

To Beep or not to Beep: On the Influence of Some Interaction Design Variables on Its Performance

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Abstract. During the construction and development of graphical interfaces, it is important to decide among a huge number of possible feedbacks (colors, sounds, etc.) with graphical variants (circular or rectangular shapes) and graphical behaviors (Close- and X-Button in title-bar e.g. to close a window). In this paper, the results of a long-term experiment comparing mouse- and touch-based interaction are presented. The aim of this work is to compare design variables of interaction in order to explore the influence of these variables on the interactions performance. The obtained results, for mouse interaction, reveal that only one studied design variable (clicking or not when reaching a target) is independent from target size. Color feedback showed to have negative influence for large objects and positive influence for small objects. For small targets circle-shaped targets and sound feedback proved to be negative, on the contrary to touch interaction. Here sound feedback saves for small objects 14.5% of interaction time. Finally the best results obtained are condensed to simple to apply design rules.

Keywords. Graphical interfaces, variables of interaction, mouse interaction.

1 Introduction

When building a Graphical User Interface, designers need to decide for a huge variety of possible feedbacks and decide among many graphical variants. Besides of graphical feedbacks like using color as a feedback for successful interaction sound feedback may be used there. Other graphical decisions are whether to take rectangular, or more fashionable, circular targets. Or whether to offer several targets for the same functionality (Close- and X-Button in title-bar e.g. to close a window) or restrict the design to a single target for each functionality.

These design variables are of interest in several areas. Firstly, GUI- and Web-Designers need that knowledge when designing new controls, for instance

new button or menu control elements. Secondly and more generally the correct decision of these design variables also may support better design of any 2D pointing instrument based interaction since large control elements like panels and boxes were investigated too. Thirdly the results presented in that article may serve GUI- and Web-Designers to calculate the operating times in advance and thus to predict or compare the performance of designs with freely chosen variables.

In this work the results of a long-term experiment comparing mouse- and touch-based interaction are presented. Especially, the influence of above mentioned design variables is studied. Fitts' Law was used to differentiate among small and large targets. The results reveal for mouse interaction that only one studied design variable (clicking or not when reaching a target) is independent from target size. Color feedback showed to have negative influence for large objects and positive influence for small objects. For small targets circle-shaped targets and sound feedback proved to be negative. On the contrary to touch interaction. Here sound feedback saves for small objects: 14.5% of interaction time. Finally the won results are condensed to simple to apply design rules.

2 Related Work

A computer is made up of different devices that allow a user to interact and control it. In this paper, it is carried out a study of the “mouse”, a device that allows a computer user to control a screen pointer or cursor and to do click in screen positions that determine a given flow of information. During the 60s, one of the pioneers of the human-computer interaction area, Douglas C. Engelbart invented the mouse device with the help of Bill K. English.

The first mention of the term “mouse” in the literature, as an input device, was made when the input device at Stanford Research Institute, Menlo Park, CA developed by [4] was created. A comparison of this input device with other ones has been done throughout the years. For example, in 1967 a comparison among mouse, joystick and a light pen was performed by [4]. The aim of that comparison was to select characters and words in the computer screen; the results obtained shown that the use of the mouse device is faster than the other ones. Other comparisons against the mouse device has been done, for example, with rare-controlled isometric joystick, step keys and text keys [1], or with other input devices such as touch screens, panel and keyboards [8], with graphic tablet and trackball [10], with absolute touchpad, relative touchpad, trackball, displacement joystick, and force joystick [5], with high precision touch screens [18], with a pen device [2], with the finger-controlled isometric joystick [12], with touchpad and multitouch input technologies [19], just to mention some of the diverse literature dedicated to performance comparison of the mouse device with respect to other ones. Here we can see the numerous research works in which the mouse device is compared with different input devices, however, it is also important to mention the manner in which the mouse device has influenced the use and construction of graphical interfaces. Perry and Voelcker [15], for instance, present a perspective

of the development of the mouse device and user-friendly interfaces. A button size and spacing on touch screen buttons experiment was made by [9]. They compared performance and input accuracy between older adults and younger adults. Their results have shown that younger adults required significantly less amount of time to complete a given input task. Input accuracy did not show significant different between older and younger adults. Authors found not any button size or spacing configuration where younger or older adults were stronger or weaker with. However, although spacing difference did not affect time performance, it significantly affects input accuracy.

