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# INVOLVING PSYCHOMETRIC TESTS FOR INPUT DEVICE EVALUATION WITH OLDER PEOPLE

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## *ABSTRACT*

*This paper presents a preliminary study of using psychometric tests when testing input devices with older people. An experiment with twelve older computer users evaluating three commonly used input devices (mouse, touch screen and tablet-with-stylus) in two common computer tasks (browsing and playing solitaire), preceded by a questionnaire and psychometric tests (Simple Reaction Time, Mini Mental State Exam and Identical Picture), and concluded with debriefing interviews, is described. The paper concludes that psychometric tests can provide quantitative data that complement the information collected through the questionnaire and interview and that some psychometric data were the best predictor of task performance.*

***KEYWORDS:*** *ageing, elderly, input device, psychometric test, user evaluation.*

## 1. OLDER PEOPLE AND INPUT DEVICE INTERACTION

As age increases, some abilities will change, most of them declining. Some of these declines will significantly affect older people's interaction with various computer interfaces, including input devices. Many papers that discuss older people's interaction with input devices concentrate on decline in motor abilities. However, when discussing task performance, perceptual and cognitive declines had been shown to affect the effectiveness of user interaction with input devices. For example, a 20 years old person is more likely to be capable of surveying 20 icons on the screen, narrowing them into three strongest candidates, and selecting the icon to click more quickly than a 65 years old person is.

Decline in motor abilities do have the most severe effect in older people's interaction with input devices. Older people take longer than their younger counterparts in performing the same movement, and their movements are more variable, less smooth, and less coordinated (Seidler, Hellenbrand, Robra, Vieregge, Nischan, Joerg, Oertel, Ulm and Schneider, 1996). The loss of fine motor skills makes it difficult for older people to position cursors on computer screens, particularly when interacting with small screen objects (Chaparro, Bohan, Fernandez, Choi and Kattel, 1999). Older people were reported to have more difficulty working with a mouse in clicking and double-clicking tasks (CREATE, 2002). Another study found that using a mouse places four burdens on many older people: a need to be highly precise; move quickly; coordinate shoulder muscles; and possess a high degree of eye-hand coordination (Laursen, Jensen and Ratkevicius, 2001). When considering that graphic user interfaces (GUI) require a person to use a mouse 30-60% of the time (Chaparro, Rogers, Fernandez, Bohan, Choi and Stumpfhauser, 2000), the stress on the wrists and arms of older computer users are considerable. Some authors suggested that a trackball

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mouse (i.e. the small button mouse usually found on laptops) is a better input device than a mouse for older people, as it potentially avoids the wear on their wrists (Chaparro, Bohan et al., 1999).

A study comparing the use of mouse in four target acquisition tasks (pointing, clicking, double-clicking and dragging) found that cursor control tasks with a mouse are more difficult for older people (Smith, Sharit and Czaja, 1999). Older people had more difficulty than younger people performing clicking and double-clicking tasks. It was also shown that age-related declines in motor control are related to age differences in mouse performance.

User studies in HCI usually consist of pre-session data collection, either through a demographic questionnaire or interview, task-related session, and finally debriefing interview to elicit more in-depth knowledge of problems, users' mental model, salient features, etc (Preece, Rogers and Sharp, 2002). Psychometric test, a test of users' general ability, is less commonly conducted than questionnaire or interview. This paper presents a case study of a task-related session complemented with a questionnaire, an interview and a psychometric test. A set of data were gathered repeatedly using these three approaches (albeit obtained slightly differently due to the nature of these three approaches). A correlation analysis was performed to investigate whether these three sets of data were related. A regression analysis was then run to investigate which set predicts task performance more accurately.

## 2. INPUT DEVICE RESEARCH

From 1945 to 1995 and beyond, continuous research has been carried out in the area of direct manipulation of graphical objects, windows, text editing, hypertext and gesture recognition. Even though advanced input devices can provide innovative ways of interacting with computers, some of the devices are expensive and are not readily available off-the-shelf. Furthermore, these devices are slow to gain popularity among older people, largely because they do not directly address users' immediate needs and are usually highly complex to learn and master. Therefore, it might be useful to go one step backward to analyse and address the needs of current potential users, e.g., by researching user behaviour, user perception, roles of user ability, and by comparing user performance when using familiar and common input devices. Using current common input devices in this type of research may reduce confounding effects (complexity in learning and operating the device) during the evaluation.

