Effect of Age and Parkinson's Disease on Cursor Positioning Using a Mouse

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ABSTRACT

Point-and-click tasks are known to present difficulties to users with physical impairments, particularly motor- or vision-based, and to older adults. This paper presents the results of a study to quantify and understand the effects of age and impairment on the ability to perform such tasks. Results from four separate user groups are presented and compared using metrics that describe the features of the movements made. Distinct differences in behaviour between all of the user groups are observed and the reasons for those differences are discussed.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *input devices and strategies, user-centred design*

General Terms

Design, Experimentation, Human Factors

Keywords

Mouse, cursor, cursor positioning tasks, performance measurement, disability, age.

1. INTRODUCTION

Positioning a cursor over a target is central to graphical user interface (GUI) interaction paradigms. Older adults, and people with physical impairments, can find this a challenging task. In order to design effective assistance for these users, it is necessary to understand the precise nature of their difficulties. This paper explores the effect of age and disability on the basic action of moving a cursor onto a target using a mouse and activating that target via a left button press. Using point-and-click data gathered from three groups of adults of different ages, and a fourth group of adults with Parkinson's disease, we describe differences in pointing performance between these groups.

The following section describes theories and measures commonly used to assess pointing performance. Next, we discuss what these measures have shown about differences in pointing between groups of different ages and motor abilities. We then present an analysis of our data with emphasis on gross submovements and velocity information and relate this to previous results.

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2. CURSOR MOVEMENT

2.1 Fitts' Law

Fitts' Law [5] provides an elegant mathematical relationship between movement time, distance and accuracy for a person performing a rapid aimed movement. It accurately describes the use of pointing devices to guide a cursor to an on-screen target for able-bodied users. Fitts' Law has been enormously valuable in the development and comparative evaluation of pointing devices, and has been standardised in this role in the ISO 9241-9 standard [9]. Soukoreff and MacKenzie [19] provide a review of 33 publications reporting Fitts' Law models of the mouse and provide recommendations for appropriate ways to apply Fitts' Law in HCI. The use of Fitts' Law gives an overall impression of speed and accuracy for pointing tasks. It can establish that differences exist, but says little about why they exist. To investigate these differences, a more detailed analysis of the components of the movement is necessary.

2.2 Movement Components

The movement optimization model [15] proposes that movement to a target consists of an initial pre-planned, or ballistic, movement which covers the majority of the distance to the target, followed by an optional secondary corrective submovement that homes in on the target. Secondary submovements are based on visual feedback.

Movement is also usefully described as consisting of an acceleration phase and a deceleration phase, where the acceleration is the part of the movement leading up to the peak velocity, and the portion of the movement following peak velocity is the deceleration phase.

Analysis of movement paths (summarised in [1]) has shown that changes in the width and height of targets are accommodated in different ways. Larger distances are accommodated with higher peak velocities (although not to the extent that movement time becomes constant). Smaller targets are largely accommodated by using a longer deceleration phase, although peak velocity is also reduced.

It remains an open question whether these theories can be applied usefully to movements made by people with physical impairments. Initial work by Hwang et. al. [7] suggests that these models may not be applicable.

2.3 Measures of Cursor Movement

MacKenzie, Kauppinen and Silfverberg [14] proposed seven accuracy measures to evaluate computer pointing devices. The measures are intended to elicit subtle differences among devices through an analysis of the cursor movement along the cursor path. The measures are:

- **Target re-entry (TRE)** – if the cursor enters a target region, leaves, then re-enters the target region, then a target re-entry has occurred.
- **Task axis crossing (TAC)** – the task axis is defined as the straight line from the start point to the target centre. A task axis crossing occurs when the cursor crosses this line.
- **Movement direction change (MDC)** – a movement direction change occurs when the tangent to the cursor path is parallel to the task axis, measured as a standard deviation.
- **Orthogonal direction change (ODC)** – an orthogonal direction change occurs when the tangent to the cursor path is perpendicular to the task axis.
- **Movement variability (MV)** – represents the extent to which the sample cursor points lie in a straight line along an axis parallel to the task axis.
- **Movement error (ME)** – the mean of the absolute distances of the cursor sample points from the task axis, irrespective of whether the points are above or below the axis.
- **Movement offset (MO)** – the overall mean distances of the cursor sample points from the task axis. Unlike movement error, this measure is not irrespective of whether the points are above or below the axis.

