Noname manuscript No.
(will be inserted by the editor)

On the usefulness of off-the-shelf computer peripherals for people with Parkinson's Disease

Miriam E. Nes Begnum · Kyrre M. Begnum

Received: date / Accepted: date

Abstract People who suffer from Parkinson's Disease face many challenges using computers, and mice are particularly problematic input devices. This article describes usability tests of standard peripherals for use by people with Parkinson's Disease in order to search for optimal combinations relative to the needs of this user group. The results are used to determine their effect upon inertia, muscle stiffness, tremor, pain, strain and coordination and show that widely available equipment could significantly improve mouse pointer control for many users. The results reflect the diversity of challenges experienced by computer users with Parkinson's Disease, and also illustrate how projector-based technology may improve computer interaction without risking strain injuries.

Keywords Parkinson's Disease · Computer Interaction · User Tests · Computer Peripherals

1 Introduction

The results of a Norwegian survey, titled "Parkinson's IT challenges" (PIKT), on the computer use of people with Parkinson's disease [18], showed that nearly 80% of computer users with Parkinson's Disease report to have significant, severe or highly severe difficulties using a computer. According to the survey respondents, alternative keyboard and mice solutions impact ease of computer use, but the user population lacks experience with and knowledge of such alternatives. As an example, less than 1/3 of the respondents (28.5%) reported having tried pointing devices other than touch pads and mice. Alternative devices considered were almost limited to a mouse for users with left-hand dominance or a joystick.

When assistance is provided to this population, the focus is on general ergonomic adaptations. The findings thus suggest there is a need to identify beneficial computer solutions for the user group which are already available in the market. However, lack of proper guidelines and methodologies on how to find the right assistive technology for disabled computer users was noted by Hoppestad in [7]. In addition, Keates [1] points out the necessity of providing information back to designers of computer peripherals on how well their design work for people with disabilities in order to make their future designs more inclusive.

People with Parkinson's Disease are responsible for acquiring and paying for relevant alternative PC equipment themselves. No governmental or organizational recommendations are available at this point, making the process laborious and costly. Some computer users with Parkinson's Disease recommend certain facilitating devices to their peers, but most individuals have to find relevant solutions themselves. The aim of this article is to investigate possible computer adaptations through user tests and thereby make recommendations. Hopefully, the results will help shed light on the complex combination of challenges facing computer users

Miriam E. Nes Begnum
MediaLT
Jerikoveien 22
1067 Oslo, Norway
Tel.: +47-97736774
E-mail: miriam@medialt.no

Kyrre M. Begnum
Oslo University College
Pilestredet 35
0166 Oslo, Norway
Tel.: +47-22 45 32 76
E-mail: kyrre.begnum@iu.hio.no

with Parkinson's Disease which could be used by manufacturers and IT personnel in order to specialize equipment for this user group.

2 Background

2.1 Parkinson's Disease

Parkinson's Disease is caused by a disorder of the central nervous system affecting the mid-brain, which is responsible for the control of movement [8]. The illness affects one in 500 people [22]. It is usually diagnosed after the age of 55 and is projected to double in the next 25 years [20]. Parkinson's Disease is progressive, degenerative and chronic. It leads to a number of symptoms, such as tremors, muscle stiffness and rigidity, pain, reduced and slowed motor skills (akinesia/bradykinesia), reduced balance, coordination difficulties and resulting clumsiness, dementia-related symptoms, weakened voice, visual disturbances and lack of energy. Often, loss of finger dexterity and of hand/finger placement control are experienced [8]. Cognitive symptoms often include apathy and memory impairment, such as reduced short term memory, attention and concentration [17].

Computer interaction challenges are mainly linked to the motor symptoms, and using the computer mouse and keyboard peripherals are main issues [18]. About half of computer users with Parkinson's Disease struggle with significant, severe or highly severe muscle stiffness when using a computer, and equally many with inertia. Tremor is also a common challenge in relation to computer use, seriously affecting about 30%. A smaller sub-group of users are *only* significantly challenged by tremors, reducing the arm/hand control.

In spite of general Parkinson's Disease ailments, people want to continue living as normally as possible, including being able to use a computer efficiently and effectively without unnecessary fatigue, pain and strain. Computer usage seems to be of particular importance [18][14], and especially for maintaining social networks, as struggles with isolation, loneliness and depression are common issues [13]. In fact, the PIKT survey shows that despite their considerable difficulties, people with Parkinson's Disease under the age of 54 use computers with the same frequency as corresponding national age categories [16][15]. Knowledge of beneficial adaptations is therefore important, however little has been done to investigate this. One other study focusing on device usability for computer users with Parkinson's Disease has been found (De Wet 2005). However only three possible adaptations were tested, none of which improved computer interaction for their seven participants, and the study focused solely on tremors as the interaction issue.

It is uncommon for people diagnosed with Parkinson's Disease to use advanced computer control systems such as eye tracking and scanning. Moreover, such solutions may not fit the user group well due to their extensive pre-use training and in-use concentration requirements. Although they relieve muscle problems, these advanced control techniques are highly time consuming compared to using standard peripherals. Further, the individual symptoms, their degree and combination vary widely within the Parkinson's Disease population. Thus, the needs of people with Parkinson's Disease are often better aligned with those of computer users with temporary disabilities, regular or strain-related injuries and the elderly.

