide a model “for investigating what level of accuracy is required for a gesture detection system to be both tolerated and experienced as useful” (2006). This report also questions whether other factors besides just throughput, errors, and latency affect a user’s decision to either continue to use or abandon a particular input mechanism. The experimental design tested for interaction context (user tolerance based on computing environment), system performance (user tolerance of errors), and user goals (tolerance based on criticality of task). The report provided two very important findings:

- 1) That user tolerance of errors was greater in a “ubiquitous” computing situation (Meaning an alternative environment outside of the typical office setting) than in traditional desktop computing situation.
- 2) Users are less tolerant of errors in situations in which tasks are critical.

Although these findings are helpful for future studies, the report was not able to tell us at what level of performance (speed and accuracy) the user decides that the gesture system is no longer usable in the “ubiquitous” scenario. The report does show that in the desktop setting, users did not tolerate any errors over 10%, showing that user tolerance of gesture based errors is very low in traditional computing settings. Also, because there was no baseline from traditional input modalities to serve as a comparison of user tolerance, it is unknown how this level of tolerance compares to traditional input modalities, like mice and keyboard. This information would be useful to determine in what context(s) gesture based interactions would be more useful. Finally, in the experiment, Fitts’ Law tests were not used to determine the level of tolerance for both errors and latency. It would be beneficial to see at what level of throughput the user experience degrades to the point that the system is no longer usable.

Recent studies conducted in the field of human factors have used a subject’s Mean Opinion Score (MOS) to assess an aspect of users overall experience of an interactive device. The MOS rating scale is beneficial because it streamlines the experimental design and statistical analysis without sacrificing accuracy. A recent investigation was done to compare the System Usability Scale (SUS), which requires subjects to provide ten individual ratings, compared to the MOS methodology that requires only one rating. The study found that the scores were highly correlated and that

MOS is a suitable substitute for multiple-rating assessments in studies needing a reliable measure of usability that can be done with less resources and in a shorter time than SUS (Guo, Sales, Doherty, Waring, & Corriveau, 2010).

Gesture Technology

Today, there are several options commercially available for vision based gesture interaction devices. Vision based interaction devices use a camera to “see” a user’s movements. The most popular example of which is the Microsoft Kinect device, which connects to the Xbox gaming console and uses whole body, arm, and hand tracking to control games and applications on the device. Outside of gaming, gesture based inputs are becoming more prevalent, and each of them typically uses a different technology to track a user’s movements and as with most technology, there are benefits and drawbacks to each of them.

A study conducted by Langolf et al. (1976) tested Fitts’ law using various limbs. The results showed that the throughput was progressively worse as the limb changed from smaller movements (finger) to larger movements (arm). For the current study, three different types of gesture inputs with three different ranges of motion were analyzed. A longer range hand/arm tracking camera, a shorter range hand tracking camera, and a horizontally placed finger tracking camera.

The first camera is considered a longer-range camera as the distance required between the user and the camera is greater than other commercially available devices. This input requires that the user be one to five feet from the camera. The camera is then placed behind the Laptop. This camera tracks larger hand and arm movements and has a 57.5×45 field of view. It requires the user to hold their arm up in front or to the side of

their body, with their palm facing the camera. This type of movement can become exhausting for users after even a moderate amount of use.

The second type of gesture input is a closer-range camera. It uses hand gestures and finger articulation to control objects on the computing device. The user sits closer, with palm facing the camera, which is typically placed on the user's computer or monitor. The camera then tracks the user's hand at a distance of approximately 6 in. to 3.25 ft. In addition to the arm exhaustion mentioned with the device above, because the user is closer to the camera, placement of the camera becomes important. If the camera is placed on top of the computer monitor or screen, the user's own hand may now become an obstruction to their view of the screen.

The final vision enabled gesture input is a camera that sits horizontally in front of the computing device or computer monitor. Here, the user places their hand over the camera, which tracks small finger movements. The range of motion for this camera is much smaller and reduces the potential for visual obstruction and arm exhaustion that is higher in the other two cameras.

HYPOTHESIS AND STUDY OVERVIEW

The current literature is rich with support for utilizing Fitts' law to conduct target acquisition tasks and assess input performance using the measures of index of difficulty, throughput and predicted movement time. However, little research exists that applies these Fitts' components to gesture-based input methods. In addition, there appears to be no research that attempts to predict user experience using these traditional Fitts' measures, or measures of error rate or error count. However, given the vast extant literature, hypothesis' can be derived that:

- 1) Similar to 1- and 2- dimensional inputs, as the Index of Difficulty increases, Movement Time will also increase in 3-dimensional inputs and
- 2) Movement Time, Throughput, and Error Rate all contribute to subjective user experience, for all input types.

In this study, Fitts' Law is investigated to determine whether it holds true in gesture based interactions. The Fitts' behavioral measures can then be used to predict user experience. Three factors are considered: error rate, movement time, and throughput. Because these three factors are not independent, stepwise multiple regression models will also be run. This study will be conducted in partnership with a large technology corporation's user experience research lab.

METHOD

Subjects

A total of 83 subjects, 35 of which are employees of a large technology corporation (25 in Arizona and 10 in Oregon) and 48 not employed by the technology corporation, were recruited to participate in this study. Because this study was conducted on-site at the corporation's facility, there was potential that research subjects are highly skilled technical employees that may be more familiar with different input types than others who do not work in a technical industry. They also tend to be between the ages of 25 – 55. To account for this, external subjects recruited from an external agency who span from age 18 – 61 and do not work at a technical company were recruited. Subjects were a mix of male and female, fluent in English, and had no reported musculoskeletal injuries in back, arm, neck, or shoulder that affect range of motion for gesture based

activities, and self-report as having regular computer use. There were no other exclusions based on demographic criteria.

Experimental setup

To assess the applicability of Fitts' law to gesture based devices, three different types of gesture based inputs were selected. As mentioned previously, gesture based modalities vary in their method of gesture recognition and it is important to account for these differences. The three devices will be named:

- Gesture S: Short-range camera (1 in. to 2 ft.), horizontally placed in front of the computing device. This camera tracks small finger movement above the camera.
- Gesture M: Mid-range camera (6 in. to 3.25 ft.), placed on laptop monitor. This camera tracks shorter range hand motions.
- Gesture L: Longer range camera (1 – 5 feet), placed behind the laptop. This camera tracks larger hand and arm movements.

In addition to assessing the performance of the three gesture input methods, gesture based performance was compared with more traditional, and familiar, input methods. To do this, touchscreen performance was assessed using a Lenovo X1 laptop and a USB mouse was connected to the computing device to assess mouse performance.

Experimental Design & Procedures

One testing workstation was setup with a Lenovo X1 touchscreen laptop. The laptop was connected to a USB notebook optical mouse and the three gesture based cameras described above: Gesture S, Gesture M, and Gesture L. To account for order

bias, users favoring one input method over another based strictly on order of testing, fatigue, learning effect, etc. subjects were randomly assigned the order of the input methods according to a predetermined randomization scheme.

Custom Fitts' test software obtained from Northeastern University was loaded onto the Lenovo for the Fitts' trials. This software was used to complete the Fitts' multi-directional target acquisition tasks and gather user data.

A movement task consisted of the user selecting a "home button" on the screen and then moving as quickly and accurately as possible to a "target" button. They selected the target by either clicking (in the case of the mouse), clicking a button on a wireless presentation clicker (for gesture based input methods), or tapping (for touchscreen). Prior to starting the tasks on each input method, the facilitator demonstrated the task several times to the subject.

For the Movement Tasks, there were three predefined target width sizes (W) and three predefined lengths for target distance (D), allowing for 9 possible combinations and 9 specific Index of Difficulties (IDs). The combinations are as follows:

Target Distance (D)	Target width (W)	ID= $\log_2(D/W+1)$
640	70	3.34
640	30	4.48
640	50	3.79
320	70	2.48
320	30	3.54
320	50	2.89
160	70	1.72
160	30	2.66
160	50	2.07

Table 1: Study Targets Index of Difficulty

Each Index of Difficulty displayed twice per session, for a total of 18 times per session. Each subject completed three session per input type. To prevent users from learning the 9 combinations, 9 random targets with widths varying between 30px – 150px were included. These appeared at random distances in various locations on the screen. These were not tracked as part of the study metrics. The 9 “dummy” targets were randomly displayed once in each session, interspersed with the 18 defined targets for a total of 27 runs per session. The within subjects design now gives us: (3 (d) x 3 (w) x 2 (repeated) + 9 (dummy/distractors)) x 3 (sessions) = 81 trials.

Upon completion of the tasks, the Fitts’ testing software created a .csv file containing all of the behavioral measures for each subject. This file included:

• Subject Number	• Target distance (home center to target center)
• Age Range	• Index of Difficulty
• Gender	• Response time
• Input Method	• Throughput
• Trial Number	• Distance traveled by user
• Task number	• Error Count
• Target size	• Distance Delta

Table 2 Behavioral Measures

The subjects were verbally asked to rate ease of use for each input method. Ease of use was defined as the ability to move as quickly and accurately as possible from one target to the next. Answers were provided using the Likert 5 point scale with 1 being “poor” and 5 being “excellent”. The 5 point scale was printed out and taped to the desk in front of the subject for visual reference. In addition, once the subject completed the movement task for all five inputs, they were asked to rank the input methods in order from most preferred (5) to least preferred (1).

DATA ANALYSIS & RESULTS

All dummy trials were removed from data analysis. Error rates were first calculated for each device and each subject. Of a total of 83 subjects, two were excluded from data analysis because they had difficulty accomplishing the task and showed high error rates of >20% (much greater than three standard deviations from the mean error rate) even in the mouse condition. Given that the mouse is fairly common amongst regular computer users, anyone whose movement time is great than three standard deviations from the average would either not have been focusing on the task or not following instructions to move as quickly as they could while trying to maintain accuracy.

Analyses of behavioral measures

The applicability of Fitts' law to gesture based devices was assessed by conducting a single regression of Movement Time on Index of Difficulty. Previous studies have shown that for mouse, we should see an r^2 of between 97% - 99%. Figure 4 shows the mean MTs as the functions of IDs for all devices. Clearly, MT increased with ID for the use of all devices. Further linear regression analyses confirmed that MT could be predicted very well from ID not only for mouse ($r^2 = 0.997, p < 0.001$) and touchscreen ($r^2 = 0.929, p < 0.001$), but also for the three gesture-based interfaces (r^2 values ranged from 0.958 to 0.986, all the p values < 0.01). This suggested the Fitts' model could be applied to the gesture-based interfaces and used to characterize three-dimensional movements during interaction.