These measures were extended by Hwang and Keates [8, 10] to include the following:

- **Missed click (CL)** – occurs when a button click is registered outside of the target.
- **Ratio of path length to task axis length (PL/TA)** – the path length is the sum total distance moved by the cursor from the point of origin to the target and the task axis length is the shortest distance between the start point and the target. This is a modification of the Distance Travelled Relative to Cursor Displacement measure [10].

3. EFFECTS OF AGEING AND DISABILITY ON CURSOR MOVEMENT

Studies of the effects of age and disability on mouse use have identified that advanced age and disabilities make mouse use and movement increasingly inaccurate [2, 17, 20]. For example, Trewin and Pain [20] found that 14 of 20 participants with motor disabilities had error rates greater than 10% in a point-and-click task. Participants had difficulty positioning the cursor over small targets, and keeping the cursor over the target while clicking. Many of the participants also clicked the mouse button unintentionally before reaching the target.

Smith, Sharit and Czaja [18] examined the influence of age-related changes in the component skills required to use a mouse, specifically processing speed, visuo-spatial abilities and motor coordination. They studied 60 participants in 3 age groups performing pointing, clicking, double clicking and dragging tasks. Groups were balanced for experience level (little or none for most participants). Smith et al. defined 'slip errors' as occasions when the cursor left the target without completing the task (either clicking or double clicking on the target). Participants in the older age group had more slip errors, and these errors proved to be a major source of age-related differences in movement time and distance travelled. The sole predictor of slip errors was motor co-ordination. After controlling for differences in this ability, age was not a significant predictor of these errors.

Other studies (summarized in [13]) have demonstrated that older adults cover 10-70 percent less distance with their primary submovement compared with young adults. While the velocity profiles of young adults are typically bell shaped, where the acceleration phase equals the deceleration phase, older adults show asymmetrical profiles with a longer deceleration phase. Furthermore, older adults produce movements with 30-70 percent lower peak velocity compared with young adults

Interestingly, young children have also been shown to have difficulty homing in on targets in computer-based point-and-click tasks. A study of four and five-year-olds by Hourcade et al. [6] found that Fitts' Law modelled their movements well only up until they first entered the target. After entering the target, the children had many target re-entries in their attempts to home in. Target size had a significant effect on their overall performance while target distance did not.

Chaparro et. al. [4] examined joint wrist motions and grip strength for a sample of 147 adults aged over 60. They found that older men in particular experience significant decreases in wrist range of motion. Their comparison with prior studies of wrist flexion while using a mouse suggests that this is likely to have a significant impact on mouse use.

Hwang et al. [7] studied the cursor trajectories of six motor-impaired computer users, in comparison with three users with no impairment. They used a point-and-click task, and focused on analysing the submovement structure of the movements. They examined pauses in the movements, verification times (pauses between the completion of the movement and the subsequent click), number of submovements, peak speed of submovements and submovement accuracy. They found that some motor-impaired users paused more often and for longer than non-impaired users, required up to five times more submovements to complete a task, and showed long verification times.

Qualitative results from interviews with thirty individuals including those described in the following section were reported by Paradise, Trewin and Keates [16]. Twenty-one difficulties with mouse use and twelve compensatory strategies were found. Pointing issues reported included difficulty in:

- keeping the hand steady when navigating;
- slipping off menus;
- losing the cursor;
- moving in the desired direction;
- running out of room on the mouse pad; and
- the mouse ball getting stuck.

Although the number of participants was too small to allow statistical analysis, it is worth noting that difficulty in keeping the hand steady, and in moving in the appropriate direction were reported only by older adults and people with Parkinson's disease.

Running out of room to move the mouse was the most commonly reported issue, and was common across all the groups.

Keates et al. [10] showed that the measures proposed by Mackenzie et al. [14] could be used to differentiate between the point-and-click behaviour of able-bodied users and users with quite severe motion impairments, primarily arising from cerebral palsy. Keates, Trewin and Paradise [12] showed that some of the cursor measures are capable of differentiating between even quite similar groups of users. Most successful ($p <= 0.01\%$) were the cumulative measures of ODC and MDC. TAC and PL/TA also showed significance at the 5% level. Measures that are normalised over time (the 'mean' measures: ME, MO, MV) did not show significance.

