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Original Article

Effects of screen size on smartphone functionality and usability for stroke patients with hemiparalysis

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Abstract. [Purpose] The effect of screen size on smartphone functionality and usability for patients with stroke, considering both the non-dominant and dominant hand smartphone usage, was investigated in this study. [Subjects and Methods] Thirteen patients with stroke participated in this study—five pre-non-dominant hand users and eight pre-dominant hand users. The smartphone screen sizes used were 4.2, 4.5, and 5.6 inches. Usability was assessed in terms of discomfort experienced during dragging operations, which was self-reported using a four-point Likert scale. Functionality was assessed in terms of completion time and the frequency of errors in the task requiring users to quickly touch numbers 0 through 9 in order on the keypad. [Results] For all three screen sizes, a significant difference between the dominant and non-dominant hands was found in usability, completion time, and frequency of errors. For dominant hand users, differences in usability and completion time were found among the three screen sizes. Among the three screen sizes, no difference in the frequency of errors was found in either of the groups. [Conclusion] This study will be useful as basic research on usability and functionality with stroke patients using only pre-non-dominant or pre-dominant hand.

Key words: Smartphone functionality, Smartphone usability, Stroke

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INTRODUCTION

Cell phones are a necessity in modern society. Moreover, modern smartphones are subject to customization. Smartphones allow users to easily utilize information from websites. Through participation in social networking services, important relationships can be formed[1)]. As smartphone functions become more varied and complex, the number of available screen sizes has increased. Studies on the functionality and usability of smartphones[1–3)] and their effects on the body[4, 5)] have been conducted to address these trends.

Many people use only one hand to operate their smartphones[6)]. Three scenarios that require users to operate smartphones with one-hand have been identified by Jeon[7)]; namely, when they are carrying baggage in one hand, when they are walking, and when they cannot use two hands owing to a physical disability.

Most stroke patients are afflicted with hemiparalysis; as a result, regardless of whether it is pre-dominant hand or not, these patients must only use one hand. The functionality and usability of smartphones will be different for stroke patients than for non-disabled people. In some cases, stroke patients must change their dominant hand because the side of their pre-dominant hand is paralyzed. The aim of this study was to investigate differences in functionality and usability among three smartphone screen sizes for stroke patients who are limited to the use of one hand, and to investigate the differences in terms of smartphone usage between the pre-dominant hand and non-dominant hand.

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Table 1. General characteristics of participants

		Group for pre-non-dominant hand (N=5)	Group for pre-dominant hand (N=8)
Gender	Male	4	6
	Female	1	2
Age	40s	2	4
	50s	3	4
Affected side	Right	5	0
	Left	0	8
Pre-dominant hand	Right	5	8
	Left	0	0
Duration of smartphone use after onset	Less than 3 years	1	0
	More than 3, less than 5	1	1
	More than 5	3	7
Thumb space (cm)		11.90±0.82	12.40±0.49

*p<0.05

Table 2. Characteristics of the used phones

Type of the mobile	Size of the mobile	Size of the display
G** mobile phone by 'S' company	125.3*66.1*8.49	4.2
V** mobile phone by 'S' company	132.9*71.4*9.35	4.5
N** mobile phone by 'S' company	151.2*79.5*8.3	5.6

*p<0.05

SUBJECTS AND METHODS

The patients included in this study were those who (1) had hemiplegia following a stroke, (2) were able to understand the task and express themselves, (3) had some experience in using a cell phone, and (4) provided consent to participate in the study. This research was approved by the Institutional Review Board of Inje University.

Patients excluded from the study included those suffering from tremors, involuntary movements, cognitive impairment, or visual problems. Thirteen patients with stroke participated in the study. All patients were right-hand dominant before the onset of stroke. Five participants suffered from right hemiplegia and eight suffered from left hemiplegia; thus, there were eight pre-dominant hand users and five pre-non-dominant hand users (Table 1).

Three smartphone screen sizes—4.2, 4.5, and 5.6 inch screens—were used in this study. In a previous study[8], these were identified as the smartphone screen sizes most often used in Korea. The smartphones in this study are listed in Table 2. For usability testing, the prototype containing the screen sections was printed on transparencies fitted to the sizes of the smartphone screen, which were subsequently attached to the smartphones. Participants performed dragging operations along the sections, using the simplest operation among the six common input interactions[8]. The participants assessed discomfort while performing two-way drags in the sections between numbers 1–3, 5–7, 9–11, 1–9, 2–10, 3–11, 1–11 and 3–9. Data coding for left-hand users was converted to be symmetric with that of right-hand users. The discomfort was measured using a four-point Likert scale: one point indicated that the operation was extremely comfortable, two points indicated that it was easy, three points indicated discomfort, and four points indicated extreme discomfort (Fig. 1).