3 Approach

3.1 Selecting peripherals to test

The individual differences between computer users with Parkinson's Disease complicates the process of identifying suitable candidate devices for testing. From the PIKT survey it is clear that the computer mouse is particularly challenging, as 42% of the respondents say they have a significant, severe or highly severe challenge using this peripheral. 27% say the same about the keyboard. Mice and keyboard alternatives should therefore receive focus when selecting candidates.

According to Brodwin [5], computer assistive technologies (CAT) can be categorized into 28 different categories, including alternative keyboards, keyboard emulating interfaces, key guards, switches, trackballs, mouse sticks, hands-free mouse, pointing and typing aids, eye-tracking, Morse code and OCR. Of these, 9 are linked to visual impairments, and not directly relevant for the Parkinson's Disease population. Furthermore, 4 are linked to reduced cognitive and learning abilities. Of the remaining 15 categories, which address motor impairments, this study includes 12. The 3 categories omitted are Morse code, eye tracking and speech technologies. The first two are highly advanced interaction techniques believed to be generally poorly suited to the user population. The third alternative, speech control technologies, were unfortunately not available. At the time of the tests, no Norwegian speech recognition technology for PC interaction and control existed, neither speech commands nor dictation (the first Norwegian speech command system, VOMOTE, was released in October

2010).

As is evident from the available alternatives described above, the Parkinson's Disease user group's needs may be met by available and affordable standard devices, by largely unattainable and advanced special aid technologies, or by *the middle ground* aid technology/shelf ware peripherals with a specialized design. Testable equipment was acquired based on the priorities, and in addition emphasis was made on ensuring a wide range of technologies and types of adaptation, as well as including new and innovating solutions. In the following paragraphs, some of the adaptations selected for the testing, and the reasoning behind them are presented.

Several software and hardware adaptations exist to address tremor related troubles, such as the Mousecage software (Softpedia), the IBM Assistive Mouse Adapter [21] and various key guards of different sizes. These adaptations were all made available for the tests. Many specially designed mice were also included, among others a pen mouse, a tablet with a pen stylus with optical character recognition capabilities, the Perific handheld mouse, the PIP iFinger prototype and the Norlink NC mouse. In addition, special design keyboards exist with fewer keys, larger keys and enhanced key label visibility. Examples of these peripherals were included, such as the X-keys programmable keyboard and the "Easier life" keyboard. Keyboards with less recoil are also available, some made of soft rubber, and others employing laser technology. These are all examples of specialized equipment, that is usually easily attainable, but whose existence is often unknown to the average user. Examples of specialized aid technologies included from Brodwin's categories, are foot mouse, head mouse, programmable joystick mice with changeable heads and switches.

In addition to the categories listed by Brodwin, some non CAT peripherals – standard off-the-shelf peripherals with alternative input approaches or design – were included. Examples are computer mice and keyboards. Although few standard peripherals are designed to lessen the impact of such symptoms as akinesia, muscle stiffness and pain, a wide variety of ergonomically designed equipment, keyboards and computer mice are available. These are typically designed to avoid strain injuries for non-disabled computer users, but they may also prove useful to the target user group. A number of ergonomically designed keyboards and mice where thus included, such as the Maltron ergonomic keyboard, the Whale mouse and the AirOrbic mouse.

A wide range of computer mice are also obtainable, providing alternative sensitivities, weights, pointer control techniques and buttons. Many of these are optimized towards computer gaming, and are easily accessible products. Examples are the joystick and trackball mice, mice that glide well on a surface and mice with adjustable weights. Different mice of this kind were added to the equipment to complement the already selected ergonomic and special design mice options.

In all, 54 desirable adaptations were identified, 9 of which unfortunately could not be made available for the tests. 45 available test adaptations were therefore arrived at.

3.2 The test group

Through collaboration with the Norwegian Parkinson Foundation, a test-group of eight persons with Parkinson's Disease was selected for the user tests: five men and three women. The age span was 48 to 65 years. Two of the eight participants were working full-time, two were disabled and four were working part-time. All participants had general computer skills and used computers on a regular basis, all but one on a daily basis. However, their experiences using a computer and their type and range of symptoms varied.

A sub-goal of this project was that the participants would build and share competence on possible beneficial adaptations. This knowledge would then be spread to other members of the Parkinson community through the peer assistance initiative and a web forum. Thus, they were recruited from different parts of the country to act as local contacts within the Foundation and for computer users with Parkinson's Disease in their communities.

All the participants experienced challenges using a computer due to their symptoms. Detailed information about each participants' individual challenges, experiences and computer use were identified through pre-test interviews and questionnaires. Participants were also asked to prioritize their challenges on a nominal scale of *seriousness*, depicting the perceived detrimental effect the challenge had on computer use.

The information from the questionnaires was discussed during pre-test interviews, were they were asked to articulate and explain in more depth their main issues and needs. In addition to specific symptoms, the overall computer interaction complexity was investigated.

Their challenges were articulated as concretely as possible, and a test-centered view was taken as possible improvements were discussed and identified. This allowed the mapping of their difficulties to difficulties discovered earlier in the PIKT survey, thereby making them assumed representatives for the same population. Their main interaction challenges indicated that the test group was fairly representative. This conclusion was further supported when their detailed interview responses were compared to those in the PIKT survey, both with respect to the challenge distribution and their perceived seriousnesses. It also confirms that the participants in this study are somewhat younger than the majority of the Parkinson's Disease population, but that main age-categories within the population are still represented. All participants fitted within the same population as the survey with regard to age, level of experience in computer use and types of difficulties.