The analysis in this paper aims to build a deeper understanding of where and how these significant differences originate.

4. STUDY OF CURSOR MOVEMENT

As in any study in this field of research, access to users is a key determining factor in the success of any experiment. It is worth noting a number of special considerations for empirical work with motion-impaired users and their impact on statistical analyses.

In performing empirical work with motion-impaired computer users, practical limitations can restrict the application of detailed statistical analysis. The main limitations involve the increased heterogeneity of motion-impaired users compared to able-bodied ones, and the small sample set. Because of the small number of available users, repeated measures designs are generally employed, as in the experiments presented in this paper.

Ideally users would be classified and screened by levels of motor co-ordination, visual acuity, computer experience, etc, and an effort would be made to isolate motor co-ordination issues by controlling for these other factors. Unfortunately, the small number of individuals available under pragmatic research conditions often makes this level of control unachievable, and that was the case in this study.

4.1 Participants

Participants were selected from four groups that represented a range of age and motor capabilities. The groups were:

- young adults (YA; ages 20-30)
- adults (A; ages 35-65)
- older adults (OA; ages 70 and older)
- adults with Parkinson's Disease (P; ages 48-63)

A preliminary pre-session interview was used to establish each user's level of computer expertise, computer usage (types of software and frequency of use, etc.) and physical impairment symptoms (e.g. tremor, RSI, etc.). All users were living in private accommodation, not residential care, and for the study sessions all wore the glasses or contact lenses that they would do normally when using a computer. Most users had considerable experience of using a computer mouse. However, some of the older adults did not, and the implications of this are discussed further in Section 6.1.

The participants are discussed in more detail in [16] and Table 1 provides a summary of each individual's gender, age, years of computer experience, location and motor difficulties.

Table 1. Participant characteristics.

Participant	Gender	Age	Years Exp.	Location	Motor Difficulties
YA1	M	21	16	Local	N/A
YA4	M	25	7	Local	N/A
YA5	F	20	6	Local	N/A
YA12	F	23	8	Local	N/A
YA13	M	22	8	Local	N/A
YA15	M	26	20	Local	N/A
A2	M	59	37	Local	Some RSI
A3	F	45	19	Local	N/A
A7	M	44	20	Local	N/A
A8	M	40	24	Local	N/A
A9	F	40	20	Local	N/A
A16	M	52	32	Local	Minor RSI
OA1	F	81	10	Local	N/A
OA2	F	82	5	Local	N/A
OA3	F	78	4	Local	N/A
OA4	M	74	10	Remote	N/A
OA5	F	73	3	Remote	Shaky hand
OA7	M	82	6	Remote	N/A
P1	F	58	20	Remote	Hand out of synch; Tremor
P2	F	48	19	Remote	Immobility; Tremor; Fatigue
P3	F	56	22	Remote	Fine motor skill; Slowness
P4	F	57	12	Remote	Tremor; Dyskinesia
P5	F	63	44	Remote	Slowness; Rigidity; Hands out of synch
P6	M	61	17	Remote	Tremor; Slowness; Fine motor skills;

The young adult and adult groups were recruited locally at IBM. The average age for the young adult group was 23 (SD=2.0) and the average age for the adult group was approximately 47. (SD=9.4) These groups were recruited as an "expert" baseline for the study, and in general had more computer experience than the other groups. It is also important to note though that there were individuals in the Parkinson's group with as much, or more, experience than some of the individuals in the young adult and adult groups. All participants in these groups took part in the study on-site.

Of the older adults, the average age of this group was 79 (SD=4.5) with 4 female and 2 male participants. In general, this group had the least amount of computer experience. The majority of these participants are novice computer users, some of whom only use a computer several times a month. The initial three participants in this group participated on-site for the study, whereas the remaining three took part remotely.

The participants with Parkinson's disease were recruited through the American Parkinson Disease Association (APDA). Five of these participants (P2-P6) had had some form of computer training in addition to years of experience and all could be considered experienced computer users. Their average age was 57 (SD = 5.2). All participants in this group took part in the study remotely at home or at work.

