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Effects of computer skill on mouse move and click performance

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Abstract

This study focuses on the use of computers in the field of education. It reports a series of experimental mouse move and click tasks on constant and moving stimuli. These experiments attempt to explore the efficiency with which individuals of different skill level and age group perform using a mouse. Differences in performance between high-skill and low-skill computer users on low-level mouse operations tasks are examined. Four experiments are employed, using special software, in an effort to tackle the practical issue of mouse use and its constraints for both adults and younger users. Results showed within-subjects variation in performance on mouse operation tasks. Performance differences among groups were also observed.

Keywords

Educational technology, mouse use, computer skills

Introduction

During the last decade the use of computers and other automated technologies has rapidly increased in both work (Richter et al., 2000) and classroom (Kerawalla & Crook, 2002) settings. It is becoming evident that due to technological developments a growing number of people is confronted with the use of computers (Birch et al., 2000; Richter et al., 2000), or involved in using some form of computer technology (Chaparro et al., 1999a; North & Noyes, 2002). The pervasive use of computers im-

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plies that both young children and older adults with different levels of skills and abilities are "obliged" to use computers in a variety of tasks (Czaja et al., 1998). What's more, as Marquié et al. (2002) mention, the ability for some age groups to master new technologies is necessary for their integration into the new era of information society. Thus, users are no longer restricted to computer specialists (Czaja et al., 1998), but to a vast range of professionals. This is an important factor that people engaged in developing software, should bear in mind.

Some authors argue that the computer is an increasingly used learning tool within all levels of formal education (Dickhäuser and Stiensmeier-Pelster 2002). The use of computers and the development of educational software have established a new and rather challenging reality for both teachers and students. Teachers have begun to incorporate computers into their teaching practice. Although some of them may feel incompetent when using a computer, the vast majority actually think of them as an extremely useful tool, holding a positive attitude towards computers (Panagiotakopoulos et al., 2005). Computer-assisted instruction has a number of benefits to offer. Steele et al. (2002) mention a number of reasons for employing educational software in teaching practice. Efficiency, portability, consistency and effectiveness are some of them. As Kerawalla and Crook (2002) argue, computers can extend students' learning opportunities, not to mention the increased preference that students show toward computer-based instruction (Steele et al. 2002, Saunders and Klemming 2003). Despite that fact interfaces for educational software are not studied in detail (Strommen et al. 1996).

Lately, education of all levels seems to face another challenge. "*Increases in class size, the diversity of student population and changes in the expectations of students*" (Saunders and Klemming 2003, p. 74) establish a new reality. Teaching practice and learning processes should be re-examined (Saunders, 2000).

Despite the continuously expanding use of computers, we as yet know little of how children and adults respond to this novel situation. For example, how children interact with educational software or how well children could handle input devices, or how human factors are associated with mouse use (Strommen et al., 1996; Phillips & Triggs, 2001).

All the above-mentioned issues have led researchers in this field to pose some important questions. An attempt to group them would result in two major categories. The first refers to research on human-computer interaction (Richter et al.; 2000; Light et al., 2000; Marquié et al., 2002), whilst the second concerns computer control (Crook, 1992; Joiner et al., 1998; Trewin & Pain, 1999).

The rapid growth of computing has made effective human-computer interaction essential (Butler et al. 1994) and there is a growing body of research in this field (see Joiner et al. 1998 for a review). Light et al. (2000) examined computer-based learning, Richter et al. (2000) focused on students' attitudes towards computers, Marquié et al. (2002) checked between elderly and younger people for the level of their computer self-efficacy beliefs.

However, a vast number of questions concerning computer use remain unanswered. Mouse control for example, is a topic that needs to be further explored (Phillips and Triggs 2001), since *"a mouse is the input device children principally use to control a computer in school"* (Joiner et al., 1998, p.513).

The educational software used in modern teaching practice is constructed to be handled through a graphical interface. And, as Baber (1997) argues, graphical computer interfaces are the standard mode of human – computer interaction. Novice computer users (especially adults) find it difficult to handle a graphical computer interface using a mouse (Walker et al., 1997). Walker and his collaborators (Walker et al., 1996) report that older experienced computer mouse users face similar problems in mouse control tasks. Despite that fact, there is a consistent finding that both children and adults are quicker when using a mouse over other input devices (trackball, joysticks etc.) for controlling a graphical interface (Chaparro et al., 1999b; King & Alloway, 1993).

Although most people feel quite confident that they could easily use a mouse, when confronted with a specific task, something seems to go wrong (Crook 1992). Recently, there has been a shift in the field of HCI research towards the notion of Affective Computing (Paiva et al., 2003; Axelrod & Hone, 2005). Picard (1997) introduced the term Affective Computing to refer to all computing that relates to emotions. Even though Affective Computing is not the focus of the present study, it should be noted that it is considered essential for a computer system to be adaptive to the user's emotional state. Suggestively, it has been well documented that significant improvements in both task performance and users' subjective feelings can be achieved as a result of adapting an application on the basis of affect recognition (Axelrod and Hone 2005). Moreover, usability benefits in both performance and satisfaction can arise from recognizing and responding to user affect at the interface. Research on this field has led to the conclusion that users' attitudes towards educational software are influenced by usability problems (Bourges-Waldegg et al., 2000).

Difficulties in controlling hand movements occur when people are asked to use a mouse in order to perform simple tasks, such as grasping the mouse or accurately pointing to a target. It has been reported that mouse control comprises four burdens on computer users. These are the need to be highly precise; move quickly; coordinate shoulder muscles; and possess a high degree of eye-hand coordination (Laursen et al. 2001). Things get worse when tasks become more complex. Clicking, dragging or dropping a target, despite being frequent tasks while using a computer, are considered to be very difficult (Trewin & Pain, 1999; Smith et al., 1999). The mouse is an indirect pointing device (Greenstein 1997) in the sense that the user must map the movement of the device in one plane (on the mouse pad or desk surface) with movement of a cursor on a different plane (the computer screen). The efficiency of a pointing device, a mouse in our case, suffers if movement control is difficult to the extent that the pointer must re-entered a target several times before selection (MacKenzie et al. 2001). Smith et al. (1999) showed that novice older adults experienced great difficulties in pointing tasks, particularly for double-clicking operations. Similar problems in controlling fine motor movements are also reported by Jagacinski et al. (1995) and Liao et al. (1997).

The point-and-click task is a rapid, goal-directed movement and may be segmented into three stages: first, acceleration towards the target, second, a slowing of the mouse as the cursor approaches the target, and third, a fine manipulation aligning the cursor with the specific target (Dennerlein & Yang, 1999).

Methodology

This study aims to explore the individual variations that affect mouse use. The performance of different groups and computer-skill levels is assessed using reaction and duration times on simple and complex tasks. Speed and accuracy are the most common measures of performance evaluation on computer control (Jacob, 1996; MacKenzie et al., 2001). Speed performance on low-level control tasks is also considered an effective measure for examining relationships between motor activities and stress (Macaulay, 2004). Computer system usability problems may be one reason older adults tend to lag behind their younger counterparts in computer ownership and Internet access (Charness, 2005).

This research has been conducted from March to May, 2005. One experimenter was used to collect the data in order to control variations in testing. Our goal was to explore presumable performance variation, in terms of speed, on a number of low-level mouse control tasks. The experiments constructed for this research (described further down) are in step with the general principle that if the user can perform six element tasks (e.g. selecting, positioning, orienting or rotating, path following, quantifying and text manipulation) then he can perform any computer-based task (Foley et al., 1984). Thus, four out of six tasks (selecting, positioning, orienting or rotating, path following), all essential when controlling educational software, are involved in our study.

Software and Hardware

For the needs of this research, specific software was constructed, using object based, high level programming language Microsoft Visual Basic 6.0, using an IBM compatible computer. The software was under Microsoft Windows XP Professional Edition.

