A Comparison of Selection Times from Walking and Pull-Down Menus

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ABSTRACT
This paper reports on an experiment that investigated factors which effect selection time from walking menus and bar or pull-down menus. The primary focus was on the use of impenetrable borders and on expanding target areas on the two menus types. The results show that both factors can be used to facilitate menu selection, with the use of borders being most beneficial. In addition, the results suggest that even on large monitors, the time required to access items from a bar menu is less than that required for the best walking menu.

KEYWORDS: Motor Movement, Menu Selection, Mouse movement.

INTRODUCTION
This experiment had two major purposes. The first purpose was to combine the findings of our earlier work [2] to try to create an optimized walking menu. The second major purpose of this experiment was to compare movement times for a walking menu that pops-up at the location of the pointer to those for a pull-down menu located at the top of the screen.

Fittsizing Menus
Our earlier work [2] investigated motor movement in selecting from walking or cascading menus that pop-up at the current cursor location. In three studies, we investigated the factors which determined the speed and accuracy of motor movement when selecting from a walking menu. We found evidence that when accessing a walking menu, users tended to move diagonally, from the initial location of the pointer to the activation area of the desired first-level item. In doing this, users made more selection errors depending on the distance the pointer had to travel. For example, when moving to the top item on a menu (with the cursor starting to the left of the middle menu item) users incorrectly accessed the second-level menu 15% of the time. Our experiment suggested that this was due to the narrowness of the path that the pointer must travel to access the menu, as the number of incorrectly accessed menus increased with the distance from starting pointer location to the target menu item. This strongly suggests that selection time (and selection errors) from a walking menu can be reduced by expanding the size of menu items in relation to their distance from the starting location of the cursor.

Expanding the size of the target area, depending on the distance from the starting location will be referred to as *fittsizing*. By *fittsizing*, we mean that the size of the target area in the menu was increased in relation to the distance of the target area from the initial position of the pointer. For example, in a nine-item walking menu the pointer will begin to the left of the fifth menu item. This item is size 1. If the fittsizing factor is 1.2, then items six and four will both be 1.2 in size (or 20% larger than menu item 5), items seven and three, 1.44 in size, and so on (see Figure 1). Increasing the size of an item proportional to the distance from the initial pointer condition reduces the index of difficulty. The savings in movement time associated with this proportional increase in target size with distance are predicted by Fitts' law [1] to be small in relation to the total movement time. However, increasing the size of the menu items also increases the path width. As suggested by our earlier work, this should result in a small, significant savings in movement times with walking menus.

Impenetrable Borders
Our previous work also investigated the use of impenetrable borders on targets to reduce movement time. We found that when a target was backed by an impenetrable border, movement time to a target was greatly reduce. In relation to Fitts' law, the use of impenetrable borders seems to effectively reduce the index of difficulty, as the user can make one long ballistic movement without the fear of overshooting the target. This basically eliminated the need for corrective submovements. Based on the these results, we calculated that menus that maximize the number of items that are backed by a border will require less movement time for selection. In this study we will compare selection times for walking menus that pop-up at the current cursor location to bar menus that are located at the top of the screen. The use of borders on these two menu types will be varied.

Walking Menus vs. Pull-Down Menus

The final major comparison made in this experiment was between walking menus and a pull-down or bar menu. Recently, several system developers (e.g., The Sun Microsystems Open Look) have announced that their systems will make use of menus that pop-up at the current pointer location. The assumption behind this design decision is that pop-up menus will eliminate the need for a large initial movement to the bar at the top of the screen or window. However, as the top of the screen serves as an impenetrable border to pull-down menus, this initial movement may not require as much time as the initial movement in a walking menu. In addition, the movement required to access the correct second-level menu in a pull-down menu does not require a movement along a narrow path as does movement in a walking menu. These two factors combine to suggest that the average time to the correct second-level menus will be shorter for pull-down menus than for walking menus that pop-up at the current pointer location.

Hypotheses:

1) Movement times will be less for menus that are fittsized than for menus that are not fittsized.
2) Movement time will be less for menus with borders than for menus without borders.
3) Time to the correct second-level menu will be shorter for pull-down menus than for walking menus.

METHODS

Subjects

Ninety-six students at the University of Michigan were recruited for participation in the study. All students had experience using a mouse, although none had experience using walking menus. The students were paid $8 for participation in the study. Each student was randomly assigned to one of the eight experimental conditions.

