Gender and 3D CAD Experience Differences in Usability Evaluation of a PC Mouse

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Abstract: Evaluation of a standard lightweight computer mouse was carried out by 16 subjects performing pointing, dragging and steering tasks. The aim of the paper is to analyze differences across women and men, as well as across experience with CAD and lack thereof. Subjects filled in 3 scales (discomfort, ease of use and effort), each holding several items. The psychometric characteristics of the 3 scales were also evaluated. Significant associations were unveiled between efficiency as well as effectiveness objective variables and items from the subjective scales as well as anthropometric dimensions of the hand. This suggests that only one device (with its fixed features, including weight and geometry) cannot fit all users and hence, achieving better efficiency and effectiveness requires the use of different models of pointing device, according to the person. No significant associations were found involving experience with CAD. Women versus men determined statistically significant differences for effectiveness of pointing at medium sized targets and with the effectiveness of dragging with the left button indicate lower effectiveness for female subjects than for male subjects.

1 Introduction

In the current times, the digital society is a reality. Digital devices and computers permeate a great part of activities developed both as leisure or work (the boundaries between these two categories tend to get blurred, making it increasingly hard to differentiate between personal time and work time). Computer usage has been indicated by several research studies to play a role in the development of neck and upper extremity pain, especially hand and forearm musculoskeletal pain associated with intensive mouse use [1]. Efforts have been ongoing towards proposing alternative pointing devices, albeit these have persisted in triggering hand and forearm musculoskeletal pain in conjunction with intensive use of the pointing device. Additionally, the recent and rising use of Touch Screens (e.g. in tablet PCs) has been subjected to study with results showing that the risk of developing musculoskeletal symptoms remains when they are intensively used for a long period of time. It

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seems that touch-screen tablet users are exposed to extreme wrist postures that are less neutral than those assumed with other computing technologies [2] and may be at greater risk of developing musculoskeletal symptoms. Tablet PCs entail antagonist ergonomic parameters (screen and keyboard conflict for optimal positioning) even when adopting palm rejection technology [3] as it generally reduces discomfort but with increased wrist extension and with no benefit to shoulder unloading. Musculoskeletal disorders are on the rise [4]. Extended use of computer pointing devices is bound to endure in the future, because touch screens have so far not been able to replace the PC mouse, especially in 3D Computer Aided Design [5]. Moreover, while ordinary users of computerized workplaces perform tasks that can switch between using the keyboard and using the pointing device, CAD operators use the computer pointing device in a continuous way. Due to the specificity of this work, some operators use two devices simultaneously, one for the left hand (knob) and one for the right hand (Mouse) [6].

The literature review performed resulted in the need to develop and, or, improve a computer pointing device based on a wide range of information of an ergonomic nature, seeking to improve their performance and reduce the risks of musculoskeletal disorders, providing it still with useful features for envisaged use by CAD operators. This study is part of the doctoral work of the first author that comprises several phases; the first one includes a systematic review of the literature, helping to select the product more suitable to improve; the second phase is planned to include the ergonomics-oriented development of a computer pointing device. Thus, as a starting point, the traditional PC mouse was selected, the objective being its equally universal use but with special application in the CAD field where accuracy is required, with handling improved, speedy movements and long periods of use in a continuous way. Given the reality of greater gender equality in work, the aim of the paper is to analyze differences across women versus men, as well as across experience with CAD and lack thereof, in the evaluation of the standard computer pointing device focused.

According to Chen et al. [7], the mouse weight might influence the wrist motion and the forearm muscle activity when using a PC mouse in a high operation speed, while such effect is diminished in a low operation speed and the mouse with a proper weight would promote improved movement efficiency and decrease the muscular costs during the fast operation. The proper mouse weight could hence benefit the users in terms of increasing the movement efficiency (during fast operation in high speed tasks), dimensions and geometry based on anthropometry, hand gestures and comfortable hand postures [8]. In the case of the standard PC mouse included in this study (Fig. 1) the mass of the device is 57 grams (taken from weighing the device on a precision scale with the wires horizontally supported; the total weight including the cable and plug is 78 grams). Interestingly, the same device size and geometry in a wireless configuration has a greater mass, due in part to the extra mass of the battery (much greater to that of the non-existent cables).