The desktop PC that was used during the testing process had a microprocessor P4/2.8 GHz/512 RAM, a CRT display adapter 17''. The screen resolution was 800x600 pixels with a refresh rate of 85 Hz.

A typical wired optical two-button + wheel with USB connection, Microsoft Intelli-mouse type mouse was used for controlling the software with Microsoft Windows default settings. A typical dark blue mouse pad was also used.

In two of the experimental tasks moving visual stimuli appeared on the screen. Special calibration tools determined speed parameters of the moving stimuli. This was considered necessary for using the software in PCs with different microprocessors.

The software involved a simple user interface. Icons or features that may mislead subjects or attract their attention were not used. Thus, subjects could focus on the tasks undistracted.

Experimental Procedure

An ordinary small office with abundant light and no external noises was selected for conducting the experiments. During the procedure only the experimenter and the subject were in the office. Participants were sitting on an ergonomic, height adjustable office chair, approximately 80 cm away from the screen, so that the visible screen surface was within their optical field. It should be noted that the light had no effect, such as reflections, on the computer screen.

Before the experimental procedure, personal information, such as age, possession of a PC, frequency of using the PC and applications used (Internet, word processing, games etc.) were recorded in a spreadsheet by the experimenter.

Then, the experimenter asked the subject, using the specific software, to work with three subprograms for 3 min. These subprograms were used in order for the subject to become familiarised with the software and especially with the mouse move and click tasks.

Another task was used for assessing "computer skill". A white frame and a progressive bar appeared on the screen. After 10 sec the progressive bar disappeared and subjects were asked to click on two constant stimuli presented on the upper side of the screen. Two round red-colour stimuli with a diameter of 32 pixels appeared in specific positions within the white frame. Subjects had to click on both stimuli. After the completion of the task the elapsed time was recorded. A median split was employed for allocating subjects into one of the two computer skill categories.

Right after the "familiarisation process" the experimental procedure started. For all subjects this session did not exceed 12 min for the four main tasks. The experimenter used exactly the same verbal instructions for guiding subjects through the experiments. Additional coloured cards were used for explaining what exactly the subject was about to see on the screen and what actions he/she was supposed to take for successfully completing the tasks. The sequence of the four main tasks was rotated across the testing session.

The sample

Overall, 131 subjects participated in this research. Individuals with special needs, learning or kinetic, were excluded from the sample. Participation was voluntary. All subjects had normal or corrected vision and all of them were right-handed. Individuals, for all four groups, were allocated to one of the two computer-skill categories (Table 1).

The sample categorization followed three major trends of current research. The first concerns the existence of performance variation among different age groups in mouse control tasks, as it is reported in the international bibliography (Chaparro et al., 1999a; Chaparro et al., 1999b). The second aspect refers to performance variation in low-level mouse control tasks among experienced and novice computer users (Sutcliffe, 1995; Walker et al., 1997). It should be noted at this point that performance variation among adults and children, in relation to computer skill, is considered a safe way to tackle issues such as usability difficulties with mouse manipulations and other precise movements required to operate a user interface (Sikorski, 1998).

Participants that had been working with the computer more than twice a week were allocated to the "experienced" group. All other were allocated to the "novice" group. This split was considered to be appropriate for three reasons. The first concerns a median split on the subjects' rt scores, obtained at the "familiarization process", that had indicated a clear break off between two distinct groups. That is participants that were using a computer less that twice a week and all the others. Additionally, we wanted to separate occasional users (those that use computers only within a classroom setting) from those who use computers systematically. The second reason was the fact that similar group sunders were used by relevant researches (Donker & Reitsma, 2004). Finally, the third reason involves educational software design per se, which was initially teacher-oriented (Luk et al., 2006). This fact entails teachers (regardless their experience on computers) to control the software. Recently there is a shift towards student-oriented software (Luk et al., 2006). Our categorization aims to tackle all these issues that differentiate mouse control performance. So, we tried to employ this research to groups that are (or will be) engaged to the educational process (e.g. teachers, students and university students). We do not intent to evaluate cognitive or special kinetic abilities, but rather we wish to track differences among our sample in mouse control.

Table 1. Subjects allocated to group and computer skill categories

GROUP	High computer skill	Low computer skill
Primary school pupils	14	23
Secondary school pupils	16	15
University arts students	16	15
Primary school teachers	17	15
Total	63	68

Pilot test

Two months before the main experimental procedure a pilot test was conducted. Overall 18 subjects participated in the pilot test (4 primary school pupils, 5 high-school students, 5 university students and 4 primary school teachers). None of them participated in the main experimental procedure. Data from the pilot test and the obtained results led to revisions both on the software and on the calibration functions. Thus, the software was adjusted for all age and level of competence groups. The key factor for determining speed options was the idea of giving participants (skilled or not) the opportunity to complete all tasks successfully within a reasonable time.

The experiments

Each subject completed four main tests. Tests were presented in rotation for each subject. Thus, the first subject of the first group started with the first test, the second subject with the second test and so on. The rotation was sustained also within each test - for tests with different speed options or multiple trials.

As mentioned before, apart from the software and the hardware, coloured cards were also used in this research. These cards represented the interface of each experiment. This was estimated to be crucial, since the experimenter could prepare the subjects for the appropriate actions to be taken. In that way subjects knew exactly what they were about to see. The experimenter answered questions or gave instructions when this was considered necessary.

Experiments 1 and 2 – Mouse move and click on multiple and successive stimuli

For the first experiment, a white frame and a progressive bar appeared. After 10 sec the progressive bar disappeared. Then, five round stimuli appeared in random positions within the white frame. The stimuli were red with a diameter of 32 pixels. The experimenter had already prepared the subject, using the coloured cards, for the necessary actions he was supposed to take. The subject had, as quickly as possible, to click on the stimuli one by one (Figure 1). When clicked on, the stimuli disappeared.

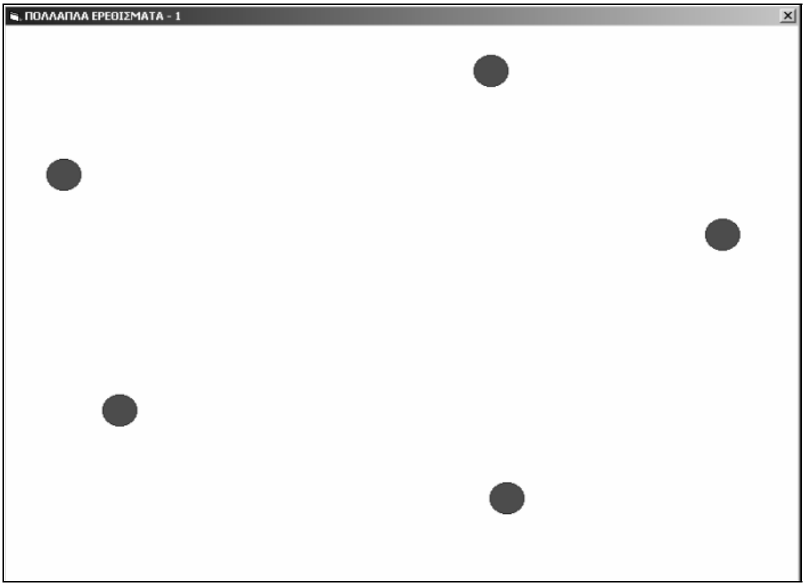

Figure 1. The software interface for the 1st experiment, after the total diminution of the progress bar

Then a second trial started. The subject had to repeat the same actions. It must be noted that the stimuli appeared in completely different positions for the second trial. Stimuli positions for both trials were the same for all subjects. For each trial two measurements were recorded; reaction time and duration. First, the reaction time elapsed between the appearance of the stimuli and the first click and, second, the total time needed/consumed to complete the task (clicking on all five stimuli).

The same procedure was followed for the second experiment. The only difference was that stimuli appeared successively. After clicking on a stimulus the next one appeared on the screen (Figure 2).