3 Methods

3.1 Experimental Design

The experiments were conducted in fairs, exhibitions or laboratory sessions using a Windows program as shown in the Figure 1. After a short poster-based introduction into the experiments and privacy issues, the participants performed the test undisturbed.

When the program is started the user is first asked to convey some socio-demographic and basic data (age, gender, device type) in a pop-up window. Furthermore, binary test variables were set in that window: sound feedback on/off, color feedback on/off, circular or rectangular targets, and display of one or several targets at once (only one of these needed to be hit). These are considered as test variables for this article.

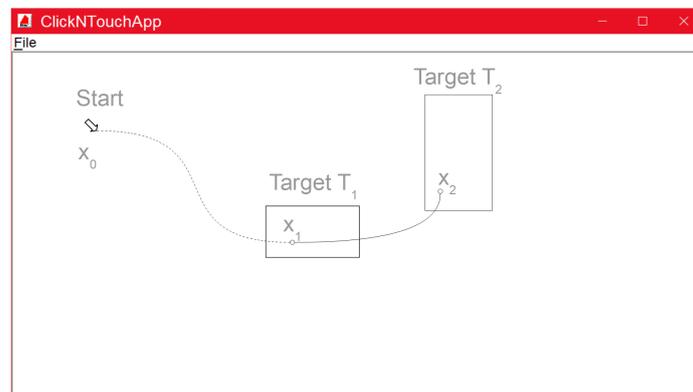


Fig. 1. Basic experimental design.

Right after that basic data acquisition, the user is shown targets by the program (rectangles or circles, see Figure 1 and the user clicks or touches on these. As soon as the target is hit, and only if it is hit, the next target is shown. So in Figure 1 the user starts at position x_0 , begins to move to position x_1 and

clicks in target $T1$. Directly after that Target $T1$ vanishes and Target $T2$ is shown. Thereafter the user moves from x_1 to x_2 and clicks in Target $T2$.

The picture's inscriptions for explanation in the picture ($Start, x_0,$) and the mouse-traces were not shown in the real experiment. The application was opened in full-screen mode, so the title bar and File-menu were not visible. Actually only the targets and the mouse pointer became visible. Depending on the experiments context (sessions in fairs and exhibitions or laboratory sessions) the users had to hit between 50 up to 300 different targets (average 99.6 targets). In total 15,689 hits were stored, 35 were peaked out before (0.22%) since the users used more than 3000 ms to hit the target.

The targets areas were sized randomly between 440 and 84213 pixels (0.012% 4.4% of the screen's area). The x- and y-positions for the next targets were as well chosen randomly; the cases that the next target does not move or does move only little in comparison to the last target was not excluded.

3.2 Subjects

The experiments took place from 2013 to 2017; the subjects used either standard PCs with HDTV Monitors (27%) or smaller Laptops (73%, Asus Slate and Microsoft Surface) where the touch capacities of these were used for touch/mouse comparisons. In total 163 experiments were conducted (38 female, 125 male). Since the experiments took place several times on fairs and exhibitions a wider range of ages is covered (average age 31 years, standard deviation 18 years).

3.3 Analysis

The data of the experiments was stored as CSV-files on disk and afterwards an import tool was used to integrate all data into an SQL database. SQL queries were used to peak out and to calculate the Fitts Law regression parameters as defined in [10].

In order to check the significance of the differences furthermore the average interaction time and its standard deviation for the lower and upper half of the ID-interval was calculated. In the variable-comparing plots (e.g. in Figure 3) these IDs are depicted by diamond symbols.

The R program for Statistical Computing was used as an SQL interface and it was used to calculate the significance of differences using Rs Welch Modified Two-Sample t-Test. Furthermore R was used to plot the results.

Fitts Law. The analysis of the given data is based on Fitts Law [6]. There are several variants of that law available, see [3] for details on the ongoing discussion. We used the definition of the Index of Difficulty (ID) as being proposed in [10] since it is standardized in [13].

That definition of ID and the measured interaction times (in ms) were used to calculate Fitts Law linear regression as shown in the figure 2.

