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IE 577 Human Factors

Design Project Description

| Reaction Times via Varying Interface Methods |

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December 6th, 2021

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# Section 1 | **Introduction**

When a hazardous event begins to escalate into a mishap event, individuals may respond quickly to the situation to limit the impacts of the mishap or possibly stop the event from propagating altogether. This study proposes software to test an individuals' reaction time during onset events with various input methods. This proposed software design includes developing clear criteria for evaluating this or similar software. These criteria will be used to analyze reaction time data gathered through a prototype module created in Scratch, a visual coding service, and the Lifelong Kindergarten Group project at the MIT Media Lab (n.d). This project will impact various industries, including military, manufacturing, and agriculture but, this study will focus mainly on the manufacturing sector for reaction-based events. The main research question for this study is, in case of manufacturing machine failure, such as a CNC mill or lathe, or process error that needs to be corrected rapidly, which type of interface control produces the least response delay from a human? The second question is what principles of human factors engineering will be used to evaluate the design of this software? The third question is to what extent was the prototype able to gauge participants' reaction time?

In comparing the performance of different control devices, Baber (1997) found a tradeoff between speed and accuracy in positioning devices. The study tasked participants with interacting with an object on a screen and "dragging" that object to a given position. Baber defined two categories of devices, direct position controls in which the movement and position of the human body directly correspond to the cursor's movement, i.e., Touchscreen, light pen. The second category, described as indirect control, has the human movement corresponding to the motion, but the surfaces are not connected, i.e., Mouse, trackball, and isometric joystick. Baber found that the largest benefit of direct control devices was the control for complex positioning tasks such as handwriting but lacked the precision afforded to many indirect methods such as a mouse. Baber suggests that a tradeoff between speed and accuracy will control the best interaction method for a stop control device (1997). Ensuring the ease of access to this stop command by lowering its complexity will allow for a faster reaction time as less time will be required in positioning. More research is needed into interaction methods as in the nearly twenty-five years since Baber's study, the proliferation of technology in the general public, especially that of Touchscreen and other direct control devices, may have altered the perceived preference of these devices.

In a 2016 article published by statcounter, they noted that worldwide mobile and tablet internet usage had exceeded desktop usage for the first time (Simpson, 2016). The recent shift in technology from mostly stationary devices to mobile creates new avenues for research in mental chronometry as what was once a niche interface device is now the most common way individuals interact with a digital environment. Similarly, joysticks have seen a meteoric rise in popularity for controlling objects in video games. The Entertainment Software Association (ESA) estimates that nearly 227 million Americans play video games, with 57% of the respondents using a smartphone for gaming while 42% are playing on a personal computer, and 46% are playing on a game console such as the Nintendo Switch, PlayStation 4, or Xbox One (Samdo 2021). This increase in familiarity and increased muscle awareness could result in a faster reaction time, but more research is needed to assess the impacts of the proliferation of video games and smartphones on reaction time.

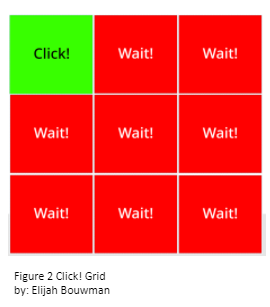
Currently, the only reaction time test available online can only accept one of two inputs, either Mouse or Touchscreen, depending on if it was designed for mobile or desktop computers. These tests allow users to interact with a screen that changes color and when the screen changes and the interaction is displayed or recorded. To help reliability, these software applications tend to run locally, even if they are found online. This software lacks the ability to test different methods of interaction such as joystick or keyboard, and they do not account for either hardware or software differences or hindrances. Many of these tests clearly list these limitations on their websites, but subsequent research needs to address these shortcomings "Human Benchmark" (2007).

# Section 2 | **Methods**

To answer research question number two, evaluation guidelines need to be established. The two principles of human factors engineering are "know thy user" and "recognition of individual differences" (Stone, 2021). Keeping these two principles in the forefront will help to ensure a thorough approach to data collection. Many factors influence an individual's reaction time and making sure the data is clear enough to make it possible to confidently distinguish between individuals and noise is key to a good software tool. For the software to be reliable, it will be evaluated on how it handles and accounts for software and hardware limitations and differences and human limitations and affordances.

