An experimental evaluation of three touch screen strategies within a hypertext database.

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High resolution touch screens and novel usage strategies have overcome earlier problems with parallax and inaccurate pointing. A study testing the utility of three touch screen strategies within the Hyperties hypertext environment was performed. This provided a replication and extension of an earlier touch screen strategy comparison that focused on small closely-spaced targets. The experiment compared three touch screen strategies in three experimental tasks that reflect hypertext usage. The results showed that a strategy that only uses the initial impact with the touch screen causes the user to miss the target more than other touch strategies. However, no significant difference in task completion time was found. Our results should encourage system implementers and touch screen hardware designers to support "touch mouse" strategies that enable cursor dragging on the touch screen surface.

1.0 Introduction

The embedded menus of Hyperties and the natural pointing input style of touch screens are a powerful combination. This study examines how the touch screen selection strategy impacts the utility of the Hyperties/touch screen combination. Several studies have been performed evaluating the effectiveness of touch screens. However, most of these studies compared one touch strategy with some other input device and/or considered the touch screen as an abstract device where the subjects must select targets that have no meaning or purpose other than the challenge of selecting them. This experiment includes the selection process within Hyperties and attempts to evaluate several touch strategies in terms of how well the strategies function in this realistic task. This practical task could produce substantially different results than an abstract task of touch screen effectiveness since it takes into account the effects of the cognitive load the user must maintain in the task domain.

Hyperties is a simple but powerful hypertext system that allows users to browse a collection of related articles. Users may change from one article to another in three ways. The first is by way of embedded references which are highlighted words (cyan as opposed to white) that appear in the text of the articles (see figure 1). A user may be reading and then see the word 'Linz' written in cyan and know that more information can be obtained by selecting that word. In response to the selection, the computer displays a definition along with an option to see a full article on the term. If the FULL ARTICLE command is selected then the present article is pushed onto a return-to stack so that users can jump back to the previous article with a single selection. The second way is by selecting the RETURN TO ... option that appears on the screen in cyan. Upon selecting this item, the previous article seen by the user is redisplayed. The third way of changing articles is by way of an INDEX that contains an alphabetical listing of the titles of all the articles in the database (see figure 2). The titles are highlighted in cyan and the process is much the same as selecting embedded references within other articles. This version of Hyperties did not have string search and a Table of Contents as does the commercial distributed version (Cognetics Corporation, Princeton Jct. NJ).

Touch screens make an ideal input mechanism to Hyperties. Hyperties was originally implemented to enable selections by either touch screen or keyboard. The users were able to choose highlighted terms by using the cursor movement keys to move a selector box among the terms. When the desired term had the selector box on it, the user could select the term by pressing the ENTER key. The property of Hyperties that made it particularly suited to touch
selected, the cursor remains visible on the screen where the finger last positioned it.

In addition to the cursor considerations, *take-off* received other minor enhancements to take advantage of its unique qualities. Since the cursor traveled on character positions in the 80 x 25 grid, there existed boundaries where minute shifts of the finger would cause the cursor to jump back and forth by an entire character position. Cursor stabilization was added so that users could better keep the cursor in one place while deciding if its placement was desirable. There also existed an interval from the time the user placed the cursor on the desired item to the time the user's finger was released. This introduced the ability to highlight the entire item by inverse video during this time. This highlighting gave the user even more feedback as to what would be selected should the finger be removed from the touch screen.

Related research includes both device comparison studies and touch strategy comparison studies. There are several studies showing that a touch screen is faster and less accurate than either a keyboard or a mouse. Touch screens are also shown to be favored by users (Muratore, 1987; Ostroff & Shneiderman, 1988). Another study compared an all keyboard task with the same task where the menu selection portion was performed using a touch screen. The introduction of the touch screen produced faster times but error rates and user satisfaction were not significantly different (Ellis et al., 1986). A preliminary report of another experiment indicates that a touch screen is faster than a keyboard or a mouse, whether or not a typing subtask is included (Ahlstrom & Lenman, 1986). An interesting experiment that introduced a problem solving element to the experiment task showed a touch screen to be faster than either a keyboard or a mouse (Karat et al., 1984). This was true whether a typing subtask was introduced or not, although the subjects showed a preference for the keyboard when the typing subtask was included. Without the typing subtask, the touch screen and keyboard were almost equally preferred.