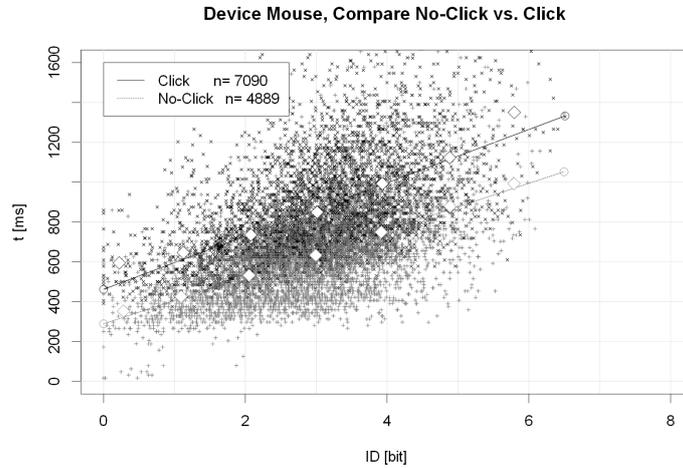


Fig. 2. Scatter plot to compare click and no-click interaction all scatters.

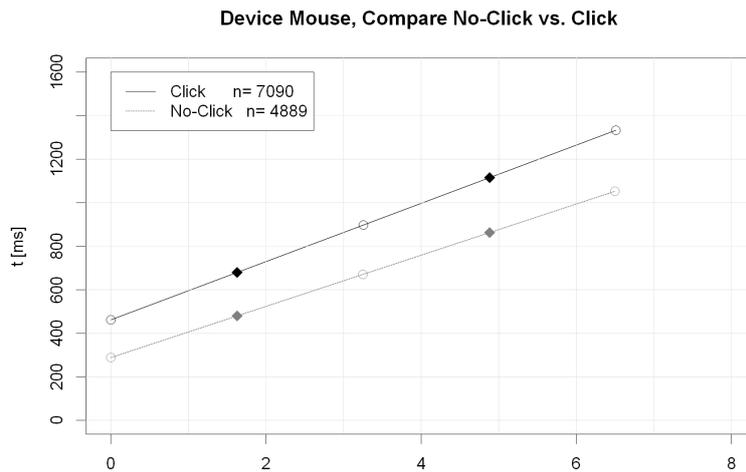


Fig. 3. Regression plot to compare click and no-click interaction.

The small x- and +-symbols depict a single interaction. The regression lines are ended by circle-symbols. In order to show the linearity of the averaged IDs these are shown in that figure too (white diamond symbols). For the sake of clearness these and the x- and +-symbols for a single interaction are omitted in the subsequent figures.

Significance Tests. Figure 3 shows that reduced variant of the scatter plot in Figure 2. The diamond symbols depict the points on the x-axis (thus ID-values) for which a significance tests of the differences between the different outcomes

of the studied variable(s) were conducted. This was done by using R's Welch Modified Two-Sample t-Test for both pairs of diamond symbols.

For the left pair ($ID = 1.63bit$) we measured an average width and height of the targets of 113x75 Pixels (0.46% of screen size). For the right pair ($ID = 4.88bit$) we have 79x61 pixels (0.19%). The left pair is denoted from now on as "Large Targets" and the right pair as "Small Targets".

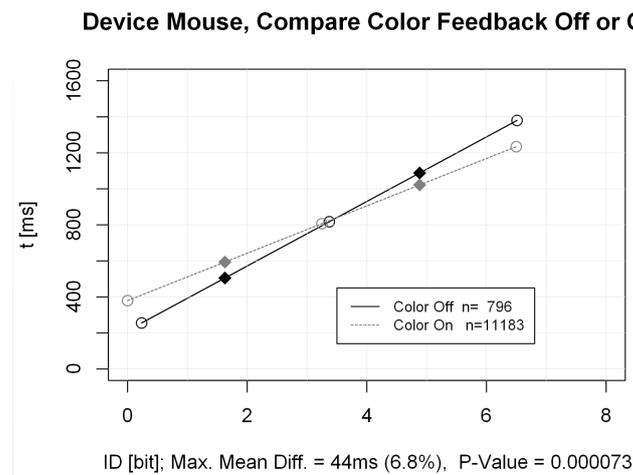


Fig. 4. Using color feedback.

4 Results

For all investigated devices (touch and mouse) and variables (circular or rectangular targets, sound feedback on/off, click needed or not, single or multiple targets on screen, color feedback on/off) the Fitts Law regressions and the average interaction times for small and large targets were calculated. Furthermore the p-value of the t-test was computed to check if the differences of the averages are significant. In the following paragraphs only those variables are presented, for which the average interaction times for small and large targets differ more than 6% and have a $p - value < 0.02$.