The proposed reaction time software will have a grid of squares that shows a red image showing "Wait!" with variable dimensions, but the simplest would be a three by three or two by two format. In a three-by-three format, one of the nine squares will change into a green "Click!" sign, shown in Figure 1 below, when the participant interacts with the square. A built-in timer records when the square turns green, and the participants must maneuver to the square and interact with it as quickly as possible. The built-in timer records when the participant interacts with the green target square or accidentally interacts with another square that is not the target square. The test would measure the milliseconds for participants to interact with the screen as it changes color and repeat this test five times to get a more meaningful average response time. While the location of the green square might appear random to a participant, researchers can preselect them ahead of time to test different individuals on the same set of squares.

**Figure 1**

*Click! Grid*

The timer function is key to reliable data. The hardware and software used to collect this data can impact the accuracy of the timer function. When it comes to hardware, there are various sources of variation, screen refresh rate, memory allocation to delay from the input device depending on its connection type being wired or wireless. Most modern computer screens use a 60Hz refresh rate which determines the time between two discrete display frames (Simmons, 2021). If a computer monitor is displaying at 120Hz, there are only 8.33ms between frames, which is twice as fast as a 60Hz display that shows a new frame every 16.66ms. While this seems like a small amount of time, the range of human reaction times is between 113ms and 528ms introducing up to 10% error in the display lag between when the program switches to the green square, and the participant can begin to perceive the target (Stone, 2021). The display response time must be reported in the software to account for this error unrelated to the participant.

When evaluating the software for mobile, these hardware factors are just as variable. There is little standardization between the display characteristics of many mobile devices, and for this reason, the software should always be used on a single test device with the brightness set to max and notification disabled (Pronk, 2019). The way the phone is held can also impact the results as attempting to touch the screen with the thumb of the hand holding the phone will result in a different time than that of using a secondary hand to interact with the screen. The proposed software will need to indicate how the subjects are being tested for the touchscreen as to not introduce error and unexplained variation to the data.

The types of input methods also need to be controlled. While there are differences in individuals’ reaction time there are also differences in input delay caused by the way they are connected to the testing software and the type of device they are. The actuation distance is the amount of distance covered before an input is recognized. A touchscreen has an actuation distance of however far away a subject holds their finger from the screen, while a subject might rest their finger on the mouse or keyboard and have the actuation distance set by a mechanical limitation. The software will need to account in differences in input brand and construction as two keyboards may have different actuation distances and impact the results of the test. Similarly, the way a device is connected to the testing software via either wireless, i.e., Bluetooth. Wireless USB, or wired may impact the time required for signal to be sent back to the software.

Fitts' law allows researchers to calculate the time a movement will take based on the distance to and size of the target. Fitts's law is important to consider when determining the difficulty of a movement as it allows for researchers and developers to calculate both the time it takes to reasonably reach for control and a quantifiable metric for the difficulty of the task. For stop conditions, Fitts' law means the device or button needing to be interacted with should be as large as reasonably possible to minimize the time it takes to get into position for using the device. Likewise, Eagle et al. (2007) explained that the stop-signal reaction-time (SSRT) task measures the ability of individuals to stop. Sometimes, the person acts impulsive, which could be channeled to allow for swift stop conditions if paired with other design principles.

Tun and Lachman (2008) demonstrated the effects of age, education, and sex on complex reaction time. Slower responses were found in older adults, lower education, and women. It was important to include gender and age in the demographic information design to see any difference between responders. For the study, it is important to measure if the participant is familiar with technology instead of measuring the education level. Because the participant could have a low education level, but he could easily use the computer. Understanding who the test subject is and being able to account for these

Norman's affordance, (Stone, 2021), states the test results can be dependent on the experience, knowledge, culture of the actor. In this project, the demographic survey asked how familiar you with technology (Figure 1) are, and this question covers the participant's experience, knowledge, and culture. The colors chosen might have an effect on response time as they impact both the nature of the signal and the cultural conditioning surround the test. Red being a color that draws a swift reaction from subjects may cause subjects to accidently interact with the wrong stimulus.

Harrison et al. (2016) explain that anticipation of action effects is a basic process observed even for key-pressing responses in a stimulus-response paradigm. Therefore, the effect of anticipation affects all, perceptual, cognitive, and motor. This creates an expectation effect in the data when the subject might be surprised by the first round of testing score substantially worse on round one, while being prepared for the subsequent rounds and scoring better. After the subject is expecting the target to appear they will be able to respond faster than when they were caught in a state of surprise.

# Section 3 | **Experiment**

To answer the third research question, a prototype was constructed in Scratch and would be used to give a preliminary answer to the first research question. This prototype was designed similarly to the described software above, but only consistent with one square instead of a grid of nine and could only accommodate three input methods, Mouse, keyboard, and touch screen.