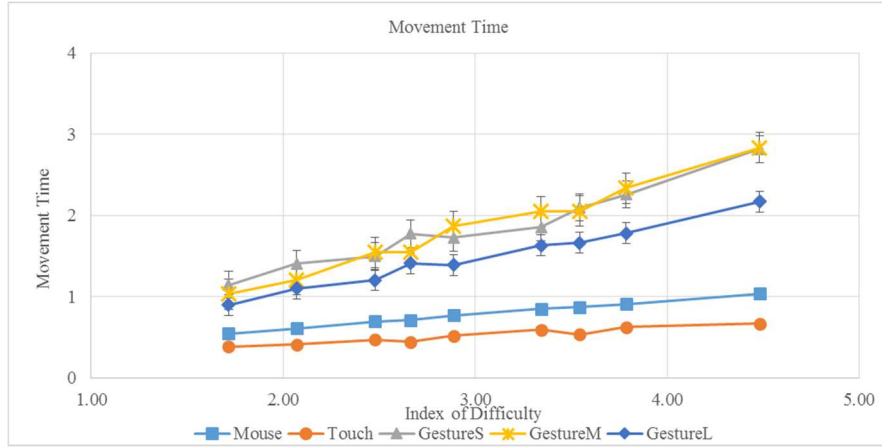


Figure 4: Mean response time as a function of ID

Figure 5 shows the mean throughputs, averaged across all subjects, for the five devices. Throughput was calculated for each subject and each device as

$$TP = \frac{1}{N} \sum_{i=1}^N \frac{ID_i}{MT_i}, \text{ (Soukoreff \& MacKenzie, 2004)}$$

where N denoted the combinations of target distances and sizes, using the MT obtained from those trials with no errors. Of the five devices, the mean throughput was largest for touchscreen, and smallest for GestureS and GestureM. One-way repeated-measures ANOVA confirmed that this difference was significant ($F(4,320)=965.72, p<0.001$, partial $\eta^2=0.93$). Further comparisons among the devices with Bonferroni corrections revealed that the mean throughputs for mouse and touchscreen were significantly larger than those gesture-based devices (paired t-tests with Bonferroni corrections, $t(80)>18.32, ps<0.001$, Cohen's $d_s > 4.09$). No statistically significant difference was found between average subject performance with GestureS and GestureM (paired $t(80)=0.63, p=0.99$ with Bonferroni correction, Cohen's $d = 0.14$). Interestingly, both throughputs were significantly lower than that for GestureL (paired $t(80)>7.52, ps<0.001$ with Bonferroni corrections,

Cohen's $d_s > 1.68$), which was inconsistent with Langolf et al.'s (1976) findings that throughput was worse for larger limb movements.

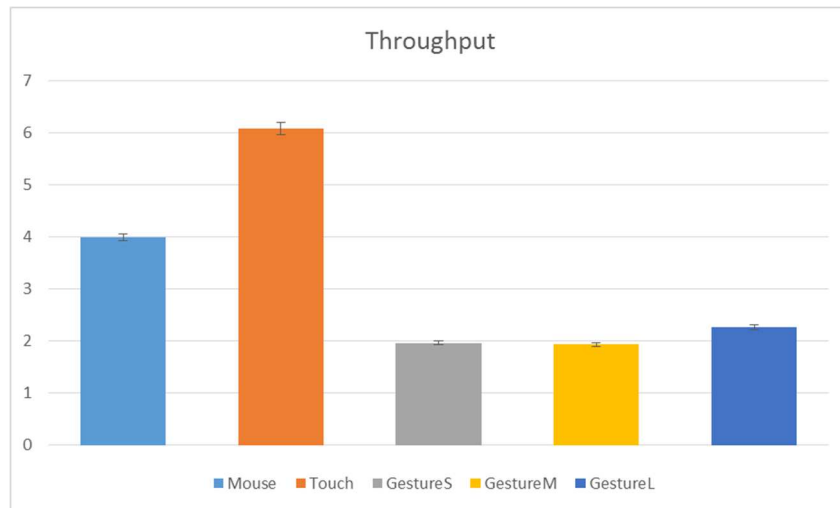


Fig. 5. Average throughputs (TP) for 5 input devices.

In addition to throughput and movement time, error rate was another useful measure of performance. As shown in Figure 6, the lowest error rate was observed in the Mouse condition (paired t-tests with Bonferroni corrections, $t_{s(80)} > 9.03$, $p < 0.001$, Cohen's $d = 2.02$). Subjects made considerably more errors with the touchscreen than with the mouse (paired $t_{s(80)} = 13.55$, $p < 0.001$ with Bonferroni correction, Cohen's $d = 3.03$). This partly explained why the movement time with touchscreen was faster than that with mouse. Although the instruction to subjects emphasized both speed and accuracy, the subjects made trade-offs and their performance might be biased more towards accuracy than speed in the mouse condition because mice are designed for precise pointing. As to the three gesture-based devices, similar error rates were found for GestureL and GestureM (paired $t_{s(80)} = 1.94$, $p = 0.55$ with Bonferroni correction, Cohen's $d = 0.43$), and the error rate with GestureS was found to be significantly lower as compared

to GestureL (paired $t(80) = 9.30$, $p < 0.001$ with Bonferroni correction, Cohen's $d = 2.08$) and GestureM (paired $t(80) = 8.20$, $p < 0.001$ with Bonferroni correction, Cohen's $d = 1.83$).

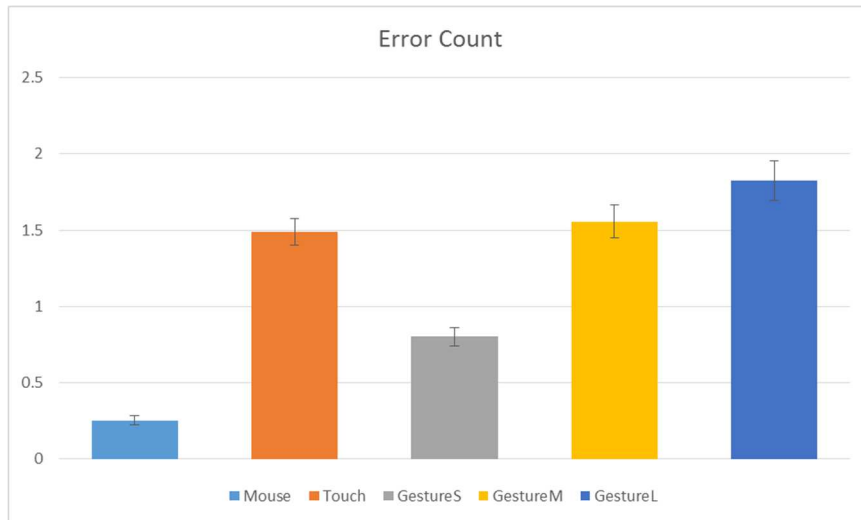


Fig. 6. Average error count for 5 input devices.

Further analyses were conducted to examine the influence of movement distance and target size, respectively, on the error rates. As shown in Figure 7(a), the rate was almost uniform across the range of movement for all devices. A two-way (Device x Distance) repeated measures ANOVA followed by Bonferroni post-hoc tests found only a significant difference between the error rates for the shortest and longest movements (paired $t(80) = 2.50$, $p = 0.04$, Cohen's $d = 0.56$) and a weak main effect of Distance ($F(2,160) = 3.97$, $p = 0.02$, partial $\eta^2 = 0.05$). In contrast, the error rates were highly correlated with target width, as shown in Figure 7(b). The observed error rate was highest for the smallest target and gradually reduced with increasing size of the target. The observed effects of target size were relatively weak for the use of mouse and GestureS, but evident for the remaining three devices. A two-way (Device x Width)

repeated measures ANOVA found a significant main effect of Width ($F(2,160)=265.33$, $p<0.001$, partial $\eta^2=0.77$) and also a significant interaction of (Device x Width) ($F(8,640)=42.71$, $p<0.001$, partial $\eta^2=0.35$). Bonferroni post-hoc tests further showed that the error rates were significantly different ($ts(80)>7.54$, $ps<0.001$, Cohen's $ds > 1.69$) for all three target sizes.

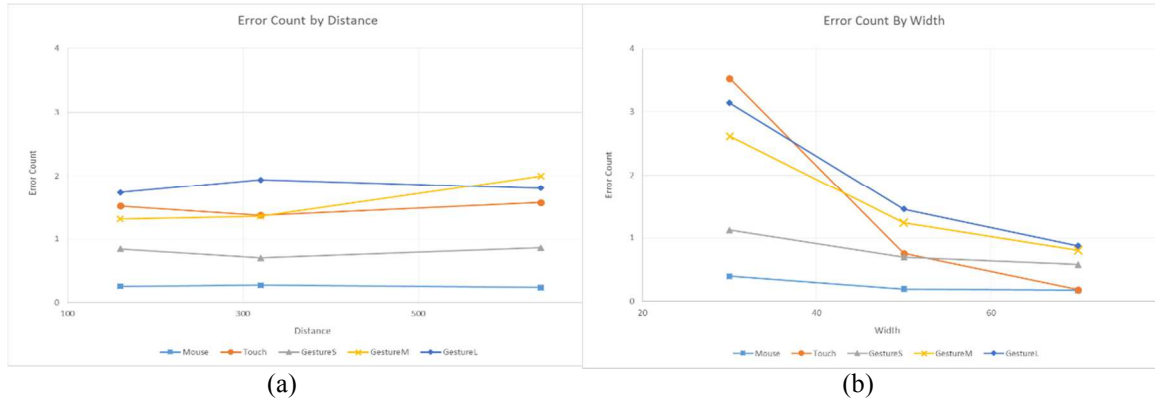


Fig. 7. (a) Error count by target width; (b) Error count by target distance.

