An Investigation into the use of Fitts's Law as a Discriminant for the Identification of Dyslexia in Primary School Children

Sam Dixon
40056761

Submitted in partial fulfilment of the requirements of
Edinburgh Napier University for the Degree of
MEng (Hons) Software Engineering

School of Computing

2017

Authorship Declaration

I, Sam Dixon, confirm that this dissertation and the work presented in it are my own achievement.

Where I have consulted the published work of others this is always clearly attributed;

Where I have quoted from the work of others the source is always given. With the exception of such quotations this dissertation is entirely my own work;

I have acknowledged all main sources of help;

If my research follows on from previous work or is part of a larger collaborative research project I have made clear exactly what was done by others and what I have contributed myself;

I have read and understand the penalties associated with Academic Misconduct.

I also confirm that I have obtained informed consent from all people I have involved in the work in this dissertation following the School's ethical guidelines.

Signed:

Date:

Matriculation no:

Data Protection Declaration

Under the 1998 Data Protection Act, The University cannot disclose your grade to an unauthorised person. However, other students benefit from studying dissertations that have their grades attached.

Please sign your name below one of the options below to state your preference.

The University may make this dissertation, with indicative grade, available to others.

The University may make this dissertation available to others, but the grade may not be disclosed.

The University may not make this dissertation available to others.

Abstract

This dissertation records and describes the process and evaluation undertaken while attempting to discern whether Fitts's Law analysis of Movement Times was a valid metric for the identification of Dyslexia. Described within is motivation for conducting the study, the design and methodology of the technologies and systems used to collect and manipulate data, descriptions of how data gathered during the project was analysed, and the results and conclusions that can be drawn from such analysis.

The aim of the project was to provide information to aid in the assessment of Dyslexia in children from a younger age, allowing for appropriate support to be provided during key developmental stages of there lives. A substantial amount of movement data was collected from volunteers, which was later processed and evaluated using Fitts's Law, regression analysis, and statistical analysis. Results of said testing indicate that the Fitts's Law Index of Performance varies very little between Dyslexic and non-Dyslexic task participants, and an alternative metric for detection in the form of anaylsisng the number of errors made during the motor test is suggested.

Contents

List of Tables

List of Figures

Acknowledgements

I would like to offer my gratitude to the supervisor of this project, Prof Jon Kerridge for his initial suggesting of the project, as well as all the support, ideas and guidance he has offered over its progression.

I want to thank the friends and peers I have made over the years I have spent at Napier, without whose inputs, criticisms, and distractions the outcome of this project would have been much different (for better or for worst).

Thanks to, to my caring family, for their constant belief in my abilities, even when I doubted it.

And a final thank you to my wonderful girlfriend, for her unparalleled support, unwavering hope, and willingness to proofread, without which this dissertation would be illegible.

1 Introduction

This Chapter aims to provide context and reasoning for the execution of this project. Excluding the reasons presented below the project also held personal value, as I was assessed and deemed to have Dyslexia at the age of six. Being Dyslexic was a key motivator during the course of the project and it is my hope that the information and conclusions of this dissertation will provide some aid in the future of Dyslexia and Learning Difficulty assessment and mitigation.

1.1 Background

Provided is context of the major areas of interest that comprise this project, namely; Dyslexia, the Dot-to-Dot Task and Fitts's Law.

1.1.1 Dyslexia

Dyslexia is the most common Learning Difficulty in Britain (British Dyslexia Association, n.d.; NHS Choices, n.d.-a), it is present in around 10% of the British population, to varying degrees from person to person, and about 4% of the population have severe Dyslexia . Dyslexia typically affects a person's ability to read, with traits such as difficulty with spelling, slow reading speed, issues 'sounding-out' syllables, or writing abilities.

While Dyslexia cannot be cured, the ways in which it affects an individual can be mitigated, typically in the form of learning support provided by schools and the utilisation of specific teaching and learning techniques (British Dyslexia Association, 2016).

While the understanding and acceptance of Dyslexia has improved greatly in recent years, the assessment of whether a person has Dyslexia has remained relatively stagnant. Dyslexia does not have an official, formal assessment funded by the NHS and no mandatory training in regards to Dyslexia is required by NHS staff (NHS Choices, n.d.-b) . The current and most accurate form of assessment remains in the form of traditional "pen-and-paper" tests and while these existing Dyslexia assessments have been proven to be accurate, they typically cannot be taken by children under the age of five, mainly due to the fact that younger children's reading abilities can develop over differing periods of time and individual children experience differing levels of cognitive development.

1.1.2 Dot-to-Dot Task

The Dot-to-Dot Task is a system developed by Professor Jon Kerridge (Willis, Piotrowska, Bannach-brown, Maclean, & Kerridge, 2010; Piotrowska, Willis, Maclean, Murray, & Kerridge, 2015). The goal of this Task is to measure a child's ability to draw lines between a series of points as they appear on the screen, using a standard drawing tablet and stylus. It has been hypothesised that a child's performance on the Dot-to-Dot Task could be used as a possible indicator of Dyslexia.

The Dot-to-Dot Task interface comprises of two panels - in the top panel is displayed a dot and the bottom panel remains blank. Task participants can move an onscreen cursor via the use of an attached drawing tablet. As a participant moves the cursor in the lower panel, the path of this movement is traced in the upper panel. When the participant moves the cursor within the range of ten pixels to the dot in the upper panel, a new dot will appear, which becomes the new target for the participant to trace towards. Each participant is asked to complete a set of two distinct patterns four times, first with their dominant hand, and then their non-dominant hand. The major challenge one faces in the task is to avoid making a disjointed tracing of the line in the top panel when the cursor is suddenly moved into the lower panel. The task can often feel alien to task participants: a feeling which can be amplified by the use of a drawing tablet and stylus - equipment that many participants do not use on a regular basis.

The Dot-to-Dot Task records a number of variables while in use, including the amount of time taken to draw a line from one point to another, the number of errors a user makes (for example, lifting the stylus, pausing, or drawing a loop) and the difference between the drawn line and the optimal line.

Historically, motor abilities were not often considered a skill affected by Dyslexia, but the spectrum of affected areas and the severity thereof varies greatly from individual to individual and is often extremely prominent at younger ages.

1.1.3 Fitts's Law

Fitts's Law is a form of modelling used to predict the movement time required for a user to move between targets on computer User Interface (UI) (Mackenzie & Scott, 1992; MacKenzie, 1995). Paul Fitts (1912 - 1965) originally proposed the idea for Fitts's Law in a 1954 paper entitled "The information capacity of the human motor system in controlling the amplitude of movement." (Fitts, 1954) and this metric is still considered valid and is well used, especially in the fields of Human Computer Interaction (HCI) and software ergonomics.

Fitts's Law has been reviewed and discussed extensively since its inception, with a number of revisions and alternative equations being presented with compelling arguments for their usability and suitability (Mackenzie &

Scott, 1992; MacKenzie, 1995). The original Fitts's Law equation is presented thusly,

$$IP = \left(\frac{ID}{MT}\right)$$

IP, or Index of Performance is the measure of how a individual executed a movement between two points. Fitts calculates IP simply as the Index of Difficulty of a sector (ID) divided by the time taken to complete said sector (Movement Time or MT).

$$ID = \log_2\left(\frac{2D}{W}\right)$$

ID or Index of Difficulty is the estimation of how difficult a movement between two point is. The parameters required for its calculation being; the distance between the two points (D) and the Width of the target being moved towards (W).

The larger the ID of a movement, the harder the move is to execute, either due to the distance between the two targets, the size of end target, or some combination of both. for IP the smaller the value, the faster the movement was executed, indicating a superior performance.

As previously stated, Fitts's Law is used to calculate the potential time it would require to move between UI targets. Typical targets might consist of text boxes, buttons and checkboxes. Fitts's Law is not only used for prediction, but also for evaluation. Fitts's Law can return an Index of Performance (IP) which is calculated in the time required for a user to move from one target to another and the Index of Difficulty (ID) of said move (Fitts, 1954). The ID of a movement can be calculated based on the distance between each point and the size of end target.

Fitts's Law presents itself as a fitting metric for the analysis of Dot-to-Dot Task results for a number of reasons. The task itself consists of the tracing of straight lines between points - movements which Fitts's Law can calculate the difficulty and execution of. The Dot-to-Dot Task already records the time taken by participants to complete movements, which allows Fitts's analysis to be applied to results without needing to alter the existing system.

Applications utilising Fitts's Law have previously been used to attempt the identification of a number of disorders in children - for example, Cognitive Development Disorder (CDD) and Developmental Coordination Disorder (CDC). The fact that Fitts's Law has been used previously for the identification of Learning Difficulties in children does present itself somewhat as a 'double edged sword', in the sense that it raises the question: has Fitts's Law not been used for the detection of Dyslexia because it is potentially fallible or because it is not well known outside of the HCI community?

1.2 Aims and Goals

The main aim of this project is to determine whether the use of Fitts's Law analysis is suitable for the identification of Dyslexia in children, but there are a number of caveats that must be addressed to ensure accurate and fair analysis and evaluation of this project.

One of the primary concerns of the project is the fact that it consists of applying a new form of analysis to a pre-existing system. Traditionally, experiments investigating Fitts's Law consist of participants drawing straight lines between two points, each subsequent stage of the test altering the given parameters in some way, then increasing the distance between the two targets, or altering the size of the end target. The Dot-to-Dot Task on the other hand, consists of drawing lines between a series of targets of equal size and while the length of each line is relatively similar, the angles of each sector can vary greatly. While Fitts's Law analysis can be applied to to the Dot-to-Dot Task, it may not produce the expected results, due to the similarity of the lines being drawn by the participants.

A second potential issue with the project is in the existing Dot-to-Dot Task data. This pre-existing data was collected from participants who were all pupils from a number of different primary schools around the Edinburgh area and while it did provide a substantial sample size on which to run tests, it was missing a crucial information point: whether the participant was Dyslexic or not. The original test participants were primary school children between the ages of four to eleven, rendering them too young to be accurately assessed for Dyslexia. While this existing body of collected data does provide the benefit of being able to test the hypothesis over a large spectrum of participants, the lack of scientific control makes it impossible to determine if the Fitts's Law analysis has correctly identified an individual as Dyslexic.

With these aforementioned caveats in mind, the following objectives were defined, each operating as a checkpoint and upon the completion of each, allowing for the titular question to be answered: whether or not Fitts's Law is a suitable identification metric for Dyslexia.