For the prototype, the examiner conducted the experiment face to face to avoid errors. At the end of the reaction test, the examiner will take a screenshot of the results as evidence of the test. The demographic survey and the results obtained from the reaction time test will be input manually by the examiner into the google form.

1. **Demographic Information**

This survey is divided into six questions. Figure 2 shows the demographic information survey. The first question is the ID to identify the user (anonymous) with the reaction time test. Question 2 and 3 will measure the gender of males or females with different timing reactions.

**Figure 2**

Graphical user interface, application, Teams

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Graphical user interface, text, application, email

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Question 4 and question 5 will ask for the age and ethnicity to compare if the reaction time of an old or different group of ethnicities influences the test result. Finally, it is important to know how familiar the person with technology is because if the knowledge is about 1 or 2, it could be slower than a person who knows well the usage of an electronic device.

**Data Reporting for reaction time test**

Figure 3 shows the data reporting reaction time. The first question asks for the ID. The second question is about the method used for the test. Each participant should do it three times (Mouse, spacebar, and Touchscreen). The following questions ask about the results of the reaction time test, from round 1 to round 5.

**Figure 3**

*Data reporting for reaction time test.*

Graphical user interface, application, Teams

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Graphical user interface, application, Teams

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A correction will be done for outliers and comparing participants' performance between the three input methods. The main goal is to collect data from around 25 participants, including biographical data, test results, and a small exit survey about their inactions with the test. The goal of this prototype was to determine which of the three method types, mouse, spacebar, or touchscreen, produce the quickest reaction during the Reaction Time Test?

The test consisted of a version of the test described in Figure 1 with only one square. The design was done for simplicity, but also to test the validity of the Scratch software itself. After an input method was selected the red “Wait!” square would appear and after a random amount of time between three and five seconds the square would change to the green “Click!” square. The module would record the difference in timer values between when the square turned green and the software received the participant interaction. If the participant interacted with the green “Click!” square a blue “Good!” square would appear and the module would advance to the next round. If the participant interacted with the red “Wait!” square a brown “Try Again!” square would appear and reset the round. This would repeat until five successful rounds were completed.

Finally, a screen then displayed the five round reaction times in a list for recording. Researchers then entered that information in the previously discussed Google Forms for further analysis. When researchers were not present, participants were able to access this model on their personal devices and send a screenshot to the researchers of the results.

# Section 4 | **Procedure**

Each participant was asked a series of demographic questions before starting the module. The researchers loaded the Scratch module and waited for the browser to reach a stable speed. When a mobile device was used for the test, the screen was set to max brightness, and the notifications were turned off. Each participant completed five rounds of reaction time testing in each of the three methods for 15 rounds total. Each method was tested five rounds at a time, with researchers recording the times at the end of each set of five rounds. Images of the reporting tools are in Figure 3.

Each session lasted no more than 20 minutes with about three minutes for demographic questions and two minutes for setup and explanation. Each set of five rounds took no longer than four minutes to complete and the participants were given rest while the researchers recorded the times for that set. Then the next method was setup and tested.

# Section 5 | **Results**

Table 1 shows Min, Max, Mean (M), Median, SD, and Mode of the different methods. The Mouse average (.314), median (.323), and mode (.329) appear to be close to each other. The Spacebar average (.298), median (.296), and mode (.296 & .329) appear to be close to each other. The Touchscreen average (.324), median (.328), and mode (.333 & .363) appear to be close to each other. The variation around the mean for Mouse data set (SD= .09), Space bar data set (SD= .07), and Touchscreen data set (SD= .08) are small values, and there is no high difference between them. As a normally distributed data set's mode, mean, and median are equal, the Mouse, Space bar, and Touchscreen data set are highly likely to be normally distributed.

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| **Table 1** |  | |  | |  |  |  |  | | |  | | |
| *Descriptive Statistics for Mouse, Space bar and Touchscreen* | | | | | | | | | |  | | |
| Variable | | N | | Min | Max | M | Median | SD | Mode | | |
| Mouse | | 20 | | .033 | .494 | .314 | .323 | .09 | .329 | | |
| Space bar | | 21 | | .221 | .429 | .298 | .296 | .07 | .296 & .329 | | |
| Touchscreen | | 20 | | .108 | .495 | .324 | .328 | .08 | .333 & .363 | | |

Data was collected in Table 2. For the Mouse variable, the value of its skewness (-1.070) and kurtosis (4.861) is not close to zero, indicating not normal distribution. The normality cannot be accepted.

For the Space bar variable, the value of its skewness (.600) and kurtosis (-.514) are close to zero, indicating normality. Further, the skewness ratio to its SE is .501, and the kurtosis ratio to its SE is .972. Both ratios are within +/- 2, indicating a normal distribution. The normality can be accepted.