Analyses of user experience

The subjects' subjective impressions of the input devices were analyzed in the same way as in the previous section. To begin, the MOS (Mean Opinion Score) ratings were compared across the devices. As shown in Figure 8, the two conventional devices (>4.0) were rated higher than the gesture-based devices (2.4 – 3.1). A one-way repeated-measures ANOVA found a significant difference among the devices ($F(4,320)= 143.56$, $p<0.001$, partial $\eta^2=0.64$). Further pairwise comparisons with Bonferroni corrections found the subjects' experience with the conventional and gesture-based devices was quite different (paired t-tests with Bonferroni corrections, $ts(80)>10.39$, $p<0.001$, Cohen's $ds > 2.32$). No significant difference was found between user's MOS ratings for Mouse and Touchscreen (paired $t(80)=2.02$, $p= 0.47$ with Bonferroni corrections, Cohen's $d = 0.45$).

Among the three gesture-based devices, the MOS of GestureM was significantly lower than those of GestureS and GestureL (paired $t(80) > 5.27$, $p < 0.001$ with Bonferroni corrections, Cohen's $d_s > 1.18$), while no significant difference was found between GestureS and GestureL (paired $t(80) = 1.04$, $p > 0.99$ with Bonferroni corrections, Cohen's $d = 0.23$).

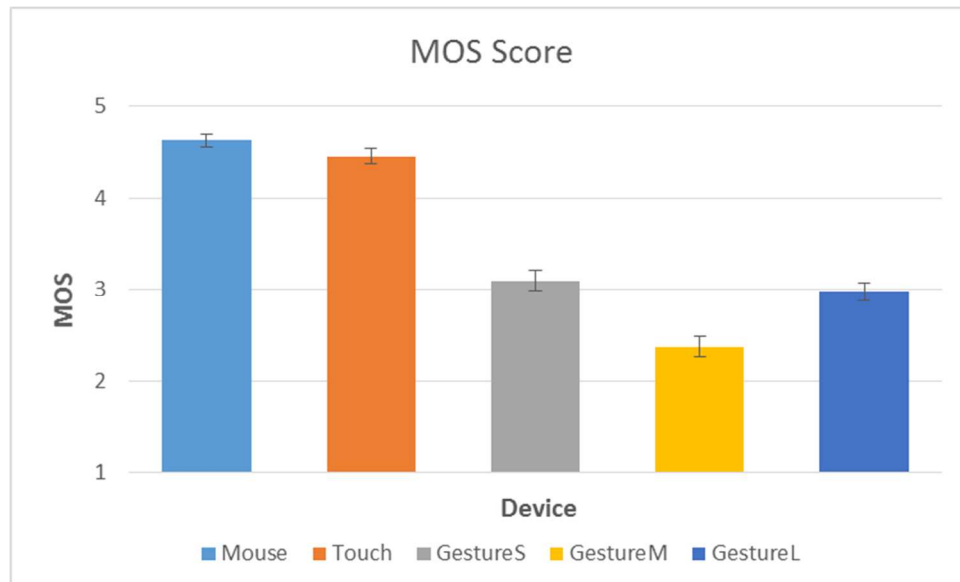


Fig. 8. MOS score across all input types.

Next, subject's device ranking was analyzed. In this study, subjects ranked each device from 5 – most preferred, to 1 – least preferred after he or she had tried all devices. The ranking data (Figure 9) shows a similar pattern to the MOS data (Figure 8). The most significant distinction was observed between gesture-based and conventional devices: More than 95% of the subjects selected Mouse (40/81) or Touchscreen (38/81) as the most preferred device, while the gesture-based devices were generally ranked from 3 to 1. This difference was statistically significant (one-way repeated-measures ANOVA : $F(4,320)= 196.34$, $p<0.001$, partial $\eta^2=0.71$). Pairwise comparisons among these devices found that there was no significant difference between user's preference for Mouse or Touchscreen (paired t-test with Bonferroni correction, $t(80)=0.18$, $p> 0.99$, Cohen's $d = 0.04$), and the two devices were significantly more preferable than any gesture-based devices (paired $t_s(80)>12.07$, $p_s<0.001$ with Bonferroni corrections, Cohen's $d_s > 2.70$). The comparisons among the three gesture-based devices found that GestureM has a relatively lower ranking than GestureS and GestureL (paired $t_s(80)>6.49$, $p_s<0.001$ with Bonferroni corrections, Cohen's $d_s > 1.45$), and no significant difference was found between GestureS and GestureL (paired $t(80)=1.44$, $p>0.99$ with Bonferroni corrections, Cohen's $d = 0.32$).

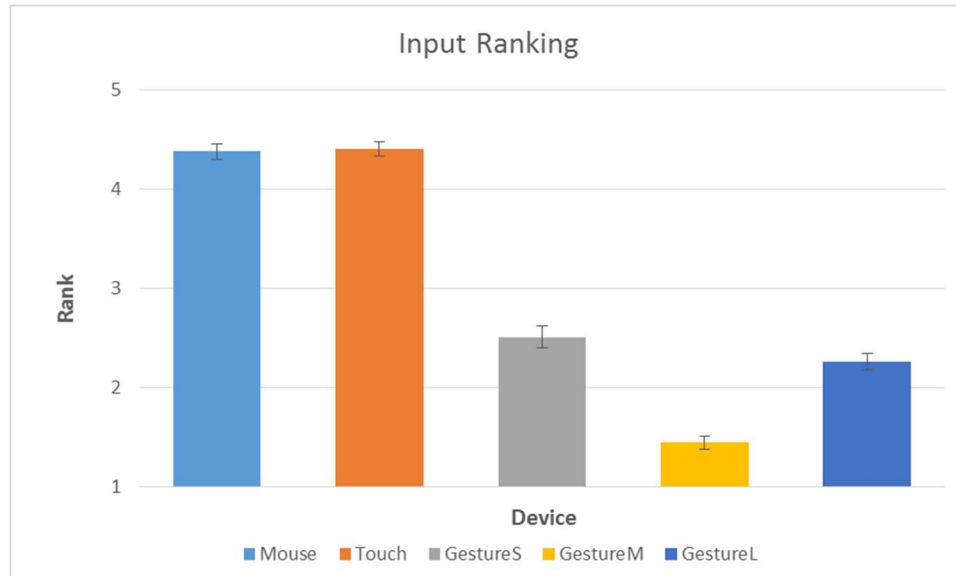


Fig. 9. Device ranking for all input types.

Modelling user experience with behavioral measures

How well can a user's subjective experience with a device (i.e., MOS rating and ranking) be predicted from his or her behavioral performance? To answer this question, we performed regression analyses to relate each subject's MOS and ranking data to the observed Throughput and Error Count. We used throughput because the current ISO documentation utilizes throughput as the single measure of user performance.

A linear regression of MOS on throughput found that the two variables were positively correlated with a coefficient of 0.44 ($adjusted\ r^2 = 0.37, p < 0.001$). In contrast, MOS was found to be negatively correlated with Error Count (coefficient = -0.38 ; $adjusted\ r^2 = 0.09, p < 0.001$). Note that Throughput was derived from Movement Time. Thus not surprisingly, a higher MOS was given to a device when users could perform the task with fewer errors and less time (i.e., higher throughput). Next, we constructed a multiple regression model using both variables and raised the $adjusted\ r^2$ to 0.44. Although the model cannot account for all variance in the data, as shown in Figure 10, the predicted MOS ratings match pretty well with the actual MOS scores for all five devices.

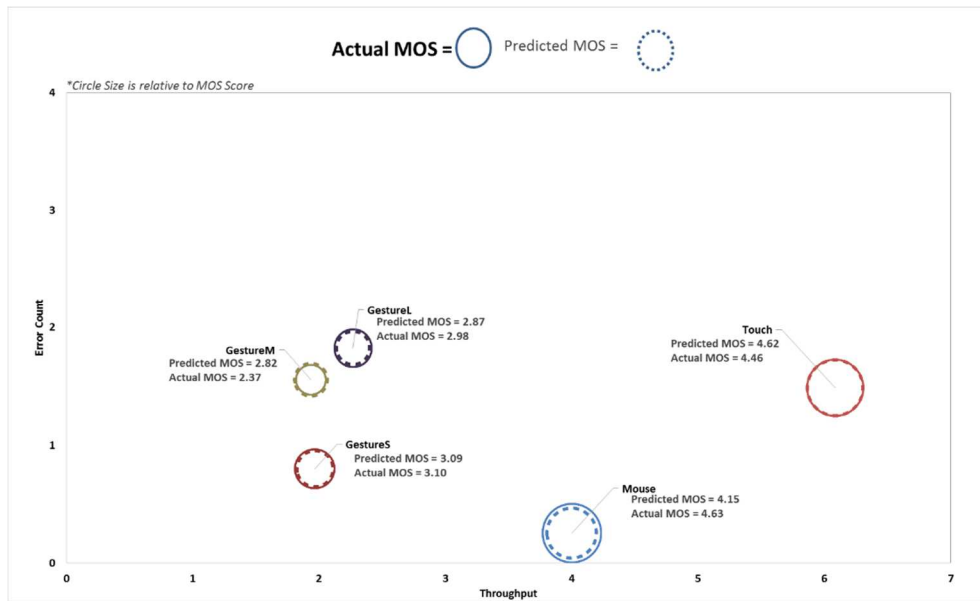


Fig. 10. Actual vs. Predicted MOS scores for each input type.

Similar regression analyses were conducted on the Ranking data. The results found that 58.8% of the total variance in ranking could be accounted for by throughput and error count ($p < 0.001$) and the coefficients were 0.58 and -0.39 for throughput and error count, respectively. Figure 11 shows the predicted and actual ranks for all five devices.