Collect Dot-to-Dot Task data from a range of Dyslexic and non-Dyslexic participants. Dot-to-Dot Task data must be collected from participants that are aware of their Dyslexia status. This provides evidence that Fitts's Law analysis can correctly discriminate between Dyslexic and non-Dyslexic Dot-to-Dot Task participants. If the originally collected primary school data were to be used, there would be no way to prove if an individual was actually Dyslexic, despite having been identified as such through Fitts's Law analysis.

Calculate the Index of Difficulty for each sector of the Dot-to-Dot Task. To perform Fitts's Law analysis, two pieces of data must be known: the ID of a movement and the amount of time a participant needs to make this move. With the movement times being provided by task participants, only the ID of the sector remains uncalculated. To calculate the ID, both the the size of targets and the distance between them must be known. The Dot-to-Dot Task records all the targets as dots with a radius of ten pixels, giving each target a width of twenty pixels. The X and Y coordinates of each target are also recorded and from this data the lengths of the lines being drawn can be extrapolated.

Calculate each individual's Index of Performance for each sector. With both the ID and Movement Time (MT) of each sector known, the IP can be calculated, the result of which being the crux of this project. The smaller the value of the IP, the more efficient a movement was performed. The hypothesis of this project is that Dyslexic participants would produce an IP significantly different from non-Dyslexic participants, most likely of a higher value.

Analyse Fitts's Law results of the different groups to identify distinct patterns or traits. Once the IP has been calculated for every sector that a participant completed, analyses of effectiveness can begin. A standard method of evaluating whether two populations of results are significantly different is via the use of a Student t-test. In the scenario of this project, the two populations will be the Dyslexic and non-Dyslexic Dot-to-Dot Task participants.

Evaluate Fitts's Law effectiveness in terms of discerning between Dyslexic and non-Dyslexic Dot-to-Dot Task participants. Upon completion of t-test analysis, the only remaining goal is to determine whether Fitts's Law can be deemed a suitable identifier of Dyslexia when used to analyse Dot-to-Dot Task results. It may be the case that Fitts's Law is only able to identify partial groups of Dyslexic participants, or it may highlight key sectors of the Dot-to-Dot Task patterns that Dyslexic participants have a harder time tracing than their non-Dyslexic counterparts.

2 Literature Review

2.1 Introduction

As stated in the introduction, at the time of writing there exists no published papers, journals, or studies concerning the detection or assessment of Dyslexia via the use of Fitts's Law. While literature relating directly to this project may be non-existent, there is a substantial amount of existing material concerning both Fitts's Law and Dyslexia detection, as well as the detection of Learning and Developmental Difficulties via applications inspired by Fitts's Law.

2.2 Fitts's Law

In 1954, Paul M. Fitts published his thesis, consisting of a study of human motor skills and how the average person's motor speed and accuracy varied proportionally to a number of test variables and could be accurately predicted (Fitts, 1954). Fitts originally conducted his study by having test participants carry out a number of physical tests, such as tapping a stylus between two conductive strips, moving a set of washers from one pin to another, and moving a number of pegs from one set of holes to another (Fitts, 1954). While Fitts's original study may appear dated in style and delivery, the hypothesis and results of the experiments which were carried out proved that the prediction of an individual's ability to execute motor tasks was not only feasible but extremely accurate (Fitts, 1954). Fitts's research gained so much traction that it gained partial support from the United States Air Force, an organisation where the assessment of a person's motor skills is of critical importance (Fitts, 1954).

Fitts's original research was conducted before the commercial availability of personal computers, with the intent of predicting how quickly and accurately an individual could carry out a physical task , but his work and analysis can also be easily and readily applied to digital tasks. A number of reassessments of Fitts's original work have been conducted since its publishing, with the aims of refining and readjusting the original equations for modern usages.

The first investigation of the use of Fitts's Law in a HCI context was conducted in 1978 (Card, English, & Burr, 1978). The study in question was a comparison of the usability of a number of computer input methods, exploring the speed that users could move an onscreen cursor to various targets and the amount of errors made in the process. The devices used in the study were a mouse, joystick, and keyboard. The results of the investigation were as expected, with the mouse being the usable input device in terms of speed accuracy, but more importantly - for this project - it demonstrated that Fitts's Law could be applied to computer use, even when physical movement of a device was taking place in the form of using keyboard keys.

One of the more comprehensive reviews of Fitts's Law is a study provided by Ian MacKenzie (1995). MacKenzie has produced a number of studies in relation to HCI, a field in which modeling human motor skills is of extreme importance. MacKenzie raises the point that the tests conducted in Fitts's original study are entirely one-dimensional, i.e. the distance between the two targets as well as their widths were always altered along the same axes. This means that the ID can change variably depending on the angle of approach towards non-uniform targets, such as rectangular buttons or words. Fortunately, the Dot-to-Dot Task targets are all uniform circles, meaning that their width always remains the same, regardless of the angle of approach. MacKenzie also provides details into a slightly altered MT prediction equation in the form of,

$$MT = a + b \cdot ID = a + b \cdot \log_2 \left(\frac{2D}{W} \right)$$

Values a and b are calculated via regression analysis, where the results from previous tests are plotted in order to produce a more accurate prediction model.

Fitts's Law has been used in a number of diverse projects, even including the evaluation of motor skills in monkeys (Ifft, Lebedev, & Nicolelis, 2011). Two monkeys were trained to move a cursor to various sized targets using a joystick and the MT required was recorded. It was found that the monkey's IP was within the expected Fitts's prediction, providing further proof to Fitts's Law's accuracy, even across species.

It should be noted that in the studies presented previously, the ID of the tests was scaled in a uniform manner, thus the IDs of the tests would be 1, 2, 3, etc. The Dot-to-Dot Task, on the other hand, does not consist of sectors of gradually scaling ID, which affects the viability of the use of regression analysis and ultimately the altered equation for this project.

2.3 Detection via Fitts's Law

As the previous literature shows, Fitts's Law has shown its extended used as a metric for the measurement of human motor abilities, both for physical and digital-based tasks. A number of applications based on Fitts's Law have been utilised in the past for the detection of a number of Learning and Developmental Difficulties.

A study conducted in the Netherlands (Smits-Engelsman, Wilson, Westenberg, & Duysens, 2003), which investigated the performance of Dyspraxic children made heavy use of Fitts's Law, from the design of tests conducted, to the assessment of the individuals. Dyspraxia - also known as DCD - is a neurological disorder that primarily affects an individual's movements and coordination. The investigation tested a number of children by having them draw straight lines of various lengths using a drawing tablet and stylus, not dissimilar to the Dot-to-Dot Task used in this project. The study in question found that the individual's IP varied very little, regardless of whether the children were Dyspraxic or not. It was found that there was a significant error difference between the two groups of children - while Fitts's Law may be an appropriate metric for measurement, it may not always be appropriate for the differentiation between children with and without certain Learning Difficulties. This is of particular note, as Dyspraxia has the potential to affect fine motor skills to potentially severe degrees, implying that the IP between the two groups would be distinct enough for clear detection.

Fitts's Law has also been used to assess individuals with physically induced motor impairments, for example, due to injury or partial paralysis (Maruff & Velakoulis, 2000). The study had two groups of participants draw vertical lines of different lengths, one group consisting of individuals suffering from arm injuries or paralysis and the other consisting of healthy individuals feigning motor impairment. It was found that the individuals suffering from injuries produced an IP conforming to Fitts's Law, whereas the group feigning injury were below the anticipated IP. While this may indicate that Fitts's Law's accuracy is refined, it becomes accurate when an individual is attempting to falsify results, but it should be noted that there was a major disparity in terms of the groups sizes, with only one injured subject and ten healthy (albeit feigning impairment) subjects.

This was a second study conducted to compare the motor abilities of Dyspraxic and non-Dyspraxic children (Wilson, Maruff, Ives, & Currie, 2001). The study consisted of drawing a straight line to a target and then back to the initial starting location. A number of different target sizes were used, allowing for number of different difficulties to be tested and regression analysis to be performed on the results. Two kinds of experiment were performed with the participants: a standard motor skill test, in which the children physically drew a line, and an imagined test where the children would envision themselves drawing the line and state when they had completed the imaginary movement. It was found once again that the Dyspraxic childrens' individual IPs were within the expected limits of Fitts's Law as were the non-Dyspraxic childrens' IPs. Interestingly, even though their physical movements were within the expected tolerance, the Dyspraxic childrens' imagined movements did not align with the Fitts's Law expectation.

2.4 Summary of Literature

Baring the papers and studies that were undertaken exclusively to review Fitts's Law's usability, the investigations presented previously documented little to no analysis of Fitts's Law - suggesting the metric is credible enough to use without making major considerations. This fact proved encouraging, as it fortifies Fitts's Law's reliability and its use as a research and analysis metric. Additional the range of studies conducted with use of Fitts's Law was staggering considering the search for existing litre had relatively narrow criteria, results ranging from traditional HCI, to learning difficulty detection, and even animal motor skill analysis once again solidified Fitts's Law as a known and valid prediction model.

It should be noted that the experiments performed in the previous studies were all designed with analysis via Fitts's Law in mind, this is a direct contrast of this project where the use of Fitts's Law was decided after development and initial use of the Dot-to-Dot Task. While this does not discount the Fitts's Law entirely, it does mean that steps performed in other investigations were unrepeatable with the data and systems available for this project.

3 Methodology

This chapter aims to detail the manner in which the experiments were carried out over the course of this project, as well their justification. Included in the chapter is information on how data was collected from task participants and the development of a system to process said data.

3.1 Collection of Dot-to-Dot Task Data

The core of this project was the analysis of *MT* data, which of course requires the collection of said data. Ethical clearance was provided to allow the collection of data using the Dot-to-Dot Task from Edinburgh Napier University students and staff. After applying for and receiving ethical clearance for the collection and processing of Edinburgh Napier data, an email requesting volunteers was distributed to advertise the data collection process.

Data collection took place on Edinburgh Napier University's Merchiston campus, in the upstairs portion of a café. The environment in which the experiments were to take place was crucial to limit any possible distractions and ensure a fair trial for all participants. The location was well lit and had a low level of background noise. A desk and a chair were provided for participants, to ensure that the drawing tablet was at a comfortable height for use.