Each participant's interaction challenges was further clarified and confirmed based on test observations. Any additional details or adjustments to the pre-test evaluations were noted. Based on this input, and verified against post-test data from test observations as well as through post-test dialogues with participants, seriousness ratings on each individual's interaction challenges were finalized.

The members of the test-group were next categorized according to computer interaction challenges and their seriousness. Table 1 shows an excerpt of what computer interaction areas each tester's challenges are related to along with their seriousness. Based on the findings, the participants were grouped into four categories, summarized in Table 2. The even distribution is coincidental, as the participants were not paired when categorized.

3.2.1 Category A

Persons in this category are mainly challenged by using the mouse. In addition, these challenges are mainly related to tremor. Thus, the interaction challenges are not as complex and hard to solve as those of the main population.

3.2.2 Category B

Categories B and C are both multifaceted with regards to challenges and symptoms. Members of category B rate tremor as their main challenge/serious symptom but also state other symptoms as important influences on their computer use. They say ergonomics is the overall major problem, and not device specific usage, although both the keyboard and mouse are problematic.

3.2.3 Category C

Unlike the participants grouped in categories A and B, persons in categories C and D do not view tremor as the single most troublesome challenge. Like category B, persons in category C describe a complex situation, with multifaceted interaction difficulties. Tremor is a part of the picture, but not as major a part as for the previous two categories.

The participants in category C are somewhat hard to define, as they do not focus on a specific symptom or peripheral. Rather, both tremor, fatigue, pain and muscle stiffness are rated as seriously affecting computer use, and both ergonomic, mouse and keyboard issues are described as major interaction challenges. Focus seems to be on relieving and supporting arm and hand muscles in specific situations. One of them was also very seriously affected by inertia. Both had major interaction challenges related to complex arm/hand control issues, pain and endurance.

3.2.4 Category D

Unlike the other categories, tremor is not considered a challenge for participants in category D. One of the participants describe problems such as experiencing keyboard related troubles due to having stiff fingers: not being able to hit the desired key, hitting keys twice instead of once and only being able to type at a painfully slow speed. Mouse control is also not optimal.

The most prominent challenges for persons in category D are muscle stiffness and inertia. Like category A, the interaction challenges seemed rather focused on these central problems, though fatigue and pain are also challenges mentioned. This last category of users may thus be viewed as a second subgroup within the population, where not tremor, but rather other issues related to the loss of fine motor skills, are in focus.

The reported and observed challenges experienced by the participants, and their combination, coincide with the findings from the PIKT survey. For example, 53% of the survey respondents report significant to severe inertia, whereas 4 of the 8 participants say the same and 46% of the survey sample experience significant to serious muscle stiffness, reported by 3 participants.

Table 1 The main computer interaction challenges of the test users

	Ergonomics	Keyboard	Mouse	Screen
Par.1	Serious	Quite Serious	Quite Serious	-
Par.2	Serious	-	Serious	-
Par.3	-	-	Quite Serious	-
Par.4	Very Serious	Quite Serious	Quite Serious	Quite Serious
Par.5	-	Quite Serious	Serious	-
Par.6	-	Quite Serious	Quite Serious	-
Par.7	Serious	Serious	Serious	-
Par.8	Serious	Serious	Very Serious	-

Table 2 Test user categories

Category	Participants	Short Description
A	3 and 5	Mouse related problems are the only, or by far the most prominent, area of difficulty. Tremor is the only, or by far the most prominent, challenge related to computer mouse control.
B	1 and 4	Ergonomic challenges are the most significant, with related difficulties regarding using keyboard and computer mouse. Tremor is a central problem area. Muscle stiffness and inertia are less problematic but present.
C	7 and 8	The participants in this category have serious issues related to both computer mouse and keyboard, as well as ergonomics. The most prominent ergonomic challenges are pain and fatigue. Tremor and arm/hand control is also a challenge for this category.
D	2 and 6	Muscle stiffness and inertia are the main challenges. Fatigue and pain may be problem areas. Tremor is an insignificant issue. The participants focus on device related issues.

Table 3 Test user challenges relative to sample in the PIKT survey

Problem Area	Percentage experiencing significant to highly severe difficulties in PIKT survey	Number experiencing significant to highly severe difficulties in user test group
Inertia	53%	4
Muscle stiffness	46%	3
Tremor	30%	6
Using a standard computer mouse	42%	5
Using a standard keyboard	27%	3

3.3 Test methodology and implementation

The user tests were held over a two-day period at two locations. Based on the results of the pre-test interviews and assessments, a compendium of recommended tests was constructed for each individual tester. Possible testable solutions and adaptation were identified from the 45 available test adaptations, and evaluated in collaboration with the tester. The compendium contained both solutions the interviewer thought beneficial based on defined usefulness assumptions as well as technologies the tester personally found interesting.

