User handedness affects physical discomfort and task performance when using desktop touchscreen.

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ABSTRACT

Objective: The main objective of this study was to examine how the target location and user handedness would influence physical efforts of desktop touchscreen users. **Background:** Desktop touchscreen is not as popular as smaller devices such as smartphones and tablet PCs due to physical efforts to reach the display using entire arm movements. To improve usability and user performance when using desktop touchscreen, quantitative relationships between touch target location and user's task performance and physical efforts need to be investigated. **Method:** Twenty one participants who were grouped into 3 groups by their handedness (left handed, right handed, ambidextrous) participated in a laboratory experiment. Participants repeated reach-and-tap motions on 15 targets that were evenly distributed on a 23" touchscreen display while their hand movements, upper extremity muscle activities and task completion time were measured. **Results:** Results found significantly greater cumulative activity of shoulder muscles when tapping upper and corner targets compared to tapping lower and center targets. Significant differences in the muscle activity and completion time were also found between the three handedness groups, suggesting that user fatigue or discomfort when using desktop touchscreens could vary depending on user's handedness. **Conclusion:** It is suggested that the usability and user comfort of desktop touchscreen can be improved if target location and size is determined based on user handedness. **Application:** Results of this study could be used to develop user interface (UI) design guidelines for large desktop touchscreen interface.

Keywords: touchscreen, touch interface, usability, muscle activity

1. Introduction

Touchscreen interface has been common for most mobile devices such as smartphones and tablet PCs. Despite the growing use of touchscreen interface for computing equipment, large desktop touchscreen interface has been relatively less popular compared to touchscreens in mobile devices due to inevitable physical discomfort or efforts to reach and touch the display with full arm movements (Shin & Zhu, 2011).

In previous research, it has been found that the use of large touchscreen on a desk surface or on the lap could cause larger physical discomforts and efforts compared to when using the computing equipment with traditional data entry devices such as keyboard and mouse. It has also been suggested that the amount of physical discomfort or touch performance could be affected by user's handedness (Shin & Zhu, 2011; Kang and Shin, 2013).

For better user-interface design for large touchscreens, it should be examined how users would interact with the touchscreen depending on target location and their handedness. The main objective of this study was to understand how the location of touch targets and user handedness would influence the amount of physical effort and touch performance by quantifying muscle activities and task completion time. Results of this study could be applied to desktop touchscreen UI improvement by considering the arrangement of touch targets and their size depending on user handedness.

2. Method

Twenty one participants were recruited in three handedness groups by following the scores of Edinburgh Handedness Inventory (Oldfield 1971). Participants who scored below -40 were grouped in the left-handed. Those who recorded above 40 were grouped into the right-handed, and the rest were grouped into the ambidextrous (Table 1). All participants had no difficulties in conducting the reach-and-tap task. Prior to participating in the experiment, each participant provided informed consent on a protocol approved by Institutional Review Board.

Table 1. Participant information (mean, SD).

	#	Age (yrs)	Height (m)	Weight (kg)
All	21	20.2 (1.8)	1.645 (0.076)	59.1 (9.3)
Left-handed	7	20.9 (1.9)	1.616 (0.078)	60.3 (11.2)
Ambi-dextrous	7	19.4 (1.1)	1.652 (0.084)	56.2 (8.2)
Right-handed	7	20.3 (2.2)	1.666 (0.069)	60.8 (8.9)

Experiment was conducted in a quiet laboratory. Computer workstation consisted of a height adjustable table and an office chair. Also 23” multi-touch display (IPS236V, LG Electronics, Korea) and a desktop PC run by the Microsoft Windows 8 were used (Fig. 1). Three-dimensional motion capture system (NaturePoint, Inc., Corvallis, OR, USA) was set to capture participant's arm and hand movements while conducting repetitive reach-and-tap tasks. Reflective markers are attached to upper arm, lower arm and hand to track the participant's upper extremity movement. Surface electromyography (EMG) sensors were attached bilaterally to participant's shoulder, upper arm and forearm to collect muscle activities. Maximum voluntary contraction (MVC) EMG data were obtained for each muscle before data collection.

Each participant conducted tap gestures on fifteen targets equally spaced in three columns and five rows within the screen (Fig.2). Each target was a 20 mm crossed shape (same height and width) and randomly labelled from 1 to 15. Participant's task was to touch each target with a preferred hand when the number is called by the experimenter. The task was repeated twice for each participant.