4.2 Method

Participant sessions involved a set of semi-structured interviews and computer sessions using a mouse movement recording program. The semi-structured interviews were designed to complement the mouse movement data to gain a fuller understanding of the participants' use of computers. The interviews addressed issues such as physical impairment symptoms, computer expertise, which software was used and any coping strategies employed to make using computers easier. The results of these interviews are described by Paradise et al. [16]. To minimize fatigue, the interview sections were broken into five shorter sections conducted sequentially between the sessions on the computer.

In between interviews, participants used a program developed to collect mouse movement data. The study program presented a within-subjects repeated measures set of targets that participants had to click on like a button. There were three target sizes (16. 32 and 64 pixels) and target distances (192, 384 and 768 pixels) and each data collection session consisted of four targets of each size and distance combination generated randomly. The angle from last target was also varied randomly, within the confines of the size of the screen (1024*768 pixels). Each set of targets was preceded by a zero calibration task.

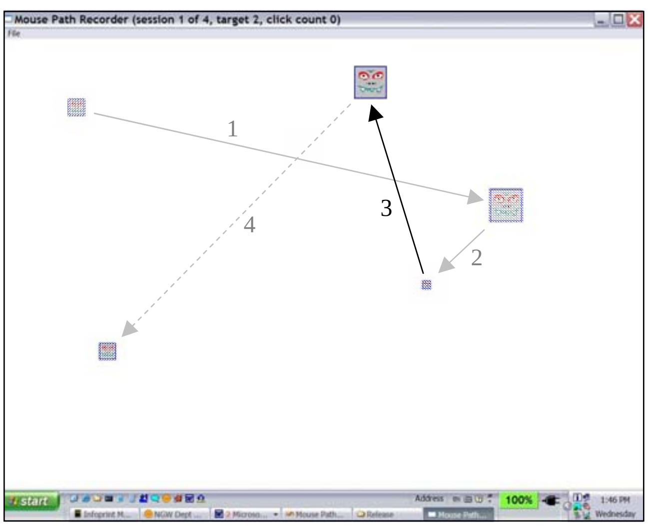

Figure 1. A screenshot of the point-and-click task showing an example sequence of the first 4 targets out of a series of 37. Note the 3 sizes of targets and 3 distances to targets, along with the random angle of approach.

Thus there were four data collection sessions in total, each with 37 targets. An initial set of 4 targets was first presented as a practice session where the researcher explained some features of the study program. During these sessions and the remote sessions in particular, participants were encouraged to report if something was too difficult for them.

Remote participants were called at the pre-established time and completed the study using either a headset, a speaker phone or by putting down the phone during the computer sessions. These participants emailed the automatically generated log file back to the session co-ordinator. Several features of the computer program used for this study were designed to aid the remote study sessions. For example, each time a participant successfully clicked a target, the program emitted an audible ping. Most participants had speakers that could be turned up loud enough that this could be heard over the telephone.

5. RESULTS

Data were collected on both the cursor movement and button pressing measures. As a baseline measure, there were statistically significant differences in timing across the four groups ($p<0.001$). The means and standard deviations of the movement times for each user group are shown in Table 2.

5.1 Pauses

A pause is a period in which no mouse movement is reported. Tables 3 and 4 show the average number of pauses per move for each user.

Table 2. Means and standard deviations of movement times (in seconds)

User group	Young	Adult	Senior	PD
Mean	1.02	1.10	2.89	1.91
Std Dev	0.10	0.07	1.33	0.49

Pause values of 100 msec and 250 msec are presented. These values were chosen based on the Model Human Processor [3] in which a physical action consists of component perceptual, cognitive and motor function times.

In an earlier study by Keates et al [11] these times were measured as 70 msec for able-bodied users and 110 msec for users with motor impairments. Thus 100ms appears to be a satisfactory compromise boundary across the groups to represent pauses in which there is a break between motor functions. 250 msec corresponds to a typical user's reaction time to a simple stimulus and represents one perceptual cycle, one cognitive cycle and one motor function. Pauses that are longer than this are likely to indicate the user engaged in forward-planning.

Note that pauses do not correspond precisely to submovements, since submovements may be combined without pausing the motion of the mouse, but wherever a pause occurs, a submovement break occurs.

Pauses are most likely to indicate periods of motor planning based on visual feedback, mechanical/physical difficulty in moving the mouse (e.g. the mouse falls off the mouse mat or hits an obstacle), or instances where the user was distracted from the task.

Table 3. Average number of pauses > 100 msec per movement.

