Simulation of Motor Impairment in Head-Controlled Pointer Fitts' Law Task

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ABSTRACT

Participants with motor impairments may not always be available for research or software development testing. To address this, we propose simulation of users with motor impairments interacting with a head-controlled mouse pointer system. Simulation can be used as a stand-in for research participants in preliminary experiments and can serve to raise awareness about ability-based interactions to a wider software development population. We evaluated our prototype system using a Fitts' Law experiment and report on the measured communication rate of our system compared to users without motor impairments and with a previously reported participant with motor impairments.

CCS Concepts

•**Human-centered computing** → **Empirical studies in accessibility;** *Accessibility systems and tools;*

Author Keywords

Accessibility; Head-Controlled Mouse Pointer; Camera Mouse; Motor Impairments; Simulation; Fitts' Law

INTRODUCTION

Improving accessibility software for people with motor impairments (MI) is challenging because researchers and software developers may not have consistent access to participants with disabilities who can test the software. Furthermore, mainstream user interface (UI) developers may have a *lack of awareness* about diverse user needs, or when they are aware, they are unsure of how to design or test their interfaces to work for people of all abilities.

Recent work proposes to address similar challenges for people with color blindness (Impaired Color Vision) through the use of simulations [9]. The simulations allow a person to see what a color-blind individual would see and can be used both to raise awareness and to improve the use of color in designs.

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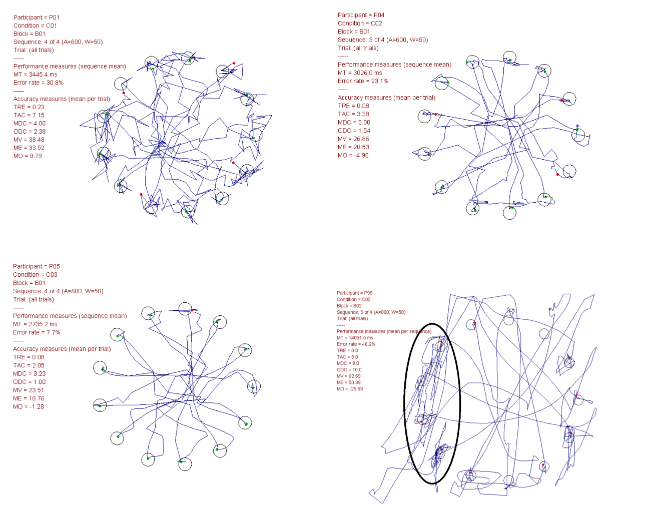

Figure 1. Mouse traces from Fitts' Law task. Top traces depict our simulation conditions C1 and C2. Bottom-left depicts non-MI user with no simulation baseline (C3). Bottom-right shows trace of a participant with MI in a previous study.

In this paper, we propose to simulate a user MI using the Camera Mouse[1] [1], a computer-vision-based mouse-replacement interface that tracks head motion to move a mouse pointer on the screen.

Access to research participants with MI is challenging; partnerships with organizations in the community are necessary to access a pool of participants that are representative of the target user population [4, 3, 16, 17]. Simulations may help reduce the burden on participants with motor impairments, especially at early stages of research or software development [15].

We extend prior work intended to adapt to an individual's motion abilities in controlling a mouse pointer with their head [12, 13]. The previous work is an ability-based interaction [21] technique for a user with MI. Here, the adaptations work the opposite way: we intend to simulate the abilities of user with motor impairments for a user with typical motor control.

We conducted an evaluation using Fitts' law (Fig. 1), a widely used standard for evaluating pointing devices [10, 11, 18].

[1]The Camera Mouse is freely available as a download at `http://www.cameramouse.org/`

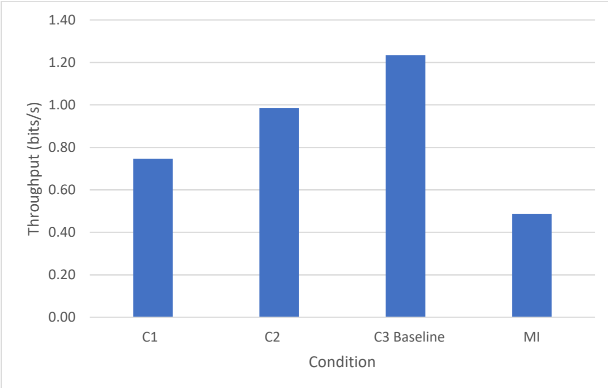

Figure 2. Throughput (bits/s). Left two bars show our simulation conditions. Third bar shows non-MI users with normal condition. Fourth bar shows MI user previously reported.

