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Parker A. Williams
Brigham Young University, parkerwilliams@email.arizona.edu

Jeffrey L. Jenkins
Brigham Young University, jjenkins@byu.edu

Joseph S. Valacich
University of Arizona, valacich@arizona.edu

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Parker A. Williams
Brigham Young University
williams.parker002@gmail.com

Jeffrey L. Jenkins
Brigham Young University
jeffrey_jenkins@byu.edu

Joseph S. Valacich
University of Arizona
valacich@arizona.edu

ABSTRACT

Millions of people experience hand-tremors—rhythmic oscillation of the fingers, hands, or arm that cause shaking in the hand. People who experience hand tremors often experience difficulty in human computer interactions. For example, when browsing a website, people with hand tremors may have difficulty navigating or clicking on links in the website. With sever hand tremors, effective computing is difficult without assistance. Past research has developed interventions that can be automatically deployed by a website to make it more accessible to people with hand tremors. We build on this research by creating a methodology to unobtrusively detect hand tremors, allowing these mitigation options to be offered or automatically deployed. In an exploratory study, we found that hand tremors influence 5 mouse movement statistics. Based on these results, we discuss our next steps in our research agenda (predicting hand tremors, and improving website usability), as well as research and practical implications.

Keywords

Hand tremors, human-computer interactions, mouse cursor analysis, accessibility

INTRODUCTION

Hand tremors pose a challenge for positive human-computer interactions. A hand tremor is a rhythmic oscillation of the fingers, hand or arm (Deuschl et al. 2001). The most common movement disorder is called "pathological tremor", and increases its prevalence with ageing (Rocon et al. 2004). These tremors can cause shaking that makes it difficult to navigate a website, select links on a webpage, and perform various other every-day computing activities. Sixty-five percent of people suffering from upper limb tremor report serious difficulties in performing their activities of daily living (Rocon et al. 2004).

In this paper, we propose a method for detecting hand tremors in real time on websites by monitoring mouse-cursor movements. This allows websites to dynamically adjust to create an easier more enjoyable experience for people with hand tremors. Past research has identified various interventions to make computers more enjoyable for people with hand tremors, such as filtering out misclicks, smoothing algorithms for mouse movements, and intelligent design (Riviere et al. 1996). However, an understudied area in this research is the ability to first detect if hand tremors are present, so that websites can offer or deploy the use of such techniques. We address this need by exploring how analyzing users mouse-cursor movements can be an effective method for detecting hand tremors in users. In summary, this research-in-progress paper explores the three following research questions: 1) what characteristics of users' mouse cursor movements predict if a user has hand tremors, 2) how accurately can we detect hand tremors in users by analyzing mouse-cursor movements, and 3) does automatically detecting and deploying mitigation tools for hand tremors improve the end-user experience with a website?

Using participants from the International Essential Tremor Foundation and Mechanical Turk, we monitored and analyzed mouse cursor movements on a website in an exploratory study. We found five characteristics of users' mouse-cursor movements that were influenced by hand tremors. As next steps in our research, we will create a prediction algorithm to detect hand tremors, and report the accuracy rate. Finally, we will run a study to detect hand cursor movement, and automatically deploy mitigation techniques (e.g., smoothing). From this study, we will explore how the detection / mitigation of hand tremors influences the users' experience. The results of our research will not only help make websites more accessible for users with hand tremors, but also have a variety of implications for health monitoring and advancing mouse-cursor research.

LITERATURE REVIEW

Mouse Tracking

Mouse cursor tracking as a scientific methodology was originally explored as a cost-effective alternative to eye tracking to denote where people devote their attention in a human-computer interaction context (Byrne et al. 1999; Pappas et al. 2014; Tarafdar et al. 2007). For example, research has shown that eye gaze and mouse-cursor movement patterns are highly correlated with each other (Liljander et al. 1997; Pappas et al. 2014; Tarafdar et al. 2007). When scanning search results, the mouse often follows the eye and marks promising search hits (i.e., the mouse pointer stops or lingers near information), suggesting where people devote their attention (Rodden et al. 2008). Likewise, people often move their mouse while viewing web pages, suggesting that the mouse may indicate where people focus their attention (Lu et al. 2009). In selecting menu items, the mouse often tags potential targets (i.e., hovers over a link) before selecting an item (Unsworth et al. 2010).

As the ability for more fine-grained measurement and analysis of mouse-cursor movements has improved, research expanded the use of mouse cursor tracking to explore a more diverse set of neuromotor and psychological responses. In a concise review of mouse tracking literature, Freeman et al. (2011) suggest that the "movements of the hand…offer continuous streams of output that can reveal ongoing dynamics of processing, potentially capturing the mind in motion with fine-grained temporal sensitivity." Accordingly, hundreds of recent studies have chosen mouse tracking as a methodology for studying various cognitive and emotional processes.