User	Young	Adult	Senior	PD
1	1.27	2.77	5.91	2.46
2	0.72	2.09	2.79	3.75
3	1.90	2.25	3.12	2.56
4	1.49	1.71	4.08	3.01
5	1.28	1.20	4.59	2.47
6	1.74	2.09	7.73	3.10
Mean	1.40	2.02	4.70	2.89

Table 4. Average number of pauses > 250 msec per movement.

User	Young	Adult	Senior	PD
1	0	0.29	3.16	0.42
2	0.08	0.06	0.27	1.70
3	0.09	0.18	0.45	0.28
4	0.08	0.12	0.56	1.12
5	0.15	0.01	1.76	1.01
6	0.40	0.30	2.47	1.47
Mean	0.13	0.16	1.45	1.00

For both long and short pause values, the average number of pauses per movement rises with increasing age. The group with Parkinson's disease showed results consistent with the age of the group, falling between the adult and older adult values.

Analysis of variance showed statistically significant differences between the groups in the average number of pauses per move ($p = 0.0019$ for 100 msec and $p = 0.0015$ for 250 msec, $df = 22$). Tables 5 and 6 show correlation values obtained for these pause count values with the cursor measures.

Table 5. The Pearson correlation coefficient and the level of statistical significance attained for the relationship between pauses > 100 msec and the cursor measures.

Cursor measure	Pearson coefficient (r)	Level of significance
Path length / task axis length (PL/TA)	0.565	1%
Missed clicks (MCL)	0.564	1%
Task axis crossings (TAC)	0.750	1%
Target re-entries (TRE)	0.699	1%
Movement direction changes (MDC)	0.582	1%
Orthogonal direction changes (ODC)	0.815	1%
Movement error (ME)	0.274	n.s.
Movement offset (MO)	0.1981	n.s.
Movement variability (MV)	0.183	n.s.

Table 6. The Pearson correlation coefficient and the level of statistical significance attained for the relationship between pauses > 250 msec and the cursor measures.

Cursor measure	Pearson coefficient (r)	Level of significance
Target re-entries (TRE)	0.492	5%
Path length / task axis length (PL/TA)	0.433	5%
Missed clicks (MCL)	0.374	n.s.
Task axis crossings (TAC)	0.619	1%
Movement direction changes (MDC)	0.690	1%
Orthogonal direction changes (ODC)	0.762	1%
Movement error (ME)	0.269	n.s.
Movement offset (MO)	0.238	n.s.
Movement variability (MV)	0.062	n.s.

Significant correlations were found between the number of pauses over 100 msec and the cumulative cursor measures PL/TA, MCL, TAC, TRE, MDC and ODC, while the normalised measures ME, MO and MV did not show a correlation. Correlations for longer pauses remained strong for the TAC, MDC, and ODC measures, was weaker for PL/TA and TRE, and was no longer significant for MCL. Note that the critical values for the Pearson correlation coefficient for significance at the 5% and 1% levels are 0.404 and 0.515 respectively.

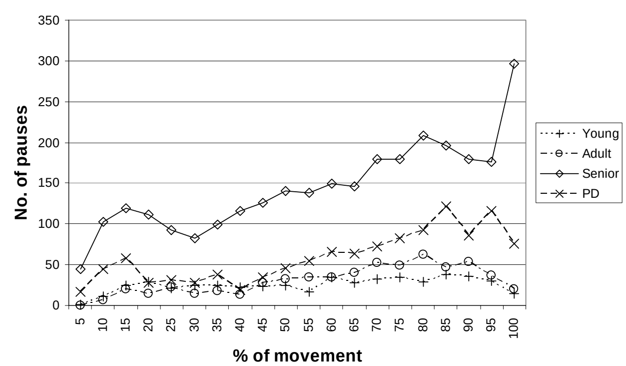

Figure 2. Location of pauses over 100 msec within the movement as a percentage of the movement time.

Figure 2 shows where in the movement the pauses over 100 msec occurred, for each group. Young adults and adults show similar profiles, with pauses distributed fairly evenly over the course of the movement, while older adults and people with Parkinson's disease show pause counts tending to increase towards the end of the movement. Both groups also show a peak around 10-15% into the movement.

5.2 Verification Pauses

Table 7 shows the number of pauses of 100 msec or longer that occurred within 500 msec of the final button press on the target. Each group contains 912 individual movements.

