



Index of Difficulty Measurement for Handedness with Biometric Authentication

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Abstract. This study attempts to identify the variance between right- and left-handed users when utilizing touch screen devices. Three experiments were created in Flutter to gather data and identify the differences in functionality by left- and right-handed users on touch screen devices. These experiments focused on speed and accuracy while also using mirrored images. Experiment one focused on Fitts' law while two and three focused on steering law. This paper focuses primarily on the Fitts' law experiment. The collected data were analyzed and visualizations created to provide insight into whether these biometric experiments prove or disprove the existence of deficiencies in touch screen devices for left-handed users. Data was collected from the native touchscreen and timing features for each participant. A preliminary visual analysis of the data indicates a significant variance between right- and left-handed users, but a machine learning analysis is necessary to verify this hypothesis definitively.

Keywords: Human-computer interaction · Fitts' law · Steering law · Flutter · Firebase authentication · Biometrics

1 Introduction

1.1 Background

Touchscreen technology interfaces may have inadvertently been designed to favor right-handed users. The right-handed favored design reaches across all interfaces, including computers, tablets, mobile phones, gaming consoles, and other user interactive machines. Settings can be adjusted on mouse buttons to reverse the controls for left-handed users, however the hand and extended forearm get in the way of displayed content on touchscreens as the fingers replace the mouse cursor control. Typing and keyboard use does not have the same right-handed bias. Interestingly enough, an individual typing with both hands in the conventional

manner on standard ‘qwerty’ keyboard can type in the neighborhood of 3400 words with solely the left hand, whereas only 450 words are typed solely with the right hand. There are many theories on skills and adaptability of left-handed users ability to use a right-handed tool easier than a right-handed individual’s ability to use a tool built for left-handed individuals. However, there is very little public awareness of left-handed accessibility issue and accommodation in UX/UI and HCI, human computer interaction.

Fitts’ law calculates the time to click a point on the screen as a function of the distance traveled and width of the target. It is used in HCI to design UI/UX of mobile apps. Using time, distance, and width the difficulty coefficient can be calculated. In the following formula, the variables MT , A , and W represent movement time, moving range, and the breadth of the target, respectively [1].

$$MT = a + b \cdot \log_2\left(\frac{A}{W}\right)$$

Index of Difficulty, is also called the difficulty coefficient and is represented by ID [1].

$$ID = \log_2\left(\frac{A}{W}\right)$$

Fitts’ law predicts movement from one location to another [1]. It has been concluded in an experimental study of right handed users that the screen quadrant measured most difficult to access should be avoided when designing touchscreen apps [2]. However, if one is using the left hand, that display area may not be difficult to access. This research, based on the study by Zhang, et al., includes both right-handed and left-handed participants performing the experiment using each hand in succession. Hypothesis one is that there will be a symmetric, or mirror difference for right and left-handed subjects. Steering Law, derived from Fitts’ Law, is used to calculate accuracy while swiping across a mobile device. This law is a predictive model of subject movement that describes the time required to navigate or steer through a tunnel. Below is the mathematical equation where A = length of tunnel, and W = width [3]. Figure 1 illustrates this concept:

$$IDs = A/W$$

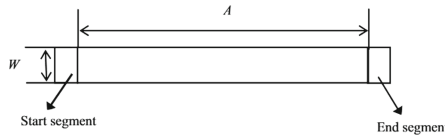


Fig. 1. Steering law [3]

Based on Inkpen’s research, any application requiring on-screen input (i.e., Left-Handed Scrolling 105 hyperlinks, buttons, text entry forms, context menus,

etc.) should make the placement of their input widget dynamic based on handedness [4]. For example, it is common for applications to left align their drop-down menu or sub-menus. This works well for readability as English is read left to right but is inefficient given right-handedness. Left-handed users receive the benefit of not having to reach across the screen to select the drop-down bar, where right-handed users have to occlude their screen to make the interaction.

1.2 Objectives

The purpose of this work was to gain additional insight and data on the responsiveness of self-identified left and right-handed individuals using a mobile application developed in Flutter.

To that end, this research study set out to accomplish the following:

- Develop a biometrics application to measure the variance between right- and left-handed users using Flutter, supporting both Android and iOS mobile devices.
- Record data for right handed users, left handed users, right handers using their left hand, and left handers using their right hand.
- Create a database using Firebase to perform data analytics and summarization of variance on the data that was collected from the experiments.
- Calculate the Index of Difficulty using Fitts’ law and steering law formulas with consideration of the movement time, as well as the direction of hand movement.
- Use machine learning to test for any significant authentication biometrics.