In input device evaluation research, users are usually required to perform a task. Douglas and Mithal (1997) assert that a comprehensive understanding of the influence of task on performance is critical for the evaluation. Six elemental tasks of input devices were: selecting, positioning, orienting or rotating, path following, quantifying and text manipulation (Foley, Wallace and Chan, 1984). In principle, if a computer system enables users to perform these six elemental tasks, then the user can use the computer system to perform any computer-based task.

Users' task performance with input devices depends on several factors, one being the speed of hand movement to target (Jacob, 1996). This explains why older people usually have poorer task performance than younger people (e.g. Charness and Bosman, 1990). Task performance may also depend largely on the task itself (Milner, 1988). For example, when the tasks require precision pointing, input devices that are operated with one's finger may take longer and result in more errors due to the relative sizes of the user's finger and the sensitive area on the screen. Thus, older people with tremor or unstable hands may have poor task performance in this type of task. And finally, task performance is highly affected by user characteristics, including: frequency of use, discretionary usage, computer familiarity, user knowledge, general abilities, physical abilities and skills (Sutcliffe, 1995). Most of user characteristics are usually obtained through pre-session questionnaire. One characteristic that is more difficult to obtain objectively through a questionnaire is general abilities. General abilities include developed skill, competence or power to do something, especially existing capacity to perform some function, whether physical, mental or a combination of the two, without further education or training (Colman, 2003).

## 3. PSYCHOMETRIC TESTS

General abilities can be tested to measure a person's current level of performance or to estimate future performance. Ability tests are also known as achievement, aptitude, or intelligence tests. Many of these tests are grouped as psychometric tests. The psychometric test is an assessment tool that consists of any standard procedure for measuring sensitivity, memory, intelligence, aptitude or personality (Colman, 2003).

In HCI, motor, cognitive and perceptual abilities are thought to affect task performance. The most widely used psychometric test to measure older people's cognitive abilities is perhaps the Mini Mental State Examination (MMSE) (Folstein, Folstein and McHugh, 1975). MMSE represents a brief, standardised method by which to assess cognitive mental status. MMSE is a common test conducted to examine the cognitive level of the subject (Folstein, Folstein et al., 1975). This test is also recommended by the UK's National Health Services (NHS) for deciding whether treatment for Alzheimer's disease should be prescribed. It was considered effective as a screening tool for cognitive impairment with older adults (Kurlowicz, 1999). The MMSE is a tool that can be used to systematically access mental status. The test consists of eleven questions that measure five areas of cognitive functions: orientation, registration, attention and calculation, recall, and language. It takes only 5 to 10 minutes to administer. The maximum score is 30; a score lower than 23 indicates cognitive impairment. This instrument relies on verbal response and reading and writing; hence we excluded participants with hearing and uncorrected visual impairments, with low English literacy, or those with other communication disorders, who may perform poorly even when cognitively intact.

There are various measures of motor abilities, such as eye-hand coordination, motor speed, fine motor control, etc. The two basic ones for measuring motor speed are called simple and disjunctive reaction time tests. In Simple Reaction Time (SRT) tests, the signal and response are both known in advance, and the reaction time is therefore essentially the time needed to recognise that the signal has occurred and to initiate a previously prepared response. The disjunctive test may involve choice of reaction, where several signals are each associated with a corresponding response. Another type of disjunctive reaction involves several signals all calling for the same response; or a response that has to be made to only one or some of the signals presented.

Perceptual ability tests range from tests conducted by opticians to perceptual speed tests to visual search tests. Perceptual speed is the speed in comparing figures or symbols, scanning to find figures or symbols, or carrying out other very simple tasks involving visual perception (Ekstrom, French, Harman and Dermen, 1976). The two most common tests are Number Comparison (NC) and Identical Picture (IP). The number comparison test requires the user to look for pairs of multi-digit numbers and indicate whether the two numbers in each pair were the same or different. The identical picture test requires the user to identify which one of five numbered geometrical figures or pictures in a row was identical to the figure given at the left end of the row. These tests have been used in bibliographic retrieval systems research. The result shows that users with a high score can scan quickly for content, and can make quick judgements about what they see (Allen, 1992).

## 4. THE STUDY

Even though psychometric tests have been proven to reliably measure general abilities, which in various HCI research were shown to affect task performance, psychometric tests have not been widely used in input device evaluation. Exceptions include studies by Smith et al. (1999), where several user abilities were tested in the evaluation of computer mouse tasks. The tests included were measures of abstraction, spatial ability, processing speed, visuo-motor ability, perceptual speed and motor coordination.