For the Touchscreen variable, the value of its skewness (-.397) and kurtosis (1.838) are not close to zero, indicating not normal distribution. The normality cannot be accepted.

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| **Table 2** | | | | | | | | |
| *Skewness and SE Results for Mouse, Space bar and Touchscreen* | | | | | | | | | |
| Variable | SE Skew | | Skew estimate | | SE Kurtosis | | Kurtosis estimate | | |
| Mouse | | .512 | | -1.070 | | .992 | | 4.861 | | |
| Space bar | | .501 | | .600 | | .972 | | -.514 | | |
| Touchscreen | | .512 | | -.397 | | .992 | | 1.838 | | |

**Graphical Depiction to Evaluate the Data Normality**

Figure 4 consists of the normal distribution of Mouse, Space bar, and Touchscreen. The three curves of normal distribution appear to be bell-shaped, symmetrical. In each normal distribution, the mean, median, and mode appear to be close to each other. Figure 5 includes the boxplots of the three methods. Both boxplots do not appear symmetrical, with the mean and median in the center. In addition, there are a few outliers. Based on descriptive statics, the variables do not meet the assumption of normality.

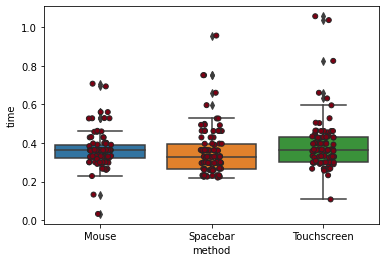
**Figure 4**

*Normal Distribution of Mouse, Space bar and Touchscreen*

Graphical user interface, chart

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**Figure 5**

*Boxplots of Mouse, Space bar, and Touchscreen* 

**Using the Shapiro-Wilk test for Assessing the Data Normality**

The Shapiro-Wilk test is utilized to assess whether the data is normally distributed. Researchers take the alpha level of .05. The hypothesis will not be accepted when the *p*-value is less than .05. Based on the R output, the results of the Shapiro-Wilk test (Shown in Table 3). The Touchscreen is the only group greater than .05. Thus, it is normally distributed. However, Mouse and Space bar are not normally distributed.

|  |  |
| --- | --- |
| **Table 3** |  |
| *Shapiro-Wilk Test Results* | |
| Variable | *p*-value |
| Mouse | .006 |
| Space bar | .041 |
| Touchscreen | .473 |

In the current research, Levene's test (Table 4) is utilized to test the homogeneity of variance. The alpha level is set as .05. The null hypothesis for this test is that the variances are equal, and the research hypothesis is different. According to the R output, Levene's test is F (2,58) =. 065, *p*=. 938. The *p* for Levene's test exceeds .05, resulting in failing to reject the null hypotheses. Thus, there is no statistically significant difference between the variances in the time. Hence, the conclusion that the assumption of homogeneity of variance has been met.

|  |  |
| --- | --- |
| **Table 4** |  |
| *Levene Test Results* | |
|  | *p*-value |
| Center Mean | .937 |
| Center Median | .938 |

**Select the Appropriate Test**

ANOVA test compares three groups, used when the variables are normally distributed. In this case, the assumptions did not satisfy the requirement. Thus, the Kruskal-Wallis test will be used for this research.

**Hypotheses**

The research hypothesis (that is the basis for H1) states that, on average, at least one group will outperform another group. The null hypothesis (H0) is stated to anticipate that the methods (Mouse, Space bar, Touchscreen) fail to shorten the time, indicating that on average, participants who are issued these alternative forms will take just as long to react as those who are issued the Mouse only; in other words, there is no difference between the reaction time among these three groups.

H1: At least one group outperforms another in terms of reaction time

H0: There is no difference in reaction time across the groups

**Kruskal-Wallis Test**

Table 5 shows the results of the Kruskal-Wallis Test. Since the *p-value* is more than .05, the groups have not detected a significant difference. Therefore, there is no evidence to reject the null hypothesis.