A related experiment used an infra-red touch screen that could register multiple touches (Murphy, 1986). Seven touch strategies were tested in the experiment. The subjects selected from 60 targets which were 3/4 inch square and displayed in a grid that was six high by ten wide. One of the strategies tested was similar to the *take-off* strategy and another was similar to the *first-contact* strategy. There were no significant differences between these two strategies in task completion time or number of errors. We have recently become aware of other attempts to create a *take-off* strategy (Eller, 1987).

This study follows up a comparison of the same three touch strategies in a task with small and densely spaced targets (Potter et al., 1988). That study had a simple 'real' task
In Phase II the subject was given 4 questions to be answered from the Hyperties database. It was up to the user to choose the path that would lead to the answer. The questions were designed so that the subjects would be highly directed in their search for the answer. The hypothesis was that even in a more realistic atmosphere, the touch strategies would still show measurable differences in time to complete a task, which in this case was to answer a question using the database. The dependent variables were time and blank space errors.

In Phase III the subject was asked to locate as many occurrences as possible of the name 'Eichmann'. They were given a maximum of 10 minutes for this task. The hypothesis was that subjects would be able to coordinate the selection and search subtasks within their mind better with a touch strategy that they felt more 'comfortable' with and thus would be able to cover more area and find more occurrences of the sought after text. The dependent variables were area in pages, number of selections, and blank space errors.

2.2 Pilot study results

A pilot study was conducted with 5 subjects. Certain questions in Phase II were found to be too ambiguous and therefore needed to be stated more clearly in order to maximize the chance for subjects to discover the most direct paths to answers. It was decided that both the paths and questions should be reduced to four of each to reduce the overall time of the experiment and minimize the chance of participant disinterest. Sample questions to aid in the subject’s introduction to the experiment were added. These would allow the subjects to become comfortable with the touch strategy, and at the same time, form a pattern for answering the questions. To eliminate unnecessary discrepancies in our results, the timing of the questions was changed to begin with the subject confirming they comprehended the question, instead of the issuance of the question itself.

2.4 Materials

Two practice questions were asked of the subjects to begin the experiment. The three phases of the experiment utilized a Hyperties database written by Marsha Rozenblit titled "The Holocaust and Its Origins: The Case of Austria". The database contained 106 articles covering people, places, events, and social movements. Hyperties was run on an IBM PC/AT with hard disk and EGA display. A subjective questionnaire was issued to the
indicating that the question was understood, the experimenter pressed one of the function keys to record the starting time in the computer log file. The subject was allowed to search freely, and when the page with the answer to the question was found, the experimenter pressed one of the function keys to record the ending time for the question. This procedure was repeated for the other three questions. The questions were:

1. Which Polish town was the largest death camp built near?
2. When was the leader of the Pan-German Party born?
3. In what year was the first concentration camp to be built liberated?
4. What was the fate of the 1934 Gestapo leader?

The subject was asked to read a short paragraph explaining Phase III of the experiment. The important points of the paragraph were emphasized and the Hyperties browser was positioned at the start of the index. The experimenter then pressed a function key and for the next 10 minutes the subject was allowed to search for pages that included the name "Eichmann". The subject was told to stop after 10 minutes and the software was exited which automatically saved the log file.

To conclude the experiment the subject was asked to fill out a subjective questionnaire. Since all of the subjects were from the psychology subject pool, each was given a credit slip before they left.

3.0 Results

One-way analyses of variance were conducted for the performance of the subjects on each of the three phases as well as for the ratings they made on the subjective questionnaire. In the results that follow, references made to wrong hit errors indicate the subject selected a wrong target while blank space errors indicate that the subject selected a blank portion of the screen.