Before commencing the Dot-to-Dot Task, all test participants were asked to sign a wavier (Appendix D). This was to comply with the previously received ethical clearance and to ensure that the volunteer was content with collection and processing of their data and understood the reason for the collection of their data. This provided them with time to ask questions about the collection process and about the project as a whole. Prior to the meeting of volunteers, they were asked to provide some basic personal information, including their age, sex, dominant hand and Dyslexia Status - either Dyslexic, not Dyslexic or possibly Dyslexic. Ideally all participants would have been in either the Dyslexic or non-Dyslexic groups, but the possibly Dyslexic group was included to cater for volunteers who believed they portrayed Dyslexic tendencies, but had not had an official Dyslexia assessment. In total 76 individuals volunteered to participate in the project with 17 being Dyslexic, 31 being non-Dyslexic and 28 being possibly Dyslexic or unknown. Considering the national average of Dyslexia is $\sim$ 1:10, the turnout of Dyslexic participants compared to non-Dyslexic was extremely humbling.

Each participant would complete a practice pattern before the task began properly. This was to familiarise them with using the stylus, a HCI input device that many of the volunteers were not accustomed to using on a regular basis. Once a participant completed the practice pattern, they were then tasked with completing pattern 3 and pattern 4 three times each. The task was performed two times, first with the individual's dominant hand and the second with their non-dominant hand. This resulted in a total of 14 patterns being drawn by each participant.

The following script was read to task participants,

'The test begins when the stylus is in contact with the tablet and the cursor is moved to the starting position. If at any point you lift the stylus from the tablet, the test will be paused until the stylus is making contact with the tablet and you have moved the cursor back to the location from which you lifted it. The goal of the task is to move the cursor to target as quickly and accurately as you can. When the cursor gets close enough the target it will disappear and a new target will become visible.'

The same script was used for every participant to ensure each individual began the task with the same information. The script was delivered while also demonstrating a sample Dot-to-Dot Task pattern, providing the subject with visual and vocal information of the task.

The Dot-to-Dot Task records data by login the X/Y position of the stylus, as well as a timestamp to a MySQL database. A data point was logged every time the X or Y coordinate of the stylus was updated. The system also logged when a task participant lifted the stylus from the drawing tablet. By recording the lifts, positional coordinates and timings of a Dot-to-Dot Task participant, it was possible to extrapolate all other required data that was required for Fitts's Law analysis and thus, this project.

3.2 Data Processing System

Due to the sheer amount of data collected, a system was developed to automate the processing of said data, as well as to present it in a more usable format. A number of attractive options existed for the building of the processing system. In the end, Python was chosen as an appropriate language, thanks to its ability to allow for rapid prototyping as well as the mathematical and statistical libraries it provides. Other options for tools or frameworks that could have been used included SQL and Groovy.

SQL is a powerful data processing tool that allows for the scripting and automation of data processing on large amounts data. One of the benefits of a SQL based processing system would be the fact that all the data required for the project was already stored in MySQL database, making operation on said data trivial. While incredible useful when dealing with large data sets, SQL has a number of drawbacks, including the languages notoriety in terms of complexity and verboseness. It was deemed that a purely SQL based system would be too impractical to justify. Regardless of the language that the processing systems would be written in, a number of SQL scripts were prepared and used to aid in the formatting, cleaning and accessing of the Dot-to-Dot Task data.

Groovy was also a language option that was considered for the data processing system. A partial system for extracting and processing Dot-to-Dot data was already available, but due to the unfamiliarity with the language as well as Python's attractive features, it was ultimately decided that Python would be the primary development language for the project.

There existed a number of prerequisite stages to calculating an individual IP. These included calculating the ID for each Dot-to-Dot Task sector; identifying and removing the sectors in which errors occurred; performing regression analysis of the average MT and sector ID; and calculating individuals' IP.

3.2.1 Calculating the Index of Difficulty

As previously stated, the ID of a movement is calculated as: $ID = \log_2\left(\frac{2D}{W}\right)$.While the width of every target in the Dot-to-Dot Task is known - a circle with a diameter of twenty pixels - the distances of each sector are not recorded in the database, only the X and Y coordinates of each target. Given the start and end coordinates of a line, its length can be calculated via Pythagorean theorem. Python's inbuilt mathematics functions allowed for the simple calculation of a sector length once the coordinates were selected from the database. Once the lengths of the sectors was known, the IDs of each sector could be calculated.

Table 1: Pattern 3 - Sector IDs

Sector No	1	2	3	4	5	6	7
Fitts's ID	4.43	4.04	3.59	2.00	4.15	4.26	3.75

Table 2: Pattern 4 - Sector IDs

Sector No	1	2	3	4	5	6	7	8
Fitts's ID	3.68	3.82	3.82	3.68	3.48	3.32	3.97	3.61

As seen in tables 1 and 2, the ID varies very little over the course of either pattern, with the difference of difficulties for pattern 3 being 2.43 and 0.64 for pattern 4.

3.2.2 Error Identification

To ensure a fair comparison of IPs, it decided that any sector in which an individual made an error (a lift, loop or pause) would be excluded from analysis. The Dot-to-Dot Task already logged occurrences of when a participant lifted the stylus from the drawing tablet, and several SQL scripts were provided to calculate the coordinates of where loops and pauses took place. With the coordinates of the error events stored, it was possible to compare the X coordinate of each event and each sector delimiter in order to determine the number of the sector in which an error occurred, and exclude said sector from the analysis process.

3.2.3 Regression analysis

Once the Sector difficulties were calculated, it became possible to perform regression analysis. Fitts's Law states that as the ID increases, so to does the MT, in a linear manner. The regression analysis of Patterns 3 and 4 (Figures 1 and 2, Appendix E) produced unexpected results, creating trend lines that were atypical of the hypothesized Fitts's model, and examples from existing literature.

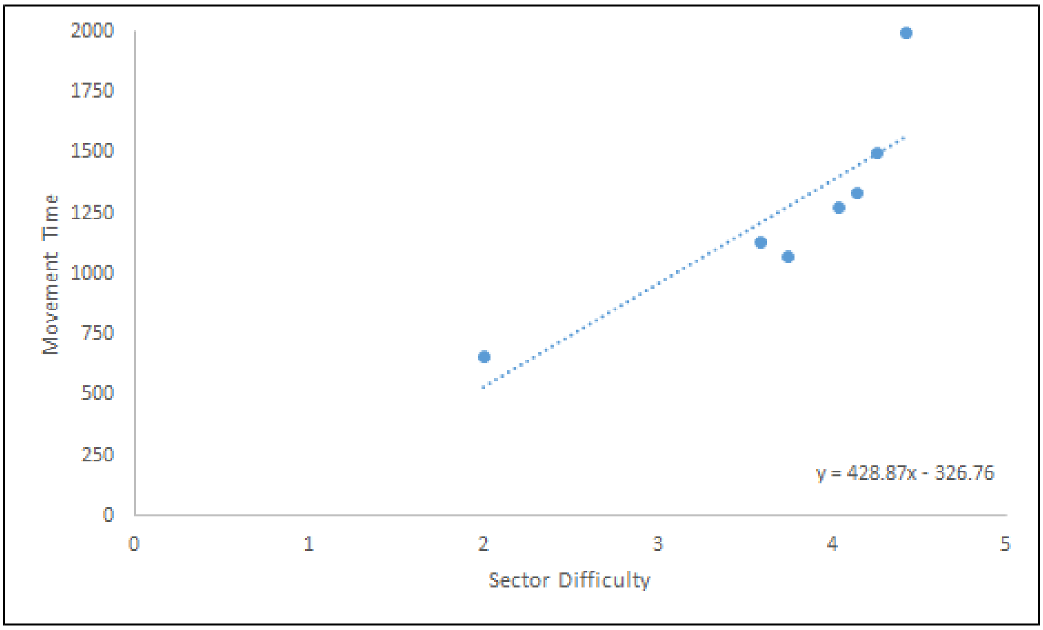

Figure 1: Regression Analysis of the Movement Times for Pattern 3 sectors.

There exists a number of possible reasons as to why the regression analysis trend lines were so unexpected. One likelihood is that it was caused by the

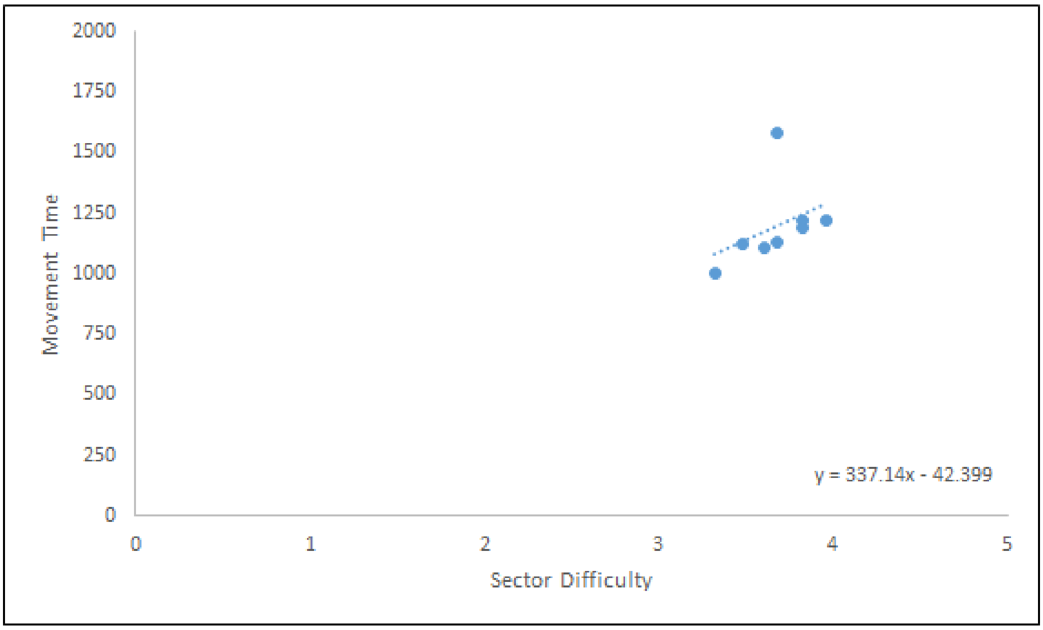

Figure 2: Regression Analysis of the Movement Times for Pattern 4 sectors.

lack of diversity in the sector IDs, causing excessive node clustering. Another possibility is that the non-uniform angles at which the lines had to be drawn affected the difficulty of the sector in ways that could not be measured by Fitts's Law. A third potential explanation of the regression analysis results is the possibility that the continuous drawing of lines affected the MT - in most studies concerning Fitts's Law, participants will draw a single line at a time, rather than in the Dot-to-Dot Task where several lines are drawn in succession.