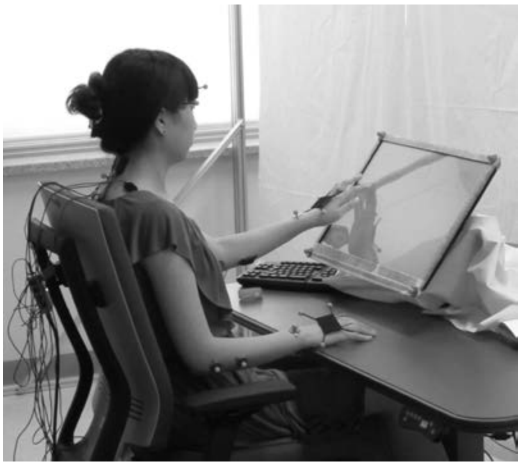

Figure 1. Setup for data collection.

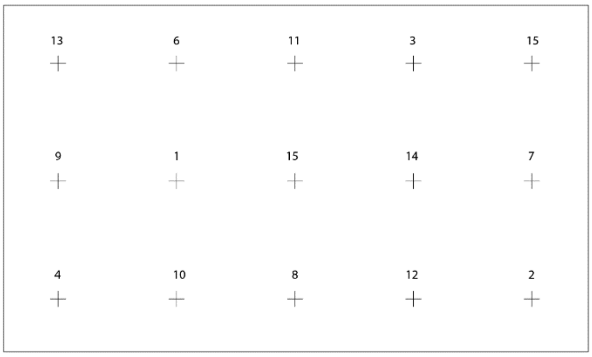

Figure 2. Crossed shape labeled targets with touch marks.

Independent variables of this study was fifteen target locations within the display (3 rows * 5 columns = 15 targets) in three handedness groups. Dependent variables were the cumulative amplitude of EMG of each muscle per target touch and the duration for each tap motion.

3. Results and Discussion

In general, ambidextrous participants produced less cumulative EMG amplitude than other groups, suggesting the frequent switching hands while using the touchscreen could moderate the severity of overall muscle fatigue of the shoulder (Fig. 3).

The lowest cumulative EMG value was observed when ambidextrous participants were touching the bottom-center targets, and it might be attributable to the short task duration for tapping the targets. Targets that registered the longer task duration reported greater cumulative EMG of the shoulder muscle (Fig. 4).

Within each group, cumulative EMG amplitude of the shoulder muscle of the chosen side varied significantly between targets for the right-handed and ambidextrous groups, indicating that target location could influence the overall fatigue or discomfort for the ambidextrous and right-handed users.

LEFT-HANDED

1151.2 A	1286.4 A	1318.6 A	1325 A	1324.9 A
1184.5 A	1231.9 A	1268.7 A	1133.1 A	1175.4 A
963.4 A	1122.4 A	1079.3 A	992.7 A	1077.1 A

AMBIDEXTROUS

831.5 ABC	878.6 ABC	759.2 BC	1072.8 AB	1335.8 A
742.9 BC	924.7 ABC	888.7 ABC	1005.6 ABC	935.9 ABC
711.8 BC	717.2 BC	535.3 C	825.9 ABC	845.9 ABC

RIGHT-HANDED

1202.5 ABC	1039.6 BCD	1299.2 AB	1287.8 AB	1536.7 A
818.7 CD	1257.1 ABC	1082.8 BCD	1224.2 ABC	1185.2 ABC
658.3 D	819.1 CD	990.7 BCD	985 BCD	1034.9 BCD

Figure 3. Cumulative EMG of shoulder muscle of the chosen side for each target. Cells with different letters are significantly different by Tukey comparison (p<0.05).

LEFT-HANDED

1.3 AB	1.3 AB	1.3 ABC	1.3 AB	1.5 A
1.1 BCDE	1.2 BCDE	1.2 BCDE	1.2 BCDE	1.3 ABCD
1.0 E	1.0 E	1.1 BCDE	1.1 CDE	1.0 DE

AMBIDEXTROUS

1.3 ABCD	1.3 AB	1.3 ABC	1.3 AB	1.4 A
1.2 ABCDE	1.2 ABCDE	1.2 ABCDE	1.2 BCDE	1.1 BCDE
1.1 BCDE	1.1 CDE	1.0 E	1.0 DE	1.0 E

RIGHT-HANDED

1.7 A	1.6 AB	1.5 ABC	1.5 BCD	1.7 A
1.4 BCDE	1.4 BCDE	1.4 CDEF	1.4 BCDE	1.4 CDEFG
1.3 EFG	1.3 DEFG	1.2 FG	1.2 G	1.2 G

Figure 4. Mean of task duration (unit: sec). Cells with different letters are significantly different (p<0.05).

4. Conclusion

Results of this study explain that switching hands when using desktop touchscreens could lessen the cumulative discomfort of the shoulder and help users use the touchscreen more comfortably. In addition, bimanual use could lessen the task duration and improve the task performance in touchscreen use. UI design of desktop touchscreen can be improved by considering user handedness when positioning touch targets.

References

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