Table 7. Number of 100 msec or longer pauses within the last 500 msec of movement.

	Young	Adult	Senior	PD
Count	496	888	841	949
Per move average	0.54	0.97	0.92	1.04

The data suggest that the young adults often do not pause for long before clicking on the target. The other groups usually do pause for at least 100 msec, and tend to pause once per target.

Figure 3 shows a histogram of the times of the start of these pauses within the 500 msec before the button was pressed. Note that a pause extends for a minimum of 100 msec from the time of the start of the pause and often longer. Thus many of the pauses shown in Figure 3 lead directly in to the mouse button down event on the target.

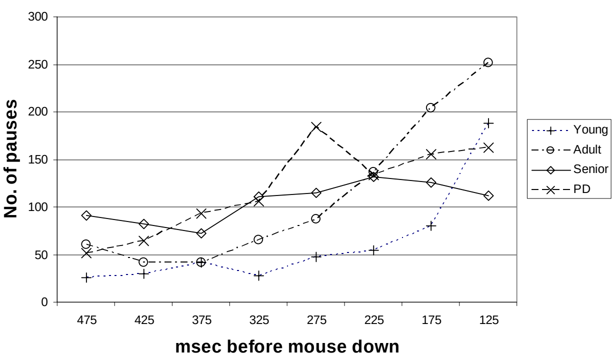

Figure 3. Pauses before successful target selection.

Young adults and adults show similar profiles, with pause counts increasing towards the end of the movement. Older adults and people with Parkinson's disease showed a quite different, flatter profile, with pauses distributed more evenly throughout the time, suggesting that they are pausing for longer times than the adults and younger adults before clicking. The Parkinson's group showed a peak in pauses 250 to 300 msec before pressing the button down which did not occur in the other groups. This *may* indicate that the mouse is starting to slip before the button down.

5.3 Peak Velocities

There were significant differences between the groups' peak velocity values, summarised in Table 8. The mean peak velocity, mean time in milliseconds before the peak was reached, and the mean percentage of the movement completed when the peak velocity was reached all showed significance with $p < 0.01$.

In general, the peak velocity decreased with age. Those with Parkinson's disease showed the lowest peak velocity of the groups, less than half that of the adults and young adults.

Adults and young adults reached peak velocity after approximately 200 msec, while older adults took almost four times as long and showed very high variability, and those with Parkinson's disease took twice as long. Young adults, older adults and those with Parkinson's disease typically reached peak velocity about a quarter of the way into the movement, while the adult group did so earlier, 20% into the movement.

Table 8. Peak velocities.

	Young	Adult	Senior	PD
Mean peak velocity (pixels/msec)	4.60	4.28	2.52	1.94
Std. dev.	*2.74*	*2.30*	*2.28*	*1.38*
Mean time to peak (msec)	222.93	191.83	741.50	392.28
Std. dev.	*250.33*	*108.61*	*1346.12*	*399.89*
Mean % of movement time to peak velocity	24.08	19.86	26.17	25.26
Std. dev.	*11.74*	*10.70*	*16.98*	*14.15*

Looking at whether there was any correlation between the magnitude of the peak velocity and the distance to the target, there was a strong positive correlation across all user groups. However, there was only a very weak negative correlation between peak velocity and target size.

Table 9. Correlation between magnitude of peak velocity and target distance for each user group.

User group	Pearson coefficient (r)	Level of significance
Young)	0.433	1%
Adult	0.374	1%
Senior	0.619	1%
PD	0.492	1%

However, there was a strong ($p < .01$) positive correlation between target size and where the peak velocity occurred within the move (as a percentage of the total move time) across all user groups. These results are in line with those reported by Bootsma et al. [1] as discussed earlier in this paper.

6. DISCUSSION

6.1 Movement behaviour of older adults

The results from this user study indicate that seniors take longer to complete the task and pause more frequently than the other groups. Previous research suggested this was because of lower peak velocities and increased deceleration time. Our results are partially consistent with this. Older adults did have a comparatively low peak velocity, although the Parkinson's users had the lowest peak velocities on average. Based solely on the difference in peak velocity between the seniors and the younger adults, it would be expected that the movement time for the older adults would be 1.86 sec (4.60/2.52 * 1.02) rather than the 2.89 sec observed in Table 2. This difference implies that there must be another mechanism causing the increase in movement time.