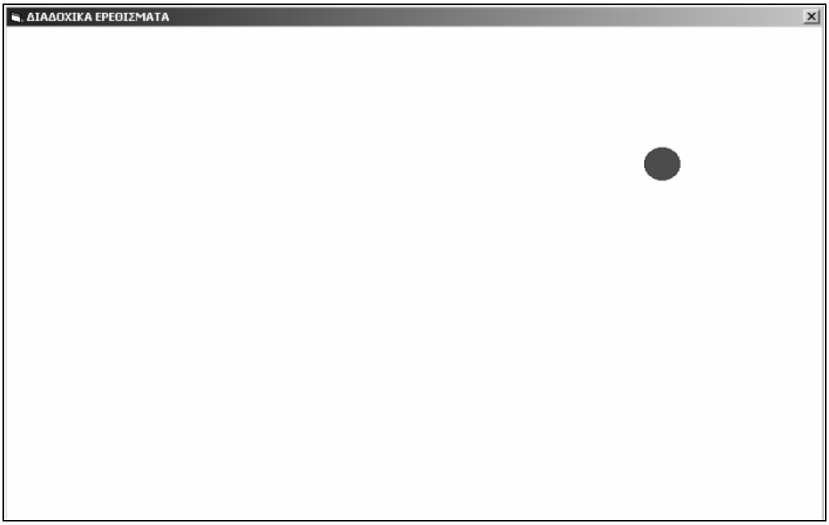

Figure 2. The software interface for the 2nd experiment

Experiments 3 and 4 – Mouse move and click on moving stimuli

For the third test appeared: (a) two parallel dark blue lines on the upper section of the screen and, a red round optical stimulus with a diameter of 32 pixels on the left, (b) three speed-adjustment buttons indicated by numbers ("1", "2", "3") on the bottom left, and (c) two buttons on the bottom right (Figure 3). The left one activated the moving stimulus, while the right led to the main option menu (exit).

The experimenter had already prepared the subject verbally by showing him the appropriate coloured card. After selecting one of the three speed-adjustment buttons,

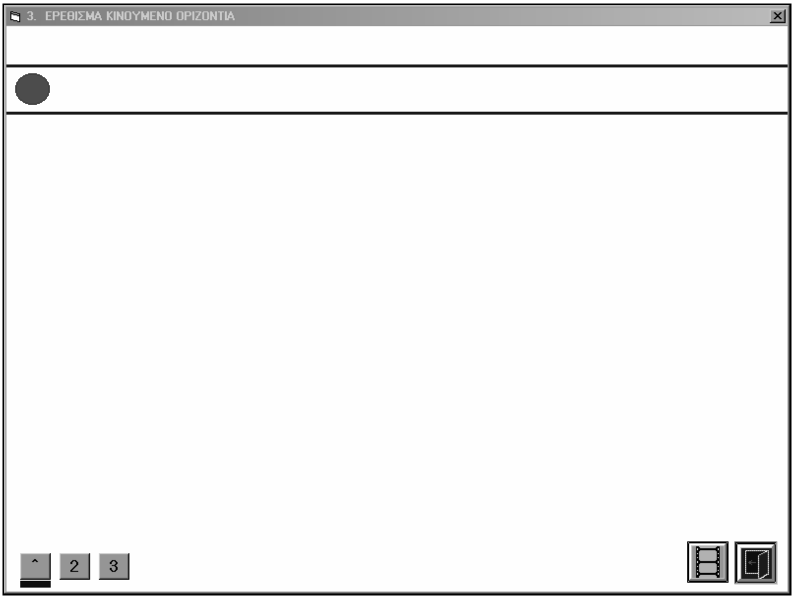

Figure 3. The interface of the 3rd experiment

the red stimuli started to move from left to right. It should be noted that the stimulus performed a straight linear motion with constant velocity. When the stimulus reached the right edge of the screen it disappeared and reappeared again on the left of the screen continuing its movement. The subject had to click on the moving stimulus as quickly as possible. When he/she succeeded, the motion stopped and the time elapsed was recorded.

The test ran in each of the suggested speed options. The speed options were: 1) v_1=7.43 cm/sec (t_1=3.5 sec), 2) v_2=5.78 cm/sec (t_2=4.5 sec) and 3) v_3=4.73 cm/sec (t_3=5.5 sec). The times needed for the stimulus to move from the left to the right side of the screen are shown in the brackets.

The fourth test presented: (a) two wide stripes of white and grey in the middle of the screen, (b) three speed-adjustment buttons indicated by numbers (“1”, “2”, “3”) on the bottom left, and (c) two buttons on the bottom right. The one on the left started the movement of the stimulus, while the one on the right led to the main option menu (exit) (Figure 4). The rest of the procedure was the same as for experiment 3. The only difference was that the stimulus performed a sinusoidal motion from the left to the right of the screen. The test run in each of the three suggested speeds and corresponding times ($U=\lambda*\nu$, $\nu=1/T$): 1) v_1=2.26 cm/sec (t_1=11.5 sec), 2) v_2=1.79 cm/sec

(t_2=14.5 sec) and 3) v_3=1.49 cm/sec (t_3=17.5 sec). The times needed for the stimulus to move from the left to the right side of the screen are shown in the brackets.

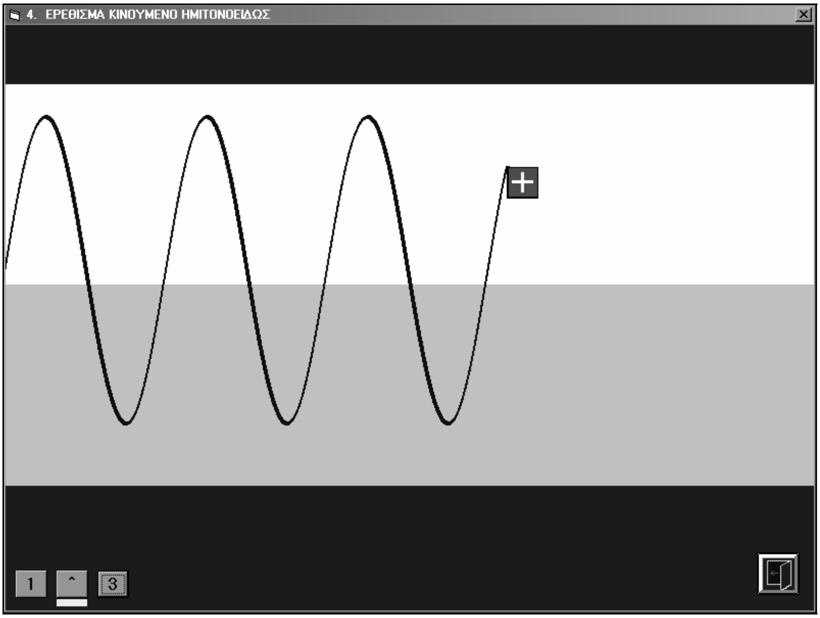

Figure 4. 4th Experiment - The course of the stimulus is shown. During the actual testing procedure the stimulus left no trace on the screen

Results

Experiment 1 – Mouse move and click on multiple stimuli

Reaction time: A 2x4 ANOVA was calculated with computer skill (high and low) and group (primary school pupils, secondary school pupils, university students and teachers) as the two between-groups factors and reaction time scores as the dependent measure. There was a significant main effect of group, $F_{(3,123)}$=7.89; p<0.001. Post hoc multiple comparisons were in all cases conducted with the Tukey's HSD test (p<0.05). Multiple comparisons revealed significant differences between teachers and all the other groups for the "low computer skill" category, but no other significant differences (Table 2). There was also a significant main effect of computer skill, $F_{(1,123)}$=26.99; p<0.001. Analysis also revealed a significant group x computer skill interaction, $F_{(3,123)}$=5.04; p<0.01 (displayed in Figure 5).