Design

The experiment employed a factorial, mixed design. The between-subjects variables were fittsizing (equal or expanding target sizes), border, and menu type (walking or pull-down). The within-subjects variables were cue (cued, uncued) and blocks of trials (5 blocks per subject), with cue nested within blocks. This resulted in eight experimental conditions. Cue was again used to make the results of this experiment more generalizable, and was collapsed for the analyses.

Materials and Apparatus

The program for this experiment ran on the same equipment as the earlier experiments [2]. The program also recorded button presses and menu selections.

The walking menus were designed so that the first-level menu had nine selection areas (no title was used) each of which had a second-level menu. All of the second-level menus also had nine selection areas. The menus were drawn with each selection area on the menu being three centimeters wide and 7.8 millimeters high, with selection areas separated by a horizontal line (see Figure 1). This resulted in an overall menu length of seven centimeters. Second-level menus were activated when the pointer was moved into the activation area on the first-level menu. This activation area was the last 7 millimeters of the far right of each selection area. The width of the activation area remained constant across all menus. The activation area was marked by an arrow that began at the beginning x-coordinate of the activation area and was centered on the y-coordinates of the activation area.

The menus used for cued and uncued trials differed in the information placed on the menu (See Figure 1 below).

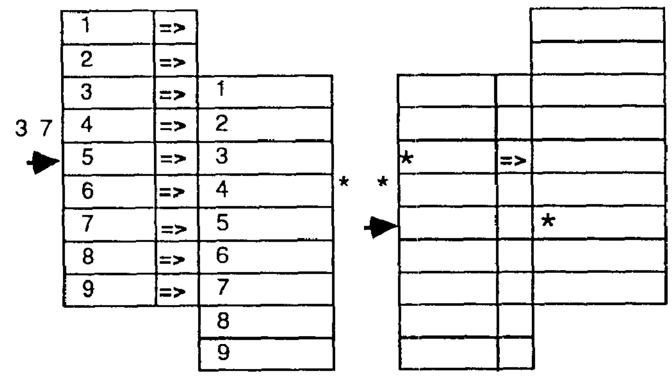

Figure 1: Cued and Uncued Walking Menus

Cued menus had numbers and were used to simulate an experienced user selecting a menu item from a known location. The uncued menus had asterisks identifying the target items, allowing us to test motor movement time without prior knowledge of target location. Both of these conditions reflected our decision to use menus with low levels of visual information. We made the decision for two reasons: First, it eliminated the need for subjects to learn the location of commands in the system. Second, it eliminated most of the visual processing demands normally found in a menu selection task, allowing a more robust test of the effect of the independent variables on motor movement.

When the walking menus were in the fittsized condition, the center item of the menu (number 5) was the same size as that of the non-fittsized menu. Each item from the center was increased by a factor of 1.2 in vertical size.

The pull-down menus also used a 9 by 9 design. That is, there were nine menu titles displayed across the top of the screen and each second-level (pulled-down) menu had nine items. For pull-down menus, each menu item was 2.9 centimeters wide and 0.78 centimeters high. As with the walking menus, in the fittsized condition the vertical height of each subsequent item changed by a factor of 1.2. This increment provided the largest increase that still allowed the nine-item pull-down menu to be displayed on the monitor. The pull-down menu was placed at the top of the screen and the menu titles were constantly displayed during the experiment. This menu is similar to those presented by Macintosh software, such as Microsoft Word.

Procedure

At the start of the experiment, students were told that the experiment was investigating the speed and accuracy of selections from different types of menus. The students were then shown a demonstration of the menu type that they were to use. Each student proceeded through 5 blocks of selection trials. Each block of trials consisted of 64 selections, 32 from each cue type. The 32 selections of each cue condition were based on two practice trials, where the student was given a randomly selected target from any of the 81 possible menu items. The other 30 test trials consisted of two selections of 15 menu items. These items were from first-level menus 1, 3, 5, 7, and 9. From each of these menus, subjects were asked to select items 1, 5, or 9 of the second-level menu.

For students using pull-down menus, each trial began when the start box was presented on the screen. The student placed the pointer in the box and pressed and held the mouse button. The start box was located 15 centimeters below the bottom of the menu bar, approximately half of the vertical distance of a 19-inch diagonal screen. This distance is most similar to pull-down menus located at the top of the screen of a system with a large screen. The start box was centered under the fifth item of the pull-down menu. As with the walking menu program, timing began when the student pressed the button in the start box and continued until the button was released. The only difference between the selection procedures of this program and those used on a Macintosh is that the button had to be held down while the mouse was being moved to the menu bar.