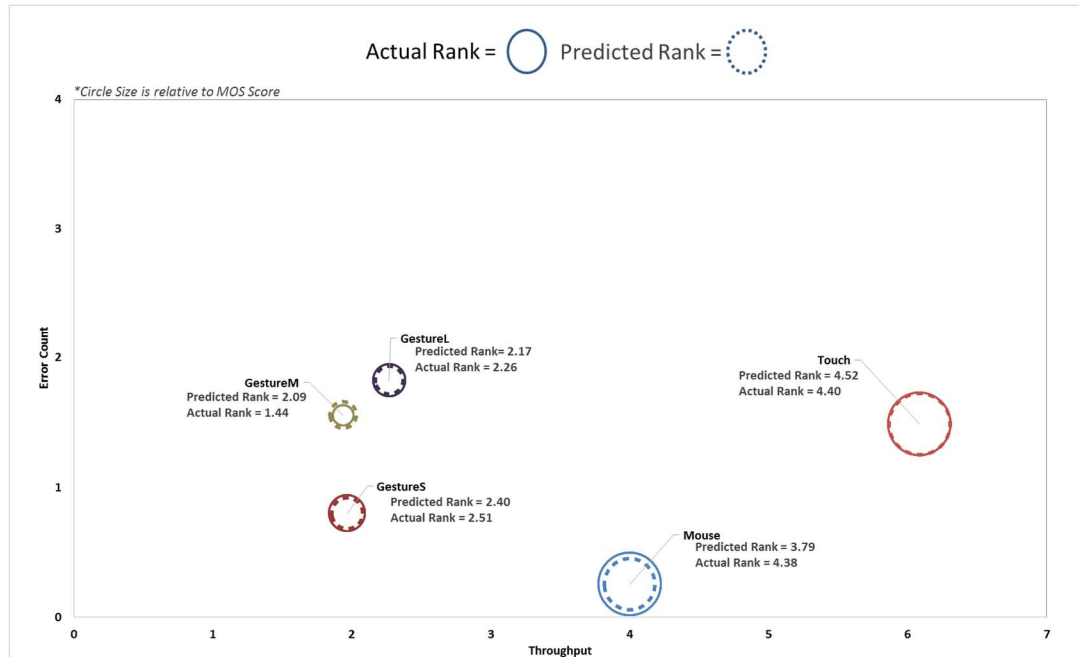


Fig. 11. Actual vs. Predicted Device Ranking for each input type.

DISCUSSION

In this study, three gesture-based interfaces were evaluated in a pointing task and compared to two conventional input devices, namely, mouse and touchscreen. Although the five devices are very different in terms of how users interact with them, a common pattern exists in the users' performance with the devices. The movement time linearly increased with the target's index of difficulty. Such linear relationships provide support for the notion that the Fitts' law can be generalized to 3D and used to characterize the gesture-based devices in a similar fashion like conventional 1D or 2D devices.

As compared to mouse and touchscreen, the gesture-based interfaces have lower throughputs. This is likely partially due to the dimensionality of motor behavior involved in using these devices. Our brain carries out actions by coordinating the activities of agonist and antagonist muscles at the joints. The control becomes more complicated when the degrees of freedom in limb movement increase and more muscles and joints are involved (Van Galen & De Jong, 1995). For example, the movement of a mouse can be achieved by slightly rotating hand around wrist, whereas a precise 3D pointing response with Gesture-L, for example, requires the movements of upper-arm, forearm and hand. Not surprisingly, the duration of such movements in 3D space would be affected more by task difficulty than 1D or 2D movements. However, since 3D gesture based input technologies are still relatively new, there are performance limitations that could be impacting the results.

Another interesting finding comes from the comparisons among the gesture-based devices. In contrast to Langolf et al.'s (1976) results that throughput became worse as the amplitude of limb movements increased, our results find a slightly but significantly larger throughput (2.25 bits/s) for using Gesture-L with larger limb movements as compared to Gesture-S (1.90 bits/s) and Gesture-M (1.91 bits/s). Note also that the throughputs reported here were considerably lower than 10 bits/s reported by Langolf et al. (1976) for arm movements. The low absolute throughputs might be accounted for by the differences in the experimental task. Langolf et al.'s (1976) experiment used a reciprocal tapping task and their subjects were instructed to tap as quickly as possible with little concern for accuracy. Here the subjects were instructed to perform a single movement toward a target on each trial as quickly and also accurately as possible. So the low throughputs obtained

in the present experiment were partly due to the accuracy demands. In addition, it is reasonable to expect that throughputs could be limited by some technical aspects of the devices such as temporal and spatial resolutions. It is possible that the relative ranking of the devices might largely be due to the technical differences.

This study also evaluated whether a user's experience can be predicted using measures of error count and throughput obtained using the Fitts' target acquisition testing method. Analysis discovered that the two variables can account for approximately 44% of the variance in the mean opinion score of subject's. Although such a simple linear model is far from perfect, it does provide us a general understanding of how to design an input device that creates a positive experience for users. Figure 12 demonstrates the relationship between throughput, error count, and MOS score. For example, in order to design an input device that garners a MOS score of 4, manufacturers need to reach a throughput of at least 3.5. Moreover, given that user errors cannot be avoided, throughput has to be improved by approximately 0.8 for every increase in error count.

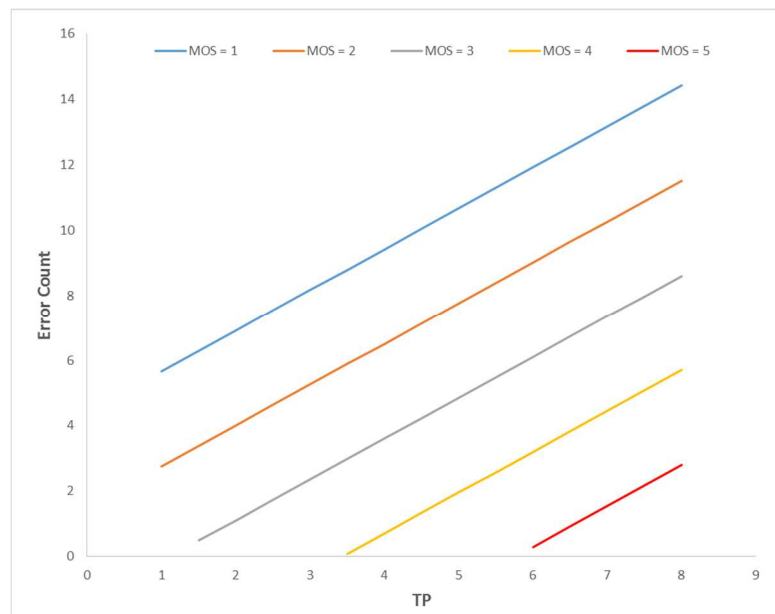


Figure 12: Prediction of MOS from throughput and error count.

There is still a great deal of unexplained variance that does influence subjective ratings. While completing the behavioral experiments, the researchers noted several factors that subjects commented on that may be influencing their opinion scores: Arm fatigue, inability to see the target due to camera placement, and device latency. Several users commented that even in short stints, having to hold their arm up to complete the task was exhausting, even with the one minute breaks between tasks. Additionally, the placement of the mid-range camera on the computer monitor created a “line-of-sight” issue. For example, for right handed subjects, if the target displayed on the right side of the screen, the subject’s arm would block their view of the target, and they would need to move their entire body to see around their own hand. Finally, several users complained of the “jumpiness” or lack of response from the cursor when using the gesture-based devices. This could be attributable to several factors, including frame rate delays in the camera, or the amount of time it takes for the input device to “feedback” data. Further analysis should be done in each of these areas to determine which of these factors may also be influencing usability of gesture based input devices.

This experiment followed the ISO 9241-411 (ISO/TS 9241-411, 2012) standard and assessed subjects’ performance with different devices using the behavioral measures such as throughput and error count. The remaining questions are: Are factors such as temporal and spatial resolutions, arm fatigue, camera placement, or system latency affecting the user’s mean opinion score and does the usage model for these gesture based inputs alter the application of Fitts’? These questions will also be investigated in future work.

CONCLUSION

In this paper, the ISO 9241-411 (ISO/TS 9241-411, 2012) standard was applied using a pointing task to evaluate and compare five input devices, including three gesture-based interfaces. The results demonstrated that Fitts' law can be generalized to 3D gesture interaction with computing devices, and consequently used to characterize gesture-based devices. As compared to mouse and touchscreen interfaces, gesture-based interface had lower throughputs; this presumably reflects the dimensionality of the motor behavior involved in using these devices. In addition, error counts – a measure of accuracy - for all input devices were found to be highly correlated with target width, but not movement distance.

Additionally, a subject's Mean Opinion Score regarding ease of use of the input types was obtained. Throughput and error count obtained from the pointing task was analyzed against the MOS score to determine if user experience could be predicted. Throughput and error count accounted for almost half of the variance in the usability rating. These same measures were also assessed against a device ranking that users performed after completing the task on all five devices. The results confirm that these two measures account for approximately 50% of the variance in device ranking as well. These findings can enable engineers to take a data-driven approach when designing gesture-based devices. Designers can make tradeoffs and informed decisions to allow for the best possible usability score given business goals, resources, and budgets.

REFERENCES

- Albinsson, P.-A., & Zhai, S. (2003). High Precision Touch Screen Interaction. *CHI*, 105 - 112.
- Brainard, R. W., Irby, T. S., Fitts, P. M., & Alluisi, E. A. (1962). Some Variables Influencing the Rate of Gain of Information. *Journal of Experimental Psychology*, 105 - 110.
- Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of Mouse, Rate-Controlled Isometric Joystick, Step Keys, and Text Keys for Text Selection on a CRT. *Ergonomics*, 601-613.
- Douglas, S. A., Kirkpatrick, A. E., & MacKenzie, I. S. (1999). Testing Pointing Device Performance and User Assessment with the ISO 9241, Part 9 Standard. *CHI*, 15 - 20.
- Fitts, P. M. (1954). The Information Capacity of the Human Motor System in Controlling the Amplitude of Movement. *Journal of Experimental Psychology*, 381 - 391.
- Guo, Y., Sales, H., Doherty, R., Waring, D., & Corriveau, P. (2010). *SUS vs. MOS*. Hillsboro, Oregon: Intel Corporation.
- Halarnkar, P., Shah, S., Shah, H., Shah, H., & Shah, J. (2012). Gesture Recognition Technology: A Review. *International Journal of Engineering Science and Technology*, 4648 - 4654.
- Hoffman, E. R., Drury, C. G., & Romanowski, C. J. (2011). Performance in one-, two-, and three-dimensional terminal aiming tasks. *Ergonomics*, 1175 - 1185.
- ISO/TS 9241-411. (2012). *Evaluation methods for the design of physical input devices*. Switzerland: ISO/TS.
- Jota, R., Ng, A., Dietz, P., & Wigdor, D. (2013). How Fast is Fast enough? A study of the effects of Latency in Direct-Touch Pointing Tasks. *CHI 2013*, 2291 - 2300.
- Karam, M., & Schraefel, M. (2006). *Investigating User Tolerance for Errors in Vision-Enabled Gesture-Based Interactions*. Venezia, Italy: ACM.
- Langolf, G., Chaffin, D., & Foulke, J. (1976). An investigation of Fitts' Law using a wide range of movement amplitudes. *Journal of Motor Behavior*, 113 - 128.
- MacKenzie, I. S. (1992). Fitts' Law as a Research and Design Tool in Human-Computer Interaction. *Human-Computer Interaction*, 91 - 139.