2 Literature Review

Although keystroke analysis lacks the amount of studies compared to other biometric modalities, it is one that demands our attention. The first reference to the conceptualization of keystroke analysis dates to Spillane’s research in 1975 [5]. At first, studies proved that keystroke dynamics work well when enough data is acquired to create the model of a user. Now, the same can be done without demanding a plethora of data from the user. Studies on keystroke analysis all attempt to provide a powerful yet economical authentication method.

In a study that exemplifies this, a novel keystroke biometric system for long-text input was developed and evaluated for user identification and authentication applications. The system consisted of a Java applet that collected raw keystroke data, a feature extractor, and pattern classifiers that made the final decision in authentication. Data was collected from over 100 participants to investigate two input modes (copy and free-text) and two keyboard types (desktop and laptop). This study used 239 feature measurements to characterize a typist’s key-press duration times, transition times between keys, the percentage in the use of non-letter keys and mouse clicks, and typing speed. By varying between the two input modes as independent variables, the distinctiveness of keystroke patterns

can be determined. The data yielded four quadrants: desktop copy, laptop copy, desktop free text, and laptop free text. These are the four ideal conditions. It was determined that accuracy was greater under these four conditions, however, it decreased as the population size increased. Longitudinal studies were also incorporated to study the accuracy of identification and authentication over time. Results showed that only about 300 keystrokes were needed for sufficient accuracy for various applications. Therefore, it reduces the text input requirement to less than half of that used in the experiments. An equal error rate (EER) value was obtained in the authentication study under ideal conditions. Ultimately, the study found that keystroke biometrics is useful for identification and authentication applications, if two or more enrollment samples are available and if the same type of keyboard is used to produce both the enrollment and questioned samples [6].

In yet another study that exemplifies keystroke analysis as an economical tool and how it can be integrated into existing computer security systems with minimal alteration and user intervention, the majority of the keystroke dynamics research works from the last three decades are summarized and analyzed [6]. The advantages of implementing keystroke analysis are undeniable. Understanding the history of keystroke dynamics can help researchers further their studies in the appropriate direction (Fig. 2).

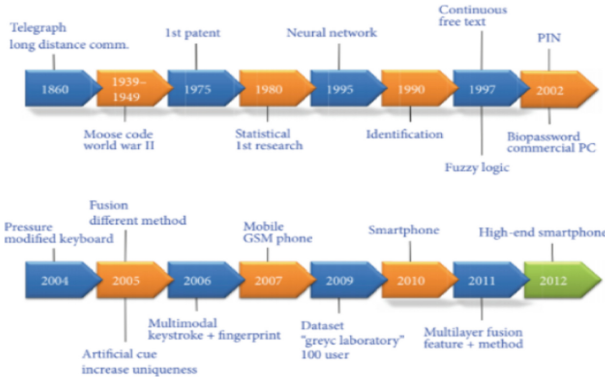


Fig. 2. A timeline on the overview of keystroke research work evolution

3 Methodology

3.1 Flutter

To design the experiments for this study, a new application development software, Flutter was used. Flutter 1.0 was released in 2018 and is being used by over 250K developers and counting. Flutter is an efficient way to build applications for

both iOS and Android devices. Most application development software options in the past require a developer to create their app in either iOS or Android. The Apple iOS SDK, or Software Development Kit, was released in 2008, and the Android DSK in 2009. These kits were based on different languages, and require that a developer understand both languages to properly code an app. Flutter takes a different approach. Unlike its predecessors that required a bridge to communicate between the native language and the application, Flutter uses a “compiled” programming language called Dart, that removes the requirement for the bridge between the native code and the application code. By removing the bridge, apps run faster, and require a programmer to only learn Dart, rather than both iOS and Android programming languages. Another key feature of Flutter that makes it a significant improvement from other development kits is the way it manages widgets. Widgets need to be fast, customizable, and have an appealing look and feel. Flutter provides its own widgets which allows for quick development of attractive, fast widgets within applications. More specifically, Flutter was chosen because it is open source, it creates cross platform apps and it has hot reload, meaning as soon as we make any change in the code, it gets reflected on the simulator. It uses Material Design which is the design language and it gives very aesthetic and distinctive look to the UI (Fig. 3).