Regardless of the reasons, the results of the regression analysis were atypical to those that Fitts's Law are normally expected to produce and a decision had to be made: either use the results of the regression analysis with the MacKenzie version of the equation as originally planned, or abandon the regression analysis and use the original Fitts's equation of IP. Even though regression analysis is currently the typically used method of Fitts's Law analysis, it was opted that the original equation should be used over the MacKenzie version due to the unexpected nature of the regression analysis results, especially for pattern 4.

3.2.4 Calculate Index of Performance

With the choice of performance equation decided, the final stage of development could begin. Using the original simplified equation made the calculation of an individual's performance a simple task of dividing a sector's ID by the time taken for a participant to complete said sector. Tables 3 and 4 depict average movement times for each sector, though the system allowed for the calculation of IP on a person to person basis.

Table 3: Pattern 3 - Average Movement Time in milliseconds for each sector.

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dyslexic	Dominant	2054	1288	1157	680	1361	1539	1073
n-Dyslexic	Dominant	1955	1258	1110	639	1319	1478	1074
Dyslexic	n-Dominant	1972	1291	1125	683	1509	1419	1199
n-Dyslexic	n-Dominant	1955	1387	1213	686	1511	1571	1256

3.2.5 Exporting Results

Python is well renowned for the ease at which it can read, manipulate and export data. Using the Python csv libraries allowed data processed by the Fitts's analysis to be quickly and simply converted and saved as csv file type. By saving results csv, it allowed data to be read and manipulated by a number of tools and frameworks including Microsoft Excel and R. The exporting of data to csv made tasks such as the visualisation of charts trivial.

Table 4: Patter 4 - Average Movement Time in milliseconds for each sector.

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dyslexic	Dominant	1789	1205	1162	1145	1085	955	1233	1063
n-Dyslexic	Dominant	1465	1228	1202	1125	1140	1027	1207	1131
Dyslexic	n-Dominant	1426	1221	1272	1099	1177	1134	1427	1058
n-Dyslexic	n-Dominant	1560	1245	1365	1225	1208	1080	1438	1245

4 Analysis and Results

This chapter of the dissertation describes the processes utilized in the analysis of data produced by the systems and procedures described in the Methodology section. Also presented is the results of said analysis, providing evidence for claims made in the Conclusion.

4.1 Statistical Analysis of Index of Performance

With the average IP of each group calculated, analysis and comparison of the results could commence. Individually the IPs reveal very little of interest, thus the analysis of demographics (Dyslexic and non-Dyslexic) was conducted to determine if any obvious traits existed to aid in differentiation.

Table 5: Pattern 3 - Average Fitts's IP per Sector Excluding Errors

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dyslexic	Dominant	3.21	4.17	3.77	3.45	3.61	3.44	4.03
n-Dyslexic	Dominant	3.08	4.04	4.24	3.69	3.55	3.75	4.01
Dyslexic	n-Dominant	3.04	3.50	4.43	3.34	3.72	3.79	4.22
n-Dyslexic	n-Dominant	3.09	3.89	3.99	3.27	3.52	4.18	3.50

Table 6: Pattern 4 - Average Fitts's IP per Sector Excluding Errors

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dyslexic	Dominant	3.68	3.71	4.47	3.80	3.77	4.03	4.34	3.77
n-Dyslexic	Dominant	4.21	3.61	4.06	3.81	3.56	3.81	4.05	4.01
Dyslexic	n-Dominant	3.29	3.50	3.49	4.57	3.81	3.78	3.52	4.21
n-Dyslexic	n-Dominant	3.79	4.06	3.70	3.87	3.45	3.60	3.30	4.18

When comparing the average IP for Dyslexic and non-Dyslexic task participants it was found that there was very little difference between the groups (Tables 5 and 6, Figures 3 and 4). The initial comparison was performed with the exclusion of sectors in which errors had been made. It was hypothesised that the exclusion of errors may have been the reason for the similarity in IPs, thus analysis was conducted again, this time with the inclusion of all sectors. Once again it was found that the average IPs of the Dyslexic and non-Dyslexic groups was remarkable similar, even with the inclusion of sectors with errors (Tables 7 and 8).

While the overall averages of the populations may be similar, this does not mean that the populations are statistically similar. There exists a number of methods for the measurement of statistical similarities between populations, including t-tests, f-tests and Analysis of Variance (ANOVA).

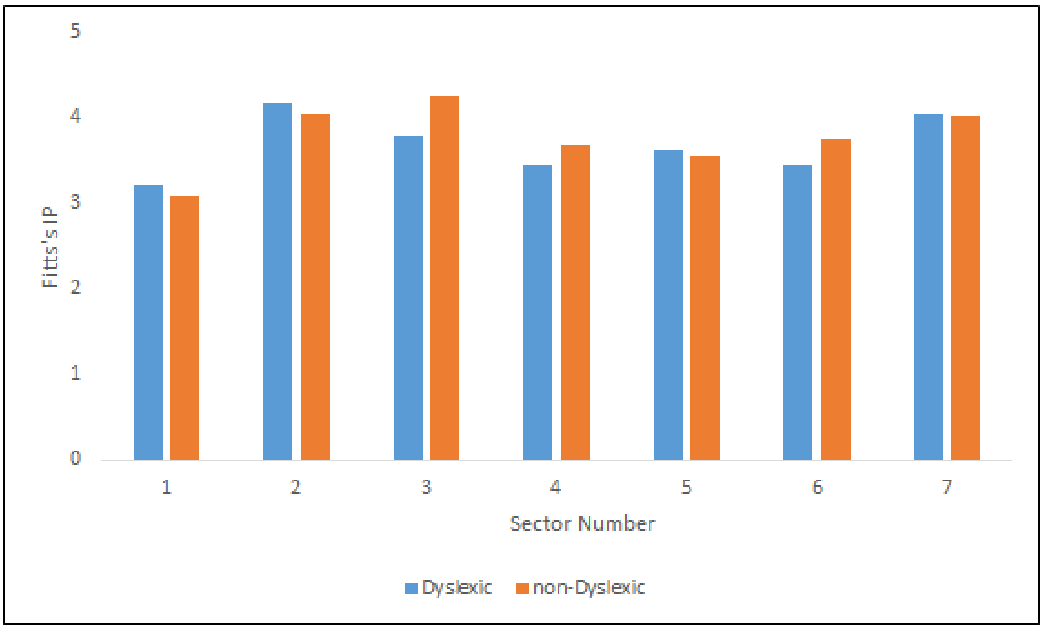

Figure 3: Average Fitts's IP for pattern 3 sectors without errors, executed with the dominant hand.

Table 7: Pattern 3 - Average Fitts's IP per Sector Including Errors

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dyslexic	Dominant	2.67	3.57	3.48	3.74	3.37	3.12	3.88
n-Dyslexic	Dominant	2.75	3.61	3.61	3.62	3.46	3.18	3.93
Dyslexic	n-Dominant	2.74	3.51	3.59	3.47	3.46	3.38	3.65
n-Dyslexic	n-Dominant	2.69	3.24	3.35	3.30	3.09	3.11	3.34

For the analysis of the Dyslexic and Non-Dyslexic IPs, a two sample t-test of unequal variance (sometimes referred to as a Welch test) was chosen. The Welch test was chosen for a number of reasons, namely that only two data sets are being compared, the two data sets are completely unrelated and the number of members in each population are uneven. If comparison of the possibly Dyslexic group was also being considered then an f-test would be more appropriate. However, it is assumed that the possibly Dyslexic population consisted of a mixture of both Dyslexic and non-Dyslexic members, meaning any statistical analysis of said group would be inconclusive.

In order to perform a proper statistical analysis, two terms had to be defined; a null hypothesis and a p-value. A null hypothesis is the formal statement of what is being tested. In the case of this project, the following null hypothesis was defined, 'Dyslexic and non-Dyslexic produce similar

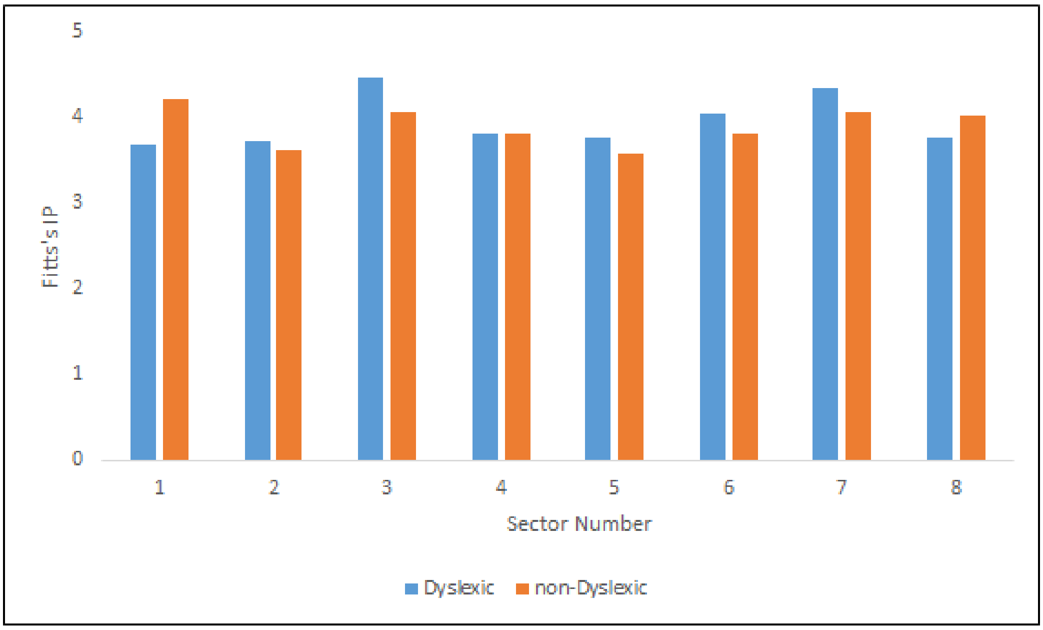

Figure 4: Average Fitts's IP for pattern 4 sectors without errors, executed with the dominant hand.

Table 8: Pattern 4 - Average Fitts's IP per Sector Including Errors

Status	Hand	1	2	3	4	5	6	7	8
Dyslexic	Dominant	2.87	3.51	3.66	3.56	3.61	3.96	3.53	3.67
n-Dyslexic	Dominant	3.11	3.45	3.66	3.71	3.50	3.72	3.72	3.63
Dyslexic	n-Dominant	2.97	3.49	3.33	3.77	3.57	3.73	3.19	3.90
n-Dyslexic	n-Dominant	3.04	3.46	3.39	3.46	3.29	3.62	3.04	3.70

Indices of Performance for the Dot-to-Dot Task.'

