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Lapointe, Jean-François

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A Comparative Study of Point-and-Select Devices for Large Screen Interaction

Jean-François Lapointe
Institute for Information Technology
National Research Council of Canada
Jean-Francois.Lapointe@nrc-cnrc.gc.ca

Abstract

This paper presents the results of a user study comparing the performance of point-and-select devices for doing selection tasks on a large screen. The performance of a handheld trackball, both in one-handed and two-handed configurations is compared with a standard mouse as a basis of comparison. The results indicate that the two-handed configuration of the trackball is significantly faster than the one-handed configuration with 13% reduction of the movement time.

Finally, the mouse is significantly faster than the two other interfaces by almost a factor of two, although it is not well suited for collaborative environments with large screens because of the need for a working surface that blocks freehand movements.

1. Introduction

Falling prices and recent advances in computer display technologies, make working with large screens more common today than ever before, for example for making presentations. Although quite attractive, the use of this kind of display needs good interaction techniques and devices to achieve efficiently basic tasks such as selection and pointing, that are common to all current GUI applications.

Since in many scenarios people are using large screens in a standing position, the techniques used to interact require a lot of freedom of movement. For this reason, the use of freehand techniques or handheld wireless input devices seems logical.

Research on pointing performance is not new, with pioneering work done by Fitts in the 1950s to establish a performance model for 1D pointing, which was latter applied to HCI [1, 6]. However, even today, it is difficult to predict accurately the performance of

specific pointing devices other than by doing empirical studies, except for common input device such as the mouse [2, 7].

We found the results of research that studied the performance of two handheld pointing devices [3]. The first device uses an inertial system and the pointer movement on the screen is controlled by rotary motion of the whole device by the wrist, forearm and arm, with a thumb-operated selection button. The second device used a thumb-operated isometric joystick to move the pointer on the screen, with a trigger operated by the index finger as the selection button. Results revealed that both devices performed poorly as compared to a standard mouse.

This paper presents the evaluation of a new kind of wireless handheld input device (a trackball in fact), namely, the Logitech Trackman Live (Figure 1). This handheld pointing device uses a different mechanism than the other two previously studied since the pointer movement is controlled by a thumb-activated trackball, with the selection button also controlled by thumb.



Figure 1. The Logitech TrackMan Live

In order to evaluate the performance of this handheld trackball (HHT), we tested it with subjects in a controlled way. Also, even if the HHT is designed to be used by one hand, our first informal use of it seemed

to indicate that the use of two hands (one for pointing and the other for clicking) could be faster and less error-prone, because the thumb is used both to control the trackball and to click on the selection button, thus leading to a potential overloading. Finally, we compared its performance with that of a standard mouse, in order to obtain a basis of comparison with typical work with desktop computers and displays.

2. Experiment

A multi-directional tapping task was used to assess the point-select performance, since that kind of task is designed to test the pointing performance when doing selection in different directions such as encountered in typical use of a GUI.

2.1. Method

The experiment was carried out in a controlled environment with the following conditions:

Subjects

Twelve volunteers (10 males and 2 females) participated in the experiment. Ten of them reported to be right-handed while the other two reported to be left-handed. The subjects had an age distribution of 24/52/35 (min/max/average) and a university-level education. They all reported a perfect or corrected vision.

All were computer literate with a lot of mouse experience. Most of them had limited experience with trackballs, with only four declaring a limited usage of at least once a month but not daily.

Task

Subjects were instructed to complete a multi-directional tapping task. This task consists in sequentially selecting a target appearing at different position along a circle. We used a circle made of 15 potential target positions illustrated by blue circles, except for the target, which was colored in red.

The subjects had to sequentially point and select the red target as it moved around the 15 spheres in a clockwise manner as illustrated in Figure 2. Therefore, once they clicked on the initial target, the subjects completed 15 selections in each trial.

The on-screen diameter of the projected circle of targets was of 195 cm with target circles of 16 cm in diameter. This whole projected circle was centered on the screen. Subjects were positioned at 2.25 m from the screen and when using the mouse, a table with a surface located 77 cm above the floor was used.

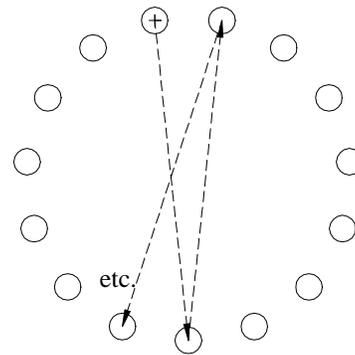


Figure 2. Illustration of the multi-tapping task

Subjects had to point inside the target and then select it by clicking the button before going to the next target. The completion time was the time elapsed between the click on the initial and the final target (which were in the same circle). This setup was chosen since it was representative of a typical task where the user has to select an icon.

System

A rear-projected display screen starting from the floor up was used for the experiment. It had a resolution of 1280x1024 pixels for a physical size of 3.05x2.28 m (HxV). The software used in this experiment was a custom-made testbed program written in C++ that used the Xforms library for the GUI. This software ran on a SGI Onyx2 computer with 640 Mbytes of RAM running the IRIX 6.5 operating system. The system displayed the images at an update rate of 60 fps, a refresh rate of 60 Hz and had a maximum total response time of 96 ms for the mouse and 184 ms for the HHT.

All the pointing devices were connected to a separate Windows-based computer that sent their input signals to the main Onyx2 computer over a network link.

The Logitech HHT has a trackball with a diameter of 16 mm and its base receiver was connected through the serial port. For the mouse, we used a standard Microsoft PS/2 mouse.