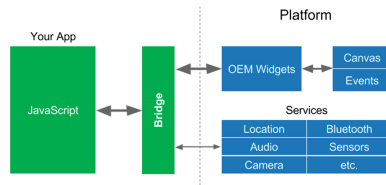


Fig. 3. App development with bridge

3.2 Firebase

Data and analytics from the Flutter app are tracked through the back-end database system, Firebase, for the experiments. With the data points gathered, the team was able to determine if there were deficiencies present for left handed users during the experiments. Firebase allows for device data to be gathered on multiple platforms such as IOS and Android in which the flutter application is deployed. Firebase also runs its own analytics on app and platform usage as well as performance of the flutter application. After data is collected, Firebase provides a dashboard view to characterize and analyze the data. The dashboard for this project is shown below (Fig. 4).

In addition to the dashboard, there are specific graphical breakdowns of the data available.

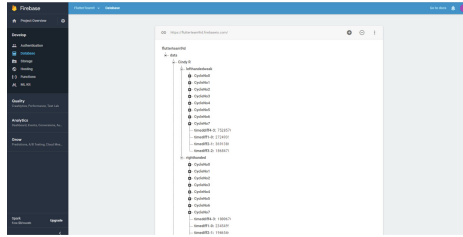


Fig. 4. Firebase dashboard

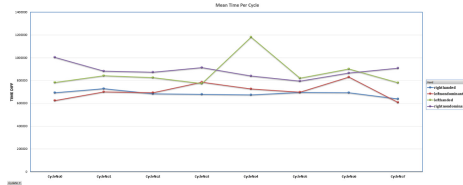


Fig. 5. Firebase dashboard

4 Hypotheses

Hypothesis One: There will be a symmetric, or mirror difference for right-handed and left-handed subjects.

Hypothesis Two: Mobile devices' native touchscreen and timing features will yield authentication biometrics for each subject.

5 Experiment One

The experiments have been designed to test and document whether there is a significant difference in response times to user interfaces and applications based on the individual's dominant hand. In this study, time was recorded in microseconds. Recorded fields include a main object called data that has all data of users. Then there is a user object for each participant having the name they entered in the experiment's opening screen. Inside the user object there are two handedness objects (generated dynamically based on left dominant hand or right dominant hand user). For right hand dominant people, the handedness objects are: righthanded, left handnondominant. For left hand dominant people, the handedness objects are: lefthanded, righthandnondominant.

We based our first experiment on Zhang, et al's paper [2]. After these data points were collected, we analyzed each category by dominant hand to see if there was a difference between speed and accuracy results for right and left, as well as the non-dominant hand. Fitts' law calculates the time to click a point on the screen as a function of the distance traveled and width of the target. While there were eight target points, only one target point appeared on screen

at a time per click test, in addition to the source point. These eight click tests around the dial comprised one cycle test. The experiment consists of eight cycle tests. Then, the subject repeated the cycle tests with their non-dominant hand.

In experiment one, the distance from the source button to the target button A is 250 pixels. The width of the target button W is 60 pixels. Therefore, as Zhang calculated, the difficulty coefficient for each angle is $ID = 1.43$ [2]. Zhang et al. conclude that the screen quadrant measured most difficult to access by Fitts' Law should be avoided when designing touchscreen apps [2]. When handedness is taken into account, that quadrant of the display screen will differ, respectively, for left and right-handed users.

The experiment tested how long it took a person to touch the center target, and then a point on the dial. They then touched the center again and the next placement on the dial. The user went around the dial, each time clicking in the center before clicking on the next target (Fig. 6).

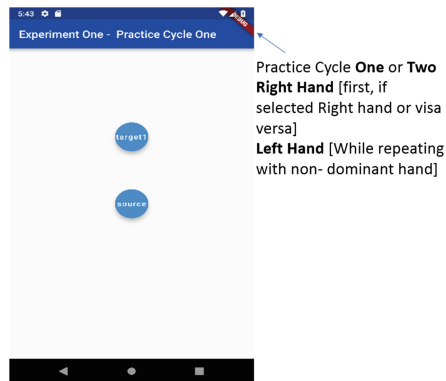


Fig. 6. Practice screen

This experiment was conducted with all subjects using the same Android device. They were presented with a screen that asked them to identify their stronger hand. The identification of an individual is based on their preference, and self-identification, rather than a scientific assessment of their skill and ability to perform with one hand or the other [7].

The experiment tested how long it took a person to touch the center source button and then click a target point on the dial. The click tests continued from source to target in each of eight target placements on the dial. This test was conducted through eight test cycles, and the results were recorded. The user was then asked to perform the same cycles using their other hand. Again, the times were recorded and assessed. These results were entered into the Firebase database, and stored as part of the overall experiment data (Fig. 7).

