A COMPARISON OF DIRECT-MANIPULATION, SELECTION, AND DATA-ENTRY TECHNIQUES FOR REORDERING FIELDS IN A TABLE

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A useful feature of data base systems is to allow the user to change the order in which fields appear in the columns of a table. The purpose of this study was to compare the usability of seven different user interfaces for performing this task in the Microsoft Windows environment. The fields to be reordered were file name, file number, size, and creation date. The seven approaches studied covered a range of interaction styles, including dragging and dropping, menu selection, text entry, and button pressing. Fifteen Windows users completed a set of two practice trials using each approach, followed by a set of twelve main trials. For each trial, the user was shown the current order of the fields and a target order to change to. The completion times showed significant differences according to the approach used. Overall, a data-selection technique using radio buttons and a data-entry technique using a single entry area were significantly faster than all of the others. Another data-entry technique, involving multiple entry areas, was consistently the slowest. Somewhat surprisingly, given the current trend toward direct-manipulation interfaces, the two approaches involving dragging and dropping were not among the most effective approaches.

INTRODUCTION

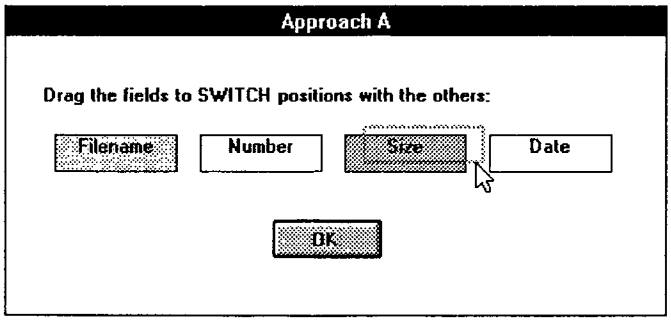
A common type of display in many computer systems is a table that shows values of several different properties for a list of files. In designing such a display for a forthcoming product, we thought it would be helpful to allow the user to change the order in which the fields appear in the columns of the table. The specific fields that the user could reorder were file name, file number, size, and creation date. In a brainstorming session we generated seven alternative user interfaces for allowing a user to reorder these fields in the Microsoft Windows environment. The approaches represented several different user interface styles, including direct manipulation (using dragging and dropping), menu selection, button-pressing, and text entry. The primary goal of this study was to determine which techniques are the easiest to learn and use, and which are the most preferred.

Several previous studies have compared the effectiveness of alternative user interface designs for performing a particular task. For example, Whiteside, Jones, Levy, and Wixon (1985) had subjects complete a series of file manipulation tasks to compare the usability of seven systems representing command, menu, and iconic interface styles. Usability differences were obtained within style types; thus, performance was affected more by style than design. Interface comparisons have also been made between text entry and keyboard selection methods of entering dates (Gould, Boies, Meluson, Rasamny, and Vosburg, 1989) and airline reservations (Green, Gould, Boies, Meluson, and Rasamny, 1988). Both studies found that text methods were more efficient and preferred over selection methods.

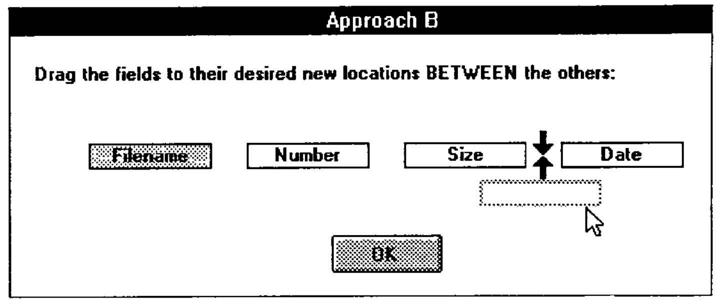
In lieu of usability testing, designers often rely on guidelines derived from models to make interface design decisions. The GOMS model and the Keystroke-Level Model (Card, Moran and Newell, 1983) are such tools that describe the user's cognitive structure in completing a given computer task. Both models include a rudimentary analysis of the physical operations of an interface. Specifically, Card et al. (1983) demonstrated that a linear relationship exists between the minimum number of required keystrokes and execution time for a text editing task. Similar results have been obtained for the entry of dates (Gould et al. 1989) and airline reservations via keyboard selection (Green et al. 1988). A secondary aim of the current study was to determine whether the results obtained could be predicted by the Keystroke-Level model.