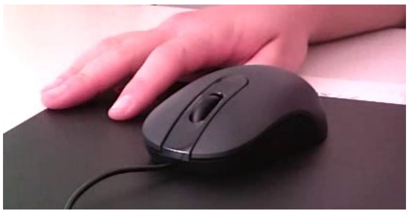

Fig. 1 Pointing device focused in the study.

2 Methods

A subjective evaluation was carried out of a standard computer mouse, with 16 subjects (9 male and 7 female), while performing pointing, dragging and steering tasks adapted from previous studies [9, 10]. All subjects performed the tasks in the following order: pointing at large targets (pointing large), pointing at medium sized targets (pointing medium), pointing at small targets (pointing small), dragging with the left button (dragging left), dragging with the middle button (dragging middle), dragging with the right button (dragging right), and, finally, steering. A comparative overview of the graphical setup of the tasks is shown in Figure 2.

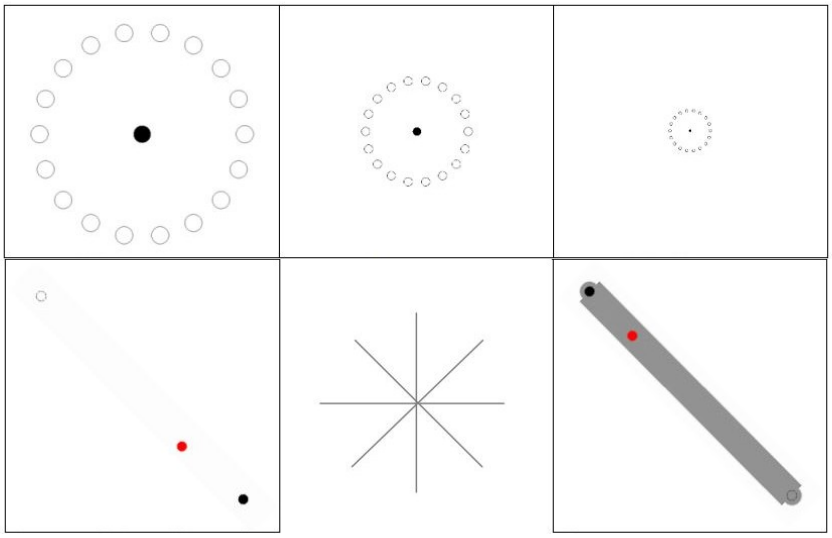

Fig. 2 Computer generated (purpose built software) graphical setup for the tasks in the individual sessions of the participants usability testing of a standard PC mouse (clockwise from top left corner: pointing large, pointing medium, pointing small, steering, dragging and steering directions and dragging).

Subjects were given 3 scales, each one composed of several items: discomfort, ease of use and effort. Ratings were provided in 6-point Likert scales completed by the subjects. The psychometric characteristics of the three scales were evaluated after the collection of data, using Cronbach's alpha (internal consistency) and principal factor analysis (to unveil the latent constructs underlying the assessments made). Additionally, principal component analysis was carried out combining the three scales in order to emphasize the dimensions resulting from the assessment. Statistical analysis was carried out using IBM™ SPSS® version 22.

The sessions lasted between 10 and 12 minutes, depending on the duration of pauses the subject shoes to undertake between tasks. A set of several non-conventional pointing devices was evaluated in the same occasion, and the order of evaluation was randomized for each subject across the several devices evaluated. This paper focuses on the usability evaluation of the standard PC mouse only. Women's hand size differ in general form men's hand sizes, the latter are bigger on average, in terms of hand length and hand width. Using a similar computer pointing device hence may pose challenges to either sex, according to the ergonomic fitness or mismatch with hand anthropometric dimensions and pointing device dimensions and shape.

3 Results

Experience with 3D CAD was registered (4 out of 7 female subjects and 7 out of 9 male subjects were experienced); no statistically significant Spearman correlations were found between this variable and the remaining variables (anthropometric, subjective and effectiveness as well as efficiency). All subjects were right handed. Hand width and hand length were measured; the Pearson correlation factor between hand length and width was 0.805 ($p<0.05$) within the entire sample. All 7 female subjects had hand size (taken as the sum of the hand width and length) below the mean; all 9 male subjects had hand size above the mean (hand size was smaller for all female subjects than for male subjects). Spearman rank order correlations were calculated between hand length and sex (coded as 0 for male and 1 for female) yielding a strong statistically significant ($p<0.05$) association factor of -0.863, with -0.839 for hand width and sex. Additionally, Pearson correlation analysis between anthropometric dimensions and subjective scales yielded no statistically significant associations across both domains.