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| **Table 5** |  |  |
| *Kruskal-Wallis Test Results and Effect Size* | | |
|  | *p*-value | *Effect size* |
| Space bar & Touchscreen | .127 | .36 |
| Mouse & Touchscreen | .665 | .12 |
| Mouse & Space bar | .251 | .21 |

**Effect size**

The effect size is shown in Table 5. Salkind & Shaw (2020) mentioned Jacob Cohen's theory, which states the effect size as large, medium, and small. The effect size Mouse & Touchscreen (.12) are between 0 to .2, which means a small effect size. Thus, the Mouse and Touchscreen tend to be very similar; there is no mean difference between the two distributions. The effect size for Space bar & Touchscreen (.36), and Mouse & Space bar (.21) are between .2 to .5, which means medium effect size. Thus, there is no significant overlap between the Space bar & Touchscreen/ Mouse & Space bar and the reaction time.

shows the results of the study between the five rounds. In the beginning, the participants had a slow response compared with the following rounds. Participants gain more knowledge in the next rounds, understand more the logic and do faster than before.

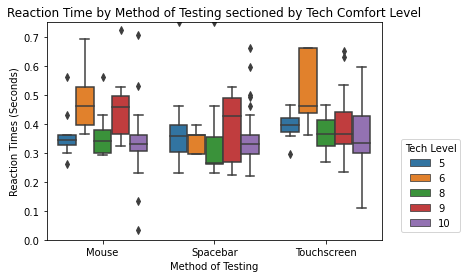
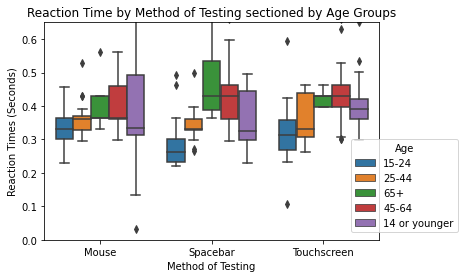
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 6** | | | | | | |
| *Round Anticipation and Acclimation* | | | | | | |
| **Group 1** | **Group 2** | **Diff** | **Lower** | **Upper** | ***q*-value** | ***p*-value** |
| Round 1 | Round 2 | 0.075 | 0.0139 | 0.136 | 4.769 | 0.007 |
| Round 1 | Round 3 | 0.087 | 0.0255 | 0.149 | 5.492 | 0.001 |
| Round 1 | Round 4 | 0.060 | -0.0008 | 0.121 | 3.833 | 0.055 |
| Round 1 | Round 5 | 0.057 | -0.0037 | 0.119 | 3.648 | 0.077 |
| Round 2 | Round 3 | 0.012 | -0.0487 | 0.073 | 0.771 | 0.900 |
| Round 2 | Round 4 | 0.015 | -0.0455 | 0.075 | 0.949 | 0.900 |
| Round 2 | Round 5 | 0.017 | -0.0431 | 0.078 | 1.116 | 0.900 |
| Round 3 | Round 4 | 0.027 | -0.0340 | 0.088 | 1.712 | 0.719 |
| Round 3 | Round 5 | 0.029 | -0.0316 | 0.091 | 1.875 | 0.653 |

Figure 6 shows the reaction time by the method of testing sectioned by Demographic Information. Females had a faster reaction time in terms of Spacebar and Mouse. Participants less than 14-year-old also had a faster reaction time in Spacebar and Mouse. Technology is also an important variable to be considered in terms of reaction time speed.

**Figure 6**

Chart, box and whisker chart

Description automatically generated*Reaction Time by Method of Testing sectioned by Demographic Information*

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# Section 6 | **Discussion**

Research question one was do determine which type of interface control produced the least amount of response delay in humans and while this study is not able to answer that question it establishes the framework for future work to continue this research. The second research question guided the construction of a prototype and principles of human factors will be used to evaluate the design of future software. These principles will be used to discuss the results of the prototype. Which leads to the third question to what extent was the prototype able to gauge participants' reaction time?

The prototype software did not produce any statistically significant difference in mean time based on the input method, which conflicts with previous research. This may be due to various sources of error present in the prototype that was not controlled for.

First, the time delay: it was discovered after testing that Scratch runs at a locked 30 frames per second, meaning the screen only updates once every .033 seconds. This source of error would impact any method tested in the Scratch software. For example, the mean human reaction time is around .314 for Mouse (Table 1), a 10% error when the screen decides to update adds an undo amount of error to the test results.

Second, the color confusion: The colors used are green, red, brown, and blue. Which red means "stop" (Wait), green "continue" (Click), and blue "Good job" (Good). Some of the participants misunderstood the blue color and clicked on a new message in brown that said, "Try again," and they were confused and wasted a few seconds to understand what had happened. The delay impacted the subsequent round putting the subject back into a state of surprise instead of expectation or anticipation. This confusion in signal should lead to further research using a simplified color palette. Ensuring clear understanding of the signal is critical to clear results.