Table 2. Mean reaction time and SDs

	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
High computer skill	1.52[a]	0.73	0.84[a]	0.20	1.18[a]	0.44	1.30[a]	0.35
Low computer skill	1.65[a]	0.51	1.52[a]	0.78	1.57[a]	0.51	2.74[b]	1.54

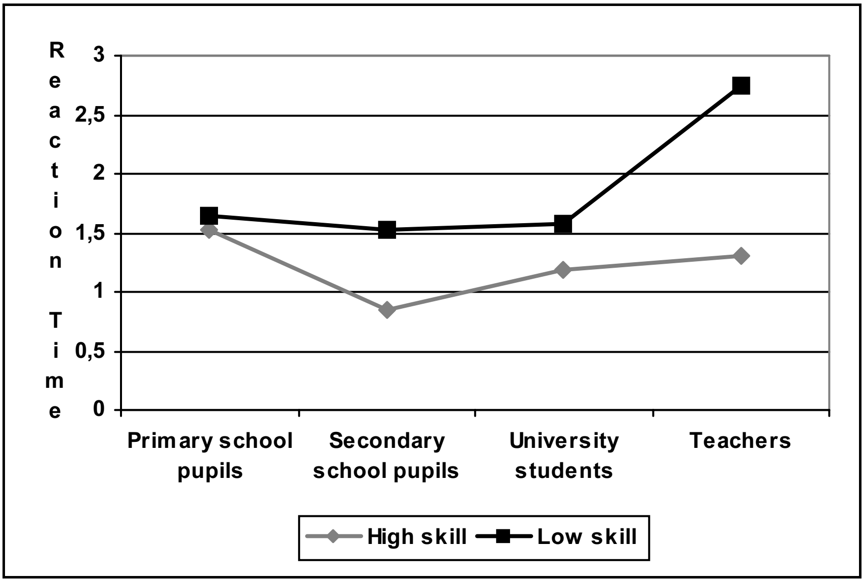

Figure 5. Mean reaction time

Duration: A 2x4 ANOVA was calculated with computer skill (high and low) and group (primary school pupils, secondary school pupils, university students and teachers) as the two between-groups factors and duration time scores as the dependent measure. There was a significant main effect of group, $F_{(3,123)}=16.08$; $p<0.001$. Multiple comparisons revealed significant differences between primary school pupils and all the other groups for the "high computer skill" category. Significant differences were also found between teachers and all the other groups for the "low computer skill" category (Table 3). There was also a significant main effect of computer skill, $F_{(1,123)}=47.46$; $p<0.001$. Analysis also revealed a significant group x computer skill interaction, $F_{(3,123)}=8.2$; $p<0.001$ (displayed in Figure 6).

Table 3. Mean duration time and SDs

	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
High computer skill	5.62[a]	2.42	3.51[b]	0.68	3.69[b]	0.70	4.57[a]	1.27
Low computer skill	6.15[a]	1.47	5.06[a]	1.61	5.27[a]	1.08	8.98[b]	2.97

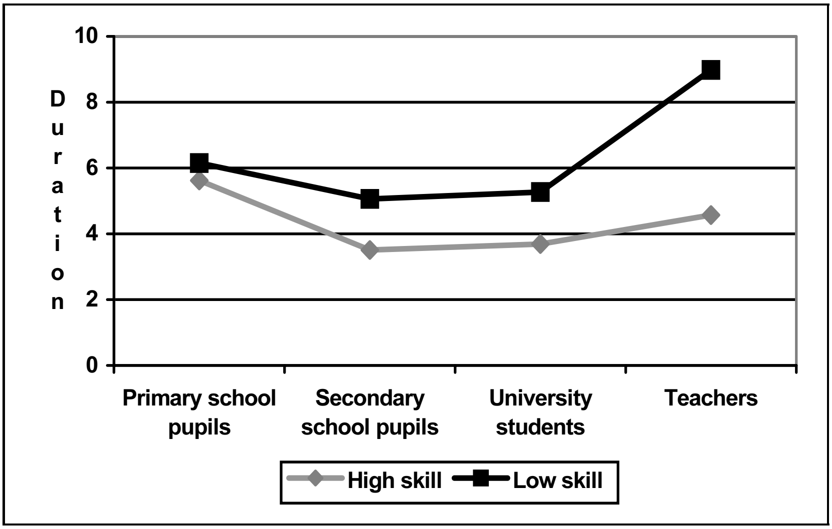

Figure 6. Mean duration time

Means in the same row that do not share the same superscripts differ at $p<0.05$ in the Tukey's HSD multiple comparison.

From the previous analysis it became clear that the effect of computer skill was the determining factor for the subjects' performance. In an effort to investigate the effect of computer skill both on reaction and on duration times for each separate group, a second simpler analysis was carried out. Results were analysed using an independent-samples t-test. Mean reaction and duration times for all four groups are displayed in Figure 7.

Primary school pupils

The analysis failed to reveal a significant difference in reaction time (rt), $t(35)= -0.65$; $p > 0.05$. Means, displayed in Figure 7, show that "high computer skill" subjects demonstrated scores, both for reaction time and for duration time, quite similar to those shown by subjects in the "low computer skill" condition. For high computer skill condition, the results were x =1.52, SD=0.73, while for low computer skill condition, they were x =1.65, SD=0.51. Nor were significant differences found in duration time between the two groups, t(35)= -0.84; p>0.05. For high computer skill condition, they were x =5.62, SD=2.42, and for low computer skill condition, x =6.15, SD= 4.47.

Secondary school pupils

The analysis revealed a significant difference in reaction time (rt), t(29)= -3.26; p < 0.01. Means, displayed in Figure 7, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary compared to those shown by subjects in the "low computer skill" condition. For high computer skill condition, the results were x =0.84, SD=0.20, and for low computer skill condition, x =1.52, SD=0.78. Significant differences were also found in duration time between the two groups, t(29)= -3.45; p<0.01. For high computer skill condition, the results were x =3.51, SD=0.68, while for low computer skill condition, they were x =5.06, SD=1.61.

University students

The analysis revealed a significant difference in reaction time (rt), t(29)= -2.26; p<0.05. Means, displayed in Figure 7, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary compared to those shown by subjects in the "low computer skill" condition. For high computer skill condition, the results were x =1.18, SD=0.44, while for low computer skill condition, they were x =1.57, SD=0.51. Significant differences were also found in duration time between the two groups, t(29)= -4.9; p<0.001: for high computer skill condition, x =3.69, SD=0.70 and for low computer skill condition, x =5.27, SD=1.08.

Table 4. Mean and SD rt's

	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
High computer skill	1.46[a]	0.43	1.07[a]	0.26	1.20[a]	0.28	1.33[a]	0.42
Low computer skill	1.63[a]	0.55	1.49[a]	0.54	1.50[a]	0.27	2.51[b]	1.20

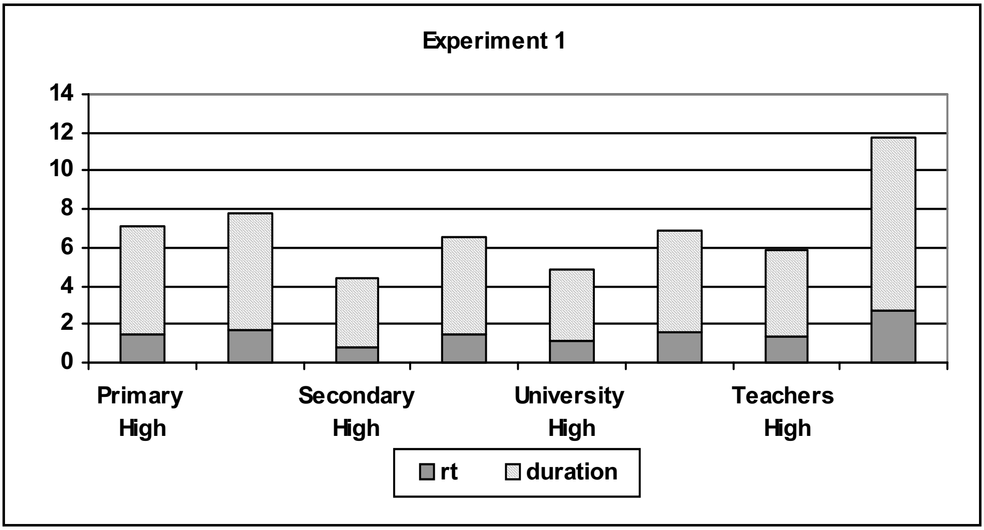

Figure 7. Mean reaction and duration times

Teachers

The analysis revealed a significant difference in reaction time (rt), t(30)= -3.5; p<0.01. Means, displayed in Figure 7, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary compared to those shown by subjects in the "low computer skill" condition. For high computer skill condition, $\bar{x}$ =1.30, SD=0.35, while for low computer skill condition, $\bar{x}$ =2.74, SD=1.54. Significant differences were also found on duration time between the two groups, t(30)= -5.3; p<0.001. For high computer skill condition, $\bar{x}$ =4.57, SD=1.27, and for low computer skill condition, $\bar{x}$ =8.98, SD=2.97.