APPROACHES STUDIED

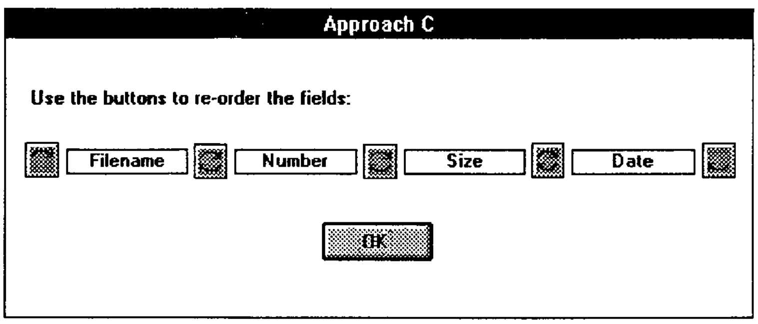
The seven approaches studied are illustrated in Figure 1. Two of the approaches involved direct manipulation; the user reordered the fields by dragging and dropping them using the mouse. In



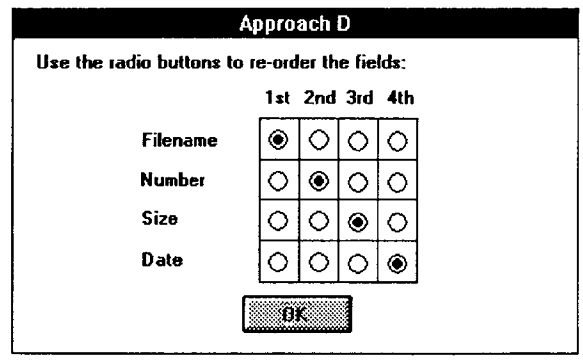
"Drag and Drop On" approach.



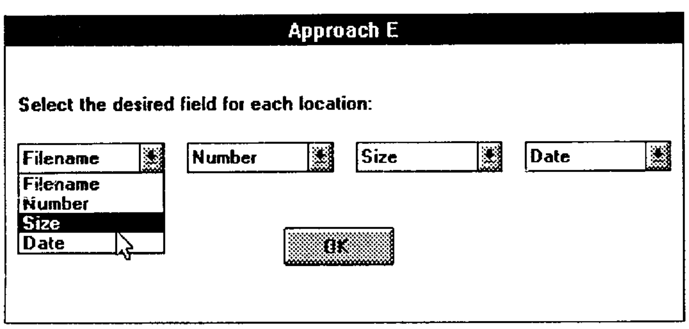
"Drag and Drop Between" approach.



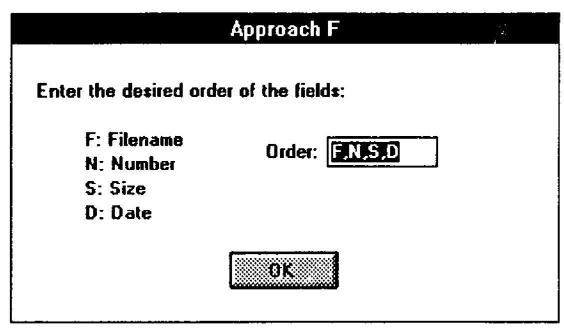
"Icons" approach.



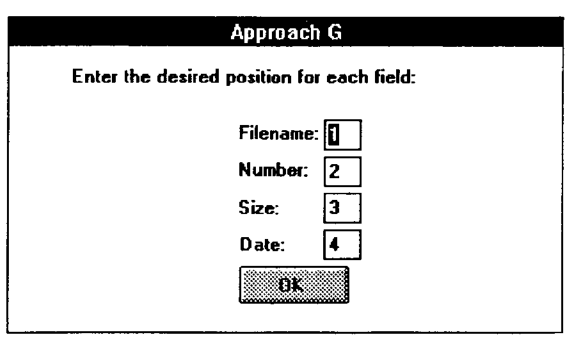
"Radio Buttons" approach.



"Menus" approach.



"One Entry Area" approach.



"Four Entry Areas" approach.

Figure 1. Seven alternative user interfaces were designed in the Microsoft Windows environment to represent possible approaches for allowing a user to redefine the order in which four fields appear in the columns of a table. Each approach was used by fifteen experienced Windows users to perform a set of twelve reordering tasks.

the "Drag/Drop On" approach, the user could only drop a field **on top of** another field, causing those two fields to switch positions. In the "Drag/Drop Between" approach, the user could only drop a field **between** two other fields (or at the beginning or end of the series), causing the fields to reorder accordingly. In both approaches, when a field was being dragged, dynamic highlighting (colors and/or arrows) showed where it could be dropped (as indicated in the examples shown in Figure 1).

In the "Icons" approach, pressing an iconic button between the fields caused the two fields on either side of it to switch positions. Icons at the ends of the series caused the two end fields to switch positions.