Even though the compiled test book for each individual provided a frame for that individual's testing, the participants were given the liberty to change test order, time spent on each test, the length and frequency of breaks etc. This was due to the fact that the participants were individuals with Parkinson's Disease and that two full days of extensive testing could be a strenuous workload. The test setting was therefore tailored to facilitate and respect individual needs for rest. Emphasis was on maintaining and facilitating a good atmosphere where curiosity and fun experimentation provided the motivation. Each participant's ultimate goal was to find potential solutions to their own individual interaction challenges, so the tests accordingly sought to aid them in this process as well as broaden their general knowledge about existing solutions. More insight into maintaining sensitivity towards the participants needs and individual challenges can be found in detail in Astell et.al [9].

The group conducted their tests together in a large room, allowing them to exchange advice and to interact. A total of 45 different input devices and adaptations were offered the participants, of which 34 were actually chosen to be tested by the users. The participants had a wide variation in their specific selection, but computer mice and related issues became a focal point for most of them - consistent with the reported challenges. The first day focused on mouse and keyboard solutions as well as Windows software adaptations. The second day also included ergonomics. The tested peripherals are listed in Table 4.

Since needs and type of computer use varied, the decision was made to ultimately leave it up to the participants to choose what peripherals they would test. It was also not required that a specific scenario had to be completed for each test. Participants feedback was obtained via a required questionnaire for each tested device. It asked participants to describe in detail how the device/adaptation worked, the aim of the trial and whether the expectations were met.

Each participant was assigned a personal observer who followed them during the tests. The observer helped guide the tester, suggested potential adaptations to try out and assisted in correctly filling out test forms. The form-filling was usually conducted in the form of a mini-interview or ongoing dialogue, where observations and user feedback were discussed, clarified and documented by the observer. The observers also functioned as technical support, solving installation problems and technical issues. An alternative approach would be to let the personal observers follow a group of peripherals instead of a participant. That way, there would be less risk that the observers might influence the motivation to test a specific set of devices. However, each tester already had a neutrally compiled list of suggested devices in their portfolio from the pre-test interviews. Moreover, having one personal observer throughout the tests was considered less cumbersome for the participants and to provide more trust. The personal observer would also be able to interpret the individual participants responses consistently in the form-filling mini-interviews.

When testing computer mice, a pre-designed scenario in addition to free experimentation was used. To more accurately and consistently determine levels of mouse pointer control, the participants were asked to follow an elliptic line with the mouse in drawing mode. This is a similar type of test as what is used by Westin [4]to determine the level of drawing impairment for people with Parkinson's Disease. The mouse control challenges and the expediency of the adaptation were demonstrated by repeating the drawing test with different computer mice, tremor filter settings on the IBM Assistive Mouse Adapter and so on. When conducting free experimentation, the focus was more on window control, such as scrolling, successfully targeting small spots on the screen and surfing the web.

4 Test results

The different peripherals' suitabilities were determined based on their documented effect upon inertia, muscle stiffness, tremor, pain, strain and coordination. During data analysis, participants as well as observers were asked to clarify and elaborate on the described results when necessary to ensure a coherent report. Before completing the analysis, summarized findings on individual test results were discussed with, and verified by, each participant. Each peripheral/adaptation was given an overall score on a scale of 5 alternatives: Very useful, Useful, Average, Less useful and Unusable. The middle choice, average, denoted that the peripheral was perceived to have no notable difference from a regular peripheral, say a normal computer mouse. The two lower categories represented a worsening in usability compared to a regular peripheral, while those on the upper end of the scale indicated an improvement.

The results of the tests can be found in Tables 5 through 8. Dashes in the tables indicate that the device was not tested by a participant in the corresponding category.

4.1 A troublesome computer mouse

Even though large individual differences exist within the user group, using a computer mouse was confirmed as the main problem for the entire group. As a result, all participants chose to put their main focus on alternative mouse devices.

Using a computer mouse poses two problems for the user group: controlling the mouse pointer and clicking the mouse buttons. The tests show that improving one of these issues unfortunately often further complicates the other. The fact that mouse clicking and mouse

Table 4 The peripherals and adaptations tested

Peripheral	Description
Mice	Tablets with a pen stylus, Pen-mouse, Perific handheld mouse, Ergonomically left-hand mouse, AirOrbic vertical right-hand mouse, Whale mouse, Touchpad, Logitech marble trackball mouse, Kensington trackball orbit expert, Kensington trackball orbit optical, Mouse with adjustable weight, Joystick-mouse with changeable top, Anir joystick-mouse, Head mouse (with reflectors), IBM Assistive Mouse Adapter, Norlink New Concept Mouse, Mouse stick, Projected Interactive PC-control prototype solution, Foot mouse NoHands Mouse.
Keyboard	Ergonomic split keyboard, Rubber keyboard, "Easier life" keyboard, Logitech ergonomic keyboard, Miniature keyboard, Key guard, Virtual laser keyboard, X-keys, On-screen keyboard, DigiScribble.
Ergonomics	Arm rest, Ergonomic chair, Adjustable height office table, Laptop pillow.
Other	Adaptations in Microsoft Windows Vista : Changing color/size of mouse pointer, High contrast screen setting, Mouse keys, Repeat keys, Slow keys, Shortcuts, Adjusting mouse button clicking rate, Automatic mouse pointer movement. Larger computer monitor.