Non-experienced male subjects showed higher ease of use mean ratings than non-experienced female subjects. Experienced female and male subjects had identical mean ratings of ease of use (Fig. 3). In terms of effort, a similar pattern is found for the similarities across experienced 3D CAD users of both sexes and dissimilarities in non-experienced subjects (Fig. 3). In what concerns discomfort of the forearm, the gap between women versus men for non-experienced 3D CAD users is greater than in the two previous cases (Fig. 3), and experienced male subjects report mean forearm discomfort slightly greater than their female counterparts. It should be noted however, that because the study resorted to volunteers, the factor experience with CAD was random in the sample, and it happened that there were less unexperienced than experienced subjects for both sexes.

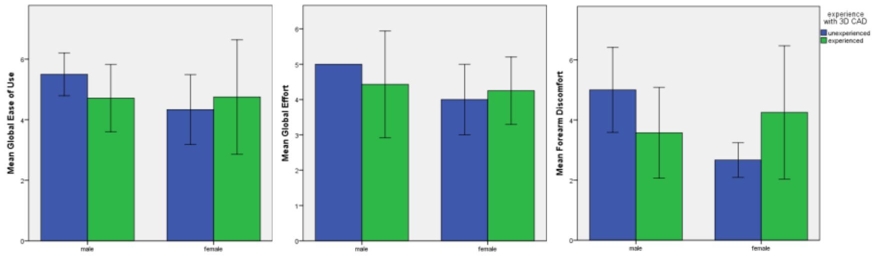

Fig. 3 Mean Global Ease of Use, Mean Global Effort and Mean Forearm Discomfort plotted against Sexes and Experience with 3D CAD (ease of use, effort and discomfort were rated from '1' – very bad to '6' – very good; error bars: +/- 1 SD).

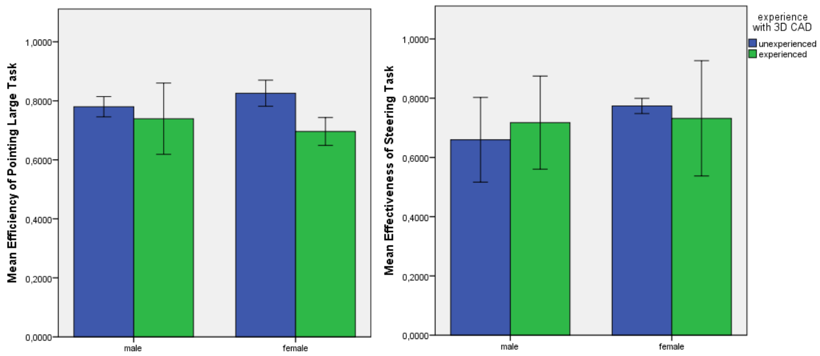

Fig. 4 Mean efficiency of pointing large task and mean effectiveness of steering task plotted against women versus men and experience with 3D CAD.

Effectiveness of task completion was calculated based on calculating one minus the ratio between the number of failed targets and the total number of targets in the task, for all tasks with the exception of steering. In the latter case, effectiveness was calculated as the minimum mean deviation for the task divided by the mean deviation incurred by the subject. Efficiency was calculated multiplying effectiveness by the ratio of minimum task completion time (within the study) and the subject's task completion time. Spearman rank order correlation analysis between sex and effectiveness as well as efficiency data yielded statistically significant ($p<0.05$) association of the former with the effectiveness of pointing at medium sized targets (rho=-0.751) and with the effectiveness of dragging with the left button (rho=-0.542). Statistically significant ($p<0.05$) Pearson correlations between efficiency as well as effectiveness objectively calculated variables and items from subjective scales (discomfort, effort and ease of use) are depicted in Table 1, while statistically significant ($p<0.05$) Pearson correlations between anthropometric dimensions and efficiency and effectiveness objectively calculated variables are shown in Table 2.

