

Online Appendix to: Two-Handed Marking Menus for Multitouch Devices

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This document contains the full results of the longitudinal study.

A. RESULTS: LONGITUDINAL STUDY

The longitudinal study was performed on the iPod Touch. Summaries of the average times and accuracies for all conditions are shown in Figure 20. We ran separate two-way ANOVAs with the factors menu technique and day on the times and accuracy of each layout.

A.1. 4-2 Menu Layout

Total Time. By day five, the average total time was 805 ms for 1HR and 682 ms for 2HS, reduced from 932 ms and 823 ms respectively on day one. Menu technique ($p = .005$) and day ($p = .009$) had significant effects on total time, but there was no interaction effect ($F_{4,16} = 0.308$, $p = .869$).

Reaction Time. By day five, the average reaction time was 590 ms for 1HR and 533 ms for 2HS, reduced from 552 ms and 633 ms, respectively. The difference between 1HR and 2HS reaction times dropped from 81 ms to 57 ms (29.6%). Menu technique ($p = .012$) and day ($p < .001$) had significant effects on reaction time, but there was no interaction effect ($F_{4,16} = 0.907$, $p = .483$).

Movement Time. By day five, the average movement time was 315 ms for 1HR and 149 ms for 2HS, reduced from 380 ms and 190 ms, respectively. The difference between 1HR and 2HS movement times dropped from 190 ms to 166 ms (12.6%). Menu technique ($p = .001$) had a significant effect on movement time, whereas day did not ($p = .277$). There was no interaction effect ($F_{4,16} = 1.263$, $p = .325$).

Accuracy. By day five, the average accuracy was 98.8% for 1HR and 96.8% for 2HS, increased from 95.2% and 94.8% respectively on day one. The day had a significant effect on accuracy ($p = .195$) whereas the menu technique did not ($p = .195$). There was no interaction effect ($F_{4,16} = 1.758$, $p = .187$).

Stroke Pairs. Figure 21 shows the total time in sorted order for each of the 16 stroke pairs in the 1HR condition (top) and the 2HS condition (bottom). For 2HS, we find that drawing strokes that are bilaterally symmetric or in the same direction (translationally symmetric), is 18% faster on average than drawing the remaining stroke pairs. For 1HR, we find no large difference in total time between groups of stroke pairs, but the pairs in which both strokes are drawn in the same direction are the four fastest.

A.2. 4-4 Menu Layout

Total Time. By day five, the average total time was 1376 ms for 1HR and 1234 ms for 2HS, reduced from 1635 ms and 1559 ms respectively on day one. Menu technique ($p = .008$) and day ($p < .001$) had significant effects on total time, but there was no interaction effect ($F_{4,16} = 0.820$, $p = .531$).

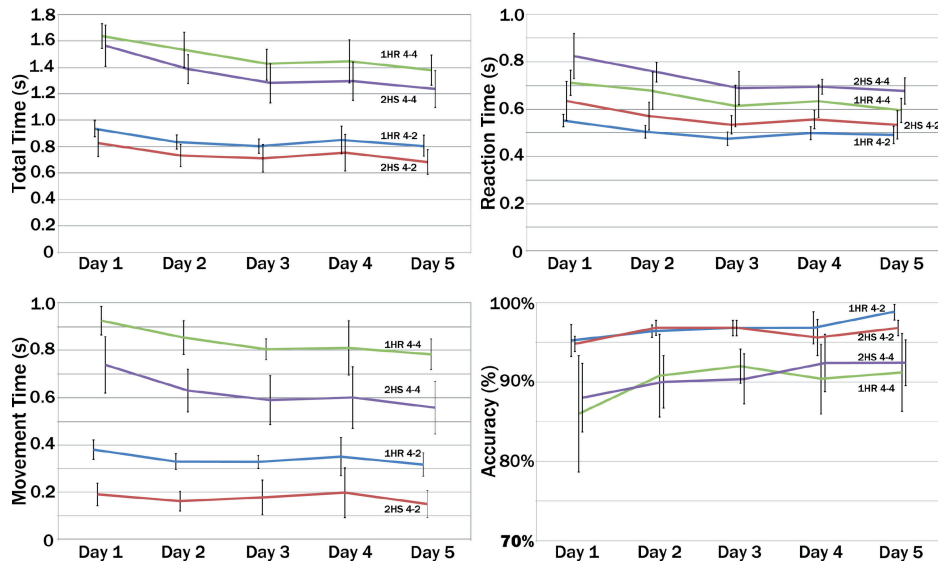


Fig. 20. Average time and accuracy (with 95% confidence intervals) for menu techniques 1HR and 2HS and menu layouts 4-2 and 4-4, across five days. The accuracy graph's baseline value is 70%.