- Murata, A. (1999). Extending Effective Target Width in Fitts' Law to a Two-Dimensional Pointing Task. *International Journal of Human Computer Interaction*, 137 - 152.
- Murata, A., & Iwase, H. (2001). Extending Fitts' law to a three-dimensional pointing task. *Human Movement Science*, 791 - 805.
- Plamondon, R., & Alimi, A. M. (1997). Speed/Accuracy trade-offs in target-directed movements. *Behavioral and Brain Sciences*, 279 - 349.
- Prytz, E., Montano, M., & Scerbo, M. W. (2012). Using Fitts Law for a 3D Pointing Task on a 2D Display: Effects of Depth and Vantage Point. *Human Factors and Ergonomics Society Inc.* (p. 5). Sage.
- Ryu, Y., Koh, D., Ryu, D., & Um, D. (2011). Usability Evaluation of Touchless Mouse Based on Infrared Proximity Sensing. *Journal of Usability Studies*, 32-39.
- Shannon, C. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, 379-423.
- Soukoreff, R. W., & MacKenzie, I. S. (2004). Towards a standard for pointing device evaluation, perspectives on 27 years of Fitts' law research in HCI. *International Journal of Human-Computer Studies*, 751 - 789.
- Steinberg, G. (2012). *Natural User Interfaces*. Austin: ACM.
- Van Galen, G. P., & De Jong, W. P. (1995). Fitts' law as the outcome of a dynamic noise filtering. *Human Movement Science*, 539-571.
- Wachs, J. P., Kolsch, M., Stern, H., & Edan, Y. (2011). Vision-Based Hand-Gesture Applications. *Communications of the ACM*, 60 - 71.
- Zeng, X., Hedge, A., & Guimbretiere, F. (2012). Fitts' Law in 3d Space with Coordinated Hand Movements. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 990 - 994.
- Zhai, S. (2004). Characterizing computer input with Fitts' law parameters - the information and non-information aspects of pointing. *International Journal of Human-Computer Studies*, 791 - 809.
- Zhai, S., Kong, J., & Ren, X. (2004). Speed-accuracy tradeoff in Fitts' law tasks - on the equivalency of actual and nominal pointing precision. *International Journal of Human-Computer Studies*, 823 - 856.
- Zhang, X., & MacKenzie, S. (2007). *Evaluating Eye Tracking with ISO 9241 - Part 9*. Berlin : Springer-Verlag .

APPENDIX A
FACILITATOR TEST SCRIPT

Fitts' Study Facilitator Script for Study Two

Before participants arrive:

1. Make sure the table and the experiment space are clean
 2. Make sure the input methods are ready for demonstration
 3. Make sure that the names of each input method cannot be seen on the gesture based cameras.
 4. Ensure the rating scale is printed and displayed on the table
 5. Have the input method randomization order ready
 6. Make sure the consent forms are printed and ready
 7. Have water and candy/snacks available
 8. Have hand sanitizer and tissue ready
 9. Make sure the incentives for the participants are ready (if external)
-

PRE-DATA COLLECTION INSTRUCTIONS: Allocated time = 10 minutes

Introduction and Housekeeping

[For external:]

Before we begin, please read and sign the Informed Consent form, which describes today's study and your rights. When you are finished if you need to use the restroom, now would be a good time to do so.

[For Internal:]

Before we begin, please read and sign the Informed Consent form, which describes today's study and your rights. Would you like to grab a drink or use the restroom before we start?

Thank you for coming in today, we really appreciate your participation! Let me go over some lab housekeeping information before we start.

- The session will take approximately 45 minutes.

- If you have a cell phone, please silence it now.
- Please keep food and drinks a safe distance from the testing equipment
- There are no scheduled breaks during the study, but if at any time you feel you need a break, please let me know.
- Since all participants will be using this same device, we ask that you sanitize your hands with the hand sanitizer provided to protect you, other participants, and the equipment. Also, we ask that you please sanitize your hands anytime you enter the room prior to touching the devices. [Facilitator provides hand sanitizer and wipes.]
- Questions regarding further details about the purpose of this study can be answered once this session is over.

Study Objectives

In today's study, you will be using five input methods to complete a computer based task: A Mouse input, a Touchscreen input and three gesture based inputs.

For the task, two types of targets will be displayed on the screen: a home target which is a square that will always appear in the center of the screen, and a solid black circle that will vary in size and location from one task to the next. Your task is to select the home target and then move to and select the solid black circle as fast as you can without sacrificing accuracy. It's okay if you accidentally hit outside the target, but try your best to move as error-free as possible. If you miss the target, try clicking it until it disappears.

Study Procedures

You will repeat the tasks multiple times for each input method. There will be several short breaks between tasks that will be indicated to you. Don't worry if you haven't used any of these input methods before. I will demonstrate how to use each input method before we get started.

Once you complete the tasks for each input method, you will be asked to rate the ease of use. When answering, consider factors such as how easy it was for you to control the cursor and how fast and accurately you were able to complete the task using that input method.

You will be rating the ease of use with the following 5 point scale. [*Gesture to scale on desk*]

At the completion of this study, we will have a brief survey.

Are there any questions so far?

Input Method Usage Demonstrations

I will now demonstrate how to use the first input method. *[Use the randomization schedule to determine the order in which you demonstrate and conduct the tests]*

Mouse

Using the mouse, move the cursor to the home button, click to select it which starts the task. Move as quickly and accurately as you can to the circle target and click the mouse to select it which ends that task. *[Demonstrate]*

[Once Demonstration Complete] You can start this test whenever you are ready. Just select the home target to get started.

[Once all three trials are complete] Using the scale in front of you, how would you rate the ease of use for this input method?

[Facilitator logs the answers in excel spreadsheet. Move to next device.]

Touchscreen

For this task, you will tap your finger on the home button to select it. Move your finger as quickly and accurately as you can to the circle target and tap it to end the task. If that target does not disappear, please touch it again. *[Demonstrate]*

[Once Demonstration Complete] You can start this test whenever you are ready. Just select the home target to get started.

[Once all three trials are complete] Using the scale in front of you, how would you rate the ease of use for this input method?

[Facilitator logs the answers in excel spreadsheet. Move to next device.]

Gesture Method 1: *[Each device will be labeled P, L, or S – no device names should be given during the course of this study]* **Method P**

This input method is based on gesture. You will see the camera attached to the top of the laptop; raise your dominant hand in front of the laptop screen with your palm open and facing the device. Once your hand has been detected, a green light will flash. While holding the presentation clicker in your free hand, move your gesture hand around until the cursor on the screen is hovering over the home target. Then

click one of the small side buttons on the presentation clicker to make the home target disappear. Once the home target disappears, move your gesture hand as quickly and accurately as you can to the target circle. Once you are inside the target circle, click one of the small side buttons on the presentation clicker again to end the task. *[Demonstrate]*

[Once Demonstration Complete] You can start this test whenever you are ready. Just select the home target to get started.

[Once all three trials are complete] Using the scale in front of you, how would you rate the ease of use for this input method?

[Facilitator log answers in excel spreadsheet.]

Gesture Method 2: *[Each device will be labeled P, L, or S – no device names should be given during the course of this study]* **Method L**

This gesture input method sits flat on the desk between you and the laptop keyboard. Please place your dominant hand above the input controller with your palm open. Then use your index finger to move the cursor on the screen. Once your finger has been detected, place the presentation clicker in your free hand. Move your gesture hand so that the cursor is over the home target and click one of the small side buttons on the presentation clicker with your other hand to make the home target disappear. Then move your gesture hand as quickly and accurately as you can to the target button. Once you are inside the target button, click one of the small side buttons on the presentation clicker to end the task. *[Demonstrate]*

[Once Demonstration Complete] You can start this test whenever you are ready. Just select the home target to get started.

[Once all three trials are complete] Using the scale in front of you, how would you rate the ease of use for this input method?

[Facilitator log answers in excel spreadsheet.]

Gesture Method 3: *[Each device will be labeled P, L, or S – no device names should be given during the course of this study]* **Method S**

For this gesture input method, you will see the camera directly behind the laptop. Raise your dominant hand in front of the laptop screen with your palm open and facing the device. Once your hand has been detected, hold the presentation clicker

in your free hand and move your gesture hand around until the cursor on the screen is hovering over the home target. Click one of the small side buttons on the presentation clicker to make the home target disappear. Then move your hand as quickly and accurately as you can to the target button. Once you are inside the target button, click one of the small side buttons on the presentation clicker to end the task. *[Demonstrate]*

[Once Demonstration Complete] You can start this test whenever you are ready. Just select the home target to get started.

[Once all three trials are complete] Using the scale in front of you, how would you rate the ease of use for this input method?

[Facilitator log answers in excel spreadsheet.]

Thank you for your participation in this study! Now that you have completed all of the tasks for each input method, I have several questions for you.

- 1) Before assisting us with this study, have you had any experience with gesture based input methods, like PC gesture cameras or Microsoft's Kinect system? If yes, what have you used?
- 2) Of all of the input methods you used today, can you rank them in order of preference, with 1 being your most preferred and 5 being your least preferred?
- 3) Of all of the gesture based input methods you used today, can you rank them in order of preference, with 1 being your most preferred and 3 being your least preferred?

After the study

Thank you for your participation! I'll walk you out.

DATA COLLECTION: Allocated time = 30-45 minutes, depending on the speed of the participant

Checklist for the facilitator:

1. Make sure the participant ID is correct
2. Make sure the participant is using the correct input method

3. Make sure the participant is positioned correctly for the gesture input methods to work properly
4. Make sure the settings are preloaded into the program correctly
5. Make sure to record responses in the correct rows and columns in the spreadsheet
6. Observe the participants during each session and make note of anything that might influence the results

APPENDIX B
PARTICIPANT CONSENT FORM

Fitts' User Experience Study for Gesture Based Input Methods

OVERVIEW AND PURPOSE: Intel Corporation (“Intel”) is conducting a voluntary study to determine what defines a positive user experience for new gesture based technologies. The results of this study will be used to help developers of new gesture based technologies better understand their users and what will improve their experience with these devices. Intel will collect and use the information listed below pursuant to the terms contained in this form. Please review the form and submit any questions to the lead researchers listed below. If you consent to participate, please sign as indicated at the end of the form.