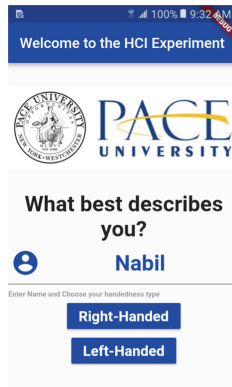


Fig. 7. Experiment one

6 Experiment Two

In Experiment Two accuracy was measured via timing features and touchscreen features with a stair step, mimicking a cascading menu. The stair traveled from upper right to lower left. Steering Law, derived from Fitts' Law was used to calculate results. Specifically, the user was asked to start at the upper right corner and trace with their index finger down a staircase, going down, right, down, right, etc, until they reach the end of the staircase. They are then asked to repeat the exercise with their opposite hand. Since the measurement points between stairs was a known factor as part of the build of the application, the data related to time and distance from Steering law was able to be collected and analyzed (Fig. 8).

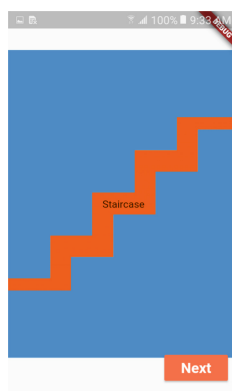


Fig. 8. Staircase data point measurement

7 Experiment Three

The third experiment aimed to see if the hand obstructed the display screen. The user was asked to click on a image and then swipe to another image. They were then asked to swipe back in the opposite direction. As with Experiment two, the user was asked to perform the same task with the opposite hand. The image was flipped symmetrically and the user performed the same test in reverse with both hands. All of the results were collected and put in the Firebase database for further analysis. The implementation was not adequate to produce meaningful data. Therefore, this experiment will constitute future work.

8 Preliminary Data

Preliminary data completed on both Experiment One and Experiment Two show trends in favor of both right handed and left-handed individuals. Experiment One shows the right-handed users were more effective with their dominant and non-dominant hands as opposed to left handed users who were slower with both dominant and non-dominant hands. The overall trend for Experiment One when comparing all users both dominant right and dominant left using their right hand showed a flat trend in favor of using your right hand while using a device as opposed to your left hand, as depicted in Fig. 5, the dashboard image.

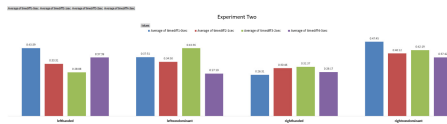


Fig. 9. Experiment two user data

Experiment Two favored right-handed individuals as the trend shows right handed individuals on average had a lower time differential. Right-handed individuals were also better using their non-dominant hand in this experiment than left-handed individuals using their non-dominant hand. Figure 9 shows the mean values of time difference for each of the four categories: left-handed, left non-dominant, right-handed, right nondominant.

9 Conclusions

The study's programmers have successfully built two working experiments from end to end on the Android platform. Preliminary data stored on the Firebase platform was retrieved and placed into visuals for the two working experiments. Preliminary data shows that touchscreen devices have deficiencies for left-handed users. This raises more questions. The focal point now moves towards further

analysis, additional data collection, and further development and alterations to the three experiments. As future alterations to the experiments are made they will focus on more challenging operations for both right-handed and left-handed users. By measuring the variance between right- and left-handers, data patterns may emerge that provide reasonable biometric authentication. That hypothesis remains inconclusive.

10 Future Considerations

There are several opportunities to continue these experiments and the associated research. Extending experiment two to include a mirror image, and fixing experiment three will provide a more complete data picture to the user experience.

For experiment one, the visualization could be randomized so that the test data does not include any learned behavior relating to expectation of what target to click next. It is possible that clicking on targets presented in a circle, the speed could be impacted by the fact that the user gets accustomed to the process and is faster not due to handedness, but instead as a result of the learned behavior of where the next click will be. Randomizing the targets would eliminate any potential learning from the order of the targets.

Additionally, designing the mirror images for experiments two and three would provide data collection of dominant hand - original image, non-dominant hand - original image, dominant hand - mirror image, and non-dominant hand - mirror image. These four data points would ensure that the measurements from steering law are equal and opposite, or symmetrical.

Future work will use machine learning on each individual user's data collected via the built-in native sensors on the mobile device, such as gyroscope, accelerometer, and pressure properties to see if these yield any significant authenticating biometrics. While preliminary visual analysis of the data indicates a significant variance between right- and left-handed users, a machine learning analysis is necessary to verify this hypothesis definitively.

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