We extend this research to explore how mouse-cursor movement can be used to detect physiological characteristics of users (e.g., hand tremors) in addition to the psychological characteristics. We identify and develop mouse-cursor movement measures when the starting position of the mouse-cursor may vary (may be anywhere on the screen as opposed to always the lower middle of the screen) and the desired final goal of the individual is unknown. We next introduce two theories that we will leverage to explain how users' mouse cursor movements demonstrate and show their hand tremor.

Hand Tremors

Hand tremors are very common. It is estimated that 10 million people have essential hand tremor (a common neurological disorder) in the United States (Stephens 2011). In addition to this, millions of others are effected by various other neurological diseases and disorders (e.g., Parkinson's) that cause hand tremors. People with hand tremors typically often have a very difficult time using the computer, and particularly navigating websites. This is because it is difficult to click on small targets (e.g., links), difficult to hover over targets, and difficult to select options in web applications (Rotondi et al. 2007).

Given the prevalence of hand tremors and their adverse influence on human-computer interactions, research has identified ways to make computers more accessible and usable to users. This research is split up into two categories: physical tools to reduce hand tremors and digital compensations.

Physical tools include mechanisms that a) apply friction to the hand to reduce shaking and b) find other ways for users to interact with the computer without the hand (Rocon et al. 2004). In this realm, companies have developed specialized arm rests that stop the arm from shaking and input devices (e.g., key boards and mice) that require more friction to operate (and thus are not influenced by shaking)[1]. Sample products include the MIT damped joystick, the controlled Energy Dissipation Orthosis, CEDO, and the Modulated Energy Dissipation Arm, MED.

Digital compensations include software and design choice that can compensate for hand tremors. Software includes digital filters that differentiate between hand tremors and actual movements. This software can be installed on a users' computer, or deploy dynamically in a website. This includes anti-tremor mouse filtering and removal of accidental mouse clicks, to name a few [2]. In addition, websites can be designed or dynamically adjusted to make them more usable for people with hand tremors. These interventions include larger links, magnetic links (links that grab the mouse cursor when it gets close to them), and websites that are compatible with alternative input devices made for hand tremors (Riviere et al. 1996; Rotondi et al. 2007).

Our research is particularly relevant to the "digital compensations" area of research. Namely, we investigate whether the analysis of users' mouse cursor movements can be used to detect hand tremors. Using this method, websites can adapt digitally to the user to create a more enjoyable and accessible user experience.

EXPLORATORY STUDY

This study specifically addresses research question #1: what characteristics of users' mouse cursor movements predict if a user has hand tremors? In this study, we had participants with and without hand tremors navigate a website while we monitored mouse-cursor movements. We then calculated a number of statistics from the mouse-cursor movement, and explored which ones were significantly influenced by self-reported hand tremor conditions. The other two research questions will be addressed in a future study.

Participants

We recruited participants from two sources. First, to find participants with hand tremors, we recruited from a pool of over 1,700 individuals through the International Essential Tremor Foundation (IETF). "Founded in 1988 as a 501(c)3 non-profit membership organization," (http://www.essentialtremor.org/about-the-ietf/) IETF's mission includes promoting and funding essential tremor (ET) research. Second, to find additional participants with

[1] http://ndipat.org/blog/computer-access-and-parkinsons-3-great-products-and-a-freebie/

[2] https://www.steadymouse.com/

and without hand tremors, we recruited participants from Amazon's Mechanical Turk (MTurk), which has been shown to be an appropriate participant tool for random sampling populations (Berinsky et al. 2012).

Two-hundred people participated in the study; 56% were male, 44% female. The average age of a participant was 43.6 years old. Eighty-six point nine percent identified as White/Caucasian, 5.1% Hispanic, 4.3% Asian, 2.5% African American, and 1.2% other. Of those who participated, 35% stated that they currently have hand tremors, and of those that currently have essential tremor 75% have experienced it for longer than 10 years.

Study Design

Participants interacted with a mock e-commerce website with various assets (i.e. drop down menus, buttons, links, forms, radio buttons, etc.). They were asked to explore the website until they found a specific product (a specified pair of socks). Once they found the specific product they were asked to place the item in the cart and proceed through a checkout process. This required a moderate degree of interaction with the website, allowing us to gather mouse tracking data. A sample screenshot from the website used in the study is shown in Figure 1.

Prior to accomplishing this task, participants completed a survey. In this survey, we asked participants a number of questions, including a) whether they had hand tremors, b) if they were currently using a device or software to compensate for the tremors while they did this experiment, and c) the severity of their tremors. Participants also answered a variety of questions regarding the ease of use of the site and demographics.