LEAD RESEARCHER: The lead researchers for this project are Rachael Burno rachael.a.burno@intel.com and Hannah Colett hannah.r.colett@intel.com with User Experience Research (UXR) at Intel Corporation. Also, Intel has contracted with Market Decisions Corporation to help facilitate this research. Market Decisions Corporation is required to comply with the terms set out in this form.

PROCEDURE: This research will consist of two components: 1) a series of basic computer-based tasks, in which you will be asked to select one target on the screen then move to the other target that appears on the screen using a mouse, a touchscreen, or a gesture based input method. 2) A brief question and answer session where you will rate your experience with each input method. This will take approximately 60 minutes to complete.

During this study we will be recording your interaction with the computer so that we can document anything that may have prevented you from completing the tasks as quickly and efficiently as possible. Additionally, we will document your responses during the question and answer session.

During the study, Intel will collect the following information from you:

- Your age
- Previous experience with gesture based computer interaction methods

POTENTIAL RISKS AND COSTS: The risks and discomforts associated with participation in this study are no greater than those ordinarily encountered while using gesture based technology. You will be compensated \$25.00 for participating in this study.

PRIVACY: Intel is committed to respecting your privacy. By agreeing to participate in the study, you will be providing the information described above. This information will be accessed and used only for the purposes of the study. Access to the information by Intel employees is subject to the Intel Code of Conduct. Intel may share information with Arizona State University solely for the purpose explained in this form. Any information

shared with third parties will be subject to the terms set out in this form and subject to a written confidentiality agreement.

We will keep the study information only as long as needed for our research but, in all cases, no longer than five (5) years. However, your name will be securely deleted within 60 days of conclusion of the study, and all remaining information will be organized by an anonymous participant number. The research materials that are shared within Intel under the terms of this consent, beyond the lead researchers, are identified by a pseudonym, not your real name. All research materials that contain personally identifiable information, like this consent form, are kept in a secure location for your protection. Intel's analysis and conclusions from the study may be retained indefinitely.

Intel may use research media (photographs, audio or video of you, if applicable) in public forums like academic conferences. If research media are used: (1) the images will only be used to enhance the validity of the research results and (2) Intel will crop or obscure images of non-participants (e.g. household members). Intel will not use these media for marketing and promotional purposes.

CONFIDENTIALITY: This study is confidential. You agree not to disclose any information about the study to anyone other than the Intel researchers and facilitators unless required by court or government mandate.

QUESTIONS AND CONCERNS: If you have any questions, concerns or complaints about this study or its procedures, please contact Intel's research leads, Rachael Burno rachael.a.burno@intel.com or Hannah Colett hannah.r.colett@intel.com or you can use the Contact Us form at (http://www.intel.com/sites/sitewide/en_US/privacy/contactus.htm), or send a letter to the mailing address listed below:

Intel Corporation
ATTN: Privacy
M/S RNB4-145
2200 Mission College Blvd.
Santa Clara, CA 95054 USA

Please include your contact information, name of the Intel study, the name of the Intel Lead Researcher or team conducting the study, and a detailed description of your request or privacy concern.

CONSENT/VOLUNTARY PARTICIPATION: Your consent to participate in this study is subject to the terms explained in this form. Your participation is completely voluntary and you may refuse to participate or leave the study at any time. If you decide not to

INTEL CONFIDENTIAL

participate in the study, or withdraw before the end of the study, it will not result in any adverse consequences to you. If at any time you decide not to participate, the consent form you signed will be destroyed, and all information gathered from you will be deleted. If you consent and participate in the study, you grant Intel and its affiliates permission to collect and use the information collected in accordance with these terms. Intel will own the information and materials collected and generated by the study including its analysis and conclusions, subject to any intellectual property rights you may have in the underlying information. You also grant Intel and its agents the right to use, reproduce, perform, display, distribute, and exercise all other rights in any information, comments or materials that you provide to Intel or its facilitator for the purposes explained in this document. You agree that you will not reveal any of your own private product concepts, inventions, or ideas that you may want to develop in the future.

SIGNATURE: By signing below, I agree that:

- The study has been explained to me, and I have had a chance to ask questions regarding the study.
- I understand and agree to comply with the terms in this form.
- I consent to participate in the study as explained in this form.
- I am at least 18 years of age, and I have full right and authority to sign this form.
[Delete when applying to Minors – use parental consent below]

Participant:

By: Name (Printed)

Participant Signature

Date

APPENDIX C

ASU IRB

Consent Form: Social Behavioral

Title of research study: *Psychophysical evaluation of gesture-based user interfaces*

Investigator:

Dr. Bing Wu, Assistant Professor in Dept. of Human Systems Engineering, Ira A. Fulton Schools of Engineering, Arizona State University.

Why am I being invited to take part in a research study?

We invite you to take part in a research study because you (1) are at least 18 years of age, (2) are NOT pregnant (if female), and (3) have normal or corrected-to-normal vision and no physical/mental disorders.

Why is this research being done?

Enormous effort has been devoted to developing natural interfaces that allows us to use computers in an intuitive way with Minority-Report-like gestures. However, far less has been done to investigate the behavioral issues associated with such interactions. Gesture-based interactions require 3D motor responses that are much more complicated than mouse or touchscreen uses. In addition, gesture-tracking devices often have relatively lower spatial and temporal responses, as compared to mice and touchscreens. How these factors influence user's performance will be examined in this study. We aim to gain a better understanding of the perceptual and motor processes involved in the gesture-based human-computer interaction.

How long will the research last?

We expect that individuals will spend about 1 hour participating in the proposed activities.

How many people will be studied?

We expect about 200 people will participate in this research study.

What happens if I say yes, I want to be in this research?

You are free to decide whether you wish to participate in this study. If you decide not to participate, there will be NO penalty to you, and you will NOT lose any benefits or rights to which you are entitled. If you agree to be in this study, you will be asked to sign this consent form.

The study will be conducted in Dr. Wu's research laboratory (Rm 223D & 233B, Simulator Building). The experimental apparatus will be mice (e.g., Logitech G400 high-precision mouse), touchscreens (e.g., Acer T232HL touchscreen monitor), and commercially available gesture interfaces (e.g., Microsoft Kinect sensor and Leap Motion controller). You will be asked to perform some simple computer operations using these devices. For example, you may be asked to control a cursor using a mouse or touchscreen or gesture interface, move the cursor to a target shown on a computer screen, and then click it. Or you may be asked to "grab" virtual objects with your hands and gesture interfaces or using a mouse or touchscreen, and then move the objects to a predetermined location in a 3D virtual environment. You will be asked to perform these tasks as quickly and accurately as possible. The response time and trajectory of your hand motion will be recorded. At the end of the experiment, you will also be asked to complete a short questionnaire to report your subjective experience with these interfacing devices.

You will receive 1 course credit for your participation.

What happens if I say yes, but I change my mind later?

Participation in this study is completely voluntary. It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time. Refusal to participate or withdrawal of your consent or discontinued participation in the study will NOT result in any penalty or loss of benefits or rights to which you might otherwise be entitled.

Is there any way being in this study could be bad for me?

There are no known risks from taking part in this study.

Will being in this study help me in any way?

We cannot promise any direct benefits to you or others from your taking part in this research. Your participation will help us to better understand the perceptual and motor processes involved in the gesture-based human-computer interaction. Such knowledge can be applied to the development of more efficient and natural interfacing technology.

What happens to the information collected for the research?

All information obtained in this study is strictly confidential. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, your data and consent form will be kept separate. Your consent form will be stored in a locked cabinet in Dr. Bing Wu's office (Santa Catalina Hall 150E) and will not be disclosed to third parties. Computerized data files will be encrypted. Paper data files will be kept in locked locations accessible only to authorized researchers. Your name, address, contact information and other direct personal identifiers in your consent form will NOT be mentioned in any publication or dissemination of the research data and/or results. In this study, you will be assigned a case number and your identity on all research records will be indicated only by that number. We will NOT collect or save any information that may associate that number with your identity.

Efforts will be made to limit the use and disclosure of your personal information, including research study records, to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the University board that reviews research.

Who can I talk to?

If you have questions, concerns, or complaints, please talk to

Bing Wu, Ph.D.
Dept. of Human Systems Engineering
Ira A. Fulton Schools of Engineering
Arizona State University
Santa Catalina Hall, Room 150E
7271 E. Sonoran Arroyo Mall
Mesa, AZ 85212
(412) 256-8168
(Bing.Wu@asu.edu)

APPENDIX D
INTEL PRIVACY PLAN

Intel Privacy Plan Form

Purpose of this document: To define the personal information details associated with your project or process and to help assist in the mitigation of any privacy related risks.

Definition of Personal Information: Any information relating to an identifiable individual that can identify, contact, or locate them. All personal information requires Intel Confidential or Intel Restricted Secret handling and protection requirements.



Note: An individual's right to privacy is not limited only to personal information, but also includes tracking an individual's online activities, or the use of surveillance/monitoring.

Instructions

This form should be completed by the Intel employee accountable for the project. 3rd party suppliers should not complete this form. Reference privacy.intel.com for additional Intel privacy resources.

If your project includes an Intel branded web site on the internet (externally facing) or external event, complete an ISEP Risk Assessment. Within two business days, a Risk Manager will be assigned to guide you through the security and privacy processes, including this Intel Privacy Form.

1. If you know your project involves personal information, go to Step 3.
2. If you are unsure if your project requires a privacy review, complete a Privacy Self Assessment. When you submit, you will receive a system generated email identifying next steps:

If the system generated email says...	Then...
<ul style="list-style-type: none">• ...“Your Privacy Self-Assessment has no identified privacy-related risks. No further action is required”.	An Intel Privacy Plan is not required. 
<ul style="list-style-type: none">• ...“Based on your responses, your project may include high-risk factors. You will be assigned a Privacy Analyst to help lead a required high risk assessment, which may result in additional documentation. Expect to be contacted by a Privacy Analyst within two business days.”	An Intel Privacy Plan is required.  Continue with the next step to save and submit the Intel Privacy Plan.