Experiment 2 - Mouse move and click on successive stimuli

A 2x4 ANOVA was calculated with computer skill (high and low) and group (primary school pupils, secondary school pupils, university students and teachers) as the two between-groups factors and reaction time scores as the dependent measure. There was a significant main effect of group, $F_{(3,123)}$= 8.09; p<0.001. Tukey's HSD test showed significant differences between teachers and all the other groups for the "low computer skill category" (Table 4). There was also a significant main effect of computer skill, $F_{(1,123)}$= 26.98; p<0.001. Analysis also revealed a significant group x computer skill interaction, $F_{(3,123)}$= 5.17; p<0.01.

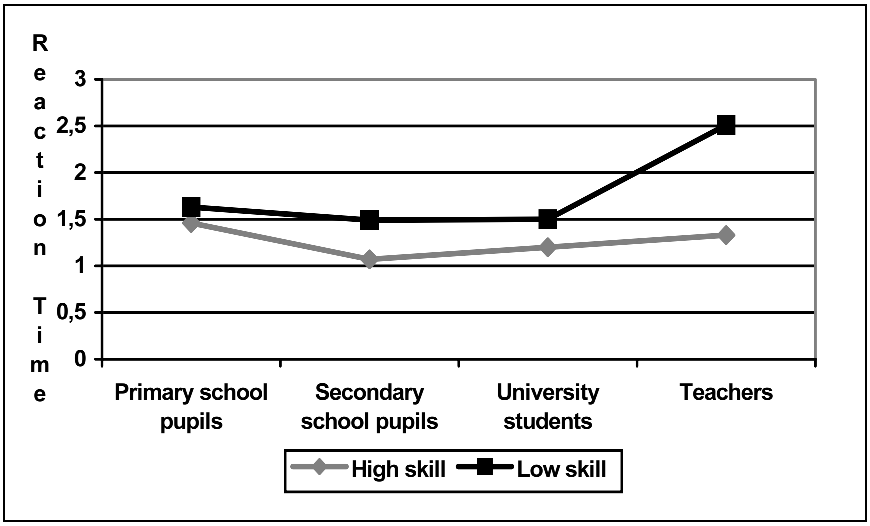

Figure 8. Mean reaction time

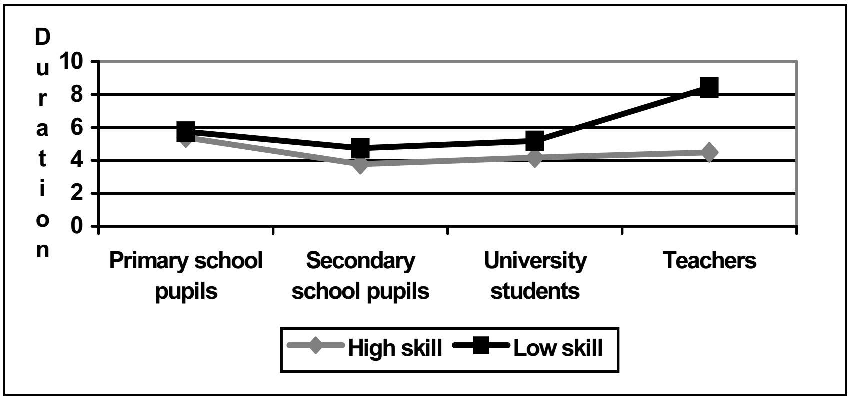

Figure 9. Mean duration time

A 2x4 ANOVA was calculated with computer skill (high and low) and group (primary school pupils, secondary school pupils, university students and teachers) as the two between-groups factors and duration time scores as the dependent measure. There was a significant main effect of group, $F_{(3,123)}=15.8$; $p<0.001$. Tukey's HSD test showed significant differences between teachers and all the other groups for the "low computer skill" category. Significant differences were also revealed between primary school pupils and all the other groups for the "high computer skill category". There was also a significant main effect of computer skill, $F_{(1,123)}= 41.32$; $p<0.001$. Analysis also revealed a significant group x computer skill interaction, $F_{(3,123)}= 0.92$; $p<0.001$.

Means in the same row that do not share the same superscripts differ at $p<0.05$ in the Tukey's HSD multiple comparison.

Table 5. Mean and SD duration

	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
High computer skill	5.39^{a}	1.88	3.77^{b}	0.46	4.17^{b}	0.47	4.48^{b}	0.92
Low computer skill	5.74^{a}	1.12	4.74^{a}	1.10	5.18^{a}	0.84	8.42^{b}	2.86

Means in the same row that do not share the same superscripts differ at $p<0.05$ in the Tukey's HSD multiple comparison.

In an effort to investigate the effect of computer skill both in reaction and in duration times for each separate group, a second simpler analysis was carried out. Results were analysed using an independent-samples t-test. Mean reaction and duration times for all four groups are displayed in Figure 10**.**

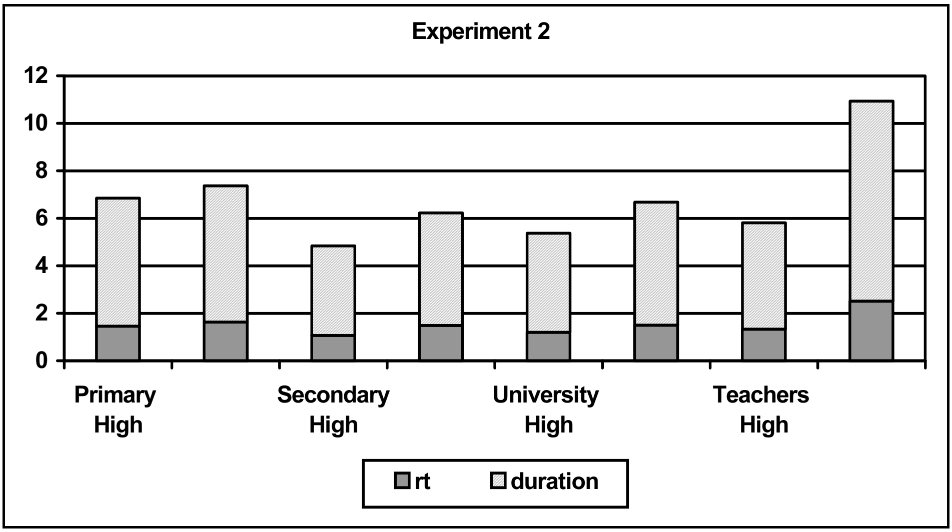

Figure 10. Mean reaction and duration times

Primary school pupils

The analysis failed to reveal a significant difference in reaction time (rt), t(35)= -1.03; $p>0.05$. Means, displayed in Figure 10, show that "high computer skill" subjects demonstrated scores both for reaction and duration time that were quite similar to those achieved by subjects in the "low computer skill" condition. For high computer skill condition, the results were x =1.46, SD=0.43, and for low computer skill condition, x =1.63, SD=0.55). Nor were significant differences found in duration time between the two groups, t(35)= -0.73; $p>0.05$. For high computer skill condition, they were x =5.39, SD=1.88, while for low computer skill condition, they were x =5.74, SD=1.12.