A key benefit of this evaluation metric is that it allows cross-study comparison of a throughput measure, or "rate of communication" in bits/s. We compare our results in this paper to previously obtained measures for an individual with a motor neuron disease and for a group of participants without disabilities [14]. The results show reasonable progress towards a simulation of the user with MI.

Various approaches to improving pointer control accessibility (e.g. [18, 7]) and clicking techniques (e.g. [19, 20, 5]) have been proposed. The performance of users with and without motor impairments [6, 8] is also a topic of interest. Accessibility simulations have been proposed within other interaction domains (e.g. [2, 15]).

METHODS

Simulation by Additive Noise

We developed two algorithms that affect how the Camera Mouse moves the mouse pointer. The first algorithm (C1) is characterized by a 30% probability that random movement ("noise") will be added to the pointer upon movement. The noise added by this algorithm randomly moves the pointer up to 50 pixels in both the X and Y directions. This algorithm was developed first, based on the hypothesis that adding random noise to the cursor when it is moved will decrease the throughput of a user with no motor impairments, resulting in a performance on the Fitts' Law evaluation like that of an individual with MI.

The second algorithm (C2) was developed as an attempt to refine C1 by including a threshold for the movement of the cursor below which less noise is added. When pointer movement is slow (than 15 pixels), additive noise is reduced from +/-50 to between -10 and 10, resulting in less dramatic aberrations from the user's intended path.

Participants and Apparatus

We performed an evaluation of the previously discussed algorithms to simulate a MI user. Four participants (M = 21), two male and two female, without motor impairments participated in the experiment.

The experiment was conducted on a 15-inch laptop screen at a resolution of 1920 x 1080, from a distance of approximately 2.5 feet. The following Camera Mouse settings were used: medium horizontal and vertical gain, 1.0 second dwell-time, very low smoothing, and "Normal" dwell-time click area.

Procedure and Design

We utilized an interactive evaluation tool called FittsTaskTwo[2] [10]. Participants move the mouse pointer to a target and click on it before moving to the next one. The mouse trajectories and click data for each participant was stored in a log file for analysis. Each participant session consisted of four sequences of thirteen targets at amplitudes of 300 and 600 with widths of 50 and 80 pixels. The independent variable was the algorithm, described previously, with the following three conditions: C1 - probability-based algorithm; C2 - probability with threshold limit; C3 - baseline Camera Mouse settings. This results in 156 trials (3 x 4 x 13) for each participant. Dependent variables are movement time (speed), throughput (bits/s), error rate (%), and target re-entries.

RESULTS

The mean throughput of each condition is shown in Fig. 2. The baseline condition (C3) throughput rate averaged 1.23 bits/s, which is consistent with previously reported results of 1.28 bit/s for non-MI users [14].

C1 achieved an average throughput closest to the individual with motor impairment. The mean movement time, throughput, error rate, and target re-entries for C1 were 3163.97 ms, 31.7%, 0.747 bits/s and 0.173, respectively. The throughput rate of 0.747 bits/s is still higher than the throughput reported of 0.488 bits/s of the MI participant in the previous study, but significantly lower than the baseline throughput. C2's throughput (0.98 bits/s) was higher than C1, and was approximately twice that of the MI participant.

DISCUSSION AND CONCLUSION

In this paper, we presented two algorithms and evaluated their effectiveness at simulating a user with motor impairments. Consistent random noise appears to be the more accurate simulation of the individual with MI based on throughput. However, the traces for the cursor movement in Fig. 1 show that the simulated trajectories could still be improved to more closely resemble the trace for the user with MI. While the trace for C2 appears closer to that of the MI individual, comparison of the measured throughputs indicates that C1 was a more accurate simulation with regard to rate of communication. For future work, we plan to apply machine learning techniques to better simulate the mouse traces and communication rate for the individual with motor impairments.

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[2]The software is freely available as a download at `http://www.yorku.ca/mack/HCIbook/`.

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