The p value is a pre-determined value that the result of the statistical analysis results is compared against. For the following analysis a p value of 0.05 is assumed. To summarise, if statistical analysis produces a value lesser than the p value (≤ 0.05), then the null hypothesis has been disproven and is rejected. If the resulting value is greater than the p value (≥ 0.05), then the null hypothesis has not been disproven. The results of the t-tests are presented in Tables 9 and 10.

Table 9: Pattern 3 - t-test results.

Dominant	0.7139	0.8733	0.5921	0.6993	0.6812	0.7923	0.8551
n-Dominant	0.8200	0.2123	0.3265	0.5139	0.1065	0.2125	0.2227

Table 10: Pattern 4 - t-test results.

Dominant	0.4200	0.7849	0.9922	0.5368	0.6723	0.3978	0.4357	0.8660
n-Dominant	0.7545	0.8909	0.7539	0.1907	0.2545	0.6804	0.4491	0.4630

It was found that none of the t-values for any pattern or any sector were lower than the predetermined p value. This was the case across all sectors of both pattern 3 and 4, as well as dominant and non-dominant hands. This infers that the previously stated null hypothesis is correct.

It should be noted that while the results of the t-test indicate that IP and thus Fitts's Law are not a valid metric for the identification of Dyslexia, the manner of performing the analysis was atypical of the the more usual Fitts's Analysis experiment.

4.1.1 Error Analysis

The original proposal of this project suggested that sectors in which errors occurred would be ignored. However, upon performing statistical analysis, this decision was reconsidered. During the reassessment of the inclusion of sectors with errors a trait in the data was identified. When the average number of errors for each sector in each population is considered - Dyslexic and non-Dyslexic - they appear to to be relatively similar, baring a single sector in each pattern(Tables 11 and 12, Figures 5 and 6).

Table 11: Pattern 3 - Average sector completion rate with no errors.

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dyslexic	Dominant	50%	24%	38%	69%	69%	45%	60%
n-Dyslexic	Dominant	56%	43%	46%	69%	78%	43%	81%
Unknown	Dominant	50%	33%	36%	74%	74%	48%	67%
Dyslexic	n-Dominant	57%	26%	7%	67%	45%	33%	55%
n-Dyslexic	n-Dominant	58%	29%	29%	69%	54%	21%	69%
Unknown	n-Dominant	48%	24%	26%	67%	48%	33%	57%

It appears that Dyslexic task participants are significantly more likely to make an error (such as lifting, looping or pausing) in pattern 3 sector 2 and pattern 4 sector 7. It is clear that ID alone is the cause for this discrepancy, as the difficulty of each of these movements is only marginally larger than other sectors in the patterns and yet the rate of errors is noticeably higher.

A potential cause for the high error rate in these sectors may be due to the angle required to draw the line. However, this hypothesis is also somewhat

Table 12: Pattern 4 - Average sector completion rate with no errors.

Status	**Hand**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dyslexic	Dominant	38%	48%	29%	62%	76%	95%	31%	48%
n-Dyslexic	Dominant	40%	58%	36%	65%	74%	94%	71%	38%
Unknown	Dominant	40%	48%	40%	64%	76%	95%	67%	31%
Dyslexic	n-Dominant	38%	19%	31%	29%	62%	88%	50%	36%
n-Dyslexic	n-Dominant	28%	31%	31%	50%	74%	88%	50%	35%
Unknown	n-Dominant	55%	36%	31%	38%	60%	83%	38%	29%

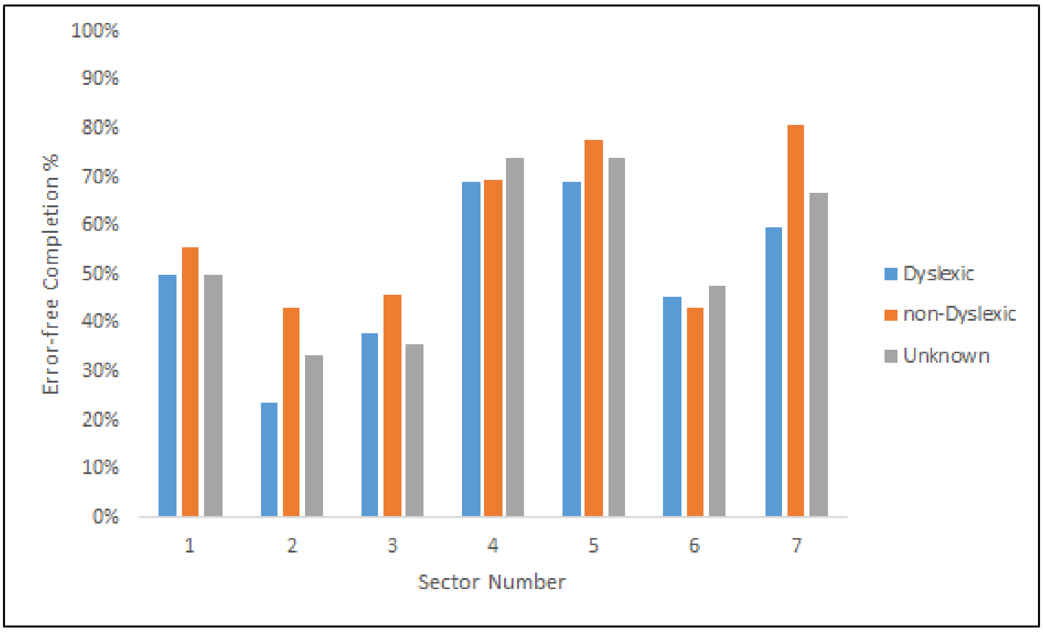

Figure 5: Pattern 3 - Average sector completion rate with no errors executed with the dominant hand.

unlikely due the fact that sectors of similar angles are also present in the patterns that do not share the same inconsistencies in error rate.

It is possible that the increase in error rate is related to the angle of previous movement. It appears that there is a higher error rate in sectors where there is a drastic change in angle from the previous sector. This is exemplified in pattern 4, where sectors 4, 5, and 6 form a gentle curve, followed by the steep angle of sector 7.

4.2 Analysis Summary

The analysis of results indicates that Fitts's Law analysis of Dot-to-Dot Task results will not provide any meaningful data in regards to differentia-

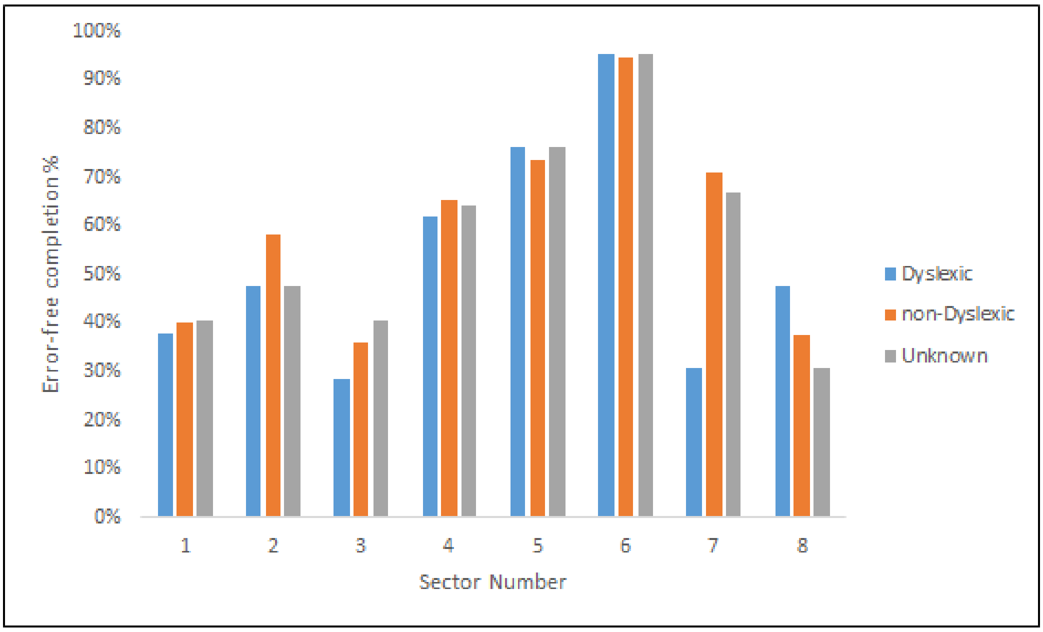

Figure 6: Pattern 4 - Average sector completion rate with no errors executed with the dominant hand.

tion of Dyslexic and non-Dyslexic task participants. While Fitts's Law may not appear to be an appropriate metric for Dyslexia detection, the analysis process revealed that the amount of errors made by Dyslexic task participants was noticeably larger the non-Dyslexic participants, suggesting that error rate analysis may be a more accurate alternative to Fitts's Law for the analysis of Dot-to-Dot task results. Unfortunately it was not possible to further investigate the error rate of task participants, due to the limited number of patterns available for the Dot-to-Dot Task. Had error-analysis been considered as a metric during the initial planning stages of the project, a more concise and dedicated effort would have been made to properly collect and analyse the errors committed by task participants.

5 Conclusion and Future Work

The aim of this project was to investigate whether or not Fitts's Law was a suitable method for the detection of Dyslexia. Within the confines of the experiments that have been run and analysed in this project, it appears not to be a valid Dyslexia-detection discriminant method.

The premise of this project was based upon the anecdotal observation of primary school children participating in the Dot-to-Dot Task. There appeared to be a correlation between reading ability and Dot-to-Dot Task performance of the children, that could unfortunately not be officially analysed, due to the age of the children, as well as a lack of hard evidence. This project's goal was to recreate and investigate in a controlled and processed manner the theory that the Dot-to-Dot Task could be used to detect Dyslexia. However, this was found not to be the case. While it may be entirely possible to detect Dyslexia via Fitts's Law there are a number of nuances and issues that did not translate from the original hypothesis to this project. These are as follows.

5.1 Fitts's Law

Fitts's Law was the metric of performance chosen for investigation, as it has been shown as a reliable tool for the prediction of human motion, as well as measuring performance. While it is true that Fitts's Law can easily determine the difficulty and execution of a movement along a straight line and the fact that the Dot-to-Dot Task patterns consist of straight lines, the task was clearly not designed with Fitts's Law in mind and, as such, Fitts's Law may not have been the optimal method to measure performance of the Dot-to-Dot Task.