RESULTS

The results of this experiment will be presented in two parts. The first part shows results based on average movement times in the first-level menus and the second-level menus for both walking and pull-down menus. This set of analyses, while providing for a comparison of menu types, does not provide a completely balanced test of the hypotheses because not all menu items are selected by the subject. Some overall comparisons of average movement times are therefore biased. For example, borders in walking menus are only on items 1 and 9, and these items are selected by the subjects. The even-numbered items of the walking menus (on which borders cannot be placed) are never selected by the subjects. Because of this, the second part of the results will look at time to the correct second-level menu and time within the second-level menu for each menu item individually. This set of analyses will allow for tests of the effects of fittsizing and borders.

The mean of each subject's total movement times for correct trials was calculated for the distances in each block of trials. These means were then analyzed by a blocks (5) by menu (2) by borders (2) by fittsizing (2) analysis of variance to determine when the students' movement times reached asymptote. The main effect of trials was followed up with a Tukey (HSD) comparison test that showed that the last two blocks did not significantly differ from each other. The averages from these two blocks were then used for all later analyses.

Total movement time was broken into two subcomponent times, time to the correct second-level menu and time within the second-level menu. Average times were calculated for each subject based on the final two blocks of trials. These means were then used for a series of 3-way analyses of variance (border by fittsizing by menu).

Time to the Correct Second-Level Menu

The analysis of variance on the mean time to the correct second-level menu revealed one significant main effect of menu ($F=49.17$, 1/88 **df.**, $p < .001$). Pull-down menus had significantly shorter movement times to the correct second-level menu (mean = 730 msec.) than did the walking menus (mean = 947 msec.). A key point to note is that, even with optimized walking menus, time to correct second-level menu was shorter for pull-down menus. The main effects of border and fittsizing and the interaction terms were not significant.

Time in the Second-Level Menu

The analysis of variance on time in the second-level menu yielded significant main effects of border ($F=4.65$, 1/88 **df.**, $p < .05$) and menu ($F=16.68$, 1/88 **df.**, $p < .001$). As expected, menus with borders had shorter movement times (mean = 792 msec.) than did menus without borders (mean = 844 msec.). Walking menus had shorter movement times (mean = 771 msec.) than did pull-down menus (mean = 864 msec.). A key point to remember in interpreting the main effect of menu type is that borders were on two of the three menu items of the walking menus and only on one of three items of the pull-down menus.

While the above analyses provide some confirmation for the second and third hypotheses, they do not provide a complete analysis of the effectiveness of borders and fittsizing on speed and accuracy of motor movement. This is because the effects of borders and fittsizing do not apply equally to all menu types and movements. Another set of analyses were performed that compared movement times to individual menu items. In these analyses the effects of fittsizing and providing borders could be more accurately assessed (See Table 1 for means).

Additional analyses were performed to test further the effect of borders on movement time. First, two two-way analyses of variance were performed on the selection times from walking menus. In these analyses, menu item (positions 1 and 9) and border (border and no border) were the independent variables. The dependent variables were the average correct selection times from the first- and second-level menus. The analysis of movement time in the first-level menus revealed a significant effect of border ($F=12.95$, 1/88 **df.**, $p < .001$). As in the earlier analysis, the movement time in the borders condition (mean = 921 msec.) was shorter than in the no borders condition (mean = 1035 msec.). In addition, the analysis of movement time in the second-level menu also revealed a significant main effect of border condition (F=28.60, 1/88 **df**, p<.001) and a significant main effect of item (F=8.30, 1/88 **df**, p < .01). As predicted, the mean movement time in the second-level menu was shorter in the border condition (mean = 813 msec.) than in the no border condition (mean = 960 msec.). The main effect of menu item revealed that movement times were shorter to menu item 1 (mean = 847 msec) than to menu item 9 (mean = 926 msec.). Combined, these results provide strong support for the hypothesis that the use of borders will significantly decrease movement time.

Table 1

Observed Movement Times in First- and Second-Level Menus for the Eight Menu Types by Menu Item

Time to the Correct Second-Level Menu

	Walking Menu				Pull-Down Menu
	No Borders		Borders		All Conditions
Position	Regular	Fittsized	Regular	Fittsized	
1	1075	994	946	897	643
3	1116	989	1088	1019	776
5	678	643	649	664	729
7	1103	979	1159	1028	768
9	1083	987	931	905	732

Time in the Second-Level Menu

	Walking Menu				Pull-Down Menu			
	No Borders		Borders		No Borders		Borders	
Position	Regular	Fittsized	Regular	Fittsized	Regular	Fittsized	Regular	Fittsized
1	942	893	775	778	673	677	734	695
5	441	558	524	643	946	937	1013	868
9	1020	983	830	868	1015	1045	922	842