Table 5 Usefulness rating of mouse adaptations

	Category A	Category B	Category C	Category D
Tablet with a pen stylus	Useful	Useful	Very Useful	Less useful
Pen mouse	Less useful	-	Unusable	Less usable
Perific handheld mouse	-	Average	Useful	-
Ergonomic left-hand mouse	Less useful	-	-	Less useful
AirOrbic vertical right-hand mouse	Average	Useful	-	Average
Whale mouse	-	Less useful	Useful	-
Touchpad	-	Average	Average	Less useful
Logitech Marble Trackball Mouse	Very useful	Very useful	Very useful	Useful
Kensington Trackball Orbit Expert	Very useful	Very useful	-	-
Kensington Trackball Orbit Optical	Very useful	Very useful	Very useful	Useful
Gaming-mouse with adjustable weights	-	Average	Useful	Useful
Joystick-mouse with changeable top	-	Unusable	-	-
Anir Joystick-mouse	Unusable	Very useful	Unusable	Very usable
Head mouse (with reflectors)	-	-	Less useful	Average
IBM Assistive Mouse Adaptor	-	Average	Very useful	Usable
Norlink New Concept Mouse	Useful	Average	-	Unusable
Mouse stick	-	Usable	Average	Less useful
Projected Interactive PC-control prototype	Useful	Very useful	Useful	Useful
Foot mouse NoHands	Less useful	Useful	Less useful	-

Table 6 Usefulness rating of keyboard adaptations

	Category A	Category B	Category C	Category D
Ergonomic split keyboard	Very useful	Unusable	-	-
Rubber keyboard	Unusable	Less usable	Average	-
"Easier life" keyboard	-	Very usable	-	-
Logitech ergonomic keyboard	-	-	Average	Very usable
Miniature keyboard	-	-	Very usable	Less usable
Key guard (for normal sized keyboard)	-	Unusable	-	Less usable
Virtual laser keyboard	Unusable	Very usable	Usable	-
X-keys	-	Very usable	-	-
On-screen keyboard	-	Less usable	-	-
DigiScribble	-	-	Average	-

Table 7 Usefulness rating of ergonomic adaptations

	Category A	Category B	Category C	Category D
Armrest	-	Very useable	Usable	Usable
Ergonomic chair	-	Usable	Usable	Usable
Adjustable height office table	-	Less usable	Usable	-
Laptop pillow	Usable	-	Average	Usable

Table 8 Usefulness rating of other adaptations

	Category A	Category B	Category C	Category D
Accessibility adaptations in Microsoft Windows Vista (Mouse keys, Repeat keys, Slow keys, Shortcuts, Adjusting mouse button clicking rate, Automatic mouse pointer movement)	-	Very usable	Usable	-
Screen adjustments in Microsoft Windows Vista (High contrast screen settings, Changing color/size of mouse pointer)	-	Very usable	-	-
Larger computer monitor	-	Very usable	Very usable	-

pointer movement are two separate actions [3] supports the findings.

In order to optimize clicking for the user group, the tests show that two device attributes are needed: 1) buttons that are easy to reach, thereby avoiding fatigue and pain when clicking, and 2) a design facilitating holding the mouse in a stable position while clicking, even with reduced arm/hand control.

For optimized mouse pointer control, the tests showed that the pointer must be easy to move while remaining insensitive to small movements, facilitating increased movement control such as being able to use multiple fingers on a trackball, was also beneficial.

4.2 Mouse pointer control

Generally, touchpad and mouse pens were not found to be beneficial for solving serious mouse control issues. Left-handed and ergonomic mice received varied feedback, with some participants finding them beneficial. Head mouse and foot mouse solutions received an overall negative rating, probably as they are alien control concepts to the users. However, touch technology, IBM Assistive Mouse Adapter and trackball mice received positive feedback.

When it comes to improving the control of the mouse pointer, trackball mice seem appropriate for people with Parkinson's Disease, especially where trembling is the main problem. Trackballs were therefore the number one improvement for the participants in category A. All participants were helped by trackball mice, which where denoted as the best mouse solution by most of the participants, providing increased mouse control. The trackballs were reported to be "easy to use", "not moving too fast", "cleaner" and more accurate than ordinary mice, "intuitive", "steady", "good grip", ergonomically fitting with the opportunity to use multiple fingers as well as both hands, "comfortable", "good ball control", "nice to scroll with" and providing good "pointer and mouse control". Trackballs of different types and sizes were tested, and the most important feature for optimized control seems to be the proper match of trackball size to the users hand size: smaller mice fitted users with smaller hands, and users with large hands required large trackballs.

Keates and Trewin [24] observed that users with Parkinson's Disease tend to show a lower peak velocity when moving the mouse cursor and spend more time pausing and aligning the cursor before clicking, compared to able-bodied users. Their research was based on point-and-click tests with regular mice. Compared to the results in this paper, it *may* indicate that the dynamics of trackballs offer a more fitting acceleration/deceleration scheme for the user group, thereby providing more control. Wobbrock and Gajos [25] also argue for the benefits of trackballs for motor-disabled users. In their research, a trackball is used for gesture-based text input and prediction.

The IBM Assistive Mouse Adapter filter for tremor was useful for some to increase drawing and precision control, and generally received a lukewarm to positive rating. Participants in category C especially benefited from the filter along with a trackball or a tablet mouse with a pen stylus. Today, medication is often used to reduce the main shaking of the hands/arms, and this may explain why the filter does not play a more important role in increasing mouse control.