As is shown in the Literature Review, a typical Fitts's Law experiment consisted of having participants drawing a single horizontal or vertical line between two targets - the size and distance between each target being altered in subsequent tests so data could be collected for a number of IDs. The Dot-to-Dot Task consists of participants drawing a continuous sequence of lines, at various angles, between identically-sized targets that are spaced at relatively similar distances. It became clear that the Dot-to-Dot Task was not a typical Fitts's experiment - as Fitts's Law does not take into account the angle of movement or continuous drawing of lines.

5.2 Age of Participants

The second major difference between the observed childrens' performance and the experiment performed in this project is the age of the participants. The original observation of the Dot-to-Dot Task and reading skill performance consisted of children from ages 4 to 11, while the ages of the participants in this project ranged from 19 to 68. While it is true that Dyslexia cannot be cured, as such, the severity and manifestations in which it affects an individual can be mitigated and reduced over time, with patience and learning techniques. It is entirely possible that the Dyslexic individuals that participated in this study had a sufficient understanding and experience of Dyslexia and thus their performance in the Dot-to-Dot task was not affected as noticeably as the children who have also participated in the task. The children that participated in the original study were too young to have an official Dyslexia assessment, meaning it is entirely possible that many of the children with low reading, writing and Dot-to-Dot Task performance were not Dyslexic. At the early ages that these children were, their levels of cognitive development can vary drastically among peers.

In summary, Fitts's Law does not appear to be a credible form of Dyslexia assessment when it is used to evaluate the results of the Dot-to-Dot Task in its current state. This is in part due to Fitts's Law as well as the current state of the Dot-to-Dot task. Fitts's Law is an extremely accurate human-movement prediction tool, but as was discussed in the Literature Review, individuals with cognitive and developmental issues that affect their motor skills typical abide to the predictions suggested by Fitts's Law. The second issue was the fact the Dot-to-Dot Task only had two patterns available to test participants, meaning there was not a broad enough spectrum of difficulties to perform adequate regression analysis.

5.3 Future Work

There exists a number of ways in which this project could be continued into the future, either focusing on further research into Fitts's Law or attempting a different type of analysis, building upon the current Dot-to-Dot data.

If further experimentation into the use of Fitts's Law is to take place, the Dot-to-Dot Task would require a significant amount of refactoring and reformatting to allow for more accurate and credible Fitts's analysis. While the back-end of the application remains an excellent data collection tool, the patterns that the participants trace would require an almost complete redesign. Current patterns all use a fixed target width of twenty pixels - varying the size of the targets allows for a variation in the ID of a movement, without the need for excessive distances between the targets.

A second issue for consideration is the continuous nature of the Dot-to-Dot patterns. Typically, Fitts's experiments have participants complete a single move at time, whereas the Dot-to-Dot patterns consist of seven to eight different movements in a single pattern. If the patterns were redesigned to be individual movements, the Dot-to-Dot Task would be similar to previously conducted Fitts's experiments, allowing for a more concise Fitts's analysis.

Another area of investigation that could be conducted in the future would be research into how the angle of sector affects its ID. The analysis of the Dot-to-Dot results revealed a significant difference in the number of errors made by Dyslexic experiment participants in upward sloping sectors that directly followed downward sloping sectors. Patterns could be designed to further test this theory, with the aim of evaluating Fitts's Law's usability in multiple movement scenarios.

Should future research focus on Dyslexia identification via the Dot-to-Dot Task in it's current state - i.e. without altering its design and collecting additional data - a number of different identification techniques could be employed. One such method of identification could be the use of an Artificial Neural Network (ANN): a form of deep learning artificial intelligence. A neural network can be trained on the previously collected Dot-to-Dot Task results of the Dyslexic and non-Dyslexic participants and learn to identify unique traits or features in each data set. Neural networks have been proven to be extremely prudent at spotting similar traits between different data sets. However, care must be taken to ensure that the system does not detect a false positive in a data set, leading to false and invalid assessments.

While Fitts's Law has been proven as an effective and reliable model of human movement, it is likely that other alternatives exist, some of which may be more effective than Fitts's Law.

6 Learning Outcomes

This project had a number of learning outcomes attached to it, the completion of which provide evidence for a well-planned and executed project. The learning outcomes and evidence of their completion are presented thusly.

L.O.1: Manage a substantial individual project, including planning, documentation and control. To ensure the project remained on track, weekly meetings with the project supervisor were arranged and attended. Evidence of this was recorded in a project blog (Appendix C) that was updated weekly, with the progress made since the last supervisor meeting. The minutes of the supervisor meetings were appended to each post as a comment.

At the beginning of the project, a basic plan was drafted in the form of a Initial Project Overview (Appendix A). This document outlined the deliverables of the project, as well as the goals to be achieved as the project progressed.

Further project management and advice was provided in the form of a mid-way meeting with the project supervisor and second marker (Appendix B).

L.O.2: Construct a focussed problem statement and conduct a suitable investigation, including literature or technology review, into the context of that problem. As the premise of the project was a novel Dyslexia assessment method, finding relevant examples measuring the efficiency and effectiveness of implementation was extremely difficult. A major concern was the fact that at the time of writing, there existed no available literature in regards to detection of Dyslexia via Fitts's Law - existing literature typically being the cornerstone of any project of this scale.

L.O.3: Demonstrate professional competence by applying appropriate theory and practice to the analysis, design, implementation and evaluation of a non-trivial set of deliverables. The prime goal of this dissertation was to investigate Fitts's Law's usability as an analysis tool for the detection of Dyslexia. Evidence of Fitts's Law's inability to differentiate Dyslexic and non-Dyslexic task participants has been provided, as well as alternative methods of the detection that could be attempted in the future, hopefully with more success. While the term 'investigate' may imply a vague or undefined project, the scope of the investigation was very well defined. The scope was also specified by the available and collected data in the form of the Dot-to-Dot Task, rather than using movement data from a number of different tasks and experiments.

L.O.4: Show a capacity for self-appraisal by analysing the strengths and weaknesses of the project process and outcomes with refer-

ence to the initial objectives and to the work of others. In terms of strengths, effort was made to find alternative solutions and methods when a dead-end was encountered. This is exemplified by choosing to use an alternive Fitts's Law equation, and exploring the possibilty that the number of errors made by indiduals may be a more usable discriminant than Fitts's Law.

A major weakness was the difficulty sustained when moving between multiple tasks, both personal and academic. Coursework and exams could often leave this project untouched for significant periods, resulting in having to constantly readjust and re-evaluate the time required to complete aims and goals.

References

British Dyslexia Association. (n.d.). *Frequently Asked Questions — British Dyslexia Association.* Retrieved from http://www.bdadyslexia.org.uk/parent/frequently-asked-questions

British Dyslexia Association. (2016). *About the British Dyslexia Association — British Dyslexia Association.* Retrieved from http://www.bdadyslexia.org.uk/about

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*, *21*(8), 601–613. doi: 10.1080/00140137808931762

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, *47*(6), 381–391. doi: 10.1037/h0055392

Ifft, P. J., Lebedev, M. a., & Nicolelis, M. a. L. (2011). Cortical correlates of fitts' law. *Frontiers in integrative neuroscience*, *5*(December), 85. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3250970&tool=pmcentrez&rendertype=abstract doi: 10.3389/fnint.2011.00085

Mackenzie, & Scott, I. (1992). *Fitts' law as a performance model in human-computer interaction* (Doctoral dissertation). Retrieved from http://www.yorku.ca/mack/phd.html

MacKenzie, I. S. (1995). Movement Time Prediction in Human-Computer Interfaces. *Readings in human-computer interaction*, 483–493.

Maruff, P., & Velakoulis, D. (2000). The voluntary control of motor imagery. Imagined movements in individuals with feigned motor impairment and conversion disorder. *Neuropsychologia*, *38*(9), 1251–1260. doi: 10.1016/S0028-3932(00)00031-2

NHS Choices. (n.d.-a). *Dyslexia - Diagnosis - NHS Choices.* Department of Health. Retrieved 2017-04-11, from http://www.nhs.uk/Conditions/Dyslexia/Pages/Diagnosis.aspx

NHS Choices. (n.d.-b). *Dyslexia - NHS Choices.* Department of Health. Retrieved 2017-04-11, from http://www.nhs.uk/conditions/Dyslexia/Pages/Introduction.aspx

Piotrowska, M. B., Willis, A., Maclean, R., Murray, J., & Kerridge, P. J. M. (2015). Visual-Spatial-Motor Integration in a Cross-Section of Primary-Aged Children : Implications for Assessing Risk of Dyslexia. , *05*(AUGUST), 443414.

Smits-Engelsman, B. C. M., Wilson, P. H., Westenberg, Y., & Duysens, J. (2003). Fine motor deficiencies in children with developmental coordination disorder and learning disabilities: An underlying open-loop control deficit. *Human Movement Science*, *22*(4-5), 495–513. doi: 10.1016/j.humov.2003.09.006

Willis, A., Piotrowska, M. B., Bannach-brown, M. A., Maclean, R., & Kerridge, P. J. (2010). Performance on a tablet-based visual-spatial-motor task is compromised in adults and children with dyslexia : implications for the development of a novel screening tool . The Dot-to-Dot Task. (2003), 3181. doi: 10.13140/2.1.4607.8723

Wilson, P. H., Maruff, P., Ives, S., & Currie, J. (2001). Abnormalities of motor and praxis imagery in children with DCD. *Human Movement Science*, *20*(1-2), 135–159. doi: 10.1016/S0167-9457(01)00032-X

Appendices

A Intial Project Overview

Sam Dixon 40056761

Initial Project Overview

SOC10101 Honours Project (40 Credits)

Title of Project:

Investigating Fitts' Law as a Discriminant for Identifying Possible Dyslexia in Primary School Children

Overview of Project Content and Milestones

The Main Deliverable(s):

The goal of the project is to produce evidence of whether or not the Human Computer Interaction theory of Fitts' Law can be used in the identification of dyslexia in children, before they develop the literary skills required to take traditional dyslexia diagnoses tests.

The Target Audience for the Deliverable(s):

The target audiences of the pre-stated evidence are; teachers, researchers and those who work in school learning support departments.

The production of evidence would not only allow said parties to more accurately identify dyslexia but also allow for identification at a younger age. It could also allow for further research into the use of HCI for the detection of learning difficulties.