Measuring Mouse Movements

Using a JavaScript script embedded into each page of the website, we tracked participants' movements on the webpage. X, Y coordinates and timestamps were stored to calculate various statistics such as velocity, acceleration, and distance throughout the interaction. Collecting the coordinates also allowed us to visualize the movements. A sample movement from a participant with tremors is shown in Figure 2. This JavaScript script and software being used allowed the users mouse movements to be tracked unobtrusively and reported the movements to a secure server for later analysis.

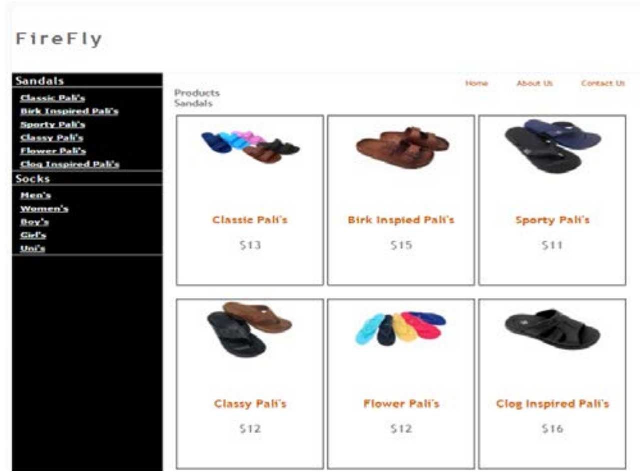

Figure 1. Screenshot from website

Figure 2. A sample mouse trail from a participant with tremors

ANALYSIS

To explore how hand tremors influence mouse cursor movements, we first calculated a number of statistics (see Figure 1 and Figure 2). We then specified a multivariate general linear model that explored whether people who self-reported hand tremors had significantly different mouse cursor movement statistics than people who did not report having hand tremors. We removed any participants who reported that they were currently using a tremor mitigation technique during the study (special hardware or software). As displayed in Table 1, we found that tremors statistically influenced five different variables. We also found that tremors do not statistically influence the remaining five variables as seen in Table 2.

Variable Name / Description	Z-Score	P-Value
Overall area under the curve[3] normalized (divided by) by speed	15.35	< .001
The total number of flips on the x axis	6.53	< .001
The total number of flips on the y axis	10.34	< .001
The average distance between destinations (clicks)	8.799	< .001
The average distance between destinations (clicks) normalized (divided by) by speed	15.35	< .001

Table 1. Variables Statistically Influenced by Tremors

Variable Name / Description	Z-Score	P-Value
Overall area under the curve	0.757	> .05
The average area under the curve between destinations (clicks)	0.007	> .05
Overall distance	0.007	> .05
Overall distance minus the minimum distance required to perform a movement	1.395	> .05
Total time	0.007	> .05

Table 2. Variables Not Statistically Influenced by Tremors

DISCUSSION

This research-in-progress paper represents the first of three steps in our research agenda. It determined which mouse-cursor movement statistics are influenced by hand tremors. The next step is to create a prediction model to determine how well mouse cursor movement statistics predict hand tremors. The third step is to explore whether the detection of hand tremors and automatic deployment of mitigation web design strategies improves users overall experience and the accessibility of the website. Our research makes several implications for research and practice.

Implications of Research

This paper contributes to research by extending literature on hand tremor mitigation and mouse cursor tracking. First, past research has examined software and design principles for creating websites that are more accessible to people with hand tremors. However, very little research has explored how to detect if someone has hand tremors, which can be used to trigger these interventions. We contribute to this research by conducting an exploratory research that will result in an easy-to-deploy and unobtrusive method for detecting hand tremors—the analysis of mouse-cursor movements.

Second, we contribute to literature on mouse-cursor tracking. Past mouse-cursor tracking research has focused on using mouse-cursor tracking as a substitute methodology for eye tracking, or to infer psychological states (e.g., emotion, cognitive conflict, etc.). We extend this research to also explore how mouse cursor movement can be used as a methodology for detecting psychological states that are relevant to human-computer interaction.

Implications for Practice

Hand tremors can severely deter human-computer interactions, resulting in websites that are difficult to use or not accessible to users. Our research can be used to create adaptive websites that are more accessible to people with hand tremors. Namely, by unobtrusively monitoring mouse-cursor movement through imbedded JavaScript in the webpage, websites can potentially detect mouse-cursor movements and dynamically adjust to create a more accessible and enjoyable experience for users. This will not only improve the users experience, but may also lead to increased use and revenue for the website.

[3] The area between the straight line representing the most direct path of a movement, and the users' actual movement.

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