4.2.1 Clicking mouse buttons

No general solution was found that solves issues related to mouse button clicking. The trackball mouse solutions did not aid users challenged with troubles related to click-control. On the contrary, participants complained that steadying the mouse pointer while clicking was difficult using these solutions. Participants in category D, where mouse clicking was problematic and tremor less of a problem, rated trackballs lower than the other participants. The trackball did however aid one of the participants in category D, but the user still preferred the joystick mouse. For participants in category B, which had complex interaction issues in addition to tremor, both the trackballs and the joysticks seem convenient. For participants in category D, joysticks paired with arm support may be the best fit.

Several participants preferred a joystick mouse for mouse clicking, because they have a different placement of mice buttons compared to a standard mouse, allow using the thumb for clicking and are more stable. The joystick mouse seems suited for users with dominating ergonomic issues such as fatigue, pain, muscle stiffness and inertia, especially when combined with other ergonomic support devices such as arm supporters. On the other hand, the joystick solution also received complaints from participants experiencing pain and fatigue, and was judged as being heavy and hard to maneuver, providing poor overall mouse pointer control.

4.2.2 Touch technology

The results showed that touch based computer interaction could prove a solution to both challenges related to mouse usage. Interactive touch technology detects pressure and positioning on a screen area, and is a promising technology for users with mobility impairments since it provides possibilities for movement of navigational peripherals on larger surfaces, reducing the need for detailed coordination skills. Two such solutions were tested: a tablet with a pen stylus and Projected Interactive PC-control (PIP) prototype solution.

The PIP solution consisted at this stage of a glove pointing device, with a point and clicking device attached to one of the fingers, and the screen projected on a table in front of the user. A sensor above the table registered the position of the glove and when it touched the surface of the table, subsequently communicating a mouse-click event to the computer. The computer picked up movements and clicks through infrared light in the pointing device: the glove. Steering the computer by directly manipulating the perceived computer screen was an easy concept to grasp for the participants, and the control solution was familiar. It seemed the direct touch with natural tactile feedback increased mouse pointer control, as well as minimizing pain and fatigue. The participants did not have to care about the whereabouts of the fingers and limbs not equipped with the pointing/clicking device since no light were projected from these. This meant the participants could lean in and support their movements if they wanted, reducing fatigue and strain, and stabilizing the pointer when steering thereby further increasing the mouse control. They could also steady the hand and finger while clicking, providing increased click precision. The solution spurred no unfavorable reactions, receiving positive ratings for being such an early prototype. This coincides with findings in other research where the same solution was tested on children with severe motor disabilities, allowing them to engage in creative activities such as drawing pictures [2].

The tablet and stylus was mostly positively rated, especially from category C in which the participants mainly struggled with pain and fatigue, though some users' initial reactions were that the interaction felt strange and difficult. They found the concept of controlling what happened at the computer screen with the tablet hard to grasp. Others at first had difficulties holding the pen, resulting in the tablet not picking up movements with the necessary level of detail. In addition, clicking on the tablet was difficult. The tablet might have proven more useful if extended user training had been provided, and if that particular peripheral were tested over a longer period in time, allowing users to get accustomed to the new control concept before judging it.

4.3 Keyboard preferences

There was a large spread in the assessment of keyboards, with often only one person in a category testing a specific peripheral, making it hard to draw general conclusions. For some users, smaller keyboards worked well, reducing the need for finger movement and thus reducing pain and fatigue. For others, lack of precision made small keyboards hard to use, and larger alternatives were necessary despite the strain effects. Individuals' main challenges and their combinations resulted in different keyboard preferences. For example, one tester preferred the "Easier life" keyboard with enlarged key labeling and improved contrast/colors, due to diminished eyesight.

In general, ergonomic keyboards were beneficial compared to standard solutions. Ergonomic and/or split keyboards seem to reduce stress, but do not necessarily resolve any specific challenges related to the use of keyboards. Participants in category A had few problems with using a keyboard, but preferred ergonomic designs for these reasons. Ergonomic and split keyboards seem appropriate for users suffering from slowness, rigidity and muscle stiffness, due to the reduction of typing errors and increased the speed. Rubber keyboards received a slightly negative rating in the test, and Key guards were not considered helpful.

4.4 Other peripherals

Different types of arm rests are described by participants as relaxing and supporting the arm, and considered beneficial in combining with appropriate keyboards and mice. They were appreciated by all participants who tried them, and seem well suited to ease both ergonomic issues, tremor, fatigue and pain. Arm support were especially positively rated by participants in category B.

Adjustable chairs and tables were favored over non-adjustable alternatives. They were used to facilitate ergonomic and variable working positions, and assessed as suitable for minimizing troubles such as strain, pains and fatigue.

Less than half of the participants chose to try the suggested adjustments in Windows Vista. However, all who did found these to be beneficial. Improved visibility of the mouse pointer as well as high contrast settings reportedly improved mouse pointer control. Settings for automatic movement of the mouse pointer reduced the users need for physical movement. Also, the ability to adjust mouse pointer speed was perceived as beneficial. The participants particularly liked the filter/bounced keys and slow keys. Shortcut possibilities were also considered useful.

5 Discussion

For most problem areas, this study indicates potential solutions. However, no single solution was identified for the user group as a whole.