This paper presents a case study of 12 older people evaluating three common input devices in two common computer tasks. Three devices and two tasks were chosen to ensure that the results are not device- or task-biased. Non-task performance related sets of data were collected using three methods: a questionnaire, debriefing interview, and psychometric tests. Below are the justifications of the selection of tasks, devices, and data gathering approaches.

### *4.1. Tasks*

Two tasks that were suggested to be the main reasons older people use computers were selected: browsing and playing games. *Browsing* (essentially pointing-and-clicking on links, no typing was required) is an essential and regular task performed when searching for information on the Internet (Byrne, John, Wehrle and Crow, 1999)). For this study, a series of web pages with 64 total links (depth = 3 levels, breadth = 4 links) were developed and hosted locally. Study on expandable hierarchy index of websites has found that users tended to prefer the user of 2- or 3- level deep menu (Zaphiris, Shneiderman and Norman, 2002). The topics were derived from the ones categorised under "Aging" and "Seniors" from http://www.dmoz.org. This website is an open directory database where volunteer editors maintain lists of the most useful and content-rich sites and categorize them under meaningful headings (dmoz, 2002). Task performance was defined as the time required for getting to the correct page.

*Playing games* was selected because it is also a regular activity in computer interaction. A survey in 1998 shows that 33.4 percent of computer users spend 1 to 5 hours a week using computers for fun and play, and 22.9 percent using their computers for play for 5 to 10 hours (GVU's 10th WWW User Survey, 1998). The "solitaire" card game (essentially a dragging-and-dropping task) was chosen as most older computer users would have been familiar with this game. Task performance was defined as the game score after 5 minutes. A computer notebook (AJP model 2200T, Intel Pentium III, 15" screen with the resolution of 1024x768 pixels) was used to run the software.

### *4.2. Input Devices*

Three most commonly used input devices were selected. The particular model used in the study is printed in the bracket:

#### *4.2.1. Mouse (Logitech ifeel optical mouse)*

A mouse is the most common input device for graphical user interfaces (GUIs) (Dix, Finlay, Abowd and Beale, 2003). Modern mouse has several advantages for older computer users, such as the fact that it can be adjusted in granularity and users will be able to keep their eye on the display. There is also a direct relationship between hand and cursor movement on the dimensions of direction, distance, and speed. A mouse allows diagonal and continuous movement and space control that will ease navigation, which might help both the browsing tasks and the card game. However, mouse has some disadvantages when used for dragging-and-dropping tasks (i.e., the card game in this study) because users have to keep the left button pressed, which might be strenuous for older people. In this study, the tactile feedback of the ifeel mouse was not utilized as it was not relevant to the tasks to the participants.

#### *4.2.2. Touch screen (CTX PV500 Beige 15" LCD Monitor)*

The second device chosen in this study is a touch screen because it is faster and easier to learn than other input devices and it is well-accepted by public (Greenstein, 1997). It is easy to use by older people because of the direct hand-eye coordination and it supports continuous motion in all directions. No command memorisation is needed (hence it helps older users with reduced working memory). However, touch screen has several problems; it may be the fastest input device for many tasks but it is the least accurate, which might influence user performance in the card game. Depending on the mounting angle, touch screens may result in arm fatigue in long-term use. A user drags her finger across the screen to move the cursor or to drag an object on the screen; the touch screen cannot do both because there is no separation between the two actions (Buxton, 1990). It can be difficult to select small targets (e.g., small links in browsing tasks) and makes for slow data entry (which fortunately is not a part of the tested tasks). Also the arm and fingers may obscure the touch screen when the user is performing a task (Sears and Shneiderman, 1991). Overlays on touch screens may lead to parallax (the apparent shifting of an object when viewed at different angles), which might be disadvantageous for older users with reduced visuospatial abilities.