Third, anticipation effect: Stone (2021) explains the importance of response expectancy. Participants anticipated the "click on" (Mouse, Spacebar, or Touchscreen) function to not miss the target. However, before the screen changed to green color, it created an error in the test. It was noted that several participants were attempting to “click” while the screen was displaying the red “Wait!” to preempt the change to the target condition. As the test did not log failed attempts, participants could attempt a round this way indefinitely to achieve a time outside the range of normally expected results. This introduced additional skew to the dataset as participants were competing for the fastest reaction time.

Fourth, differences in technology/hardware: It is important to know about the devices (mobile phone, tablet, light pen, or fingers), such as the speed, the year of the device, the size, and the shape. Stone (2021) describes all those characteristics that influence the results. For example, if the device is old, people's reaction is slower than a person with a new device. The current prototype was tested across a variety of devices with various software and hardware components. The study did not control for this factor and it may have influenced the results. More study with better documentation and a larger sample size is required.

Fifth, sample size: in this project, the sample size was not the ideal number, less than 30, and could not be representative of a population. Based on the normality distribution, the recommendation should be to get a sample size of more than 30 participants. This prototype study was conducted using only 20 participants. This size is small enough to where a few people with exceptionally slow or fast times have a great impact on the overall analysis. Similarly having a fast or slow round with a particular input method can overrepresent it in the analysis. The recommendation for having better test results is to consider the possible error before taking the reaction time test.

In summary the prototype failed to produce any meaningful results in analyzing research question one. Scratch is not recommended for the collection of further reaction time data and other software solutions should be researched. The guidelines established for research question two allow researches to evaluate those tools and eventually answer the original research question.

