Identification of Pointing Difficulties of Two Individuals with Parkinson’s Disease via a Sub-movement Analysis

Abstract
We present a study of the sub-movement characteristics of two individuals with Parkinson’s disease completing pointing tasks. We describe the performance of the two individuals and we compare it with that of young children and older able-body adults. The analysis suggests that we need new strategies that incorporate an individual assessment of difficulties, and provide personalized methods of assistance.

Keywords
Parkinson's Disease, Pointing Tasks, Sub-Movements.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors, Measurement, Performance.

Introduction
We aim to understand the challenges that individuals with Parkinson’s disease (PD) face while using pointing devices. Cursor measures have been used to describe the movement difficulties of individuals with PD, where their overall performance as an age group was between that of adults and older adults [5]. But in an analysis of mouse movements of motion impaired users, some of
the sub-movement characteristics were described as “highly individual”, and suggested that assistance methods may need to be tailored for individuals with different levels of physical capabilities [4]. Our main contribution is to describe the pointing difficulties of two individuals with PD in terms of the characteristics of the sub-movements in pointing tasks. We claim that to assess the level of difficulty that a problem may exhibit and to better deploy help to individuals with PD, it is necessary to look at each individual separately. A sub-movement analysis brings the additional advantage that it could be performed in real time, enabling adjustments of assistive settings ([1], [3]).

Parkinson’s disease

Parkinson’s disease (PD) is a brain disease that impairs motor control, speech and other functions. It is known to be chronic, degenerative and progressive. Some of the signs and symptoms of PD have been proven to impair motor dexterity when performing actions that require a high degree of skill and hand coordination. An individual with PD presents symptoms such as **Tremors**, **Bradykinesia** (slow movement), **Akinesia** (difficulty initiating movement), and **Cognitive dysfunction**, among others [10]. There are effective symptomatic therapies for PD to help improve some individuals’ control over their movements [9]. Different stages of the disease have different associated levels of motor control. The motor control in PD patients might change abruptly during the course of a day when they are in the on or off periods triggered by medication [10].

Thus, PD patients are an example of a group that would benefit from assistive technologies that provide help on a more individual basis, with adjustments in real time.

**Study setup**

We extended the pointing task testing software used in [1] and [3] to gather data remotely where participants could install the testing software into their own computers. The software was also modified to present tasks in eight different directions. We decided to gather data remotely because we want to assist PD patients in the computers they use every day, which in some cases may include customizations to address their needs, as was the case with the two participants we worked with. It proved very difficult to find participants, but we recruited two individuals and informed consent forms were obtained. To maintain anonymity we will refer to the participants as Bob and Dave. Bob is a right handed 64-year-old male with PD who averages 6 hours per week of computer usage, and uses a touchpad. Dave is a 72-year-old male with PD who uses a two-button mouse an hour per day on average. We took several rounds of data to better account for individual variability. Bob ran the test 3 times with target diameter sizes of 16 and 32 pixels and distances to the target of 128 and 512 pixels. Each test had 4 practice tasks and two blocks of 32 tasks. The cursor speed was set to 8 (corresponds to the fifth tick from the left in Windows). He reported having “Enhanced pointer precision” (EPP) enabled [7]. Dave ran the test once for same target diameter sizes as Bob but with one distance to the target of 512 pixels and EPP disabled. He had 5 practice tasks and 4 blocks of 32 tasks. The cursor speed was set to 8 (corresponds to the fifth tick from the left in Windows). He reported having “Enhanced pointer precision” (EPP) enabled [7]. Dave ran the test once for same target diameter sizes as Bob but with one distance to the target of 512 pixels and EPP disabled. He had 5 practice tasks and 4 blocks of 32 tasks. The participants ran the test one last time with target diameter sizes of 8 and 16 pixels, task lengths of 512 pixels and EPP disabled, for a total of 69 tasks. Bob, being our first participant, initially ran the software with the same parameters used for children and older adults in [1] and [3]. Software modifications were required and we decided to ask Bob to run the software two
more times. Upon Dave’s recruitment, we already had an established experiment that did not need any modifications, which explains the difference in task collection between both participants. The final testing round was to have a more homogeneous set of data to compare the participants.