Secondary school pupils

The analysis revealed a significant difference in reaction time (rt), t(29)= -2.7; $p<0.05$. Means, displayed in Figure 10, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary to those achieved by subjects in the "low computer skill" condition. For high computer skill condition, x =1.07, SD=0.26, and for low computer skill condition, x =1.49, SD=0.54. Significant differences were also found on duration time between the two groups, t(29)= -3.1, $p<0.01$. For high computer skill condition, x =3.77, SD=0.46, and for low computer skill condition, x =4.74, SD=1.10.

University students

The analysis revealed a significant difference in reaction time (rt), t(29)= -3.02; $p<0.01$. Means, displayed in Figure 10, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary compared to those achieved by subjects in the "low computer skill" condition. For high computer skill condition, they were x =1.20, SD=0.28, while for low computer skill condition, x =1.50, SD=0.27. Significant differences were also found on duration time between the two groups, t(29)= -4.1; $p<0.001$. For high computer skill condition, these were x =4.17, SD=0.47, and for low computer skill condition, x =5.18, SD=0.84.

Teachers

The analysis revealed a significant difference in reaction time (rt), t(30)= -3.6; $p<0.01$. Results, displayed in Figure 10, show that "high computer skill" subjects demonstrated scores both for reaction time and for duration time that vary compared to those achieved by subjects in the "low computer skill" condition. For high computer skill condition, they were x =1.33, SD=0.42, while for low computer skill condition, they were x =2.51, SD=1.20. Significant differences were also found on duration time between the two groups, t(30)= -5.4; $p<0.001$. For high computer skill condition, $\bar{x}$ =4.48, SD=0.92, and for low computer skill condition, $\bar{x}$ =8.42, SD=2.86.

Experiment 3 – Mouse move and click on moving stimuli

Mean duration times across the three trials are displayed in Table 6. Results were analysed using a 3 (Speed: Fast, Medium, Slow) x 4 (Group: primary school pupils, secondary school pupils, university students, teachers) x 2 (Computer skill: high, low) repeated measures ANOVA design. Speed was the within–subject factor, group and computer skill the between-subject factors. The within-subjects analysis revealed a significant effect for speed, $F_{(2,244)}$=51.1; p<0.001. There were also significant two-way interactions for speed x group $F_{(6,244)}$=5.9; p<0.001 and for speed x computer skill $F_{(2,244)}$=8.52; p<0.001. Finally a significant three-way (speed x group x computer skill) interaction emerged $F_{(6,244)}$=2.35; p<0.05. The between-subjects analysis revealed a significant effect for group $F_{(3,122)}$=12.38; p<0.001 and for computer skill $F_{(1,122)}$=21.28; p<0.001. A two-way (group x computer skill) interaction was also observed $F_{(3,122)}$=8.3; p<0.001. Furthermore, post hoc comparisons (Tukey's HSD) between the three levels of the within-subject factor showed significant differences between teachers and all the other groups for the "low computer skill" category (at the 0.05 level). These differences appeared at all speed levels.

Table 6. Mean duration times and SDs

Straight Linear Motion	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
Fast speed								
High computer skill	6.27^{a}	8.93	1.93^{a}	0.72	3.93^{a}	2.68	4.72^{a}	2.83
Low computer skill	8.37^{a}	8.01	4.29^{a}	3.04	4.68^{a}	2.91	16.88^{b}	11.45
Medium speed								
High computer skill	1.74^{a}	0.75	1.44^{a}	0.83	2.21^{a}	2.40	2.82^{a}	2.74
Low computer skill	3.37^{a}	2.23	2.71^{a}	1.85	3.36^{a}	2.26	11.64^{b}	10.49
Slow speed								
High computer skill	3.13^{a}	3.40	0.88^{a}	0.23	1.43^{a}	0.71	1.61^{a}	0.95
Low computer skill	2.53^{a}	1.34	1.82^{a}	2.09	1.46^{a}	0.46	5.23^{b}	4.30

Means in the same row that do not share the same superscripts differ at p<0.05 in the Tukey's HSD multiple comparison.