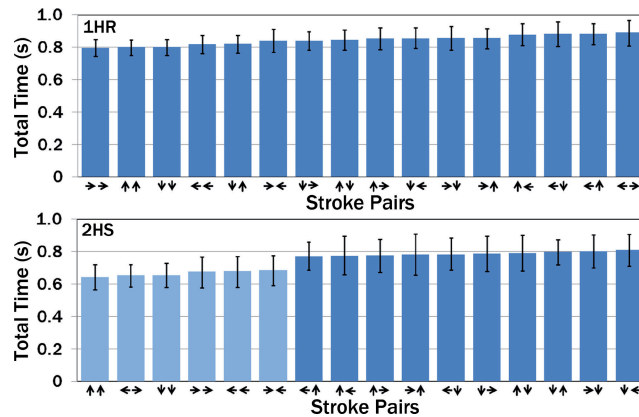


Fig. 21. Average total time (with 95% confidence intervals) per stroke pair for the 4-2 layout. For 2HS, pairs of strokes that are bilaterally symmetric or share the same direction are 18% faster to draw than the other pairs.

Reaction Time. By day five, the average reaction time was 594 ms for 1HR and 676 ms for 2HS, reduced from 711 ms and 822 ms respectively. The difference between 1HR and 2HS reaction times dropped from 111 ms to 82 ms (26.2%). Menu technique ($p = .005$) and day ($p < .001$) had significant effects on reaction time, but there was no interaction effect ($F_{4,16} = 0.484$, $p = .748$).

Movement Time. By day five, the average movement time was 782 ms for 1HR and 557 ms for 2HS, reduced from 924 ms and 737 ms respectively. The difference between 1HR and 2HS movement times dropped from 225 ms to 187 ms (16.9%). Menu technique ($p = .001$) and day ($p < .007$) had significant effects on movement time, but there was no interaction effect ($F_{4,16} = 0.389$, $p = .814$).

Accuracy. By day five, the average accuracy was 91.2% for 1HR and 92.4% for 2HS, increased from 86.0% and 88.0% respectively on day one. Neither menu technique

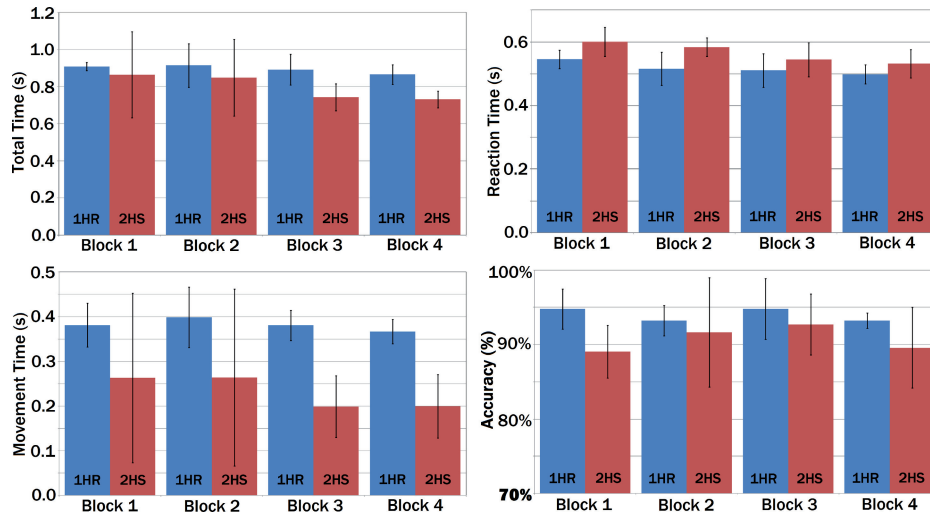


Fig. 22. Average time and accuracy (with 95% confidence interval) for menu techniques 1HR and 2HS and menu layouts 4-2 and 4-4, across five days. The accuracy graph's baseline value is 70%.