4.1 Mouse Interaction

Variables of Influence for Small and Large Targets. The only variable that exhibited advantages independently of the target size is shown in Figure 3. The difference here is that the users do not have to click in order to get the next target. That difference is for small targets 27.40%, for large targets as much as 33.20%.

This advantage is already used in several occasions in current GUIs: on the one hand for onmouseover-events in web pages [16] or for tooltips, e.g. in Microsofts ribbons [11]. Here the mouse interaction is used to trigger a functionality that does not cause an irreversible action. On the other hand, the design study in [7] shows that a click-free interaction is possible also for irreversible action – though it exhibits lacks in conformity with user expectations and suitability for learning.

For mouse interaction the usage of color feedback influences the performance depending on the target's size: small targets are clicked 6.80% faster. If we omit color feedback, large targets gain 5.60% performance (Fig. 4).

For mouse interaction the usage of several targets simultaneously showed near to no influence on the interactions performance, especially if large targets are considered. Here we noted only a difference of 3.9% Fig. 5).

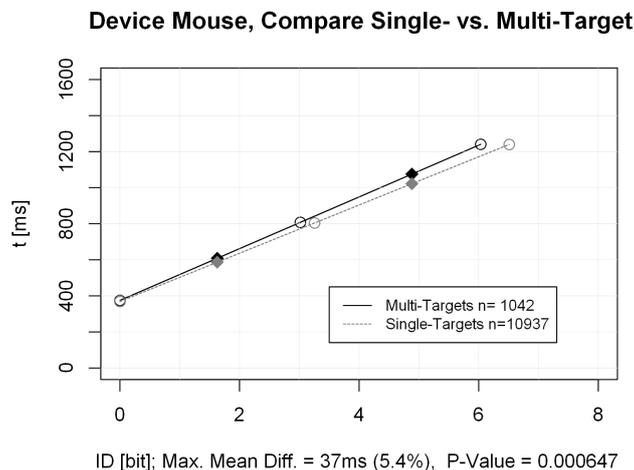


Fig. 5. Using multiple clickable targets.

Variables of Influence for Small Targets. With mouse interaction we detected a difference for small objects of 7.5% of interaction time when circles are not used instead of rectangles (Fig. 6)

For small targets using sound feedback proved to be negative: 6.8% of performance are lost. For large targets still 2.7% are lost (Fig. 7).

Combination of Variables of High Influence. In order to study the influence of the combinations of several variables we tested all possible combinations. The only exception here was the variable whether the user needs to click to get the next target. This variable was excluded since the large influence of that variable heavily shadows the influence of the other variables.

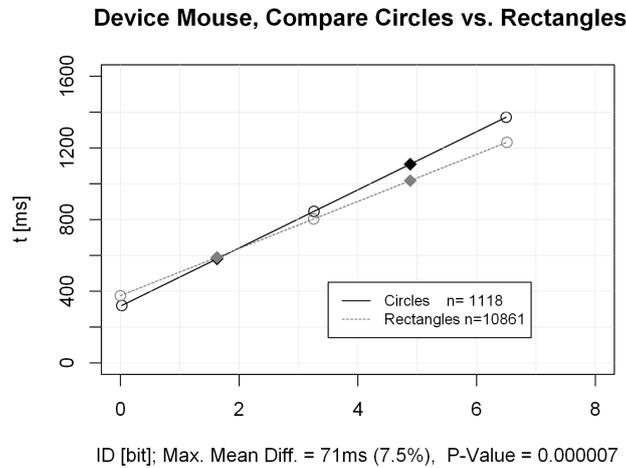


Fig. 6. Circles for interaction.

