SELECTION ACCURACY WITH PEN SELECTION SLOTS

James R. Lewis
International Business Machines Corp.
Boca Raton, Florida

This paper describes three selection accuracy experiments with the selection slot, a new menu selection device for pen-based computer systems. A selection slot is a slot into which a user places the tip of a pen or stylus for the purpose of selecting an item from a list of items. The results of the first experiment, using a prototype slot for notebook name selection with 3 mm per notebook name, indicated 100% selection accuracy. In a second experiment, the results indicated that with as little as 1.1 mm per notebook name, users could select notebook names with 100% accuracy. A third experiment evaluated page selection accuracy for 55- and 99-page slots using a 73 mm slot (0.74 mm per page for 99 pages). Participants in the 55-page condition used a single-page advance control to reach target pages greater than 55. Considering all targets, participants were slightly but consistently less accurate with the 99-page slots, but their within-slot selection accuracies were equal. All participants preferred the 99-page slot due to the inconvenience of acquiring pages greater than 55 with the single-page advance control.

INTRODUCTION

The CrossPad[1] was a device that captured a user's handwriting as the user wrote on standard note paper. To do this, the tablet had an array of sensors in the area under the paper and the pen had a small radio transmitter activated by a tip switch closed by the pressure of writing (see Figures 1 and 2).

Figure 1. CrossPad pen assembly

Figure 2. Close-up of transmitter

The CrossPad was designed to appeal to users who were comfortable working with a pen and paper notepad, but who needed electronic storage of their notes (handwriting and drawings), conveniently captured during the normal process of note taking. The product had a particular appeal to professionals who took notes as they consulted with clients (for example, architects) or who were unable to take laptop computers into certain environments (for example, lawyers taking notes in a courtroom).

Software bundled with the CrossPad had some capability for unconstrained handwriting recognition, but the primary purpose of the software was the ability to file the electronic copies of the handwritten pages (with optional keywords) into electronic notebooks for later retrieval. Users could create, rename, and delete notebook names, with the list of valid notebook names synchronized when users connected the CrossPad to a computer to upload pages of notes. These features were in support of a user requirement to allow the assignment of pages to notebooks as users took notes on the CrossPad.

Consequently, one task during product development was the design of a new selection device for pen-based systems – the selection slot. The selection slot was a slot placed in the tablet over a set of the radio receivers used for handwriting capture. To use the selection slot, the user placed the tip of the pen in the slot (activating the transmitter) and slid the pen. Activation of the transmitter in the slot caused the system to present the current set of notebook names, with one of the names highlighted.

[1] CrossPad is a trademark or registered trademark of the Cross Pen Corp. The CrossPad product line was discontinued in April of 2001.

Sliding the pen in the slot scrolled the list of notebooks, and lifting the pen out of the slot resulted in the selection of the highlighted notebook (see Figures 3, 4, and 5). Note that this lift-off strategy for selection is consistent with a well-known touch screen strategy that allows users to select very small targets (Lewis, 1992).

Figure 3. The selection slot

Figure 4. The pen in the selection slot

Figure 5. The display of notebook names

The selection slot was an absolute selection device, with the slot length evenly divided among the available notebooks plus an always-resident Other category (into which users could place pages that weren't part of any notebook in the list for later assignment to new or existing notebooks on the computer). This meant that users could pick an initial place to put the pen in the slot that would be close to the desired notebook. They could then slide the pen to the left or right if necessary to highlight the desired notebook before lifting the pen out of the slot – a useful design if the pad contained a large number of notebook names. On the other hand, if the pad contained a small number of notebook names, this would allow users to simply tap the appropriate section of the slot to assign the page to the desired notebook.

Thus, it appeared that designing the slot as an absolute selection was advantageous whether users had a small or large number of notebook names stored in their pads. A key usability question, though, was how many notebook names a user could place in the pad before the number of available names started to affect notebook selection accuracy. Based on pre-development interviews with users of the first release of the CrossPad (which did not have selection slots), we believed that users would typically want to have about five notebooks available on their pads at any given time, and that a reasonable maximum estimate for this number of notebooks was ten. Note that the selection of notebook names from a list is a specific instance of the general task of selecting items from a menu.