Four additional analyses were performed to test further the effect of fittsizing on movement time. First, three two-way analyses of variance were performed with fittsizing and menu item (items 1,3,7,9 for first-level menus, and items 1 and 9 for second-level menus) as the independent variables. The dependent variables were time in the first-level menu, time in the second-level menu, and average number of wrong second-level menus accessed. For all three of the analyses, means were calculated based only on times from the no border, walking menu condition. Only the analysis on time to the correct second-level menu revealed any significant differences. This analysis revealed a significant main effect of fittsizing (F = 8.59, 1/88 **df**., p < .01). The mean time to correct second-level menu (for items 1,3,7,9) was shorter in the fittsized menus (mean = 987 msec.) than in the regular menu (mean = 1094 msec.). Finally, a fittsizing by menu item (items 5 and 9) analysis of variance was performed on time in the second-level menu for pull-down menus with means collapsed across border conditions. While this analysis failed to reveal a significant effect of fittsizing on movement time, the means were in the predicted direction.

DISCUSSION

The most important finding of this study is that borders can be used to drastically reduce movement times within menus. As shown by the overall selection times and by the analyses of specific menu items, the use of borders on menus does change the index of difficulty by making the functional size of the target very large. This finding is also supported by the overall shorter times to the correct second-level menus with pull-down menus. These results strongly suggest that menu designs that maximize the use of borders will require less time for menu item selection.

The second finding of this experiment is the small, but generally consistent effect of fittsizing on reduction in movement time resulting from fittsizing. The observed savings in movement time due to fittsizing were small, but they were in line with predictions based on Fitts' law.

The final point of interest was that the superiority of first-level menu selection times for pull-down menus were shorter than over those for the walking menus, even those walking menus with the shortest movement times. The average 217 millisecond overall advantage found in this study is, in fact, an under-estimate of the advantage of pull-down menus. In this experiment, users only selected the odd numbered items from the first-level menu. For walking menus, borders can only be used on the top and bottom items, while in the pull-down menu all items can menu titles have a border. Therefore, if we had collected movement times for all first-level menu items, the overall advantage of pull-down menus would have been even greater. This is important for the design of menu-based interfaces for programs used on workstations or other machines that have large monitors. The common assumption (based upon the current prevalence of pop-up menus on workstations) seems to be that menus placed along the top or side of the screen are inefficient due to the long initial movement. In this study the initial movement was approximately six vertical inches. This is larger than the average vertical distance that would be required on a system with a 19-inch diagonal screen, but, with a border, the movement times are less than those of the walking menus.

Another factor that would further increase the advantage of menus arranged along the edge of a screen (so that each item has a border) is the use of what has been called a "turbo" mouse program. These programs are written so that when a certain speed is reached and maintained for a period of time, the gain between the mouse and pointer movement increases. The distance the mouse has to be moved to make the pointer move therefore decreases as mouse speed increases. With the use of a "turbo" mouse program, the time required to make the long movement to the edge of the screen will be even shorter than that found in this experiment. Therefore, the use of a "turbo" mouse will increase the relative selection time advantage of pull-down menus over walking menus found in this experiment.

"Turbo" mouse programs will have less effect on selection time with walking menus because the speed of the pointer will never be as great due to shorter travel distances.

CONCLUSIONS

The findings reported in this paper provide guidelines that should aid designers of menu systems:

1. *Borders are effective in decreasing selection time.* As shown in this paper, impermeable borders effectively eliminate the logarithmic relationship between time and the index of difficulty ratio. Systems that maximize the percentage of menu items with borders will have a decided advantage over other menu systems.

2. *The use of menus that pop-up at the current cursor location will not necessarily lead to reduced motor movement time in menu selection.* In this experiment the initial movement to the pull-down menus was larger that average distance required to reach the top of a 19 inch diagonal screen, yet the pull-downs still significantly outperformed the walking menus. Therefore, it may be more efficient to place menus at the top of the window, backed by an impenetrable border, in multi-tasking computer environments.

3. The results provide some confirmation for our earlier work that suggest that the narrow path required in some movements in selecting from a walking menu hurt performance. There are ways to avoid these movements in menu design. Further work is required before the optimal solution can be found.

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REFERENCES

1. Fitts, P. M. (1954). The information capacity of the human motor system in controlling amplitude of movement. *Journal of Experimental Psychology*, **47**, 381-391.

2. Walker, N., Smelcer, J. B., & Nilsen, E. (Under review). Fitts' law and its design implications: Attempting to optimize speed and accuracy of menu selection.