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

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# Abstract

This report covers the current progress of the development and evaluation of a system which aims to detect Dyslexia, via the use of Fitts’s Law. Within is a brief overview of the project - prior art; goals and aims; what has been achieved; what is planned; and how the system will be evaluated once completed.

# Background

## Dyslexia

Dyslexia is present in around 10% of the British population to some degree; about 4% of the population have severe Dyslexia [1], [2]. 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 is one of the few learning difficulties which does not have an assessment funded by the NHS [3], [4]. The current and most accurate form of assessment remains in the form of traditional “pen-and-paper” tests.

For the reasons stated in the above, research into more diverse – and potentially improved – detection methods could allow for potentially faster, earlier and more accurate detection of Dyslexia.

## Dot-to-Dot Task

The Dot-to-Dot Task (DtD) [5], [6] is an application that tests a user’s ability to trace lines between a set of displayed dots. Prof. Jon M. Kerridge hypothesises that Dyslexic children will produce a Dot-to-Dot solution, which contains distinct patterns or traits. These could, in turn, then be identified by a computer, aiding in the identification of Dyslexia in the examinee.

## Fitts’s Law

The metric of identification being analysed in this project is Fitts’s Law [7]–[9]. Fitts’s Law is typically used in the field of Human Computer Interaction (HCI) and ergonomic studies to model the average amount of time it will take users to access and use different elements of a User Interface. Fitts’s Law allows for the identification of the *Index of Difficulty* of a particular movement, based on the distance a user must travel (through the use of a mouse or pointer) and the size of the target – for instance, a button. Fitts’s Law can also be used to calculate a user’s *Index of Performance* based on the time it took a user to reach a location and the pre-calculated difficulty of that move.

While Fitts’s Law is traditionally employed in the design and analysis of Graphical User Interfaces (GUIs), investigation into its validity as a metric for the identification of Dyslexia is a reasonable hypothesis, especially considering the data already collected by the Dot-to-Dot Task.

# Existing Art

Before development could begin, research into similar projects was conducted. While several papers were found that made use of Fitts’s Law for the evolution of children with Developmental Coordination Disorder and similar conditions, none of these focused specifically on the detection of Dyslexia.

## The influence of task paradigm on motor imagery ability in children with Developmental Coordination Disorder [10]

This paper focuses on the use of a Fitts’s Law based system – similar to the Dot-to-Dot Task – with the intent of measuring the ability of children with Developmental Coordination Disorder (DCD) when tasked to trace lines between boxes using a tablet and stylus.

While the paper focuses primarily on children with DCD – a developmental disorder that reduces a person’s ability to perform basic motor tasks, the project utilised data collected in very similar manner to the Dot-to-Dot Task.

The paper in question also had no interest in the identification of DCD, rather comparing the results produced by children with DCD against those without.

## Fine motor deficiencies in children with developmental coordination disorder and learning disabilities: An underlying open-loop control deficit [11]

The aim of this paper was to test children with DCD and Learning Difficulties (LD), in order to prove three hypotheses – general slowness hypothesis, limited information capacity hypothesis, and the motor control mode hypothesis.

Similar to the previous paper, this project had no interest in the detection of LD – focusing purely on the results generated by children drawing a line between two targets using a stylus. While the method of data collection is similar to the Dot-to-Dot Task and utilises Fitts’s Law to determine difficulty, the goals and outcomes of the project bare very little similarity to this project.

## Abnormalities of motor and praxis imagery in children with DCD [12]

This paper was written as a follow-up to a previous project, with the aims of investigating and justifying why the results generated previously were not as expected. The paper states that children with DCD did not produce results that correlated with the parameters of testing, i.e. test parameters were systematically altered but the children with DCD results did not match as expected.

Once again, this paper made heavy use of Fitts’s Law to determine how children with developmental difficulties performed in a drawing/tracing task – but did not delve into possibility of using Fitts’s Law as a method of detection.

As can be seen, while Fitts’s law has been used as a means to measure performance of children with various Learning difficulties, it has yet to be investigated if it can be used for the detection of Dyslexia or other learning difficulties.