Even though the test group overrepresented tremor challenges compared to the assumed total Norwegian Parkinson's Disease population, the findings correlate with those in Begnum [18] in that tremor should not automatically be considered the main computer interaction challenge for people with Parkinson's Disease. Often, tremor is only one of several challenges in a more complex interaction situation, and it is often a secondary issue. Ergonomics and muscle strain, stiffness and pain and reduced arm/hand coordination and control are however often central challenges, especially among those with the largest computer adaptation needs. Nevertheless, a subgroup of the PC population do suffer mainly from tremor. Another identified subgroup is users challenged *not* by tremor, but rather other issues related to the loss of fine motor skills such as muscle stiffness and inertia.

A major computer interaction issue for the Parkinson's Disease population is controlling the computer mouse. For the sub-group of users mostly troubled by tremor and subsequently lacking mouse control, an ergonomically fitting trackball mouse seems beneficial. This was an interesting result as there were no specific expectations towards the trackball mice alternatives prior to the tests. These mice are widespread and can easily be distributed to end-users. It is therefore regrettable that only 2% of the user population has ever tried such a computer mouse alternative, something that points to the need for providing more knowledge of suitable adaptations to users [18]. Knowledge of Windows Vista customizations should also be distributed, as these proved useful too.

Clicking in general, and mouse button clicking in particular, proved to be a far greater challenge than expected. This is a problem area that needs further research. Unfortunately tests show improved button placements often collide with the need for a design giving optimal mouse pointer control. The trackball mice tested were all poorly designed in relation to ease of button clicking. On the tested trackball mice, the buttons were on the socket holding the ball, and so further tests with a clickable trackball are recommended. In [24], research indicated that users with Parkinson's Disease had more pauses in their movement and actions at the end of a point-and-click task, suggesting that the period between when the movement ends and the click is issued takes longer compared with able bodied users. This may indicate that a solution facilitating steadying the pointer during clicking could be beneficial. Touch technology proved an interesting platform for a combined pointer and click precision and control solution, and should be further looked into as a mouse alternative for this user group.

The challenge of finding an optimal mouse peripheral solution both in relation to pointer control and button placement is ongoing. It is worth noting that the optimal solution is not necessarily to find one single mouse. Switching between different mice solutions, used for different purposes and in different situations could be beneficial. The combined use of several computer mice input devices is an area worth investigating.

The IBM tremor filter did receive positive feedback, but even though the group suffered from extensive tremor issues compared to what can be expected in the total Parkinson's Disease population, it was not equally positive as the findings of Bodine [6]. In Levine [21], a test group of ten people, aged 36-79, reportedly experienced moderate to considerable improvements in computer mouse use. However, in this work the improvements were only moderate, and several participants indicated that improved medication has a greater success in removing heavy tremor. For the participants with only moderate tremor, the IBM filter did not receive a high rating compared to the actual mouse used (as the filter is located between the mouse and the computer). This might indicate that other factors than tremor, affected by choice of mouse, also influenced the PC interaction.

Several peripherals were not tested by all the participants. One could argue that the initial outset in this study had too many devices, thereby thinning out the results unnecessarily. However, the spectrum of devices was considered necessary to ensure that all types of possibly suitable adaptations were included. The large amount of available adaptations also allowed to tailor the most interesting combination for each individual, in an attempt to maximize the potential outcome for each one, based on their individual challenges and computer usage. Arguably, this individual-oriented approach limits the ability to generalize, as not all devices are tested by all participants. However, given the delicate situation of the participants and the available timeframe, it was possible to identify promising peripherals, which should be subjected to further long-term tests, as well as exclude some unfitting adaptations.

It should be noted that the user tests consisted of temporally short tests and included only typical tasks, as opposed to the approach where considerable time is spent learning and familiarizing with the devices. The results reflect this. For example, the foot mouse is a device which presents a completely different interaction approach, and, in fairness, requires time to learn to use properly. It did not receive a favorable review by the participants. However, the fact that 6 out of 8 participants *did* try it, shows that its potential to improve their situation was perceived by them. By sparking this interest, individuals are hopefully encouraged to invest time in testing such devices over a longer time. Prolonged acquaintance may result in a more positive final assessment. The results may therefore need adjustments related to issues of use over time.

Only a few weeks after the tests, the participants reported in their community forum that equipment which they considered favorable had been acquired. Here, discussions and viewpoints on the peripherals continues. This is in line with the desired outcome with regard to motivating further testing at home and raising awareness among the community. Using their feedback after prolonged use, one should be able to further adjust the results in the future.

6 Conclusion

Results from this study indicate which solutions could be beneficial for computer users with Parkinson's disease, depending on a persons main challenges. Results from this study refine and significantly extend the de Wet 2005 findings [19]. Generally inappropriate solutions are identified. Individual needs are clarified and the need for individual adaptations verified. Possible solutions for most device-related challenges seem to exist among currently available consumer devices. Challenges related to clicking proved to be a far more significant problem area than previously considered. Touch technology emerged as an interesting interaction alternative for computer users with complex challenges.

Acknowledgements The authors would like to thank to the volunteer participants, the Norwegian Parkinson Foundation and Oslo University College for invaluable contributions.