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# Section 8 | **Appendix**

Appendix 1: Response Time Results

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Timestamp | User ID# | Method used for Test | Round 1 | Round 2 | Round 3 | Round 4 | Round 5 |
| 44519 | 4973 | Mouse | 0.325 | 0.267 | 0.301 | 0.229 | 0.267 |
| 44519 | 4973 | Spacebar | 0.332 | 0.233 | 0.267 | 0.231 | 0.300 |
| 44519 | 4973 | Touchscreen | 0.299 | 0.266 | 0.290 | 0.266 | 0.299 |
| 44519 | 3007 | Mouse | 0.362 | 0.322 | 0.362 | 0.329 | 0.329 |
| 44519 | 3007 | Spacebar | 0.329 | 0.331 | 0.297 | 0.331 | 0.270 |
| 44519 | 3007 | Touchscreen | 0.307 | 0.364 | 0.299 | 0.330 | 0.308 |
| 44522 | 5678 | Mouse | 0.529 | 0.363 | 0.384 | 0.295 | 0.431 |
| 44522 | 5678 | Spacebar | 0.499 | 0.397 | 0.361 | 0.363 | 0.264 |
| 44522 | 5678 | Touchscreen | 1.599 | 0.363 | 0.428 | 0.825 | 1.056 |
| 44522 | 6948 | Touchscreen | 0.449 | 0.462 | 0.330 | 0.328 | 0.363 |
| 44522 | 6948 | Mouse | 0.332 | 0.429 | 0.363 | 0.364 | 0.333 |
| 44522 | 6948 | Spacebar | 0.362 | 0.361 | 0.365 | 0.329 | 0.330 |
| 44524 | 4660 | Mouse | 0.391 | 0.329 | 0.330 | 0.329 | 0.362 |
| 44524 | 4660 | Spacebar | 0.391 | 0.329 | 0.330 | 0.329 | 0.362 |
| 44524 | 4660 | Touchscreen | 0.455 | 0.297 | 0.261 | 0.330 | 0.268 |
| 44524 | 5396 | Mouse | 0.707 | 0.363 | 0.266 | 0.330 | 0.363 |
| 44524 | 5396 | Spacebar | 0.956 | 0.296 | 0.363 | 0.463 | 2.047 |
| 44524 | 5396 | Touchscreen | 1.454 | 0.397 | 0.358 | 0.396 | 0.595 |
| 44524 | 5333 | Mouse | 0.429 | 0.363 | 0.363 | 0.330 | 0.560 |
| 44524 | 5333 | Touchscreen | 0.429 | 0.464 | 0.398 | 0.431 | 0.396 |
| 44524 | 5333 | Spacebar | 0.364 | 0.463 | 1.241 | 0.751 | 0.396 |
| 44524 | 3369 | Mouse | 0.758 | 0.525 | 0.594 | 0.462 | 0.725 |
| 44524 | 3369 | Spacebar | 0.595 | 0.595 | 0.495 | 0.494 | 0.429 |
| 44524 | 3369 | Touchscreen | 0.496 | 0.495 | 0.561 | 0.560 | 0.693 |
| 44524 | 4272 | Touchscreen | 0.307 | 0.300 | 0.334 | 0.300 | 0.434 |
| 44524 | 4272 | Spacebar | 0.660 | 0.362 | 0.300 | 0.297 | 0.297 |
| 44524 | 4272 | Mouse | 0.401 | 0.362 | 0.329 | 0.298 | 0.363 |
| 44526 | 1000 | Mouse | 0.458 | 0.333 | 0.333 | 0.324 | 0.365 |
| 44526 | 1000 | Spacebar | 0.314 | 0.225 | 0.232 | 0.268 | 0.226 |
| 44526 | 1000 | Touchscreen | 0.359 | 0.276 | 0.297 | 0.233 | 0.264 |
| 44526 | 1001 | Mouse | 0.458 | 0.398 | 0.401 | 0.400 | 0.363 |
| 44526 | 1001 | Spacebar | 0.359 | 0.260 | 0.233 | 0.259 | 0.300 |
| 44526 | 1001 | Touchscreen | 0.327 | 0.359 | 0.362 | 0.332 | 0.367 |
| 44526 | 1002 | Mouse | 0.397 | 0.339 | 0.362 | 0.301 | 0.301 |
| 44526 | 1002 | Spacebar | 0.232 | 0.267 | 0.267 | 0.266 | 0.325 |
| 44526 | 1002 | Touchscreen | 0.401 | 0.333 | 0.325 | 0.267 | 0.267 |
| 44526 | 1003 | Mouse | 0.392 | 0.300 | 0.301 | 0.292 | 0.318 |
| 44526 | 1003 | Spacebar | 0.260 | 0.266 | 0.261 | 0.260 | 0.233 |
| 44526 | 1003 | Touchscreen | 0.425 | 0.325 | 0.300 | 0.366 | 0.359 |
| 44526 | 1004 | Mouse | 0.300 | 0.299 | 0.291 | 0.364 | 0.300 |
| 44526 | 1004 | Spacebar | 0.492 | 0.221 | 0.226 | 0.234 | 0.232 |
| 44526 | 1004 | Touchscreen | 0.299 | 0.292 | 0.108 | 0.266 | 0.257 |
| 44526 | 1005 | Mouse | 0.325 | 0.261 | 0.300 | 0.332 | 0.359 |
| 44526 | 1005 | Spacebar | 0.358 | 0.326 | 0.229 | 0.302 | 0.257 |
| 44526 | 1005 | Touchscreen | 0.358 | 0.367 | 0.297 | 0.392 | 0.397 |
| 44526 | 9360 | Mouse | 0.033 | 0.133 | 0.333 | 0.364 | 0.332 |
| 44526 | 9360 | Spacebar | 0.296 | 0.296 | 0.300 | 0.300 | 0.330 |
| 44526 | 9360 | Touchscreen | 0.503 | 0.333 | 0.367 | 0.400 | 0.366 |
| 44526 | 9689 | Mouse | 0.693 | 0.528 | 0.460 | 0.396 | 0.365 |
| 44526 | 9689 | Touchscreen | 1.036 | 0.439 | 0.462 | 0.363 | 0.660 |
| 44526 | 9689 | Spacebar | 0.397 | 0.362 | 0.297 | 0.296 | 0.363 |
| 44526 | 4596 | Mouse | 2.376 | 0.364 | 0.528 | 0.527 | 0.463 |
| 44526 | 4596 | Spacebar | 0.494 | 0.462 | 0.462 | 0.527 | 0.363 |
| 44526 | 4596 | Spacebar | 0.494 | 0.462 | 0.462 | 0.527 | 0.363 |
| 44526 | 4596 | Touchscreen | 0.631 | 0.528 | 0.433 | 0.462 | 0.429 |
| 44527 | 3678 | Mouse | 0.362 | 0.329 | 0.364 | 0.363 | 0.330 |
| 44527 | 3678 | Spacebar | 0.596 | 0.429 | 0.429 | 0.429 | 0.329 |
| 44527 | 3678 | Touchscreen | 0.505 | 0.462 | 0.430 | 0.428 | 0.428 |
| 44530 | 4731 | Mouse | 0.494 | 0.496 | 0.527 | 0.725 | 0.494 |
| 44530 | 4731 | Spacebar | 0.489 | 0.497 | 0.463 | 0.428 | 0.494 |
| 44530 | 4731 | Touchscreen | 0.651 | 0.403 | 0.436 | 0.333 | 0.534 |