#### *4.2.3. Tablet-with-stylus (Genius 4”x3” tablet with cordless natural pen)*

The third device chosen is a tablet, sometimes called touch tablet, graphics tablet or digitising tablet, because its operation has some similarities with pen-and-paper; hence it is expected that even if the participants were not familiar with the device, it would be easy to transfer their mental model of pen-and-paper operation to tablet operation (Hinckley, 2002). Tablets can be used with bare finger, a stylus or a puck (in this study, a tablet with a stylus was used – to support the mental model of pen-and-paper and to maximise the operational difference with using a touch screen). Tablets can operate in absolute and relative modes (Hinckley, 2002). In relative mode, the tablet responds only to motion of the stylus. If a user touches the stylus on the tablet, the cursor resumes motion from its previous position. In absolute mode, the cursor would jump to the new position. Absolute mode is preferred for tasks such as drawing, handwriting, tracing, or digitising, while relative mode is preferable for pointing-and-selecting or navigating through menus (i.e., the tested tasks). Therefore, the relative mode was used in this study.

### *4.3. Non-Task Performance Data Gathering Methods*

Three approaches were used to gather non-task performance data. These three approaches were chosen because they are commonly used in HCI and have been proven to allow reliable information gathering of user behaviour and perception.

#### *4.3.1. Questionnaire*

General user information, such as initial, age, ethnicity, educational level, experience using computer and the Internet, current job and status of self-assessed health, was elicited through pre-session questionnaire. Experience using the tested input devices was also investigated. Self-assessed health was asked to ensure that users are generally fit (Douglas and Mithal, 1997; Kurniawan, 2001) to perform the evaluation and are not affected by any medication. After the task-related session, users were asked to rate the devices and tasks. Users were encouraged to provide justification for each rating.

#### *4.3.2. Psychometric Tests*

In this study, cognitive abilities were measured using the MMSE for the reasons described in Section 4. Perceptual speed was measured using the Identical Picture (IP) test, consisting of two sessions, of 1.5 minutes, with 48 picture-matching tasks in each session. Motor speed was measured using Simple Reaction Time (SRT) tests using each of the tested devices. A single-stimulus simple reaction time program was used with the permission of the author, and was downloaded from the Internet (Allen, 2002). Each participant was given two to five trials (depending on their familiarity with the device) to familiarise himself with the test and the particular model of the input devices.

The tests used in this study were selected based on their simplicity of administering, ease of conducting and popularity. In some cases, the study was performed at the participants’ location, so the equipment must be easy to set up. Paper-based tests were chosen for the cognitive and perceptual abilities to minimize the time participants need to look at the screen, which might be fatiguing for some.

#### *4.3.3. Debriefing Interview*

Debriefing interview was conducted upon completion of all tasks. Users were interviewed with a few open-ended questions in a semi-structured fashion. The purpose of the interview was to understand user experience when using various input devices for different types of tasks. The semi-structured interview also attempted to find out problems when interacting with the input devices. These interview questions were adapted from Douglas and Mithal ( 1997) post-questionnaire for evaluating a new mouse. These questions serve as a guide during interviews; wordings were changed to ensure user understanding and that the objectives of the interview are met. The experimenter offered further explanation when necessary. In general, the questions can be divided into two types. The first 10 questions elicit user opinion about input devices in general (nine of which were asked in questionnaire format before the task-related session). The final four elicit users' subjective judgements and salient features/problems about the input devices on the two tasks. Due to the scope of this paper, these final four questions will not be discussed.

# 5. RESULT AND ANALYSIS

## *5.1. Descriptive Statistics*

The demographic characteristics of the participants as gathered through the pre-session questionnaire. In general, they are highly educated, quite experienced with computer, and reported good health. The age range is between 53 to 75 years old (Mean=63.0, SD=6.32). All users reported good or very good health (9-Very good, 3-Good). All of them hold diploma or higher certificate, except 2 were high school graduates. All users have good computer experience (Average=2-3 years). Generally, they use computer very often (3-Rare, 3-Often, 6-Very Often). Their internet experience varies: between half a year to 1 year. Their frequency of using internet varies from rare to very often (5-rare, 3-often, 4-very often). All users had some experience using a mouse (Mean=8.68 years, SD=9.986) but none had used tablet-with-stylus before. Their experience using touch screen was somewhat limited (Mean=0.35, SD=0.882).

The user ability scores were summarised in Table 1. Folstein et al. (1975) stated that a median of 29 indicates that the participants have good and stable cognitive status. Their IP score of 48.98% is on the low side; however this is expected in older adults. In SRT, the performance was best when users performed the test using a mouse, followed by tablet and touch screen.