3. Save this Intel Privacy Plan Form with the following name "<insertprojectname> Privacy Plan.doc"
4. Submit this form to the Privacy Office.
 - Submit online using a service request
 - Send in email *To:* pt.post@intel.com (Intel Privacy Office).
 - *Cc:* *Your Privacy Analyst or ISEP Risk Manager, if one has been assigned through another engagement method (e.g. ISEP, Secure Outsourcing).*
 - At a minimum, ensure your business unit attorney is copied for low risk assessments, and the attorney is actively involved when medium/high privacy risks are identified.

Intel Confidential

5. Your Intel Privacy Plan will be reviewed by the Intel Privacy Office and you will be contacted by "PT Post" to advise you of next steps. If there are potential risks above 'Low', a Privacy Analyst will be assigned to work with you to assist in mitigating privacy risks.
6. A Privacy Analyst will complete section 5 and will include the risk assessment results and requirements.

You are accountable for the accuracy of the information provided in this form. Please be attentive to details, accuracy, and completeness in filling out the Privacy Plan. If you have any questions, please do not hesitate to contact us.

General Information

1.1 Project/Process/Service Name	User Experience Research (UXR) for Intel Perceptual Computing
1.2 Expected Launch/Implementation Date	May 26, 2014
1.3 Description of Project, Business Objective, and Targeted Audience <i>Example: "An online fitness website for internal employees to capture exercise performed, length of time, calories burned, and weight loss progress."</i>	The purpose of this study is to determine what defines a positive user experience for new gesture based technologies. The results of this study will be used to help developers better understand their users' needs and improve their experience with these devices.
1.4 Please provide any 3rd party vendor/suppliers providing a service for, or on behalf of, Intel. Provide the Name, Address, Country and service(s) provided. <i>Examples of service(s) provided: web hosting, development, credit card processing</i>	N/A
1.5 Project/Process Owner <i>Person responsible long term if there is a privacy concern.</i>	Rachael Burno rachael.a.burno@intel.com Rina Doherty rina.a.doherty@intel.com Hannah Colett hannah.r.colett@intel.com
1.6 Project/Process Owner's <u>Business Group/Division</u> <i>Example: IT</i>	Intel labs
1.7 Project/Process Owner's <u>Org Unit/Department/Team Name</u> <i>Example: IT Engineering - EIE</i>	IL-UXR-PCL-XAM
1.8 Project/Process Owner's <u>Business Unit Attorney's Name and Email Address</u>	Jeff Schneider: jeff.c.schneider@intel.com
1.10 Privacy Plan Submission Date	May 2014

1. Personal Information Collection, Use, and/or Sharing

<i>If you check Yes on any of the questions below, please review the provided policy/guideline before continuing, and describe how the information will be used.</i>	Yes	No
2.1 Is it possible your project will collect, use, and/or share any sensitive information that might be classified as Intel Restricted Secret ? <ul style="list-style-type: none"> Reference the Personal Information Classifications List for guidance. Examples include bank information, payment card information, government identification numbers, health/ medical information, etc. 		X
< If you answered Yes, please describe how this information will be used >		

Intel Confidential

<p>2.2 Is it possible your project will collect, use, and/or share biometric information for the purpose of identification/authentication?</p> <ul style="list-style-type: none"> • More information can be found in the Biometric Privacy Policy. • <i>Examples include fingerprints, voiceprints, facial recognition, DNA, retinal images, etc.</i> 		X
<i>< If you answered Yes, please describe how this information will be used ></i>		
<p>2.3 Is it possible your project will collect, use, and/or share children's information (under 18 years old)?</p> <ul style="list-style-type: none"> • More information can be found in the Children's Privacy Policy. • <i>Examples include children's full names, children's appearance in photos or videos, etc.</i> 		X
<i>< If you answered Yes, please describe how this information will be used ></i>		
<p>2.4 Is it possible your application or website may write a cookie to an individual's smartphone, tablet, or computer?</p> <ul style="list-style-type: none"> • More information can be found in the Intel Cookie and Other Tracking Technology Policy. • <i>Examples include using a cookie to target advertising to website visitors, to collect web analytic information (e.g. Google Analytics, Adobe Omniture, etc.), to secure an online payment, to set a language preference for future website visits, etc.</i> 		X
<i>< If you answered Yes, please describe how this technology will be used ></i>		
<p>2.5 Is it possible your project will collect, use, and/or share location information?</p> <ul style="list-style-type: none"> • More information can be found in the Geolocation Privacy Policy. • <i>Example include collecting location information from an individual's device (e.g. mobile phone, computer, GPS, etc.</i> 		X
<i>< If you answered Yes, please describe how this information will be used ></i>		
<p>2.6 Is it possible your project will collect, use, and/or share information to monitor workplace activity?</p> <ul style="list-style-type: none"> • Specific policies/guidelines are not available. • <i>Examples include video surveillance, device logging, communication recordings, etc.</i> 		X
<i>< If you answered Yes, please describe how this information will be used ></i>		
<p>2.7 Is it possible your project will use electronic messaging (email) to communicate with external individuals?</p> <ul style="list-style-type: none"> • More information can be found in the External Electronic Mail Privacy Policy and the email design guide. • <i>Examples include -mail blasts, subscription based newsletters, email a friend, using purchased contact lists, notifying contest winners, etc.</i> 		X
<i>< If you answered Yes, for what purpose is your project using email? ></i>		
<p>2.8 Is it possible your project will use SMS/mobile messaging to communicate with external individuals?</p> <ul style="list-style-type: none"> • More information can be found in the Mobile Marketing Privacy Policy and the Mobile Messaging design guide. • <i>Examples include individual's texting Intel for information or Intel texting individuals to supply information, etc.</i> 		X

Intel Confidential

< If you answered Yes, please describe how this information will be used>		
<p>2.9 Is it possible your project will collect, use, and/or share an individual's information at trade shows or virtual events?</p> <ul style="list-style-type: none"> • More information can be found in the Trade Shows and Events Guidelines. • <i>Examples include collecting an individual's business card for giveaways, scanning an individual's badge for later receiving marketing materials, recording online chats, etc.</i> 		X
< If you answered Yes, please describe how this information will be used>		
<p>2.10 Is it possible your project will collect, use, and/or share photographs, audio, or video recordings of Intel employees, Contingent Workers, or external individuals?</p> <ul style="list-style-type: none"> • More information can be found in the Audio/Video Recording Policy and Privacy Guidelines for Recording of Individuals. • <i>Examples include recording Intel BUMs, Intel family events, external educational or marketing promotions</i> 	X	
<i>May record or take pictures of study participants as they use gesture based input to include in study report.</i>		
<p>2.11 Is it possible you will collect, use, and/or share personal information on the Internet (external website)?</p> <ul style="list-style-type: none"> • More information can be found in the Online External Presence Privacy Guidelines. • <i>Examples include registration web forms, social networking sign-ups, contests, sweepstakes, online chats,</i> 		X
< If you answered Yes, please describe how this information will be used>		
<p>2.12 Does your project include a mobile application that will be available for download from an external storefront?</p> <ul style="list-style-type: none"> • More information can be found in the Mobile Application Privacy Requirements. • <i>Examples include applications that are available through application distribution platforms (storefronts) such as the Apple App Store, Amazon, or Google Play.</i> 		X
< If you answered Yes, please describe how this information will be used>		

3. Personal Information Details

Use the Appendix at the end of this document to provide additional details that will help with the privacy assessment.

<p>3.1 What specific information will be collected, used, and/or shared from individuals?</p> <ul style="list-style-type: none"> • Please provide in the table. An example is provided in orange. • Reference the Personal Information Classifications List to determine if the information collected is Intel Confidential or Intel Restricted Secret. • Include personally identifiable information; including user generated content such as pictures, videos, text, files, should be captured in the table (policy).

Intel Confidential

Information Description [data elements]	Example	Information Classification [Intel Confidential, Intel Restricted Secret]	Information Shared with or Collected by a 3 rd Party or Subsidiary? [Yes/No]	Information Shared with another Internal Business Unit? [Yes/No]	Role(s) of individuals you are receiving personal information from [employee, consumer, supplier, etc.]	How will this data element be used?
Age	40 Yrs.		Yes	No	Employee, external study participant	To identify potential differences between age groups with regards to air gesture computer input methods.
Image of study participant using air gesture		Confidential	Yes			
Video of participant using air gesture		Confidential	Yes			

3.2 A **purpose statement** must be displayed to users at the point where your project will collect personal information. Provide the purpose statement you plan to display.

*The purpose statement should describe **why** Intel is collecting the personal information, **how** it will be used, and **how long** will it be retained.*

Example (customize the orange text for your project):

Intel is committed to respecting your privacy. By completing this <form> you are providing Intel your personal information. This information will be used only for the purpose of <enter purpose here>. To learn more about Intel's privacy practices, please visit <http://www.intel.com/privacy>.

You can choose whether to participate in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences to you. If you decide to leave the study early, your consent form and all your research materials will be destroyed.

PRIVACY

Intel is committed to respecting your privacy. By completing this form you are providing Intel your personal information. This information will be used only for the purposes described above. To learn more about Intel's privacy practices, please visit <http://www.intel.com/privacy>.

