A Fitt of Distraction: Measuring the Impact of Distracters and Multi-users on Pointing Efficiency

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Abstract
This paper presents the results of an experiment aimed at measuring the impact of the number of distracters and of co-located users on individual pointing efficiency. The experiment, performed with 20 users, is a variation of a Fitt's Law test in which we incrementally augmented the number of distracters on the screen and the number of co-located users. The results show that the number of distracters clearly influences users' pointing performance. Further, it shows that users are more efficient at pointing items when they share the display with co-located users than when they are alone.

Keywords
Fitt's law, Index of Performance, Collaborative work, Distraction.

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces (Evaluation/Methodology).

General Terms
Performance, Experimentation, Human Factors, Theory

Introduction

Interacting collaboratively on large displays is becoming a hot topic, in particular with the appearance of gestural interfaces. Several frameworks now enable users to interact at the same time with an application [1][5]. However, to date, there has been no experiment that has studied how many users can reasonably interact at the same time on an interactive wall without significantly decreasing their individual interaction capabilities.

For this reason, we propose to investigate the effect of distraction in a collaborative environment where multiple users can interact at the same time on a single application. Our experiment looks at this problem from a purely quantitative perspective by performing a variation of a Fitt's Law test. Distraction can originate from additional cursors visible on the screen (simulating remote users) or additional people present in the room and using the application at the same time.

This article presents the results of this experiment in which several questions were explored:

- Does user performance decrease when the number of distracters on the screen increases? Is there a threshold?
- Does the number of people interacting at the same time with an application have an impact on the pointing performance of each individual?
- Are people more distracted by virtual distracters or by the cursors of co-located users interacting on the same screen?

Experiment set up

20 users participated in the "pointing" experiment using both a mouse and a wiimote (selection made with A button which has proven to be efficient in [3]). They were asked to point-and-select a target corresponding to the color of their pointer as fast as possible. The target was of fixed sized (45 pixels by 45) and its position changed after each selection, with a screen size fixed to 1024*768 pixels.

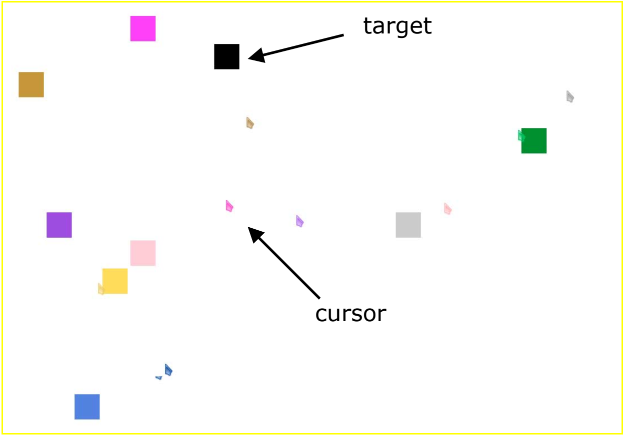

figure 1. Screenshot of the experimental set up. In this case the user had to select the black square with his/her cursor, and there were 8 additional distracters (moving_cursor/target pairs).

All users performed the experiment under three different conditions (within-subjects design):

1. The user is alone in the room and up to 9 moving cursors (and targets) are added on the screen;
2. There are 2 users in the room and up to 8 moving cursors (and targets) are added on the screen;
3. There are 4 users in the room and up to 6 cursors/targets are added.

In the three conditions above there were a maximum of 10 cursors/targets on the screen, including the ones from users. In each condition, users had to perform 10 pointing tasks each time a distracter (moving_cursor / target pair) was added, except for zero distracter for which users had to perform 20 pointing tasks so that the learning rate could be observed. Target positions were chosen so that each different a different number of distracters was given, users had to perform similar sequences of pointing tasks (distance and angle).

Measuring performance

During the "pointing" experiments described above, we logged the positions of the current and previous targets in order to derive the distance travelled to point a target. We also logged the time taken by users to perform each individual pointing task. The full logs and analysis of this experiment are available on demand.

For measuring the varying performances of users at pointing, we chose to use the ISO 9241-9 [2] standard, which is directed at the evaluation of non-keyboard input devices. Performance is measured in terms of throughput (TP), which is based on Fitts' Index of Performance or bandwidth (IP). The standard TP (in bps), or index of performance (IP), is computed by dividing the index of difficulty (ID, in bits) by the average movement time (MT, in seconds): IP = ID /MT [6]. In our experiment we used the following formula for the index of difficulty (where D is the distance to the target, and W its width):

$$ID = \log_2(D/W + 1)$$

The complete Fitt's Law is defined as MT = a + b*ID. Thus, the ISO standard TP corresponds only to 1/b (where *a* = 0). As explained by Zhai (2004) [4], this standard way to calculate IP has the disadvantage of ignoring the effect of the intercept "*a"* for measuring the quality of a device. We strongly agree. However, in our experiment, we want to measure the efficiency of a user manipulating a device in varying conditions and not of the device alone. Indeed, among the factors for non-zero *a* come various human factors, in particular the reaction time, or the time for the human brain to process and find where the target is. For this reason in our experiment, the "non informational" *a* is actually informational and the index of performance of a user pointing with a certain device should not separate *a* and *b*.