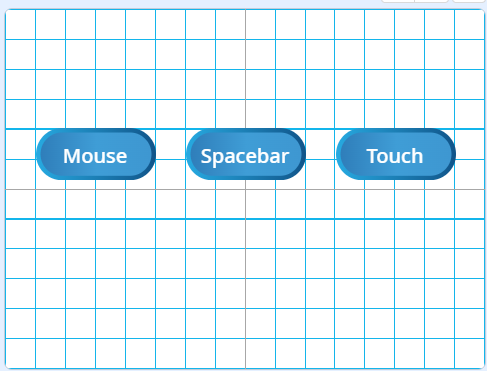
Appendix 2: Demographic Information

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Timestamp | What is your biological sex | What gender do you identify as? | Ethnicity | How old are you? | How familiar are you with technology? | Please enter a 4 digit, User ID between 1000 and 9999 |
| 11/18/2021 16:27:24 | Male | Male | Black or African American | 15-24 | 10 | 4973 |
| 11/19/2021 0:09:51 | Male | Male | Asian | 25-44 | 10 | 3007 |
| 11/21/2021 16:59:09 | Male | Male | Hispanic or Latino | 25-44 | 10 | 5678 |
| 11/21/2021 17:07:57 | Female | Female | Hispanic or Latino | 25-44 | 10 | 6948 |
| 11/23/2021 14:36:28 | Female | Female | White | 25-44 | 10 | 4660 |
| 11/23/2021 19:00:57 | Male | Male | Hispanic or Latino | 15-24 | 10 | 5396 |
| 11/23/2021 19:10:24 | Female | Female | Asian | 65+ | 8 | 5333 |
| 11/23/2021 19:22:55 | Female | Female | Hispanic or Latino | 45-64 | 5 | 5333 |
| 11/23/2021 20:24:40 | Female | Female | Asian | 45-64 | 10 | 4272 |
| 11/25/2021 13:03:52 | Male | Male | White | 15-24 | 9 | 1000 |
| 11/25/2021 13:11:24 | Female | Female | White | 15-24 | 9 | 1001 |
| 11/25/2021 13:22:27 | Male | Male | White | 15-24 | 8 | 1002 |
| 11/25/2021 13:32:28 | Female | Female | White | 15-24 | 8 | 1003 |
| 11/25/2021 13:45:36 | Male | Male | White | 15-24 | 10 | 1004 |
| 11/25/2021 14:57:39 | Female | Female | White | 14 or younger | 5 | 1005 |
| 11/25/2021 16:07:27 | Male | Male | Asian | 14 or younger | 10 | 9360 |
| 11/25/2021 16:12:32 | Male | Male | Hispanic or Latino | 45-64 | 6 | 9689 |
| 11/25/2021 16:17:54 | Female | Female | Hispanic or Latino | 45-64 | 9 | 4596 |
| 11/26/2021 19:58:55 | Male | Male | Hispanic or Latino | 45-64 | 10 | 3678 |
| 11/29/2021 20:21:37 | Female | Female | Asian | 14 or younger | 9 | 4731 |

Appendix 3: Scratch Game, Data Collection Method and Test Photos

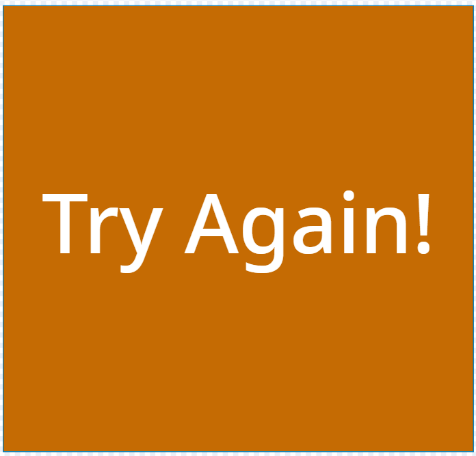
<https://scratch.mit.edu/projects/603093411/>

3.A: Method Selection



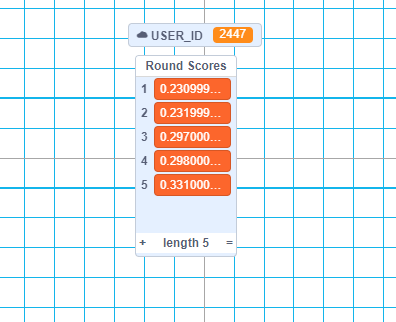
3.B: Interaction Screens





3.B: Interaction Screens

3.C: Results Screen



# **Bibliography**

American Psychological Association. (2010). Publication manual of the *American Psychological Association (7th ed.). Washington, DC: American* Psychological Association, 703.