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Using cursor measures to investigate the effects of impairment severity on cursor control for youths with cerebral palsy☆

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ABSTRACT

Individuals with upper limb impairments due to cerebral palsy encounter difficulties when using pointing devices and can be limited in communicating and accessing education tools through computers. Analysis of cursor trajectories can identify some of the factors limiting cursor movement, and provide a better understanding of human movement to assist in designing accessible computer interfaces. This study evaluated cursor trajectories from 29 individuals with bilateral cerebral palsy (CP) and different levels of function. The functional level was classified based on the MACS (Manual Ability Classification System). Results show that the contributors to a model that assesses different MACS levels are the movement time, acceleration–deceleration cycles and average speed. The model appears unaffected by accuracy measures. For both typically-developed youth and participants with CP, a good model of index of difficulty must include the following predictors: rapidity – movement time, average speed, zero acceleration crossings and accuracy, trajectory distance, linearity index, and indices of vertical and horizontal components. Models for those who are typically-developed should also include an index of diagonal component and curvature index.

1. Introduction

The use of computers is an important part of human interaction in education, work, and entertainment. In the information world, it is important to provide fair participation to effectively and efficiently access computers. However, individuals with motor control impairments, such as cerebral palsy, encounter obstacles when using computer applications or accessing computer education tools. Therefore, understanding human movement reveals insights about sources of movement differences among people, devices, conditions, and impairment levels. Understanding movement differences will assist in providing solutions to improve user interfaces to meet the actual abilities of motion-impaired users.

To develop a computer system, three elements are required: interaction methods, interaction devices and interface design (Benyon et al., 2000). A variety of interaction methods and devices has been developed to improve physical access to computers. They range from accessibility options within the operating system to enhanced input devices such as joysticks, trackball, touch screen, gesture recognition, and speech recognition software (Davies et al., 2009). However, the use of assistive technology for better computer access encounters barriers. Barriers vary from insufficient funding, lack of staff training and negative attitudes at school (Copley and Ziviani, 2004), while the main barrier in the home environment is cost (Ellis, 2007). As an example, our survey of youth with upper limb motor impairments (due to cerebral palsy), has shown that most of the youths prefer to use a typical mouse, either by hand for movement of the cursor on the screen with finger clicking for selection of a target, or by using an improved access mechanism such as the foot in combination with toe-clicking (Davies et al., 2010). Only a minority of youths with cerebral palsy use assistive technologies although the majority is aware of existing technologies, with some having used assistive devices in the past. Although we did not ask participants about the decision to return to use of a typical or modified mouse, the decision could be due to lack of offered assistive technology in educational setting (Michaels et al., 2002). Furthermore, individuals use computers in different locations including homes and the public library where access and existence of assistive technology is not always a choice. The most logical and practical decision may be to use a typical mouse at all sites.

The ability of individuals with cerebral palsy (CP) to access computers has not been researched in detail, though CP is the most common form of motor dysfunction affecting youth (Yeargin-Allsopp et al., 2008). CP is an umbrella term for a group of

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disorders of movement and/or postures which include spasticity, dyskinesia, ataxia and hypotonia (Access Economics Pty Limited, 2008). Until recently, it was believed that the prevalence of cerebral palsy had remained steady at 2 to 2.5 per 1000 live births (Yeargin-Allsopp et al., 2008), but 2002 reports suggest that the prevalence is higher, more closely approximating 3.1 per 1000 births (Yeargin-Allsopp et al., 2008). Independent and effective access to computers has the potential to address some of these barriers. However, little is known about the effectiveness with which individuals with CP access computers and what modifications are most useful.

Until recently the functional limitations as a result of CP were difficult to classify due to the heterogeneity among individuals. In line with the World Health Organization International Classification of Functioning, Disability and Health, the MACS system has been developed for youths with CP (Eliasson et al., 2006). The Manual Ability Classification System (MACS) is used to classify the level of upper limb ability in children with CP; widely ranging from MACS I (handles objects easily and successfully) to MACS V (does not handle objects and has severe impairment that require assistance to carry out simple actions) (see Table 1 for the classifications). We have previously learned that only people at levels MACS I, II and III tend to access computers using a mouse though level IV access can be achieved (Davies et al., 2010). If interfaces are to be developed that allow for access by many (universally designed), we must better understand how functional levels affect speed and accuracy of the movements. Previous work has suggested that movements by individuals with *hemiplegia* follow Fitts's law (Smits-Engelsman et al., 2007). Our research examines those with *diplegia* (two affected hands) at MACS I, II, III and IV.