**Table 1: Users' abilities as measured through psychometric test**

| | |
|---|---|
| Cognitive status: MMSE | Median=29 (max=30) |
| Perceptual speed: IP | Mean = 51.0 (max= 96), SD=10.58 |
| Motor: SRT with mouse (seconds) | Mean = 0.37, SD=0.145 (min=0.25, max=0.78) |
| Motor: SRT with tablet (seconds) | Mean = 0.44, SD=0.181 (min=0.30, max=0.98) |
| Motor: SRT with touch screen (seconds) | Mean = 0.45, SD=0.204 (min=0.28, max=0.88) |

Figures 1and 2 depict users' perception of the tested input devices, through ranking and rating. When asked to rank the three devices, most users considered the mouse as the easiest device to use, across all tasks, in post-sessions (Figures 1). Most users ranked the touch screen as the most difficult device to use. When asked to rate each individual device (Figures 2), the number of users who rated the mouse or the touch screen as 'easy' or 'very easy' were consistently higher than the number of users who rated the tablet as such, although the difference was smaller at post-task.

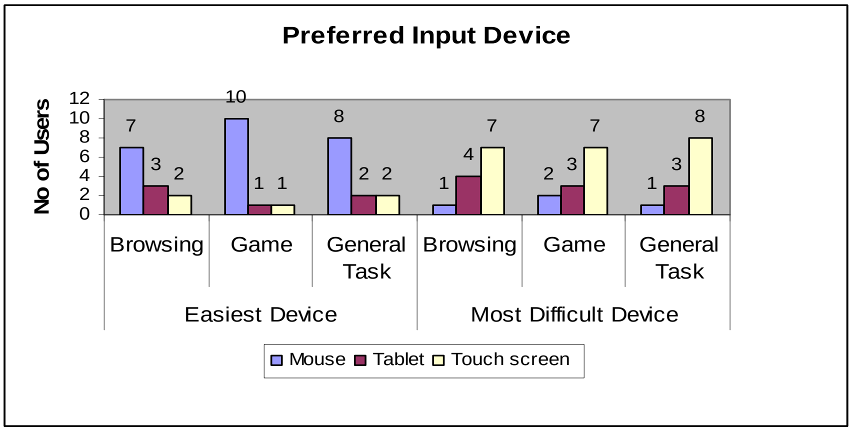


**Figure 1: The easiest and most difficult devices pre-task**

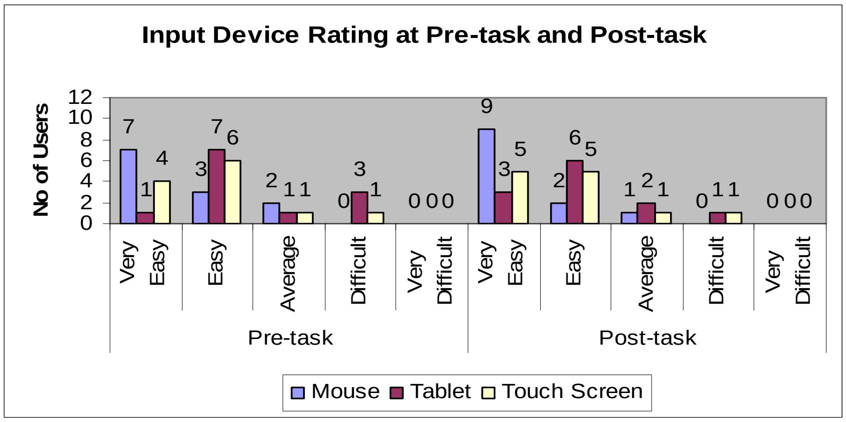


**Figure 2: Pre-task (speculative) and Post-task user ratings on input devices**

Table 2 summarises users' task performance. In both tasks, users performed significantly better using the mouse (as analysed using ANOVA, $p<0.05$). However, the device that produced the worst performance differs by task. Users took the longest in completing the browsing task using the tablet, but performed the worst in the card game using the touch screen.