Looking at the theory of an extended deceleration time explaining the increase, for this to be the mechanism it would be expected that the percentage of movement time before the peak velocity is reached to be lower for the seniors than for the younger adults and adults. However, the results do not support this (Table 8). A more likely explanation is the increased number of pauses observed for older adults (Tables 3 and 4).

The underlying causes of the pauses may vary from user to user, but most likely derive from lack of experience, lack of confidence (wanting to be sure before doing anything) and possibly difficulties with vision. Since there are not many experienced users available in this age group, it is difficult to tie down exactly what the principal underlying cause is.

Increased distractibility or chattiness of the users is not considered to be a principal underlying cause, because the seniors had almost half of their pauses between 100-250 msec duration, too short for a distraction.

The high correlation of pauses with target re-entries (TRE), plus pauses being more at the end of the movement but not concentrated in the last 500 msec (Table 7) suggests that pauses are associated with movement around/through the target. Similarly the high correlation with both movement and orthogonal direction changes (MDC and ODC) suggests the same, a lot of trouble getting on to the target itself.

Note that the peak in pauses at the end of the movement for seniors in Figure 1 is so great because the seniors' moves were long - the last 5% might contain 3 times the actual time span of those in the younger adult and adult groups.

Instead of the expected strategy of a single large move towards the target, followed by a homing phase, the older adults appear to move with quite a different strategy – i.e. many smaller submovements. This is in line with behaviour observed by Hwang et al. [8] and their suggestion that general movement models may not apply universally.

6.2 Movement behaviour of Parkinson's users

The overall group times and number and distribution of pauses of the users with Parkinson's disease appear consistent with the average age of the group. There performance falls mid-way between that of the adults and those of the older adults. This implies an interesting question over which is more dominant – the effect of ageing or the effect of the Parkinson's disease?

It is interesting to note the increase in number of pauses in last 500 msec of movement (Table 7). Initiating movement can be difficult for people with Parkinson's, and multiple pauses in last half second suggest slight movement while attempting to press the button. The same cause may account for the peak around 275 msec in Figure 2, an increased pause before button down compared to the other groups.

Since all of the Parkinson's users were experienced with computers, their observed behaviour can be attributed to the effects of the disease.

Both the older adults and the Parkinson's users showed a small peak in the number of pauses in the first part of their movement and this occurs before the peak velocity. A possible explanation for this is that both of these groups make an initial move to either locate the cursor or orient themselves with respect to the target before making the primary submovement. This reinforces the idea that both groups differ from the behaviour predicted by the theoretical models developed for able-bodied users.

6.3 Movement behaviour for adults and younger adults

Both the adults and younger adults exhibited movement behaviour that broadly agrees that predicted by previous research. This implies that the differences observed for the older adults and Parkinson's users derive from the users and not from the experimental design of this study.

However, there were some differences observed for the younger adults. Previous research suggests that acceleration profiles for younger adults are typically bell-shaped,. All of our groups had the peak velocity occurring within the first quarter of the movement time on average, suggesting a different velocity profile.

The reason for this difference is based in the realism of the task. Our task is more realistic (in terms of actual computer-based pointing activity) than standard Fitts' law tapping tasks, where the targets are typically one-third or more of the size of the screen. Also we did not ask participants to perform as quickly as possible, so they were focused on accuracy in the time-accuracy trade-off. In a typical Fitts' task subjects are asked to perform as 'quickly and accurately' as they can. This may account for the difference in our results.

Another interesting point of note is that we are measuring the total time to successfully click on a target, including failed attempts. Other analyses tend to measure up to first click and discard errors. However, since our goal is to develop tools that help people in the real world, we are measuring real behaviour, where the task is not finished until the user has successfully clicked on the target. Future analysis will separate out the movements where the first click was on the target, from those where more than one click was recorded.

7. CONCLUSIONS

This paper has examined the differences in cursor control behaviour of four different user groups performing a typical point-and-click task. Using a range of measures, the differences in overall task completion time have been discussed in detail. Important differences in behaviour with respect to established models of movement indicate that new models are required when considering users with physical impairments or who are older.

These results presented in this paper are averages over movements to targets of different sizes and at different distances and give an overall flavour of differences between these groups. Further analysis will provide more detailed information on how the groups are affected by the different task conditions.

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