The "Radio Buttons" approach used a two-dimensional array of radio buttons. For each field, the user could simply click on its desired ordinal position in the table. Selecting a new position for one field forced another field to move to the position just vacated.

The "Menus" approach used pop-up menus (also called "combo boxes") for each of the four positions in the table. The user first pulled the desired menu down by selecting the down-arrow icon to the right of the field. Selecting a different field name from the resulting menu then caused that field to move to the current position and the field that was in the current position to move to the vacated position.

The "One Entry Area" approach used a single data-entry area for the user to type the first letter of each field in the desired order, including spaces or commas between the letters (e.g., "N,S,F,D"). The entry was not case-sensitive.

The "Four Entry Areas" approach also used data-entry, but provided separate data-entry areas for each field. The user typed "1", "2", "3", or "4" in each of these areas to designate the desired position for that field.

METHOD

Fifteen people experienced with Microsoft Windows participated in the study. They were given no instructions on using the approaches. They began with a set of practice trials in which they performed two reorderings using each of the seven approaches. Next, they completed a set of main trials which consisted of twelve reordering tasks using each approach. The order of presentation of the seven approaches was randomly determined for each user. For each reordering, the user was shown the current order and the target order to change to. Each reordering involved changing the positions of 2, 3, or 4 fields. Time and accuracy data were automatically recorded. After using all seven approaches, the users were asked to rank order them from best to worst.

Predictions for the minimum keystroke/mouse event analysis were determined by identifying, for each trial, the reordering strategy that required the fewest physical actions for each approach. Each required keystroke (e.g., letter, tab key, enter key) and each mouse point and click event (e.g., on an iconic button) were counted as single actions. A mouse drag-and-drop operation was counted as two actions (selecting the target item and releasing it at its new location).

RESULTS

The time data from the practice trials was used as an indication of the amount of difficulty users had in learning to use each approach. These mean learning times for each approach are shown in Figure 2. The main effect of approach was significant, $F(6,78) = 4.90$, $p<.01$. Comparisons of means using Duncan's Multiple Range Test ($\alpha=.05$) showed that "Drag/Drop Between" took significantly more time to learn than all of the other approaches except for "Icons" and "Four Entry Areas". On the other hand, "Radio Buttons" took significantly less time to learn than "Drag/Drop Between", "Icons", and "Four Entry Areas".

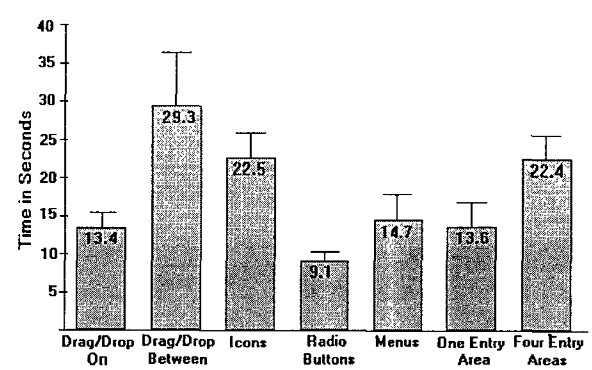


Figure 2. Mean learning times. Data are based on two practice reordering trials. Subjects were given no instructions on how to use the approaches. Error bars represent one standard error of the mean.

Analysis of the main trial data showed no significant differences in the number of errors made using the various approaches. However, analysis of the time data showed significant main effects of approach, $F(6,84) = 26.85$, $p<.01$, number of fields to be reordered, $F(2,28) = 92.85$, $p<.01$, and the interaction between those two factors, $F(12,168) = 4.84$, $p<.01$. These results are illustrated in Figure 3.

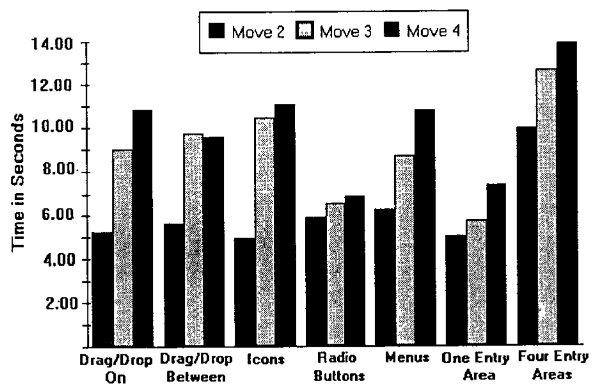


Figure 3. Mean completion times as a function of approach and number of fields to be moved. For each trial, users were required to change the position of either 2, 3, or 4 fields to attain the target order.