Table 1 Statistically significant ($p<0.05$) Pearson correlations between efficiency as well as effectiveness and items from subjective scales (ease of use and effort)

Variable / subjective scale	Ease of dragging with left button	Ease of dragging with right button	Ease of steering	(mouse) gripping effort	(mouse) controlling effort	Clicking effort
Effectiveness of pointing large	-	-	-	-	-	0.570
Effectiveness of pointing small	0.511	-	-	-	-	-
Effectiveness of dragging with left button	-	0.550	-	-	0.533	-
Effectiveness of dragging with right button	-	-0.544	-	-	-	-
Efficiency of dragging with left button	-	-	0.564	-	-	-
Effectiveness of steering	-	-	-	-0.586	-0.528	-

Table 2 Statistically significant ($p<0.05$) Pearson correlations between anthropometric dimensions and efficiency and effectiveness objectively calculated variables

Variable	Effectiveness of pointing medium	Effectiveness of dragging left	Effectiveness of dragging middle	Efficiency of dragging middle
Hand length	0.499	-	-	-
Hand width	0.512	0.501	-0.630	-0.603

As shown in Figures 3 and 4, the combined analysis for the sexes and experience with CAD, on the variables of interest (subjective scales of discomfort, effort and ease of use) and objective variables of effectiveness and efficiency, entailed the consideration of 4 subgroups of subjects. The variables of interest were hence analyzed using non-parametric statistics [11] to statistically prove or disprove the differences among subgroups, portrayed in Figures 3 and 4 (these are just a few of the variables of interest). In particular the median test for independent samples and the Kruskal-Wallis test were ran using as factor the interaction categorical variable created from crossing the sex and experience with CAD categorical variables. As a result the null hypothesis (the medians are the same across the categories of the interaction variable) was rejected with statistical significance for effectiveness of pointing at medium targets ($p=0.017$ with the independent samples median test and $p=0.024$ with the Kruskal-Wallis test) and for efficiency of pointing at large targets ($p=0.027$ with the independent samples median test only). Moreover for the latter variable a statistically significant ($p=0.049$) difference was determined for the comparison of the medians of the CAD experienced females and non-experienced females.

4 Conclusion

The analysis of the differences across gender, as well as across experience with CAD and lack thereof, in the evaluation of the standard computer pointing device using the independent samples Kruskal-Wallis test separating the categories of the interaction factor coded for the four states of 3D CAD experience and the sexes combined showed no significant results for the three dependent variables depicted in Fig. 3 (overall ease of use, overall effort and forearm discomfort). Replication of the study with a greater number of subjects would be advantageous in order to enable a greater chance of finding significant co-variance, provided it is underlying the differences shown in the charts (Fig. 3) and is not merely caused by randomness or additional factors. This notwithstanding, statistically significant differences in medians were found across the afore-mentioned 4 categories for effectiveness of pointing at medium targets and for efficiency of pointing at large targets.

The results support the consideration of differences across sexes in some of the subjective and objective variables analyzed as well as confirming the previously reported differences in hand size between sexes. A very lightweight pointing device was used in the study. It is suggested that in future studies, a combination of lightweight and heavier devices (e.g. wireless and cable linked) be evaluated to ascertain the influence of weight on the usability of the pointing device.

Analysis of correlations unveiled significant associations between objectively calculated variables efficiency as well as effectiveness and items from the subjective scales as well as anthropometric dimensions of the hand. This result suggests that only one device (with all its features, including weight and geometry) cannot fit all the users across the population spectrum and hence, achieving better efficiency and effectiveness seems to be contingent on using different models of pointing device, according to the person. No significant associations involving the categorical variable experience with CAD were found (this could have been a consequence of very limited numbers of subjects without CAD experience, i.e. only 2 out of 9 males and 3 out of 7 females).

Women versus men determined statistically significant differences for effectiveness of pointing at medium sized targets (rho=-0.751) and with the effectiveness of dragging with the left button (rho=-0.542), in both cases the negative factor indicates lower effectiveness for female subjects than for male subjects. The fact that hand size was smaller for all female subjects than for male subjects coupled with the previously mentioned results, suggest the consideration that smaller devices should be recommended for use by women, as compared to those for use by men.

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