The two performance measures for Phase I were the time needed to complete all four paths and the number of errors that were made in doing so (see figures 3-4). Although first-contact had the shortest mean time, no significant effect was found among the strategies for the time required to complete the paths. The number of errors measured was separated into three groups: wrong hit errors, blank space errors, and total errors. Take-off produced the fewest wrong hit errors but no significant effect was found between the strategy and the number of wrong hit errors. A significant effect was found between the strategy and the
the differences were not statistically significant. In a previously conducted experiment (Potter et al., 1988), the take-off strategy was shown to be significantly slower than the first-contact strategy. We attribute this discrepancy to the distance between the targets and the amount of cognitive processing necessary to complete the required tasks. In the earlier study, subjects were asked to make selections from a group of small and densely packed targets, whereas in the current experiment, the targets were typically larger and spaced farther apart. The current experiment also required substantial thought before making the choice. Since we were not able to control for these thought processes, we suspect that any significant difference in time caused by the touch strategies was obscured by these factors.

A small percentage of subjects produced data with abnormally high time and error measurements. In Phase I, this could be attributed to the subjects losing their place in the path they were following. This resulted in a delay in completing the path and often caused wrong hit errors as well. As for Phase II, one could usually find more than one path to the correct answer. In other instances, the subject either began on or simply strayed from the correct path and became hopelessly lost.

In Phase I, some participants kept track of where they were on the printed list of items with their finger. Others relied simply on memorization. However, it became apparent that a number of subjects inadvertently became lost when traversing these paths. This resulted in data that misrepresented the touch strategy. We therefore recommend that should a similar experiment be performed, the currently sought after item should be displayed on the screen until it is chosen. This would eliminate any chance of subjects losing their place during a path traversal.

Questions were evidently too difficult and therefore it was unrealistic to expect identical paths to be found by all subjects or even that the correct answer would be found in each trial without some kind of additional help. A strong argument could be made for hard-coding the shortest path to the answer into the system. This would not affect the subjects' thought processes necessary to answer the questions, but would relieve the problem of straying from the intended path.

We suspect that a correlation might be found between the touch strategy used and whether the next page target or the letter line was used to traverse through the article index (see figure 2). The letter line contained small one character targets. We feel those using take-off would choose to select from the letter line in all cases while those subjects using land-on are more apt to use the next page target for fear of error.
Austria holds a special place in the history of the Holocaust. Situated between Eastern and Western Europe, possessing a vibrant and culturally creative Jewish community on the eve of World War II, Austria had also provided the young Adolf Hitler, himself an Austrian raised near Linz, with important lessons in the political uses of antisemitism. Leading Nazis came from Austria: the names of Adolf Hitler, Adolf Eichmann, who organized the deportations of the Jews to the death camps, and Ernst Kaltenbrunner, the head of the Reich Main Office for Security, 1943-45, readily come to mind.

LINZ - city in northern Austria; childhood home of Adolf Hitler and other leading Nazis

Figure 1. This is an example an article page from Hyperties. The words in boldface appear in cyan on the EGA monitor used in the experiment. In this example, Linz has been selected and its definition has been displayed. Any of the cyan items can be selected. In particular, selecting FULL ARTICLE ON LINZ would cause the computer to display the article on the city Linz.
Figure 3. The touch strategies produced no significant difference in the time required to traverse the set paths of phase I.

Figure 4. The touch strategies produced no significant difference in the number of items that were selected by mistake while traversing the 4 set paths. However, both the blank space errors and the total errors showed significant differences (p<.01).
Figure 5. The touch strategies produced no significant difference in the time to answer the 4 questions using the Hyperties database.

Figure 6. The touch strategies produced a significant difference (p<.01) in attempts to select a non-selectable area of the screen while answering the 4 questions using the Hyperties database.
Figure 7. The touch strategies produced no significant result in the number of pages that were visited while searching 10 minutes for occurrences of 'Eichman'.

Figure 8. The touch strategies produced no significant difference in the number of touch screen targets selected while searching 10 minutes for 'Eichmann'.

Figure 9. The touch strategies produced significant differences (p<.01) in the number of attempts to select non-selectable regions while searching for 'Eichmann'.
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References