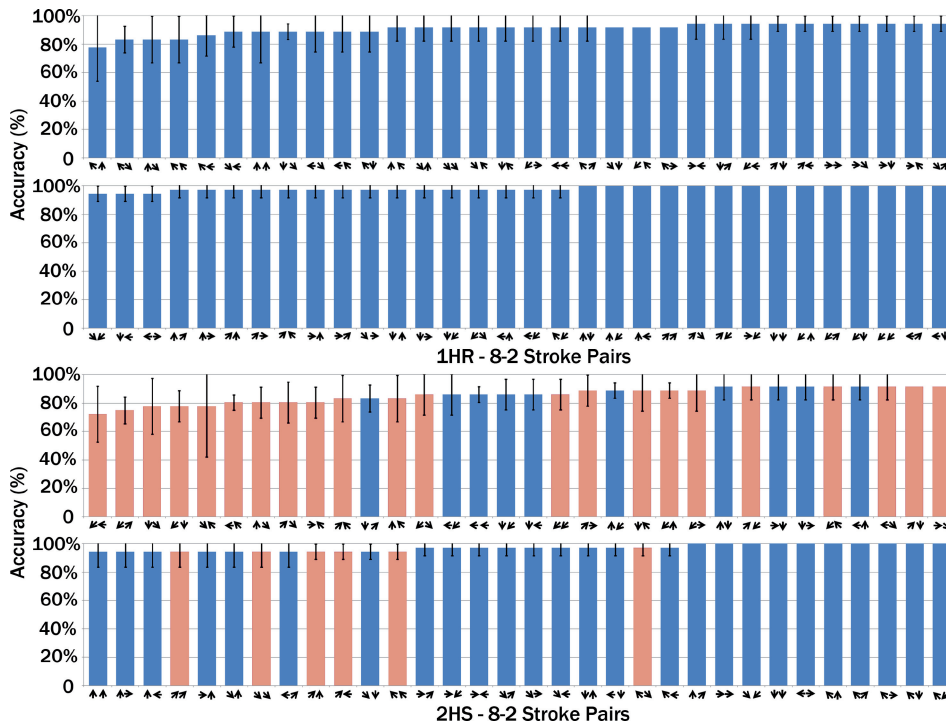


Fig. 23. Average accuracy for all stroke pairs in the 8-2 layout using the 1HR and 2HS technique. For 2HS, the pairs where the left stroke is parallel to the SW-NE axis or the right stroke is parallel to the SE-NW axis are highlighted in orange. Note that confidence intervals have zero radius when all three participants had the same accuracy.

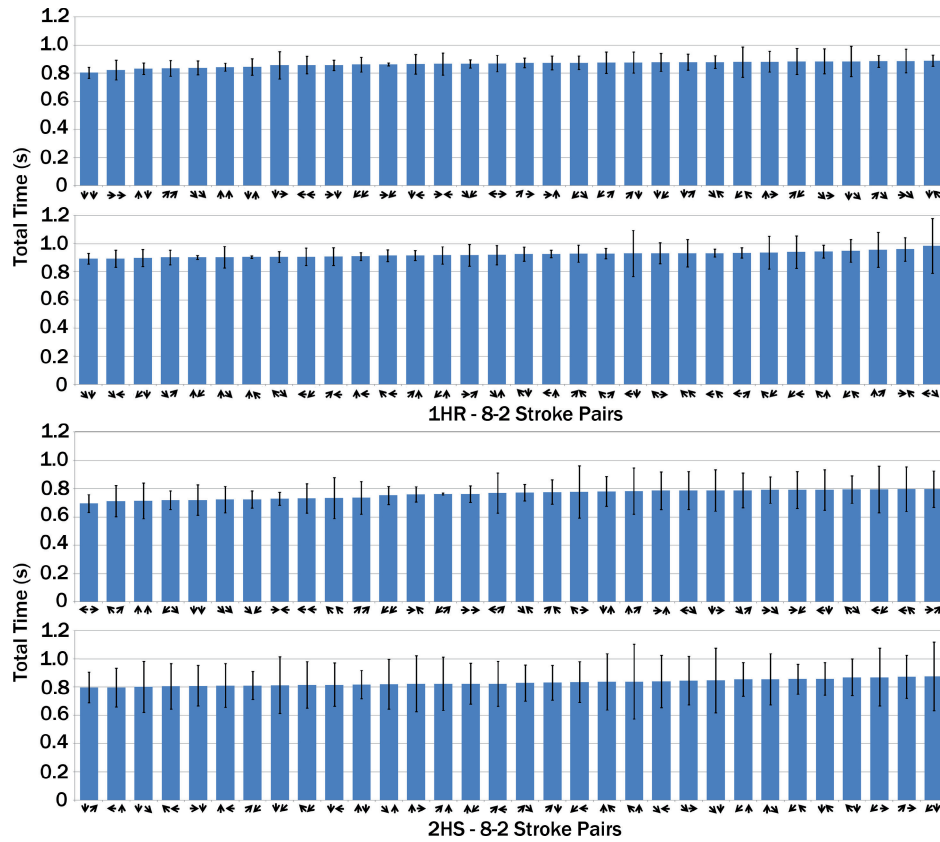


Fig. 24. Average total time (with 95% confidence intervals) for all stroke pairs in the 8-2 layout using the 1HR and 2HS technique.

($p = .774$) nor day ($p = .084$) had a significant effect on accuracy. There was no interaction effect ($F_{4,16} = 0.544$, $p = .706$).

B. RESULTS: LONGITUDINAL STUDY—8-2 MENU LAYOUT

A summary of the results are shown in Figure 22.

For block four, average total time was 864 ms for 1HR and 731 ms for 2HS, reduced from 908 ms and 864 ms respectively for block one.

For block four, average reaction time was 498 ms for 1HR and 531 ms for 2HS, reduced from 527 ms and 232 ms respectively for block one.

For block four, average movement time was 367 ms for 1HR and 200 ms for 2HS, reduced from 381 ms and 264 ms respectively for block one.

The average accuracies for block four, 83.2% ms for 1HR and 89.6% ms for 2HS, were similar to the respective accuracies for block one, 94.8% ms for 1HR and 89.1% for 2HS.

Stroke Pairs. Although 2HS was not quite as accurate as 1HR, examining the individual stroke pairs for 2HS (Figure 23), we found that when the left stroke was parallel to the SW-NE axis or the right stroke was parallel to the SE-NW axis (highlighted in orange) accuracy dropped to 86.6%, while the remaining 36 stroke pairs maintained an accuracy at 95.0%. Just as for the breadth-4 layout, we found that pairs of bilaterally symmetric or same-direction strokes (731 ms) were faster to draw than other pairs (815 ms). The average total time for each stroke pair is shown in Figure 24.