# Aims and Goals

The aim of the project is to determine whether Fitts’s Law is a valid metric in determining whether or not a child is Dyslexic. In order to achieve this final deliverable– there are several goals that must be reached first:

1. Design and implement a Fitts’s model from the existing Dot-to-Dot data as a proof of concept.
2. Collect Dot-to-Dot data from dyslexic subjects.
3. Analyse newly collected data with the Fitts’s model system.
4. Review Fitts’s model analysis for common patterns and traits.
5. Determine if Fitts’s Law is a suitable Dyslexia detection aid.

# Current Progress

After the initial research phase was completed, development of a prototype system could begin. Initial development resources consisted of a MySQL database containing the results from around five hundred test subjects. A number of Groovy scripts were also provided which extracted and operated on data from the database.

One of the first development considerations to be undertaken was which language the system would be developed in. A number of options presented themselves, each with their own advantages:

* SQL/MySQL – Native language for accessing databases.
* Groovy – Java based dynamic language.
* Python – Dynamic, interpreted language.

It was decided that Python would be the most suitable language for this project, mainly due to its implementation simplicity and developer familiarity, having used it for data analysis in a previous project.

Once the language was decided, proper development could begin. In order to calculate a Fitts’s *Index of Performance*, the time taken to complete a sector of the Dot-to-Dot Task must be compared against that sector’s *Index of Difficulty*.

A problem arose in the fact that not all the sectors recorded in the database were considered valid. Sectors where the test subject lifted the drawing stylus, paused for a significant period or looped backwards along the path they drew could not be used for Fitts’s analysis, as the times taken cannot be accurately determined. Determining invalid sectors proved to a be simple task, as the XY coordinates of each invalidating event (pause, lift or loop) was recorded in the database, along with the start and end coordinates of each sector. By comparing the event coordinates against the sector end points, it is possible to determine which sectors the error occurred in and remove these sectors from the analysis.

Once all the invalid sectors have been discarded, it can be assumed that all the remaining sectors are valid and thus the time taken to complete each section can be extracted from the database. As previously stated, *Index of Performance* requires the time taken to complete a sector and the *Index of Difficulty* for the sector*. Index of Difficulty* (*ID*) is calculated as:

With *D* being the distance of travel and *W* being the width of the target. Within the Dot-to-Dot system, all targets are identical (circles, twenty pixels in diameter), the lengths of each sector are not recorded – but the start and end coordinates are. Pythagoras’s Theorem allows the length of a line to be calculated, assuming the start and end coordinates are known.

With the *Index of Difficulty* of each sector calculated as well as the timings for all the valid sectors, the *Index of Performance* could be calculated. Fitts’s originally determined that *Index of Performance* was calculated as:

With *ID* being the previously calculated *Index of Difficulty* and *MT* being equal to *Movement Time* – the time taken by a subject to complete a sector. With all the required variables acquired, the *Index of Performance* for each valid sector can be calculated.

It is worth noting that while this project utilises the original Fitts’s Law formulae, there has been many revisions and alterations over the years – which may also be investigated in the future.

# Testing

Testing was performed throughout the development of the system- mainly in the form of White-box testing, Black-box testing and diagnoses text output. Visual comparison was also used to test the system – a tool was provided that allowed a Dot-to-Dot sequence to be displayed; which in turn could be compared against the output of the Fitts’s model system to ensure it was outputting accurate results.

# Future Work

With the prototype Fitts’s model functional with the previously gathered Dot-to-Dot data the true testing can begin. While the current data allows for development and tuning of the system, it does not actually ascertain whether or not the test subject was Dyslexic.

In order to fully test the system’s effectiveness, Dot-to-Dot data must be collected from subjects that already know whether or not they are Dyslexic. Once this data is gathered from Dyslexic test subjects and processed by the Fitts’s model system, the evaluation process can begin.

# Evaluation

One method of evaluation would be via the use of a Student T-Test. A T-Test is a statistical hypothesis test, which allows the mean of two populations to be compared and determine if there is a significant difference. In this instance, the two populations being compared will be the mean *Index of Performance* for Dyslexic and non-Dyslexic test subjects.

Research and implementation of other evaluation technics will be conducted in the case that T-Tests are sufficient or, further proof is required.

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