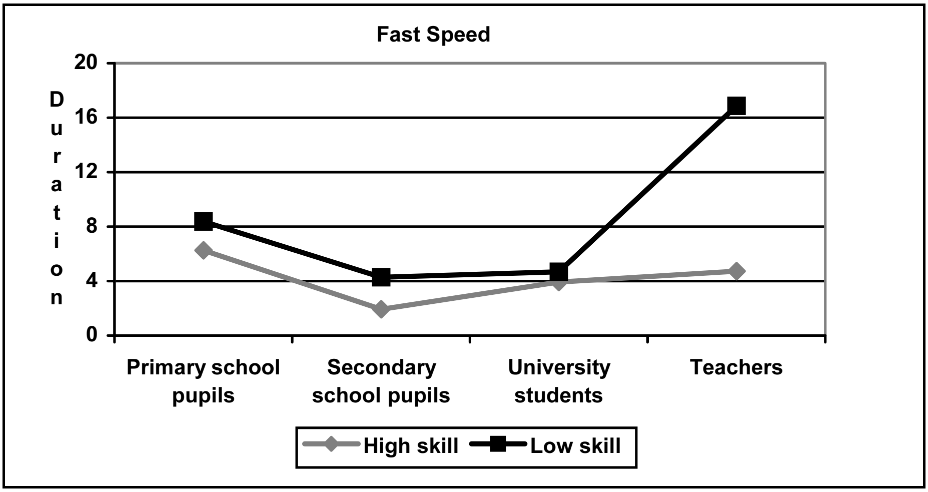

Figure 11. Mean duration times

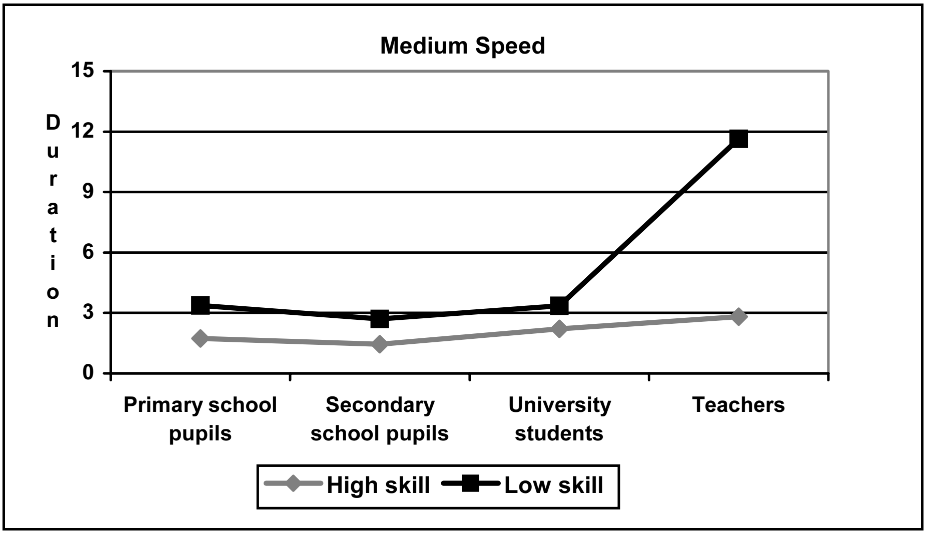

Figure 12. Mean duration times

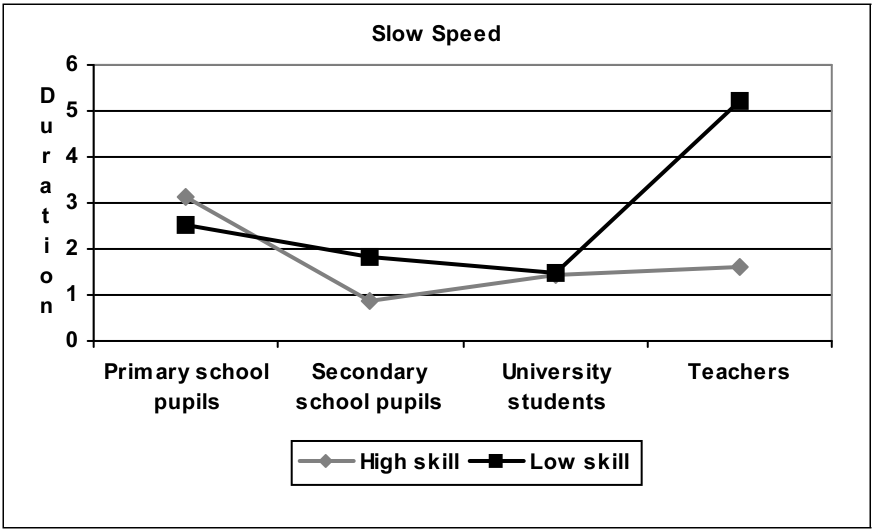

Figure 13. Mean duration times

Experiment 4 – Move and click at a sinusoidal moving stimulus

Mean duration times across the three trials are displayed in Table 7. Results were analysed using a 3 (Speed: Fast, Medium, Slow) x 4 (Group: Primary school pupils, Secondary school pupils, University students, teachers) x 2 (Computer skill: high, Low) repeated measures ANOVA design. Speed was the within-subject factor, group and computer skill the between-subject factors. The within-subjects analysis revealed a significant effect for speed, $F_{(2,232)}=55.83$; $p<0.001$. There were also significant two-way interactions for speed x computer skill $F_{(2,232)}=8.3$; $p<0.01$. The between-subjects analysis revealed a significant effect for group $F_{(3,116)}=2.89$; $p<0.05$ and for computer skill $F_{(1,116)}=21.74$; $p<0.001$. A two-way (group x computer skill) interaction was also observed $F_{(3,116)}=5.4$; $p<0.01$. Furthermore, post hoc comparisons (Tukey's HSD) between the three levels of the within-subject factor showed significant differences between teachers and all the other groups for the "low computer skill" category for medium speed level (at the 0.05 level). Significant differences were also revealed at the low speed level for the "high computer skill" category between teachers and primary school pupils, teachers and university students. Significant differences, for the same speed level and computer skill category, were revealed between secondary school pupils and primary school pupils and between secondary school pupils and university students as well.

Table 7. Mean and SD duration

Sinusoidal Motion	Primary School Pupils		Secondary School Pupils		University Students		Teachers	
	M	SD	M	SD	M	SD	M	SD
Fast speed								
High computer skill	15.71[a]	14.57	6.96[a]	6.28	14.07[a]	13.07	9.12[a]	5.90
Low computer skill	16.13[a]	13.19	17.59[a]	21.02	23.36[a]	16.75	30.22[a]	20.47
Medium speed								
High computer skill	6.87[a]	5.44	3.00[a]	2.14	4.78[a]	3.97	4.91[a]	7.56
Low computer skill	8.48[a]	7.42	7.86[a]	10.82	7.45[a]	9.57	19.11[b]	12.30
Slow speed								
High computer skill	10.61[a]	14.67	1.79[b]	1.15	3.41[a]	3.47	2.68[b]	1.71
Low computer skill	6.61[a]	6.80	4.04[a]	4.01	3.98[a]	2.76	11.28[a]	9.40

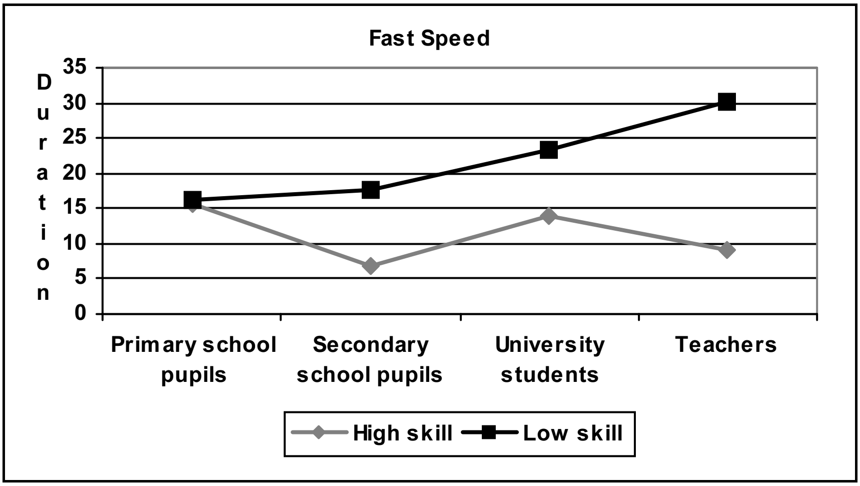

Figure 14. Mean duration times

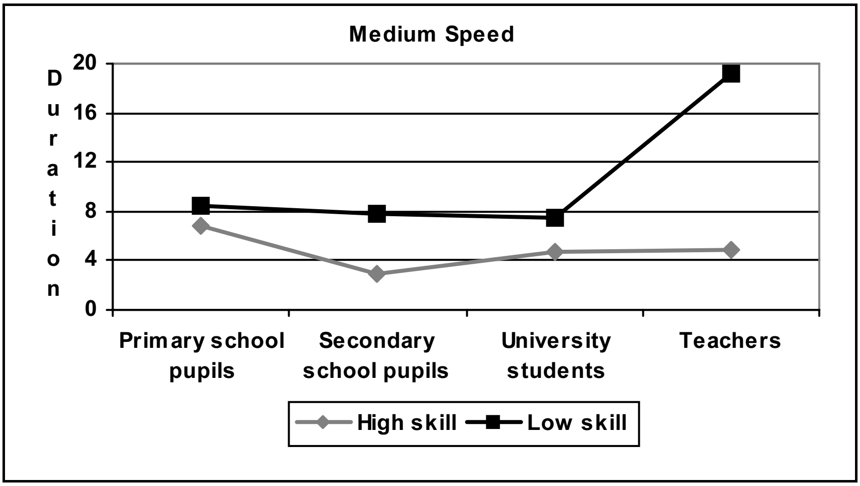

Figure 15. Mean duration times

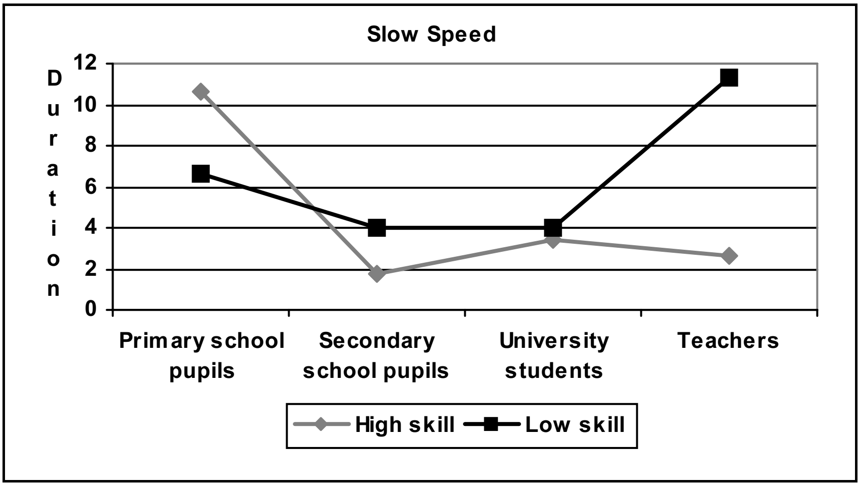

Figure 16. Mean duration times

Discussion

This study examined the performance of different groups on a number of computer tasks in relation to computer skill. Data supports the view that different competence levels can be found in a normal classroom. This diversity poses difficulties when students or teachers have to use a computer. Thus, we focused on four groups, all engaged, one way or another, to education, since computers are part of teaching practice. Our main objective was to search for presumable differences between competent and less competent computer users when controlling a graphical computer interface using a mouse. Thereby, two basic mouse control operations, comprising the four element tasks - mentioned in the methodology section - were selected; mouse move and click on constant and moving optical stimuli. Reaction and duration times were used as the dependent variables. Subjects were allocated into two computer-skill categories (high and low skill).