Sub-movement characteristics
We rely on the analysis of the sub-movements in real-time provided by the algorithm in [3]. For a detailed definition of a sub-movement refer to [6]. We characterize difficulties using accuracy measures and quantitative characteristics of the sub-movements of all tasks. We looked at sub-movement length (pixels), average sub-movement speeds (pixels/ms), average sub-movement maximum speeds, direction, number of sub-movements per task, target re-entry, and average task duration (milliseconds). We consider a sub-movement being near a target if it is less than 30 pixels away from its center and away from the target if it is more than 60 pixels away from its center.

Discussion
Bob showed difficulties reaching the target. He had high movement times (Table 1) and averaged 12 sub-movements per task (Table 2) in tasks involving 512 pixel target distances, with a click success rate of 97% (Table 1). Thus, he seems accurate but "slow". He had particular difficulty in the north and north-east task directions where there was a combination of high sub-movement count and high task duration. His high movement times (task duration) could be attributed to having EPP enabled, but two things suggest that the problem is elsewhere. First, his average speed away from the target was higher than that of older adults (Table 3), who also had EPP enabled [1]. Yet older adults had movement times of less than half as those of Bob (Table 1). Second, the combination of high average speed and average length (Table 3) of Bob’s sub-movements suggest he is not really moving slowly but rather may have difficulty initiating his movements which could account for the high movement times. In fact we know he is not moving slowly since he had the highest average speed away from the target (Table 3). From this, we infer that Bob has some level of akinesia that is most prominent in some directions, affecting his movement time and speed, but not his accuracy. Dave had no problems reaching the target. His average task durations are comparable to those of older adults (see Table 1). His high number of target re-entries (Table 1) shows his difficulties are near the target, and is comparable to that of young children that show more, less accurate sub-movements [3]. This is consistent with his average sub-movement speeds being close to that of children (Table 3), but not with the average sub-movement length. This is where Dave showed most difficulty, having the highest average sub-movement length of 45.5 pixels near a target. We attribute this lack of control near the target to tremors.

Pointing tasks examples show differences in pointing strategies employed by children, older adults and our two participants (see Figure 1). Children’s movements tend to cluster around the target. Older adults tended to land short of the target, then slowly get closer, with some difficulties keeping a steady direction towards the target. Bob and Dave’s movements are relatively controlled suggesting they are consciously making an effort to have aimed controlled movements. Both the pointing strategies employed and the performance difference in different directions of each of the two individuals studied, are indicators of the need of a real-time personalized method of assistance.

<table>
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<th>avg. length</th>
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<tr>
<td></td>
<td>128.9</td>
<td>.201</td>
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Table 3 Sub-movement characteristics near and away the target center.
Bob and Dave performed differently from each other. In the first rounds of testing Bob had high movement times, and Dave had lower movement times (Table 1); Dave re-entered targets almost twice as many times as Bob (Table 1); Bob had a high number of sub-movements away from target where Dave could complete a task in approximately 6 sub-movements. A high number of sub-movements were also noted in [4] where individuals with PD took five times as many sub-moves as able-bodied users. We see the variability in their performance in the second round of testing. Bob increased his target re-entry where Dave decreased it (Table 4). Bob took as many as 4 sub-movements to reach the target, which was 3 times less than in his first round (Table 5). Dave was consistent in his number of sub-movements yet his accuracy dropped by 4-6% (Table 4).

**Conclusion**

The results show some of the difficulties as well as the variability of both participants between themselves and within themselves. Differences between them can be attributed to different motor impairments and/or levels of motor control. Differences within them can be attributed to unknown factors like on-off periods, strategies employed or habituation effects. We know that in general, existing strategies to help with pointing tasks are not applicable to all contexts, tend to help users all the time, and do not adapt to the motor skill decay or improvement that an individual may exhibit over time. We are working to implement machine learning algorithms to identify pointing difficulties and their severity and incorporate them into PointAssist [3], together with strategies to help with each of these difficulties. We intend to assess the help that these strategies may provide in the participants’ own computers.

**Citations**