EXPERIMENT 1: PROTOTYPE

Purpose

The first evaluation of selection slot sensitivity took place with a prototype slot cut into the lower part of a standard notepad placed in a CrossPad tablet. The specially coded firmware for this tablet reprogrammed the sensors under the slot to control notebook selection. The goals of this experiment were (1) to check selection accuracy with 15 notebook names loaded in the pad and (2) to assess user preference between two methods for highlighting the notebook name – reverse video (reversed foreground and background colors) over the notebook name or an arrow pointing to the left side of the notebook name.

Method

Twelve participants (six male – one left-handed, six female) made notebook selections using the

specially-programmed CrossPad. The software displayed the notebook list as a single column in a display that could show up to four notebook names at a time. To guide the pen tip in the prototype slot, I cut the slot with an approximate length of 1.75 inches (44.45 mm), width of 0.1 inches (2.54 mm) and depth of 6 sheets of paper (about 0.02 inches, or 0.5 mm). The sides of the slot were vertical (no discernible angle to the cut).

Participants used the pen in the slot to acquire three targets, one close to the top of the list, one in the middle of the list, and one close to the bottom of the list. The experimental design counterbalanced the orders of target acquisition and highlighting method.

After acquiring the three targets with both selection indication methods, participants indicated (1) whether they preferred the arrow or reverse-video highlighting when making their selections and (2) if they felt that selection sensitivity under these conditions was too low, low, just right, high, or too high.

Results

Eleven of twelve participants preferred reverse-video highlighting. This was an observed percentage of 91.7%, with a 90% binomial confidence interval ranging from 66.9% to 99.7%.

Eleven of twelve participants rated the sensitivity of the slot control under these circumstances as just right. One participant thought it was a little low.

All participants made all selections correctly -- acquiring the designated target and leaving it in place when lifting off the pen. This 100% correct performance indicated that a 1.75-inch slot provided an adequate length for selecting among fifteen notebooks.

In using the slot, none of the twelve participants ever missed putting the pen directly in the slot, and all ink left on the paper was contained in the slot.

On the second attempt to select the designated notebook, some of the participants were able to hit the desired targets without any sliding because they remembered the locations from the first trial.

EXPERIMENT 2: FINAL DESIGN FOR NOTEBOOK SELECTION

Purpose

The final design of the slot had a length of 0.875 inches (22.22 mm). The purpose of Experiment 2 was to investigate notebook selection accuracy for 20 notebooks in this length (.04 inches, or about 1.1 mm, per notebook). This was a little less than half the length per notebook used in Experiment 1.

Method

Ten participants (five male, five female, with ages ranging from early 20s to early 60s and including two left-handed males) made notebook selections using a CrossPadXP2 loaded with beta-level firmware and containing 20 notebooks. Participants were to make four selections each, with one target close to the top of the list, one in the middle of the list, one close to the bottom of the list, and the last notebook in the list.

When users put together their personal lists of notebook names, they will have some idea about whether a specific notebook is high, medium, or low in the list. For this reason, the organization of notebook names was alphabetical, and participants received a paper copy of the list to simulate the knowledge they would likely have about personally created lists.

Results

All participants made all selections correctly -- acquiring the designated target and leaving it in place when lifting off the pen.

In using the slot, none of the participants ever missed putting the pen directly in the slot, and all ink was contained in the slot.

When asked, all participants reported that notebook selection was easy.

EXPERIMENT 3: PAGE SELECTION

Purpose

Following the success of the initial experiments and the use of the slot in CrossPads, the IBM TransNote with ThinkScribe[2] digital notepad (essentially a CrossPad combined with a subnotebook computer in a portfolio form factor to enable automatic synchronization of the devices – see Figure 6) used selection slots for a number of purposes beyond the selection of notebooks, including the selection of actions such as keywords and to-dos, and page numbers (up to 55 pages in the initial release). For a recent review of the TransNote, see Blickenstorfer (2002).

Figure 6. The IBM TransNote with ThinkScribe

The purpose of this experiment was to investigate the possibility of increasing the number of slot-selectable pages to 99 without increasing the length of the page selection slot. Doing so would provide only 0.74 mm per page, however, making this the most sensitive slot selection control yet investigated. On the other hand, failure to increase the sensitivity of the slot would mean that users would have to repeatedly tap the single-page advance control (a dimple under the selection slot) to reach notebook pages numbered higher than 55 – something that we anticipated would be very unpopular with users.