The Work to be Undertaken:

- Collection of sample data from university students – crucial as it is unknown if previous test participants were dyslexic or not
- Building of a system to analyse data for patterns – detect valid/invalid sectors in the dot-to-dot game
- Analysis and comparison of pre-existing / collected data – compare patterns from known dyslexic participants with unknown, check for similarities
- Evaluate of results

Additional Information / Knowledge Required:

Data Mining and Data Analytics

Appropriate Statistical techniques

MEng Software Engineering 19/09/2016 1

Information Sources that Provide a Context for the Project:

Prof Jon Kerridge – “Dot-to-Dot” data and system

Rasmus Monk – “An Investigation into the Dot-to-Dot Dataset”

Scott MacKenzie – “Movement Time Prediction in Human-Computer Interfaces”

The Importance of the Project:

While dyslexia detection via the use of technology is not a new concept, the benefit of focusing on Fitts’ Law has not been documented before. Evidence produced from this project could allow dyslexia to be detected from an earlier age, mitigating the effects it has on children in school and everyday life.

Evidence produced from this project could also indicate that other HCI concepts could be usable in the detection of learning difficulties, and provide hints for areas of further research.

The Key Challenge(s) to be Overcome:

As this project consists of researching a very specific, relatively unexplored area, there is very little existing literature. While there are many papers and journals explain and describing the benefits of Fitts’ Law, none relate to its use in diagnosing dyslexia.

Another key issue to be aware of is the amount of sample data available. The crux of the project is data analytics, but without a large enough sample size it may be impossible to draw a meaningful conclusion from the data. For this reason, additional data must be collected – this time from University students. By testing participants who already know if the dyslexic or not, it will provide a firm base of patterns which we can compare unconfirmed participants against.

B Review Output From

SOC10101 Honours Project (40 Credits)

Week 9 Report

Student Name: Sam Dixon

Supervisor: Jon Kerridge

Second Marker: Emma Hart.

Date of Meeting: 15-12-16.

Can the student provide evidence of attending supervision meetings by means of project diary sheets or other equivalent mechanism? **yes** **no***

If not, please comment on any reasons presented

Please comment on the progress made so far

Is the progress satisfactory? **yes** **no***

Can the student articulate their aims and objectives? **yes** **no***

If yes then please comment on them, otherwise write down your suggestions.

But consider what you might do if you don't get sufficient dyslexic students + re-evaluate aim.

* Please circle one answer; if **no** is circled then this **must** be amplified in the space provided

Does the student have a plan of work? yes no*

If yes then please comment on that plan otherwise write down your suggestions.

Yes - but not detailed

Does the student know how they are going to evaluate their work? yes no*

If yes then please comment otherwise write down your suggestions.

But might have to switch type of evaluation based on data collection.

Any other recommendations as to the future direction of the project

Read some literature / text book on basic data clustering + analysis techniques.

J.M. Kerridge.

Signatures: Supervisor Second Marker

Student

Please give the student a photocopy of this form immediately after the review meeting; the original should be lodged in the School Office with Leanne Clyde

* Please circle one answer; if **no** is circled then this **must** be amplified in the space provided

C Project Blog (Diary Sheets)

Captains Log, Stardate 07/09/2016. 07/09/16. Starting to begin my Honours project proper. I have been asked to keep a blog to allow my supervisor to easily keep track of progress. The official title of the honours project is: "Investigating Fitts Law as a Discriminant for Identifying Possible Dyslexia in Primary School Children" Being dyslexic myself, I have keen interest in the processes of identifying dyslexia, and when I found out that one of my lectures was also studying the area, I jumped at the opportunity. Lets get learning.

Week 3-4 Update. 27/09/16. Week 3: Hell of a week; Apparently there had been some confusion in the School office, and my Honours registration form had been misplaced, long story short; I spent most of the week trying to sort out admin issues, meaning I got basically no work done for any of my modules, great start to the semester. Week 4: Working with Jon data and code base. I had previously had all this stuff set up, but my laptop came down with a bad case of Windows 10, and I was forced to reformat. Managed to get the data base reconfigured, and got some code to compile. I was originally using Eclipse as my Java IDE, but over the summer I got very attached to IntelliJ and I have been able to port Jon's project over without much issue. The goal for this week is to write some code to identify good/bad sectors in each test and then analyse the valid ones. A "bad" sector is one that has a break, pause or loop in it (see the beautiful picture in the header). The admin issues should be resolved this week and I will be able to produce some data. Here's hoping.

Week 5. 06/10/16. Hectic week once again, I have started a group project in one of my modules, so a lot of my time was spent organising that. Below is a more accurate representation of what determines a valid sector. I also read some more papers on Fitts' models, the basic formula of calculating the difficulty between two points is: [picture] Pretty basic once you have it on paper. I am still trying to extract only valid sectors from Jon's data set, but once I have them it should be clear sailing to calculate their Fitts' score. Lets hope that next week is less busy, so I can get my head down and blast through some work.

Week 6. 13/10/16. A hectic week once again, no rest for the wicked. The current goal is to extract all the valid sectors from the data base, which first requires me to find all the invalid ones. To achieve this I have cobbled together a very basic python script, that loops through all the invalid events (loops, lifts, pauses), gets the coordinate of the event and then assigns the row with the appropriate sector number. As can be seen, I have appended the sector ID to the end of each list, a simple process that will prove invaluable later. Once I have compiled my list invalid sectors, extractor the valid ones will be a piece of

Week 7. 20/10/16. We are close, really, REALLY close.

After a week of tinkering I can now produce a list of every collection, and all the invalid sectors within it. Now that we have all the bad sectors named and shamed, pulling the valid ones will be super simple. I am quite annoyed I wasnt able to get the final iteration of this program complete before my supervisor meeting, but considering how close I am I cannot be too upset. Onwards to next week, and some proper data.

Week 8. 27/10/16. So. Didnt manage to get much work this week due to my other modules getting in the way. I was however able to test the results of my last weeks work, by comparing my script's output to images of the pattern's drawn by the children. My script believes that the child in the image made mistakes in sectors 1, 3, 4, 5, 6. If we look at the image above, we can see that this is accurate. There is some noise in a lot of the images, but from what I can tell my script is producing valid results, which is nice. Plan for next week: actually focus on my honours and get some more code done.

Week 9. 03/11/16. This week turned out similar to the last, with very little work being done on my honours project. I have two deadlines for other modules this week, Friday and Sunday – once I have completed these assessments I will have mountains of time to spend on this project. I quite annoyed that I haven't been able to spend any time on my honours, as it is significantly more interesting than some of the other work I am doing. Till next week!

Week 11. 17/11/2016. Real life Strikes once again. Working away on my progress report for my second marker. Looking forward to getting this finished and back to development. Onwards and upwards.

Week 12. 24/11/2016. Finally got my progress report into my second marker, hooray! Other than that, I am focusing mostly on upcoming coursework and exams. I have done a little poking around with the data i generated, but I am yet to find anything particularly interesting or outlandish – I will have to put aside a few hours for some in depth data analytics. I have a meeting with my second marker on the horizon, so I want to prepare for any potential that she may have for me – as well my next steps.

Trimester 2 - Week 1. 15/01/2017. Back in business. Spent a lot of time collecting data from various people at the university – it was good fun. I have also had a quick look at said data, and I am trying to see if I can spot any patterns. If I do notice anything common, I need to update my python scripts to also identify it. All in all, a great first week back on the project.

Trimester 2 - Week 2. 23/01/2017. Collected some more data from volunteers this week, but many of them did not show up, which was a shame. Started work on analysing the data I did collect to create a Regression analysis. but work on it has been slow, and I don't have anything to show for it as of right now. I am also considering modifying the database and analysis engine I created, as I now have more information of the test subjects (whether they are dyslexic or not) and I don't want to have to swap between MySQL and excel spread sheets to collate information. A slow week overall, but ground work has been put down which will allow multiple tasks to be completed this week, namely: regression analysis and Dyslexic / Non-dyslexic comparison.

Trimester 2 - Week 3. 30/01/2017. We have some Charts! Some of the results seem a little skewed – likely due to the difference in numbers between dyslexic and non-dyslexic test participants. The data extraction scripts I was previously using had to be completely rewritten, as the new database I am using for University test participants is using a different schema structure from the. This leaves us with a small issue in regards to loop detection – which is still in the process of being reworked. More charts, graphs and analytics to come very soon!

Trimester 2 - Week 4. 06/02/2017. Starting on the writing of the disserstion proper. Spent a little time on sorting out a Latex template and have some simple outline paragraphs for each section I am going to write. I am going to have my supervisor check over what I have so far to ensure the layout is alright, then I will try to crack out a rough draft of Lit review and methodology. I should be running some tests on the SEBE students soon, and more data will make the analysis task all the easier.

Trimester 2 - Week 5. 13/02/2017. Spent a lot of time this week dealing with other modules, so I did not get as much honours complete as I was hoping – though I did spend some time updating scripts to include loop detection. While examining the data produced by the updated scripts, I came across the information above, which seems to indicate that Dyslexic participants struggle with sector 8 the most, for pattern 4 at least. Will examine similar data further during the week, to see if I can quantify this claim any further.

Trimester 2 - Week 6. 20/02/2017. No picture this week! Been working on extracting as many varibles as possible from the data, as well as combining trhough B's data – has taken a long time but is going well. I have spent a lot of time trying to prove and quantifying my data – hence no pictures this week, once I prove that my results are valid, we will have graphs-galore! Plan is to keep working with B's and my own data, and get as much varibles as possible in order to do some pattern mathcing.

Trimester 2 - Week 8. 06/03/2017. Playing with data and making some charts. Most of the charts are fairly nondescript, mainly because I forgot to update the database before my analysis. I am reproducing the charts asap, with the correct data, and we will see if they make anymore sense.

Trimester 2 - Week 10. 20/03/2017. Not a hugely productive week overall – mainly due to other courseworks and my initial work on the poster. I was looking at the "key-sectors" – areas that had large difference between dyslexic/non-dyslexic participants. Both the sectors I am interested in are upward slopes of similar angles/lengths – but other sectors of similar proportions do not have as large differences. I am using these two sectors as "anchors" to compare possible dyslexics against. I am still parsing through B's data – it is extremely verbose so I am trying to figure out which data I actually need and what can be ignored.

D Dot-to-Dot Task Participant Permission Form

Informed Consent Form

Application of Fitt's Law to Identify Possible Dyslexia Using DotToDot

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in this research to be conducted by Jon Kerridge and Emma Hart who are staff members in the Edinburgh Napier School of Computing and Sam Dixon, an intern in the Edinburgh Napier School of Computing.

2. I have been informed of the broad goal of this research study. I have been told what is expected of me and that the study should take no longer than 10 minutes to complete.

3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researchers. I have been told that these data may be submitted for publication.