Our ultimate goal is to develop a set of requirements for computer interfaces that allows youth with physical disability (e.g. upper limb disability) to effectively access computers. To this end, we have (a) produced a systematic review of published evidence of technology used most commonly by individuals with CP (Davies et al., 2010), (b) assessed what technology is used by youths with CP in Auckland and Toronto (Davies et al., 2010) (c) sought to identify key features of interface design that are important (Davies and Stott, 2010), and we are now seeking to determine the ideal target size and placement to enable equal access. We need to better understand the characteristics of cursor movement by youths with cerebral palsy at different impairment levels, the topic of this paper.

Hourcade et al. (2010, 2008), Hourcade (2006) have examined trajectory features of cursor movement by individuals with motor control deficits including young children whose motor control mechanisms are not sophisticated, and older adults who have difficulties with motor control tasks due to decreased muscle, cognitive and perceptual responses. Hwang et al. (2003) studied six motion impaired users finding high variability among task completion times limiting the application of these data to the development of a universally accessible algorithm. However, the participants in these studies were not classified according to the MACS levels of function. To better understand trajectory motions and develop a model that explains the motion across different impairment levels, we must analyze typical cursor trajectories of movement from participants with motion impairment classified by different levels of function.

The overarching research question is: can we develop an algorithm to assist users with motion impairment due to CP to more easily access computers? The first step in answering this question is to gather information on how to describe cursor trajectories when using a computer mouse. For this paper, the research questions are:

(i) How much of a role does the degree of impairment affect the path measures?
(ii) Do participants with CP target the same position as typically-developed participants? And
(iii) How well correlated are new proposed path measures that might better relate to people with upper limb impairments to the curvature index identified in previous studies?

Once we better understand these questions, we can develop an algorithm that includes only those path measures that affect movement in children with motion impairment.

The rest of this paper is composed of seven sections: theoretical framework, related work, new accuracy measures, methods, results and discussion, future plans, and conclusions.

Table 1
Definitions of five MACS levels (Eliasson et al., 2006).

MACS level	
I	Handles objects easily and successfully
II	Handles most objects but with somewhat reduced quality and/or speed of achievement
III	Handles objects with difficulty; needs help to prepare and/or modify activities
IV	Handles a limited selection of easily managed objects in adapted situations
V	Does not handle objects and has severely limited ability to perform even simple actions

2. Therotical framework

Many studies that examine computer mouse function use the basic premise of Fitts's law as the building block on which to base further evaluation. Fitts's law is a model of human movement that relates movement time to the movement distance and size of target (Fitts, 1954). It states that an intrinsic property of human motor behavior is a trade-off between speed and accuracy. The International Standards Organization has developed a method to evaluate input devices for computer use including measurements of efficiency, comfort and effort using tasks based on Fitts's law (ISO 9241-9) (ISO, 2002). The Shannon formulation is the best representation of the index of difficulty (ID):

$$\mathrm{ID} = \log_2\left(\frac{A}{W}+1\right)$$

where A is the average amplitude (distance between center points of the targets) and W is the target width along the approach axis (Fitts, 1954).

Smits-Engelsman et al. (2007) found that children with congenital spastic *hemiplegia* (CSH) adhere to Fitts's law in a visually guided tapping task. They studied 22 children (aged 5–16) with CSH Smits-Engelsman et al. (2007). Computer task performance is different from a visually guided tapping task as a cognitive spatial mapping between the mouse and the cursor on the screen is required. We sought to explore *computer cursor movement* by youth with *diplegic* cerebral palsy.

Using the Movement Time Evaluator (MTE) (Schedlbauer, 2007), 29 youths with cerebral palsy (CP) conducted a computer target selection task with indices of difficulty of 1.6, 1.9, 2.2 and 2.5. Movement time and trajectories were collected for all different indices of difficulties.