[2] IBM, TransNote, and ThinkScribe are trademarks or registered trademarks of International Business Machines Corp. The TransNote has been discontinued.

Method

The participants were eight males and eight females, with half of each gender group over and under 40 years of age. One male was left-handed.

Participants selected four target pages (pages 25, 50, 75 and 95) using two TransNotes. The ThinkScribe of one TransNote had firmware setting the maximum number of slot-selectable pages to 55. The other had firmware setting the maximum number of slot-selectable pages to 99. Half of the participants made their selections with the 55-page version first and half used the 99-page version first.

Procedure

After receiving brief instructions regarding the purpose of the experiment and the operation of the slots, participants selected their target pages using the systems in the order indicated in the experimental design. The measure of accuracy was the difference in the number of pages between the actual selection and the target. If a participant did not select the correct target, he or she used the single-page advance or single-page return controls to adjust the initial selection. Participants used the single-page advance control to acquire target pages greater than 55 when using the 55-page selection slot. After making all eight selections (four selections with each system), participants stated which version they preferred using.

Results

Overall accuracy. The average absolute difference between actual selection and the target with 55 pages in the slot was 0.2 pages. 86% of these selections had no deviation from the target; 97% deviated by no more than one page. With 99 pages, the average absolute difference between actual selection and the target was 0.4 pages. 75% of these selections had no deviation from the target; 92% deviated by no more than one page. The difference between the mean deviations was of marginal statistical significance ($t(15) = 2.03$, $p = .06$), but of very small magnitude (0.2 pages). Analysis of variance indicated no significant effects

of gender, age, or order of use of the two ThinkScribes (all $p > .10$).

Accuracy for targets within the slot. Part of the reason that participants were more accurate in selecting pages with the 55-page slot was that their selection accuracy was perfect when selecting pages greater than 55 using the page-advance control. Restricting the data analysis to those target pages that were within the limits of the slots on both ThinkScribes (target pages 25 and 50) revealed that their within-slot selection accuracies were not significantly different ($t(15) = .324$, $p = .75$), with average deviations of 0.38 pages for the 55-page slot and 0.34 pages for the 99-page slot (a difference of only 0.04 pages).

Preference. All 16 participants indicated that they preferred using the 99-page slot for page selection. The primary reason for this preference was the inconvenience of using the single-page advance control to acquire higher-numbered pages on the ThinkScribe with the 55-page slot. With a sample size of 16 participants and unanimous preference, the lower limit of a 90% binomial confidence interval for percentage of users preferring the 99-page selection slot is 83%. In other words, the data allow 90% confidence that the true percentage of users who would prefer the 99-page selection slot should be no less than 83%, and is most likely closer to 100% (the observed percentage).

DISCUSSION

At 1.1 mm per option (Experiment 2), participants had perfect selection performance with selection slots. With as little as .74 mm per option (Experiment 3), selection accuracy was still very high, and was perceived as preferable to using a combination of a selection slot plus single-option advance controls. The selection slot seemed to work very well as a selection control for the CrossPad and TransNote products.

There are two important design elements for pen selection slots beyond the elements explored in these experiments. First, it is important to ensure that the width of the slots can easily accept the largest pen tip that people can use with the slot – not just the fine tip (a point that caught us by surprise the first time we put a broad tip in a test pen). Second, the ends of the slot must be vertical so users can move the pen rapidly from one end to the other without having the pen tip slip out of the slot. One of our earlier prototypes had a more visually appealing, gradual slope at the ends of the slot, but the problems of this design became apparent upon first use when a rapid pen movement in the slot sent the pen skittering out of the slot and across the test ThinkScribe.

It is possible that future pen-based computers might take advantage of pen selection slots, although not necessarily with the same underlying technology as that used in CrossPads and TransNotes. Slots have an advantage over unconstrained manipulation of on-screen elements (such as a scroll bar) with a stylus because the slot holds the tip of the pen or stylus, allowing very rapid one-dimensional movement in the slot. With careful attention to design (using the information provided in this paper), selection accuracy with selection slots can be very high and can produce a very satisfying user experience.

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