References

1. Keates S, Pragmatic research issues confronting HCI practitioners when designing for universal access, Universal Access in the Information Society, Volume 5, Number 3, Pages 269-278, 2006
2. Begnum M. E. N., Finstadsveen J., Begnum K., Enhancing creativity and play through accessible projector-based interactive PC-control touch technology, Unitech2010 - The International Conference on Universal Technologies, Tapir Forlag, p. 231-242, 2010
3. Hwang F., Partitioning cursor movements in "point and click" tasks,CHI '03: Conference on Human Factors in Computing Systems, p. 682-683, ACM, 2003
4. Westin J, Ghiamati S, Memedi M, Nyholm D, Johansson A, Dougherty M and Groth T, A new computer method for assessing drawing impairment in Parkinson's disease, Journal of Neuroscience methods, Volume: 190 Issue: 1 Pages: 143-148 Published: JUN 30 2010
5. Brodwin M.G., Star T., and Cardoso E., Computer assistive technology for people who have disabilities: computer adaptations and modifications, Journal of rehabilitation, v. 70, July-Aug.-Sept. p 28-33, 2004
6. Bodine C., Levine J., Sandstrum J. and Meyer L., Effects of Mouse Tremor Smoothing Adapter on Ease of Computer Mouse Use by Individuals with Essential Tremor: A Pilot Study, Universal Acess in Human Computer Interaction. Coping with Diversity, Lecture Notes in Computer Science, Volume 4554/2007, p. 632-636, 2007

7. Hoppestad B.S., Essential elements for assessment of persons with severe neurological impairments for computer access utilizing assistive technology devices: A Delphi study, Disability & Rehabilitation: Assistive Technology, 2006, vol. 1, issue 1-2, p 3, ISSN 17483107. ISBN 17483107.
8. Cunningham L.M., Nugent C.D., Finlay D.D., Moore G. and Craig D., A review of assistive technologies for people with Parkinson's disease. Technology and Health Care, Vol 17, No 3 / 2009, IOS Press, 2009
9. Astell A, Alm N, Gowans G, Ellis M, Dye R and Vaughan P, Involving older people with dementia and their carers in designing computer based support systems: some methodological considerations, Universal Access in the Information Society, Volume 8, Number 1, Pages 49-58, 2009
10. SSB Statistics Norway: Register-based employment statistics, 4th quarter 2008, http://www.ssb.no/english/subjects/06/01/regsys_en/
11. Tandberg, E., Larsen, J.P., Nessler, E.G., Riise T. Aarli J.A., The epistemology of Parkinsons disease in the County of Rogaland, Norway. Movement Disorders Vol. 10(5) pp. 541-549. (1995)
12. Larsen J.P.: Parkinsonprosjektet i Stavanger. Nevrologisk avdeling, Sentralsykehuset i Rogaland (1993)
13. Arntzen, E.: Rehabilitering av personer med Parkinsons sykdom. The Norwegian Parkinson Foundation, Cited from St.meld.34 (1996)
14. Tollefsen M., Nes, M.E.: En sekretær ville lœst alle problemer!. MediaLT (2006)
15. SSB Statistics Norway: IKT i husholdningene, 2. kvartal 2008, http://www.ssb.no/ikthus/
16. Lorentzen, K.: Kjnns- og aldersforskjeller ved bruk av IKT, Digital verden uten eldre kvinner. SSB Statistics Norway (2008), http://www.ssb.no/ssp/utg/200802/08/.
17. Aarsland D., Pedersen K.F., Ehrt U., Bronnick K., Gjerstad M.D., Larsen J.P.: Neuropsychiatric and cognitive symptoms in Parkinson disease. Tidsskr Nor Laegeforen vol 128(18) pp. 2072-2076. (2008)
18. Begnum, M. E. N. , Challenges for Norwegian PC-Users with Parkinson's Disease - A Survey, ICCHP 2010, Computers Helping People with Special Needs, Volume 6179/2010, p 292-299, 2010
19. De Wet, L., Van Aswegen W. (2005),Determining the usability of computer input devices by Parkinson's disease sufferers, African Family Practice Vol. 47, No. 1, pp. 58-59.
20. Dorsey, E.R., Constantinescu, R., Thompson J.P., Biglan K.M., Holloway R.G., Kieburtz K., Marshall F.J., Ravina B.M., Schifitto G., Siderowf A., Tanner C.M. (2006), Projected number of people with Parkinson disease in the most populous nations, 2005 through 2030, Publisher. Neurology 2007 Vol. 68, No. 5, pp. 384-386.
21. Levine J.L., Schappert M.A. (2005), A mouse adapter for people with hand tremor, IBM Systems Journal, Vol. 44, No. 3, pp 621 .
22. Parkinson's New Zealand, The Parkinson Society of New Zealand (Inc.), What is Parkinson's, 30.03.2010, http://www.parkinsons.org.nz/what-parkinsons.
23. Softpedia, MouseCage 1.05: Free Download, 30.03.2010, http://www.softpedia.com/progDownload/MouseCage-Download-28569.html.
24. Keates S. and Trewin S., Effect of age and Parkinson's disease on cursor positioning using a mouse, Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility, pp. 68 - 75, ACM, 2005
25. Wobbrock J.O. and Gajos K. Z., Goal Crossing with Mice and Trackballs for People with Motor Impairments: Performance, Submovements, and Design Directions, ACM Transactions on Accessible Computing (TACCESS), Vol 1/1, Article No. 4, p. 1-37, 2008