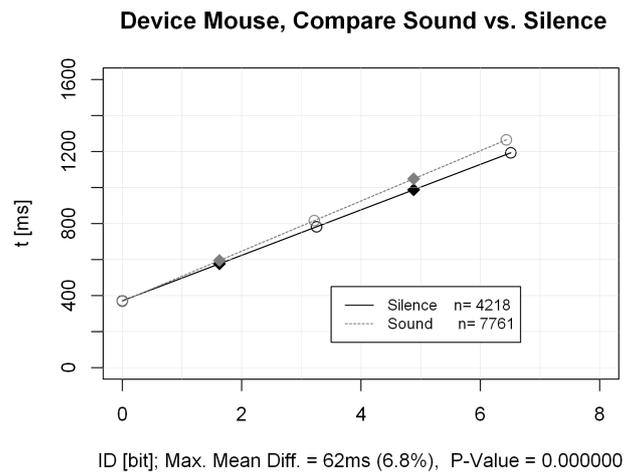


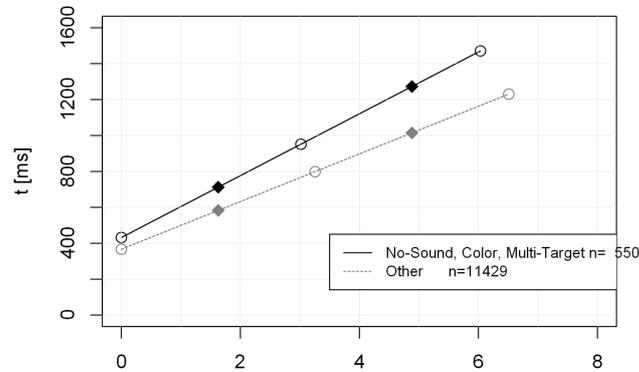
Fig. 7. Sound feedback.

The best combination was using color and multiple targets, and restrict from using sound. That delivered for small targets an advantage of 23.2% and for large targets 19.8% (Fig. 8).

4.2 Touch Interaction

Variables of High Influence for Small Targets. For touch interaction we detected a difference for small objects: 14.5% of interaction time can be won if we use sound feedback for small objects. This is a clear difference to mouse

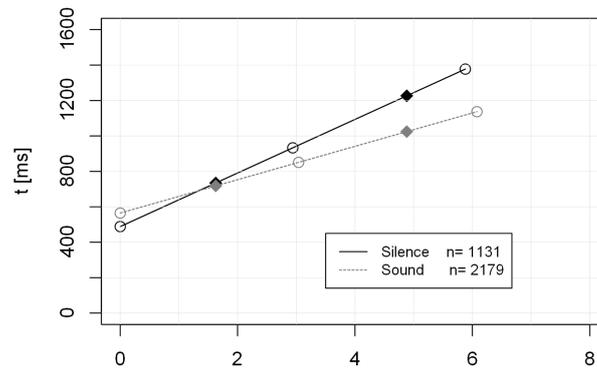
Device Mouse, Compare Sound off, Color, Multi-Target



ID [bit]; Max. Mean Diff. = 175ms (23.2%), P-Value = 0.000000

Fig. 8. Sound feedback for touch interaction.

Device Touch, Compare Sound vs. Silence



ID [bit]; Max. Mean Diff. = 148ms (14.5%), P-Value = 0.000000

Fig. 9. Sound feedback for touch interaction.

interaction: in paragraph 4.1.2 we saw a performance loss of 6.8% if sound is used (Fig. 9).

For other variables (circular or rectangular targets, single or multiple targets on screen, color feedback) we could find no clearly significant influences, probably due to insufficient number of experiments.

5 Discussion and Conclusion

One meta result of this study is the fact that when studying influences of different feedbacks the size of the targets matters. Only one variable (whether to click or not for the next target) was not influenced by the size. Others variables like using rectangles instead of circles as targets only have positive influence if the targets are small. Other variables like color feedback heavily depend on the targets' sizes: color feedback only serves for better performance for small targets, large targets are influenced negatively.

The variables also proved to be interdependent: Unfortunately, when studying the different variable combinations a simple combination of the best outcomes of each single variable in order to obtain an optimal combination did not work.

Finally, we found one variable (sound feedback) that delivered contradictive results for mouse- and touch-based interaction. Here design strategies like Mobile First as being proposed for example in [17] should be reconsidered.

To sum it up: Following main rules can be derived from the study:

- Use sound feedback for touch interaction, avoid it for mouse interaction.
- Better do not use circular targets for small targets.
- For mouse interaction a combination of color feedback, silence and using multiple targets worked best.
- If possible think about avoiding clicks to trigger an intended functionality. One hot candidate seen by the authors to do so: the annoying but necessary cookie messages in websites could be switch off by a simple onmouseover-event. See for instance [14] for details on cookies law.

For some variables of touch interaction there are needed more experiments in future to identify further significant differences.

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