Results

The first important result is illustrated in figure 2, which shows performance in the first condition, i.e. a person alone interacting with a screen, when using a mouse. The results, based on the logs of 20 users who each had to perform 100 pointing tasks (+ 10 in the learning phase) is clear: the more distracters are added on the screen, the less efficient users are at pointing to targets. The main effect of the number of distracters on the index of performance was statistically significant (repeated measures ANOVA $F(9, 171) = 5.74$; $p < .001$, $\omega = .23$). Post-hoc analysis with Bonferroni correction showed significant differences between 0 distractors and 8 distractors ($t = 5.04$, $df = 19$, $p < .01$), 0 and 9 distractors ($t = 5.48$, $df = 19$, $p < .001$), between 3 and 8 distractors ($t = 3.89$, $df = 19$, $p < .05$) and between 4 and 9 distractors ($t = 3.91$, $df = 19$, $p < .05$). Further, trend analysis revealed a significant linear trend, $F(1,19) = 24.95$, $p < .001$, $\omega = .57$ of number of distracters on user performance.

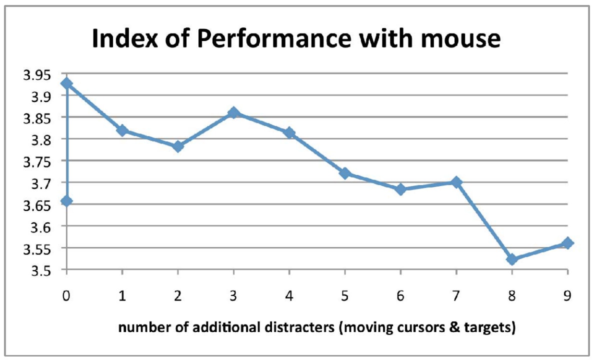

figure 2. Index of performance of users interacting with a mouse depending on the number of distracters (moving cursors with corresponding targets). There are two values for 0, since the 10 first pointing tasks were for training, and the 10 following for 0 are used in our statistics.

Figure 3 also represents the results in the first condition, i.e 1 user in front of the display, but this time using a wiimote instead of a mouse. Surprisingly, the effect of distraction is no longer evident ($F(9, 171) = 1.08$, $p > .05$). An obvious explanation is that users are not trained at using wiimotes and keep improving their pointing skills during the experiment, even though the number of distracters keeps augmenting. Another doubtful explanation might be the movement amplitude required on the interactive wall in the wii condition (2 by 1.5 meters) compared to the size of the computer screen in the mouse condition, even though the proportion target size / distance (both in pixels) were exactly the same in both conditions. From 3 distracters to 7 however, performance starts declining notably, before augmenting again, probably due to users getting accustomed to the distraction.

When plotting only the users who own a wii compared to the users not owing one, the overall index of performance is significantly higher ($F = 9.78$; $DF = 1, 18$; $p < .01$) and the impact of distracters on pointing performance becomes apparent again.

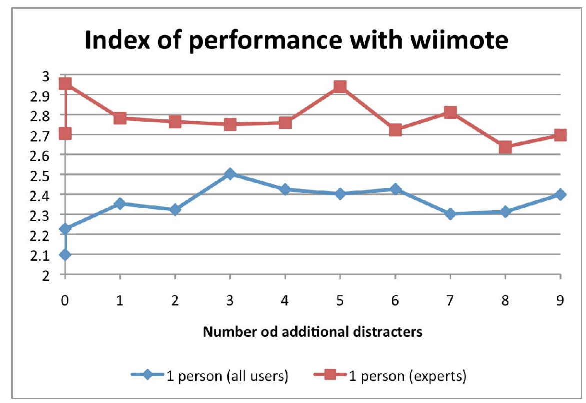

figure 3: Index of performance of users interacting with a wiimote depending on the level of distraction (moving cursors with corresponding targets).

Figure 4 represents the mean values of the index of performance for the four conditions performed by all the 20 users: person alone and number of distracters increasing from 0 to 9 (one condition for wiimote and one for mouse); 2 persons co-located (wiimote only) and number of distracters augmenting from 0 to 8; 4 persons (wiimote only) and additional distracters ranging from 0 to 6.