Comparisons of means showed that, overall, "Radio Buttons" and "One Entry Area" were significantly faster to use than all the others, while "Four Entry Areas" was significantly slower. However, when only two fields had to be moved, all of the approaches except for "Four Entry Areas" were equally fast. When three or four fields had to be moved, "Radio Buttons" and "One Entry Area" were significantly faster than all the others while "Four Entry Areas continued to be significantly slower than all the others. Interestingly, "Radio Buttons" was the only approach where the number of fields to be moved did not have a significant effect on time.

Analysis of the subjective ranking data, illustrated in Figure 4, showed a significant main effect of approach, $F(6,84) = 3.94$, $p<.01$. Comparisons of means showed that "Radio Buttons", "Menus", and "One Entry Area" were significantly preferred over "Four Entry Areas" and "Icons", while the two Drag/Drop approaches came out in the middle. The data were also analyzed to de-

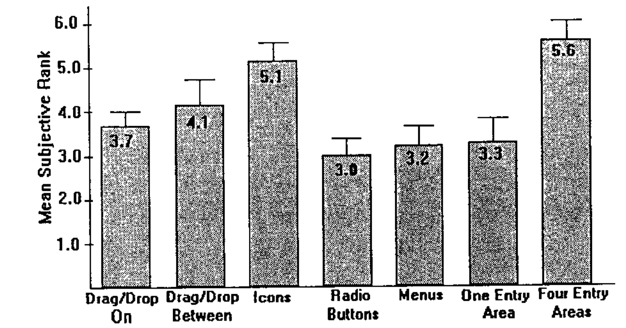


Figure 4. Mean subjective rank given to each approach. Subjects ordered the seven approaches according to preference. A rank of "1" represented the most preferred and "7" the least preferred. Error bars represent one standard error of the mean.

termine whether a relationship existed between the time data and the subjective rankings. A comparison of the mean time data and the mean ranking data yielded a relatively high correlation (r=.85).

Each approach was also analyzed to determine how accurately the time data could be predicted based on the minimum number of physical operators (keystrokes and/or mouse events) required to accomplish the task. As shown in Figure 5, the overall correlation was low (r=.08), primarily because of the large prediction error associated with the "One Entry Area" approach. The analysis predicted that either "Icons" or "Radio Buttons" would yield the fastest times while "One Entry Area" would yield the slowest time. Consistent with the prediction, "Radio Buttons" was, in fact, one of the fastest approaches, but, contrary to the prediction, "One Entry Area" was just as fast.

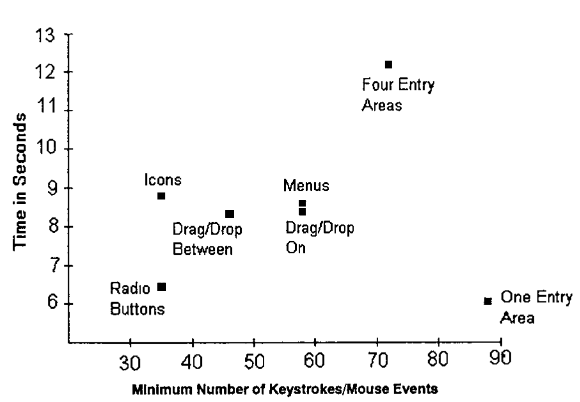


Figure 5. Correlation between the minimum number of keystrokes or mouse events and mean completion times for each approach, r=.08.

CONCLUSIONS

The analyses performed on the practice data, time data, and subjective data indicate that "Radio Buttons" and "One Entry Area" are the best of the seven approaches studied for this reordering task. In addition, "Radio Buttons" was affected least by the number of fields to be moved.

The failure of the minimum keystroke/mouse event analysis to accurately predict the time data for the "One Entry Area" approach may be attributable to a difference in the mental preparation required when using this approach. When using the "One Entry Area" approach, subjects typed the required letters and commas (e.g., "f,s,d,n") as a single string. The Keystroke-Level Model asserts that when more than one physical operator (keystroke) comprises a syntactic unit, little mental preparation precedes each physical event, and thus execution time is reduced (Card et al. 1983). In all of the other approaches, two mental operations were required to reposition a field. First, users had to identify/locate the target field; second, they had to identify/locate the target position.

The results of this study imply that decisions based on guidelines, convention, and intuition may not always yield the most effective interface design. For example, the increasing popularity of mouse-based systems has caused a trend toward more direct-manipulation interface designs, including extensive use of dragging and dropping. Contrary to this trend, we found that the dragging and dropping approaches studied here were not among the most effective user interfaces for this particular task. Other experiments and usability tests are needed to modify guidelines as they pertain to well defined tasks such as the reordering task studied here.

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