	<p>The research materials that are shared within Intel under the terms of this consent, beyond the principal investigators, are identified by a pseudonym, not your real name. All research materials that contain personally identifiable information, like this consent form, are kept in secure location for your protection. We will retain the research materials only as long as we need them for our research, but will not keep this consent form for more than five years.</p> <p>Intel sometimes uses research media (photographs or video of you) in public forums like academic conferences. If research media are used: (1) the images will only be used to enhance the validity of the research results and (2) Intel will crop or obscure images of household members. Intel will not use these research media for marketing and promotional purposes.</p>
<p>3.3 Select the appropriate Intel approved <u>privacy notice</u> that your project will use:</p> <ul style="list-style-type: none"> • For external use: <u><i>Intel's Online Privacy Notice</i></u> • For internal use: <u><i>Intel's Employee and Global Contingent Worker Privacy Notice</i></u> • If cookies are used on a website: <u><i>Intel's Cookie Notice</i></u> <p><i>If your business unit attorney creates a Terms of Use (also known as Terms or Terms and Conditions), please provide link,</i></p>	<p><u><i>Intel's Online Privacy Notice</i></u></p> <p><u><i>Intel's Employee and Global Contingent Worker Privacy Notice</i></u></p>

Intel Confidential

<p><i>attach, or include in the appendix. Also attach custom notices and/or consent forms, or include in the appendix.</i></p> <p><i>Example: www.intel.com <u>Terms of Use</u></i></p>	
<p>3.4 When the personal information is no longer required, it should be deleted/removed. Describe the operational process you will use to ensure this happens. See the <u>Retention standards for more info</u>.</p> <ul style="list-style-type: none">• How long will the information be kept before it is deleted/removed?• How will the information be deleted/removed?• Who is the Intel person responsible for deleting/removed the information?	<ul style="list-style-type: none">• When: 5 years• How: <u>Destroyed as per Intel guidelines Security DSR 40.D4- "Dispose classified Document and Information Media"</u>• Who: Rachael Burno rachael.a.burno@intel.com

4. Appendix - Additional Information

<p>Insert images, URLs, and/or mock-ups of the implementation of privacy policies. Examples: architecture, data flow diagrams, Terms of Use etc.</p>

5. Privacy Risks and Controls

This section describes the risks and controls identified for this project, and will be completed by the Intel Privacy Office.

a. Privacy Representative	<insert name>																	
b. Security Representative	<insert Name and Role> <i>Example: ISEP, Risk Manager, Security Architect, etc</i>																	
c. Initial Risk <i>(if no controls are implemented)</i>	Select One: High, Medium, Low																	
d. Residual Risk <i>(if controls are implemented)</i>	Select One: High, Medium, Low																	
e. Privacy Risks and Required Controls	<table border="1"> <thead> <tr> <th data-bbox="508 846 764 877">Risks</th> <th data-bbox="764 846 1024 877">Required Controls</th> <th data-bbox="1024 846 1372 877">Notes</th> </tr> </thead> <tbody> <tr> <td data-bbox="508 877 764 1125"> <i>Select a risk category:</i> <ul style="list-style-type: none"> Intel Policy Compliance Brand Risk Risk to individual Data protection </td> <td data-bbox="764 877 1024 1125"> <i>List the privacy requirements the customer is expected to implement, prior to go-live.</i> </td> <td data-bbox="1024 877 1372 1125"> <i>Specific information shared with the customer to implement the controls, including policy and guidance urls, why legal approval is required, capture if there is an AR- Tracker AR, etc.</i> </td> </tr> <tr> <td data-bbox="508 1125 764 1186">1.</td> <td data-bbox="764 1125 1024 1186"></td> <td data-bbox="1024 1125 1372 1186"></td> </tr> <tr> <td data-bbox="508 1186 764 1247">2.</td> <td data-bbox="764 1186 1024 1247"></td> <td data-bbox="1024 1186 1372 1247"></td> </tr> <tr> <td data-bbox="508 1247 764 1283">3.</td> <td data-bbox="764 1247 1024 1283"></td> <td data-bbox="1024 1247 1372 1283"></td> </tr> </tbody> </table>			Risks	Required Controls	Notes	<i>Select a risk category:</i> <ul style="list-style-type: none"> Intel Policy Compliance Brand Risk Risk to individual Data protection 	<i>List the privacy requirements the customer is expected to implement, prior to go-live.</i>	<i>Specific information shared with the customer to implement the controls, including policy and guidance urls, why legal approval is required, capture if there is an AR- Tracker AR, etc.</i>	1.			2.			3.		
Risks	Required Controls	Notes																
<i>Select a risk category:</i> <ul style="list-style-type: none"> Intel Policy Compliance Brand Risk Risk to individual Data protection 	<i>List the privacy requirements the customer is expected to implement, prior to go-live.</i>	<i>Specific information shared with the customer to implement the controls, including policy and guidance urls, why legal approval is required, capture if there is an AR- Tracker AR, etc.</i>																
1.																		
2.																		
3.																		
f. Validation Instructions	<p><i>Instructions to access the product/app/service, to ensure the privacy controls, provided to the customer, were implemented. When possible, include:</i></p> <ul style="list-style-type: none"> <i>website url</i> <i>the name of the app and where it can be accessed</i> <i>a link to the product security requirements or SAFE materials (SDL)</i> <i>the name of the person who can grant temporary access, demo the solution, or provide screenshots</i> <i>etc</i> <p><i>Example: from iTunes or Google's Play Store, search Intel ABC App.</i></p>																	

Intel Confidential

g. Reviews & Approvals (as required)	Name	Role	Approval Date
	<name>	<Example: BU Legal, Privacy Legal, Director of Investigations, Threat Intelligence & Privacy>	<date reviewed>
h. Other	<Emails, meeting notes, etc>		

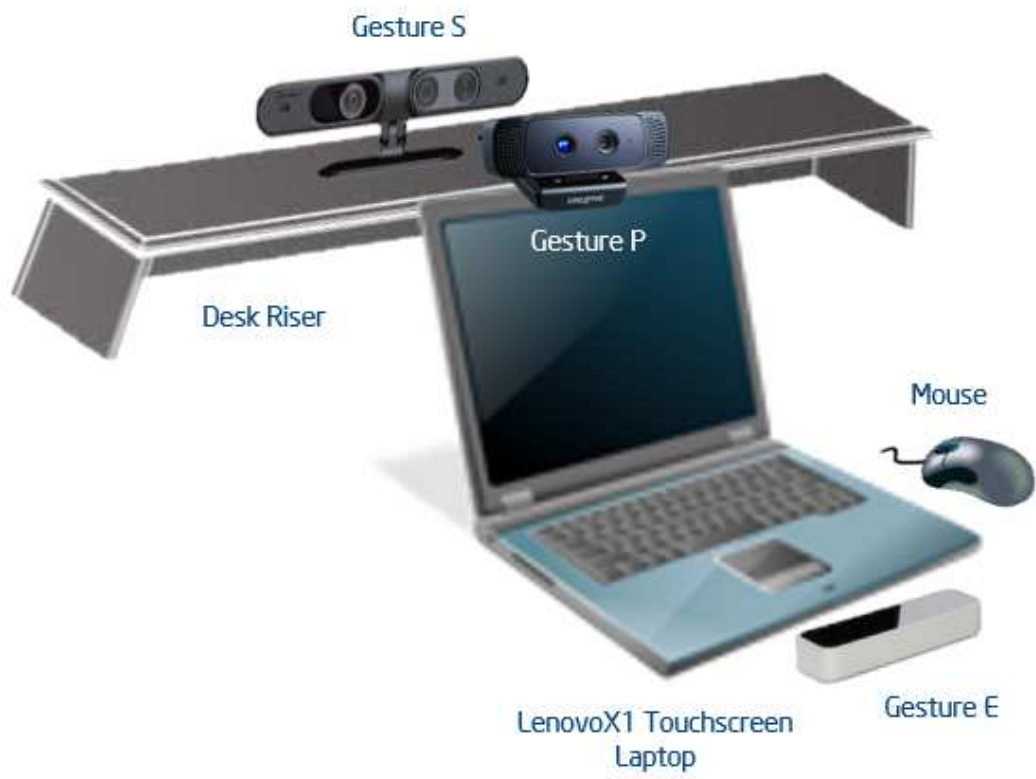
--

Date: Nov 2013, Revision: 4.20

APPENDIX E
SURVEY RESPONSE TEMPLATE

	A	B	C	D	E	F	G	H	I	J	K
1	Participant ID	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110
2	What is Input 1 (M, T, P, L, S)?										
3	How would you rate the ease of use of this input device?										
4	What is Input 2?										
5	How would you rate the ease of use of this input device?										
6	What is Input 3?										
7	How would you rate the ease of use of this input device?										
8	What is Input 4?										
9	How would you rate the ease of use of this input device?										
10	What is Input 5?										
11	How would you rate the ease of use of this input device?										
12											
13	At the end of the study:										
14	Of all of the input methods you used today, can you rank them in order of preference, with 1 being your most preferred and 5 being your least preferred?										
15	Please Explain										
16											
17	Previous Experience										
18	Have you ever used any devices involving air gesture movements to control the system before today (e.g.: Microsoft Kinect, USB enabled gesture device)?										
19	If yes, which one(s)?										
20											
21	If yes, what was your level of satisfaction with that device?										
22											
23	Demographics										
24	Age										
25	Gender (Male/Female)										

APPENDIX F
TESTING APPARATUS SETUP IMAGE

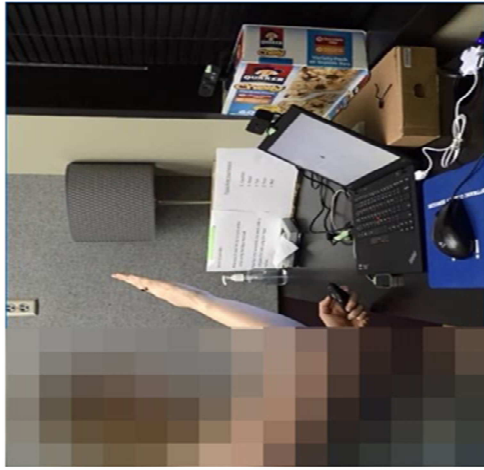


APPENDIX G

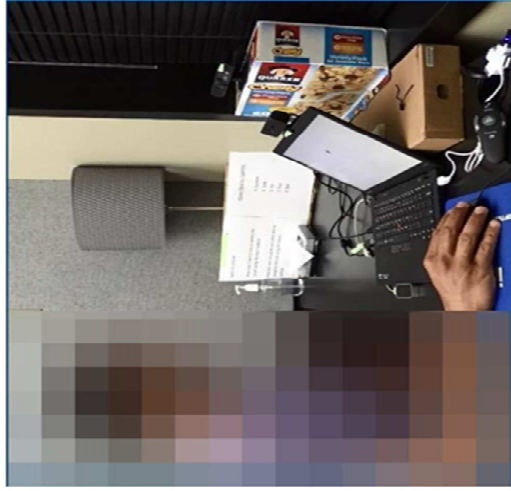
USER INTERACTION WITH TESTING DEVICES

Example Users

Gesture



Mouse



Touch