**Table 2: Means (SD) of users' task performance using the tested input devices**

| *Input Device* | *Browsing completion time (seconds)* | *Game score (points)* |
|---|---|---|
| Mouse | 59.0 (48.19) | 77.1 (45.31) |
| Tablet | 79.2 (61.48) | 72.9 (35.74) |
| Touch screen | 71.1 (27.97) | 69.7 (27.36) |

### *5.2. User Ability and Performance Analysis (Correlation and Regression)*

The first series of correlation analysis were performed to investigate whether there is a relationship between objective and subjective data of input device use. Because there are only 12 data points, a non-parametric correlation analysis was performed. Kendall's tau was selected because of the small data points with a large number of tied ranks (Field, 2000). The Kendall's tau-b correlations between SRT and users' experience using the relevant device, pre-task rating and post-task rating were observed. Significant correlations were found between $SRT_{mouse}$ and users' experience ($p\leq0.001$) as well as post-task rating

($p \leq 0.005$). Significant correlation was also found between $SRT_{tablet}$ and post-task rating ($p \leq 0.001$). Observing more closely the psychometric data, the MMSE and IP scores (i.e., the indicators of users' cognitive and perceptual abilities) are significantly correlated ($p \leq 0.005$) with all SRTs.

The next series of analysis, which are regression analyses, set to investigate which set of data (experience, pre- and post-task ratings or user abilities) predict task performance better. A forced entry regression method (or Enter as it is known in SPSS) was used in order to force all predictors into the model simultaneously (Field, 2000).

In browsing tasks, when the mouse was used, the IP score was the best predictor of task performance, followed by user experience and then by SRT. In the card game, the IP score again was the best predictor when the mouse was used, followed by user experience. The IP score was also the best predictor of card game task performance using the tablet, followed by SRT and then user experience. In the game task using the touch screen, only user experience was a significant predictor of the task performance. No other regression model was significant.

## 6. DISCUSSION AND CONCLUSIONS

This paper aims to introduce psychometric tests into input device user evaluation study. The strengths of psychometric tests were laid out in the paper. The paper then discusses a case study of 12 older users testing three common input devices in two common computer tasks with a questionnaire, an interview and a psychometric test as means of collecting non-task performance-related data.

The demographic and user ability summaries highlight that the inclusion criteria of the recruitment, which require participants to be computer-literate, had produced a slight self-selection problem. The participants are perhaps rather untypical of 'common older people' (i.e., they are highly educated, quite experienced with computer and with good cognitive status). However, this has allowed an observation of the high-end group of older computer users. In addition, these participants posses rather typical motor and perceptual states of people in their age group, i.e., they use bifocal lenses and have minor or no joint problems.

User perception of input devices produced some unsurprising and surprising results. It is not surprising that the mouse was ranked as the easiest device to use. In individual rating, the mouse was still rated by most users as 'very easy' to use. However, the touch screen did not lag behind much. Probing interview revealed that even though the participants never used computer touch screen before, they were familiar with other touch screen devices, such as museum maps and information kiosks, and were confident they could use the device without much trouble. The same could not be said with the tablet.

The mouse was again the clear winner in task performance (post-session interview pointed to familiarity as the winning factor), but the worst device for different task differs. This could not have been highlighted if only one task was used in the study.

The correlation results are more difficult to interpret. The fact that users' motor speed using all devices were correlated with other ability scores could indicate that SRT test could potentially replace the other two ability tests. Similarly, users' motor speed (albeit only for the mouse and the tablet) seems to be able to predict post-task ratings. The regression results indicate that users' perceptual speed was the best predictor of task performance in several cases. Users' experience with the relevant devices was also a strong predictor of task performance in several cases, in line with findings from many ageing related literatures on computer use (e.g.Czaja, Sharit, Ownby, Roth and Nair, 2001). Users' motor speed was a significant predictor in fewer cases.

There are several conclusions of this study. First and most importantly, user ability as tested through psychometric test seems to be the best predictor of task performance in several cases. Secondly, task performance varies by task and by device, unless other factor overrides it (i.e., familiarity in the case of mouse use).

The significant contribution of this study is the introduction of psychometrics test in input device evaluation. Though the idea is not entirely new (e.g, (Allen, 1994; Smith, Sharit et al., 1999)), the use of psychometric tests in input device evaluation has never been explored. This study has shown that psychometric tests could be a good predictor of performance when using input devices, specifically the perceptual speed.

There are several limitations of this study. Even though preliminary result shows the usefulness of psychometric test, a larger and more heterogeneous sample of participants is required to produce a more valid conclusion. Secondly, the two tasks used in the study are essentially pointing and dragging tasks, a study with more diverse tasks would be fruitful. And finally, using the mouse as one of the tested devices introduced a confounding effect of familiarity into the equation. Perhaps it would be wiser to view the results only for the two unfamiliar devices. However, the information related to the mouse use is included in this paper as it might be used as a base-line reference.

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