The key finding was the fact that novice users, primary school pupils and especially teachers - who use computers occasionally for enhancing the conventional teaching methods - had significant difficulties in controlling a simple graphical interface. Their performance on low-level control tasks was significantly lower compared to the other two groups.

Often, educational process calls for using software, where participants are asked to operate using a mouse as the main data entry and computer control device. A number of studies highlight that, when using computers in classroom settings, challenging tasks can be offered more smoothly and faster than with conventional teaching methods (Bork, 1986; Ohlsson, 1986; Armstrong & Loane, 1994).

The graphical user interface of the educational software used is not always static. For effective learning in particular, the educational software should employ a dynamic user interface that involves movement or changes (Panagiotakopoulos & Ioannides, 2002). Such environments require users to perform certain low-level mouse operations (e.g. mouse move and click). These operations may look simple when the software runs within a static environment. But when a simulation is used for example, the environment is dynamic and the user has to act using a mouse. Sometimes, the user may have to complete a task within a certain time limit.

The first two experiments involved mouse move and click on constant stimuli. Both Experiments 1 and 2 showed a significant effect of computer skill and group both on reaction and duration times. Subjects in the “high computer skill” category were faster in moving a mouse and clicking on a target than subjects in the “low computer skill” category. Data identifies skill level as an important characteristic for mouse use performance. Teachers tend to lag behind compared to all other groups. Both reaction and duration times were higher than those achieved by pupils, secondary school students and university students. Usability problems in mouse control were observed, even for the simplest operation, such as mouse move-and-click. There was a clear tendency for time scores to increase as tasks became more complex. Experiments 3 and 4 posed the greatest difficulties for teachers. These findings support the view that when designing educational software interventions should be made aiming at enhancing the ability of diverse groups to successfully perform simple mouse operation tasks. Bearing in mind that a large amount of educational software is teacher-oriented (Luk et al., 2006), one can realize the effect of usability difficulties on teachers' behalf. It often the case that teachers had to work with sections, rather than the whole application in order achieve particular learning objectives. Additionally, pupils turn to their teacher when they experience difficulties with software, giving teachers a more complete view on the usability of software. Therefore, teachers must have an understanding of controls and menus of the software, and this requirement thus increases their workload (Kirriemuir 2003). Teacher's perspective, in terms of software usability, is important because teachers decide what software is obtained for their class and how often it is used.

An interesting finding, that needs to be further explored, is that age does play a significant role on mouse control operation (a result that is consistent with Joiner et al.'s (1998) report). Findings in our study, although it was not our primary aim to search for age differences, suggest that primary school pupils (younger subjects) and teachers (older subjects) seem to have some difficulties when confronted with simple mouse operation tasks. This "difficulty" remains regardless of computer skill level. On the contrary, secondary school pupils and university students seem to be more competent. Results from experiments 1 and 2 are in step with data obtained by other studies, mentioned in the introduction's section (Chaparro et al, 1999a; Chaparro et al., 1999b; Marquié et al., 2002). It seems that two different factors may explain the age effect observed in our study. For older participants, it is obvious that decline in motor abilities do have the strongest effect in older people's interaction with input devices (Mahmud & Kurniawan, 2005). Older people take longer than their younger counterparts in performing the same movement. These are more variable, less smooth and less coordinated (Seidler et al., 1996). On the contrary, it may be more difficult for children to handle a mouse than it is for adults, since children's motor skills are not yet fully developed (Donker, 2005). This fact can explain the minor mean differences observed among novice and experienced users within the primary school children group. Congener results were also reported by Donker and Reitsma (2004). In their study expert children did not make fewer drop errors than novices, suggesting that although the experts have learned the peculiarities of the program, they did not have better developed motor skills than the novices.

A second simpler analysis revealed significant differences on performance between "high" and "low" computer skill users. Only primary school pupils showed no significant differences both in reaction and duration times, as mentioned above. Computer skill was proved to be the factor that can explain the performance variation observed in our sample. Motor abilities for both students (secondary school and university) and teachers are fully developed. Thus, the within subjects' differences should be attributed to computer skill competence. Our data reveals significant differences among novice and expert computer users both on reaction and duration time scores.

The other two experiments (3 and 4) involved mouse move and click on moving stimuli. These experiments where selected in order to tackle the practical issue of movement, often involved in educational computer games and/or educational applications. Both experiments showed a significant effect of computer skill on duration times. The within-subjects factor (speed) had a strong effect on performance for all groups. An interesting result was that primary school pupils and teachers were slower than secondary school and university students in clicking on a moving target. This finding duplicates results from the previous experiments reported elsewhere. Subjects in the "high computer skill" group were also quicker in clicking on a moving target than subjects in the "low computer skill" category. Only primary school pupils proved an exception to the general rule. On the "slow speed" condition, "low skill" computer users performed better than their "high skill" peers did. This odd finding can be explained if we consider the range of the collected scores in the "low skill" category for primary school pupils. There were some cases where subjects clicking on the moving stimulus "accidentally" quickly, forced the mean duration times down.

Almost in all speed options, primary school pupils and teachers form a separate group. This finding duplicates the results reported in experiments 1 and 2. It seems that they face more difficulties than secondary and university students, who appear to be more competent.

Time scores for all groups suggest that differences among high-skill and low-skill users tend to increase as tasks become more complex.

It is apparent that usability problems in educational software will hinder children's learning, decreasing the efficiency of the software. Additionally, educational software does not only require children to perform physical, but also cognitive actions (Donker 2005). Thus, when children work with educational software, their motor abilities are often challenged as much as their cognitive skills (Donker, 2005).

According to Squires and Preece (1996), when looking at educational software, it is inappropriate to consider learning and usability as independent issues. In this sense, learning process and student's interaction with the software should be faced as a single unity. Usability features should not just allow the software to be efficiently manipulated, but should also be appropriate for the intended learning task (Bottino et al., 2006).

Conclusions

Summing up the results from our study, we could suggest that:

(a) Diversities in subjects of all groups were observed in relation to mouse use performance.

(b) Significant differences among skilled and less skilled computer users were found for reaction and duration times.

(c) Subject variation on performance increased as tasks become more complex.

(d) Teachers and primary school pupils face greater usability problems - in low-level mouse control operations - than the other two groups.

(e) Usability difficulties occur when controlling a graphical computer interface.

Since use of educational software is common practice in the teaching process, software designers and educators should take into consideration:

- The different competence levels. Additional attention is needed when a software interface involves tasks with time limits.
- Subject variations on computer skill may occur within a classroom setting and create setbacks for both teachers and students.
- Educational software should focus mainly on expanding students' knowledge, having fewer constraints for users.
- Another point that should be considered by educational authorities is the avoidance of unevenness within a classroom setting.
- Educational software challenges not only cognitive abilities but motor skills too. Therefore, usability variables should be counted in, aiming an uninstructed and auspicious learning process.

Since "ease of use" is the key to successful application designing (Myers, 1994), software designers should limit operational difficulties. The ease of use and the uniformity of the interface may make possible a higher level of concentration on the material being studied (Edwards & Holland, 1994). Computer interface designing must provide a representation of clear, consistent and attractive communications, since the quality of the interface contributes towards the ability of the user to reach excellence (Lucas, 1991). It is obvious that this is also essential within an educational context. Educational software users (teachers and students) should take full advantage of computer technology and its benefits without drawbacks. If usability problems are not adequately taken into account by educational software designers, the introduction of computer-assisted teaching practice may fail despite having a number of educational advantages (Bourges-Waldegg et al., 2000).

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