4. I also understand that if, at any time during the session, I feel unable or unwilling to continue, I am free to leave. That is, my participation in this study is completely voluntary, and I may withdraw from it at any time without negative consequences.

5. In addition, should I not wish to answer any particular question or questions, I am free to decline.

6. I have been given the opportunity to ask questions regarding the procedure and my questions have been answered to my satisfaction.

7. I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of this consent form for my records.

Participant's Signature Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature Date

E Movement Time Regression Analysis

Table 13: Pattern 3 - Regression Analysis input data.

Sector ID	Movement Time
2.00	654.01
3.59	1127.17
3.75	1073.18
4.04	1269.22
4.15	1334.30
4.26	1500.22
4.43	1991.61

Table 14: Pattern 4 - Regression Analysis input data

Sector ID	Movement Time
3.32	1000.80
3.48	1119.50
3.61	1105.89
3.68	1584.11
3.68	1132.42
3.82	1219.60
3.82	1187.48
3.97	1216.46

F Code and Data Listings

Due to the sensitive nature of personal data, code and data listings were omitted from this dissertation to adhere with Data Protection laws and Ethical agreements. Samples of code and data are available within the media device submitted with this dissertation, and further disclosure can be made available upon request.

G Non-Dominant Hand Results

Throughout this dissertation, charts depicting the MT, IP, and similar are presented to provide aid in the visualisation of results. The previously mentioned charts all depict data collected from participants dominant hands. The non-Dominant hand equivalent charts are presented here.

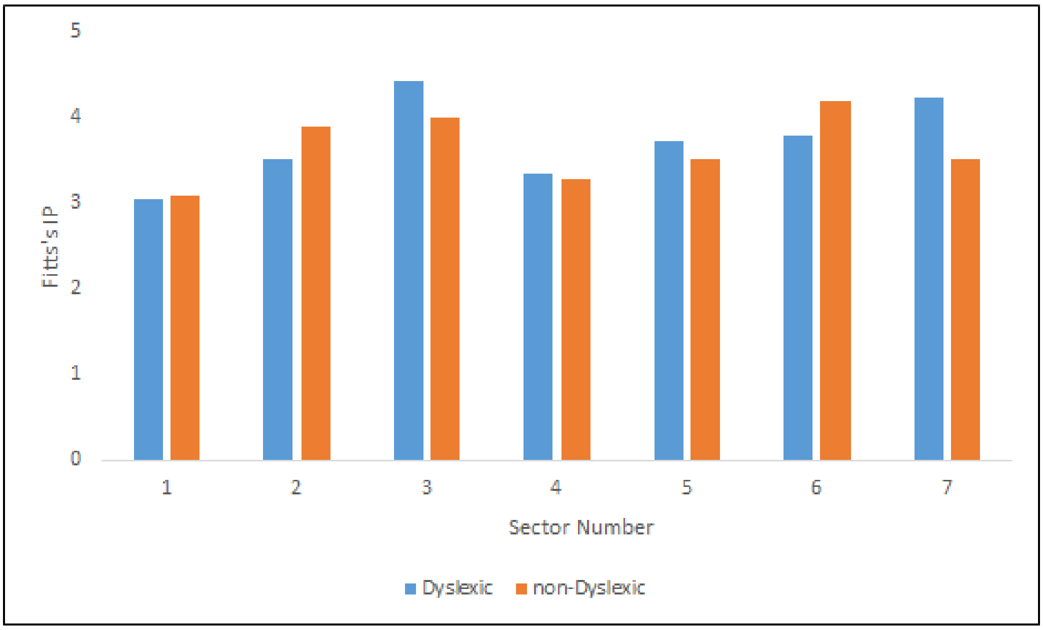

Figure 7: Average Fitts's IP for pattern 3 sectors without errors, executed with the non-dominant hand.

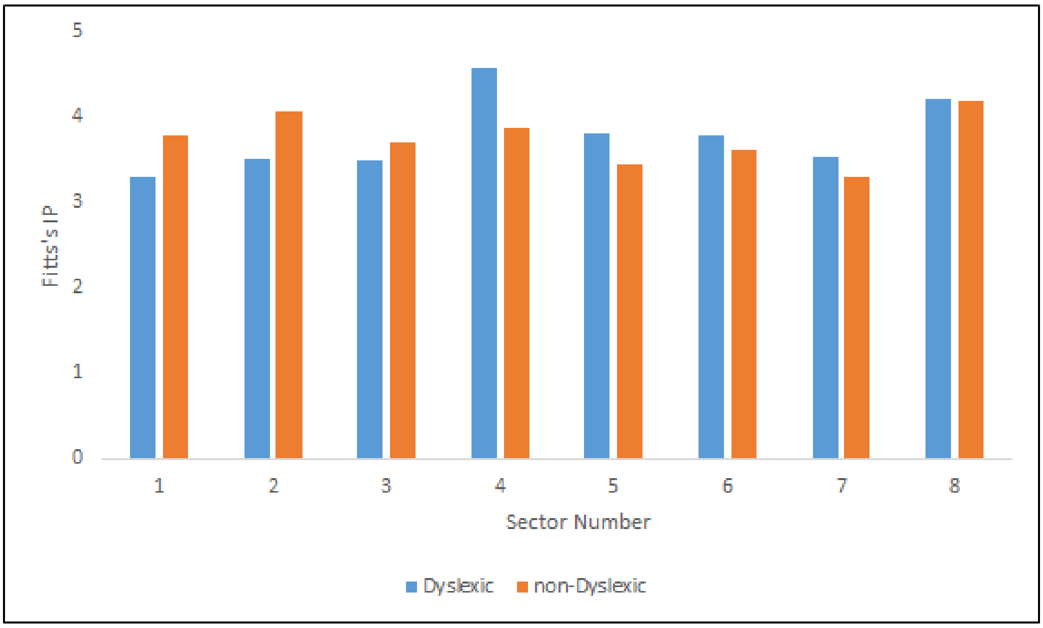

Figure 8: Average Fitts's IP for pattern 4 sectors without errors, executed with the non-dominant hand.

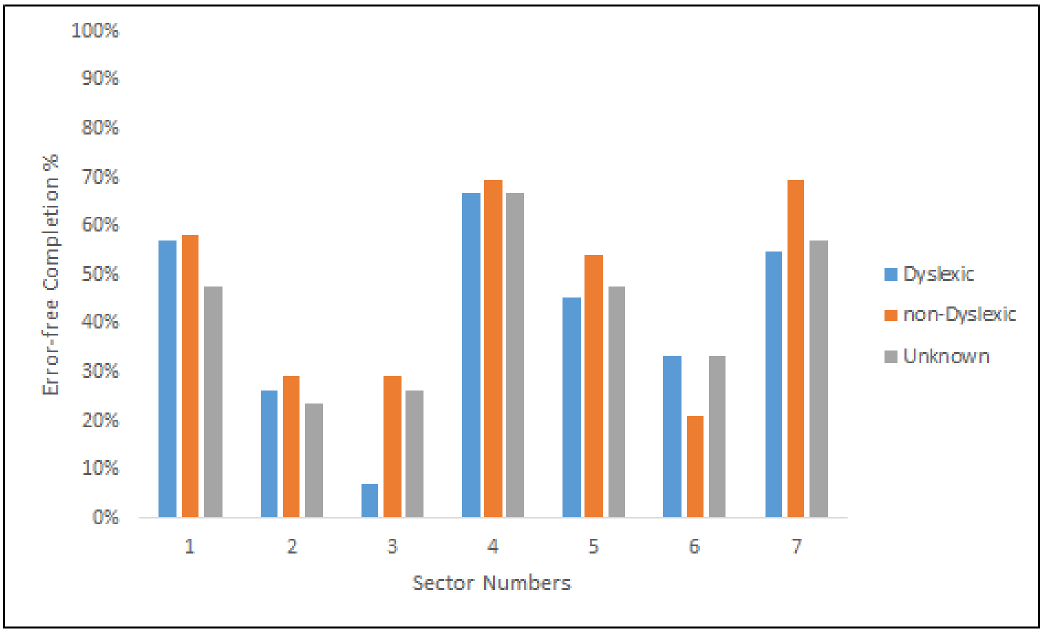

Figure 9: Pattern 3 - Average sector completion rate with no errors executed with the non-dominant hand.

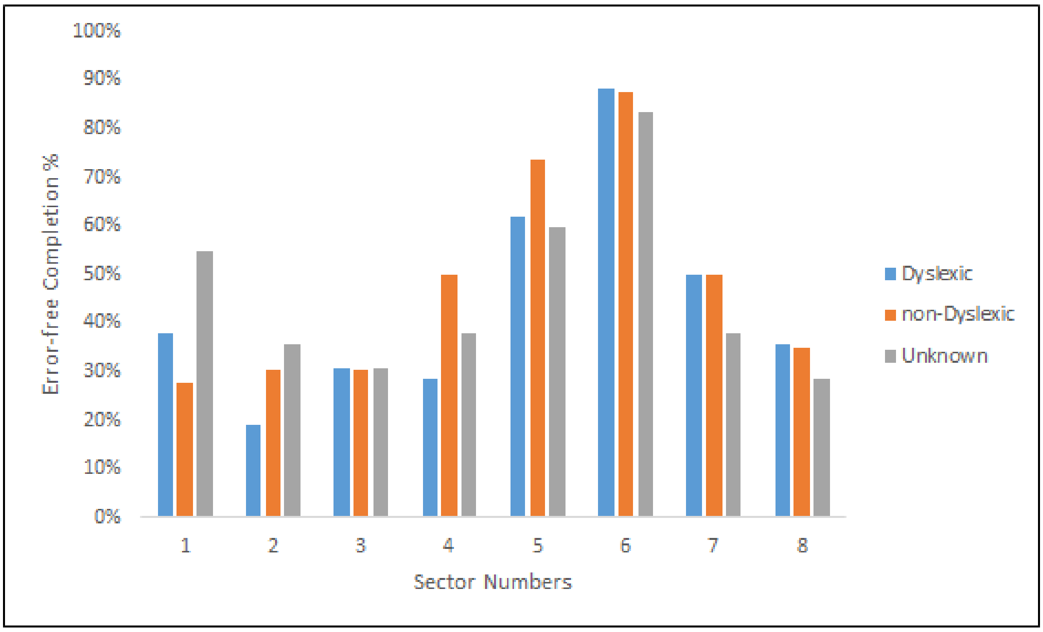

Figure 10: Pattern 4 - Average sector completion rate with no errors executed with the non-dominant hand.