All the gains for the mouse and the HHT were set to linear (no acceleration), with a movement of 4 cm of the mouse allowing to traverse the screen and a half-rotation of the trackball allowing to do the same travel distance of the screen pointer. Those settings were found, in a pilot study, to optimize the performance for each device.

Experiment design and procedure

The experiment used a within-subject design with repeated measures, and for each of the 3 conditions, each subject had right to a demo, followed by 3 practice trials before completing 4 main trials of the task. This setup was used since the pilot study revealed that this warm-up phase was necessary to stabilize the performance of the subjects related to the learning effect.

The independent variable was the interface (mouse, HHT – 1 Hand, HHT – 2 Hand) and the dependent variable was the task completion time. To minimize the possible bias from the learning effect associated with the task, subjects completed the experiment in a balanced order.

Subjects were instructed to complete the task as quickly as possible. Also, they were told to chose their preferred hand to manipulate the devices.

All the trials were automated by the testbed with the instructions displayed on-screen, the experimenter being there only for supervision and to assist when switching to a different interface.

Subjects completed the experimental trials in about 30 minutes, after what they had a question period to collect their ratings and comments on the interfaces.

2.2. Results

The results of the experiment are divided in two groups: the quantitative performance results and the qualitative results.

It is important to note that all the subjects used their right hand to manipulate the mouse and that only one (that reported to be left-handed) used its left hand to manipulate the HHT, both in one and two-handed configuration.

Performance

An analysis of variance (ANOVA) with the pseudo-F test shows a significant difference ($F_{2,22} = 91.65$, $p < 0.001$) between the interfaces, with the mouse having the shortest average task completion time (14.67 s) while the HHT-2H got 27.05 s and the HHT-1H got 31.08 s.

We also found that using two hands instead of one significantly ($F_{1,11} = 9.786$, $p < 0.01$) improves the performance of the HHT by reducing completion time by 13%.

There was no significant difference in performance between the 4 main trials, thus indicating that the training session was good enough to stabilize the learning effects.

Finally, we found no significant interaction between the interface and the trials.

Table 1 below shows the results of the experiment for each condition.

Table 1. Performance results

Interface	Mouse	HHT-1H	HHT-2H
Average task completion time (s)	14.67	31.08	27.05
Average movement time t_m (s)	0.978	2.072	1.803

It is important to remember that the task contains 15 selections, thus we have to divide the task completion time by 15 to obtain the average movement time t_m for each selection.

Qualitative Results

Once the trials completed, the subjects completed a questionnaire to collect their impression and comments. This questionnaire asked them to rate each interface on the ease of use, the fatigue, the accuracy, the operation speed and the overall preference. They had to rate all those parameters on a scale of 1 to 5, with a higher score meaning a better score. The results are illustrated in Figure 3 below.

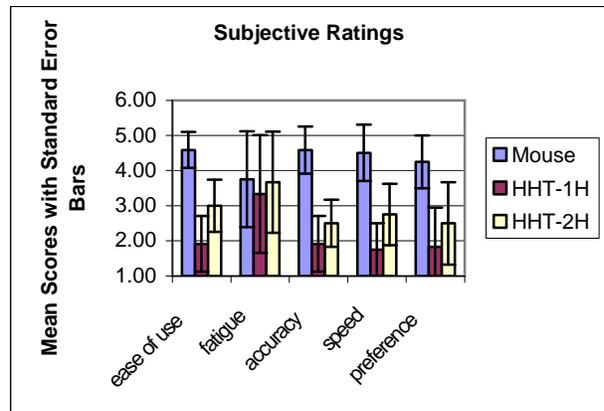


Figure 3. Subjective ratings of the interfaces

We can see that the mouse obtains the best results in every category, although there is only a negligible difference with the HHT concerning the fatigue. This can be explained by the fact that the subjects were instructed to use the mouse in a standing position. It appears from the comments they made after the experiment that this setup was uncomfortable for using the mouse since the table used to move the mouse was too low. Finally, we can see that the two-handed configuration of the HHT is rated higher than the

standard one-handed configuration on all the measured aspects.

3. Conclusion

The results of the experiment conducted here show that using two hands instead of one significantly improves the performance of the HHT. This can be explained by the fact that when only one hand is used, the thumb has to do both the pointing and the clicking, in a sequential manner, with a movement between them to switch from the trackball to the click button, thus overloading the thumb. This movement time does not appear when using two hands, hence the improvement.

The results also show that the HHT allows to effectively achieve point-and-select tasks with a complete freedom of movement although with a completion time that is about the double that of a standard mouse. This results holds true even if the total response time of the trackball had been equal to that of the mouse, for example by using faster hardware and/or communication mean than the serial port.

If we try to compare those results with what has been found before with other handheld pointing devices, it seems to be in the same range of performance although an across-study comparison is not totally valid here given the different experimental methods used in both studies. More research is then required to confirm this extrapolation of the results obtained here.

Also, the use of different levels of difficulty with the use of several target sizes and selection distances to better represent the tasks facing typical users.

A good step in that direction would be to follow the evaluation method proposed in [4], which complements the one detailed in the ISO 9241-9 standard for evaluating pointing movements in many directions [5]. This evaluation method seems to become increasingly accepted by the research community in human-computer interaction [6, 7], thus leading to the possibility of direct across-study comparisons.

The use of such a standard evaluation method is important since it potentially leads to a credible

database of evidence-based, comparable evaluations of performance of pointing devices, thus simplifying user's choice for particular tasks.

Finally, it would be interesting to compare other freehand interfaces for large screen interaction, by using performance results based on this de facto standard evaluation method.

4. Acknowledgements

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