The x-axis of figure 4 shows the total number of cursors/targets on the screen (including pointers of co-located users). This is the reason why there are no results below 4 for the condition "4 co-located wii" (and below 2 for the condition "2 co-located wii"), since there are at least the users' cursors on the screen.

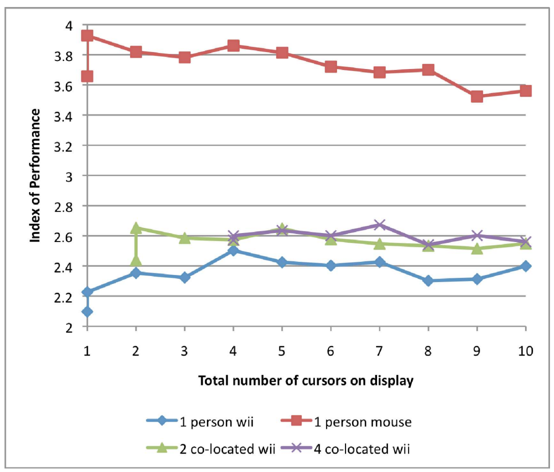

figure 4: Index of performances of users interacting alone (with a mouse or a wiimote), in pairs or in a group of 4 co-located persons. At the bottom the total number of cursors includes the cursors of co-located users.

From 4 to 10 cursors on the screen, the main effect of the 4 conditions on the index of performance was highly statically significant ($F_{3,76}=29.28$, $p<.0001$). Post-hoc analysis (with Bonferroni correction) reveals that the mouse alone condition is significantly different from all the wii-conditions ($t = 8.38$, $df = 38$, $p < .001$ for 1 person wii, $t = 6.56$, $df = 38$, $p < .001$ for 2 co-located wii and $t = 6.46$, $df = 38$, $p < .001$ for 4 co-located wii) whereas no significant differences between the wii-conditions were observed. However, there is no statistical proof that average means of individual performance (between 4 and 10 cursors on the screen) augment with the number of co-located users when the same number of cursors appears on the screen (1 user: *2.56* bps, 2 users: *2.60* bps, 4 users: *2.69* bps).

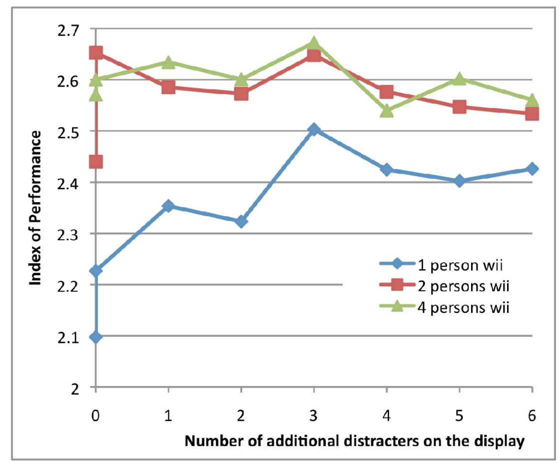

figure 5: Means of Index of performance of users interacting (a) alone, (b) in couple or (c) in a group of 4 persons.

Figure 5 compares the 3 wii conditions, but this time considering the same number of additional distracters (in addition to users' cursors). There is no overall significant statistical difference between the conditions, nor a significant effect of distracters, on the individuals' pointing performances. However, multivariate tests indicates significance (F (6, 52) = 2.49, p < .05), and notably, at the 6th level, an effect of distracters on the performance, that must be further studied.

Notably, for zero additional distracters, the main effect of the 3 conditions on the index of performance is statistically significant (F (2, 59) = 3.66; p = .32 w = .114, with means of *2.23* bps for 1 user, *2.65* bps for 2 users and *2.60* bps for 4 users). Post-hoc analysis showed significant differences between 1 user and 2 users (t = 2.48, df = 38, p < .05). This might be due to the competitive state of mind in which users put themselves when working in co-location with others, as reported by several users (an assumption strengthened by the fact that the wiimote is a gaming device). However, more evidences and studies are needed to confirm this hypothesis.

Conclusion

This study shows that the number of distracters on a screen (moving pointers and static targets) influences users' performance at pointing items (in particular with a mouse since participants were skilled at using it). Further, it shows that users tend to become more efficient on individual tasks when they share a display with co-located users. However, this is a work in progress and more evidences are needed to confirm our hypothesis. Future experiments should counter-balance properly the number of distracters, and use circular targets. We believe more studies of this type must be performed to adapt Fitt's Law to collaborative environments and in particular the index of difficulty (ID) according to the number of distracters (static or dynamic) and the number of co-located users interacting in the application at the same time.

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