For functionality, the participants quickly touched the numbers 0 through 9 in order on the keypad, and the assessor measured the completion time and number of errors. The participants performed this task three times. The average time and frequency of errors were analyzed. The tasks and the sizes of the smartphones were randomly ordered.

Data analysis was conducted using SPSS 20.0 statistical software. To test homogeneity between two groups, χ^2 and Mann-Whitney tests were conducted. To compare functionality and usability among the three sizes of smartphone screens, a Kruskal-Wallis test was conducted. If significant differences were noted among the three sizes, a Mann-Whitney test was conducted to separately compare the two sizes. The significant values in the Kruskal-Wallis and Mann-Whitney tests were set to 0.05 and 0.016, respectively. To compare the functionality and usability between dominant hand and non-dominant hand operations, Mann-Whitney tests were conducted. The significant value was set to 0.05.

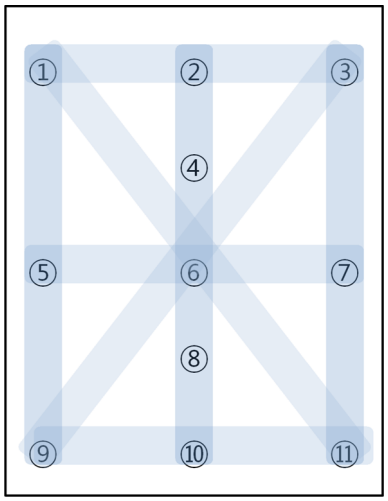

Fig. 1. Prototype

RESULTS

No significant differences were noted in the general characteristics of non-dominant and dominant hand users (Table 1). Usability differences among the three screen sizes were not found for non-dominant hand users; however, in dominant hand users, differences were found ($p<0.016$) among the three screen sizes for sections 3–11, 1–11, and 2–10. Usability differences between dominant and non-dominant hand users were found in three sections of the 5.6 inch screen, four sections of the 4.5 inch screen, and six sections on the 4.2 inch screen ($p<0.05$) (Table 3).

No differences in completion time were found among the three screen sizes in the non-dominant hand users; however, for dominant hand users, completion time differences were found between the operations performed on the 4.2 and 5.6inch screens and between the operations performed on the 4.5 and 5.6 inch screens ($p<0.016$). Among the three screen sizes, no differences in frequency errors were found in both dominant and non-dominant hand users ($p>0.016$). Completion time differences between non-dominant and dominant hand users were found for all screen sizes ($p<0.05$). Significant differences in frequency of errors between non-dominant and dominant hand users were found when 4.2 and 4.5 inch screens were used ($p<0.05$), but not when 5.6 inch screens were used ($p>0.05$) (Table 4).

DISCUSSION

When using a smartphone, users typically prefer using one-hand instead of both hands. The size of the smartphone is a key factor in determining whether users operate their smartphones with one hand or both hands[9]. Because of hemiparalysis, many stroke patients must use one hand to operate their smartphones. This study investigated smartphone usability and functionality for stroke patients and considered three sizes of smartphone screens and whether the patients used their pre-dominant hand or not.

Analysis on usability among the three smartphones screen sizes for dominant hand users showed that stroke patients experienced significantly more discomfort in only three sections: 3–11, 1–11, and 2–10. These sections overlapped a portion of the screen that is difficult to tough[7]. Im[8] reported that users operating their smartphones with one hand were satisfied with all input modes when using a 3.5 inch screen, some input modes when using a 4.0, 4.5, or 5.0 inch screen, but dissatisfied with most input modes when using a 5.5 inch screen. However, the result of this study indicated that the smaller the smartphone screen, the larger the difference in usability between the dominant and non-dominant hand. It should be interpreted that the smaller the smartphone size, the more it required thumb sensitivity.

Regardless of the size of the smartphone, the completion time and usability between dominant and non-dominant hands were significantly different. It was considered that the pre-non-dominant hand user was not skillful at using a smartphone than the pre-dominant hand user. Both hands must be assessed because the performance of the dominant and non-dominant hands is different, as reported by Perry and Hourcade[10]. To the best of our knowledge, this is the first study to analyze smartphone functionality and usability for stroke patients while considering both the pre-dominant and pre-non-dominant hand. So, this study has a special meaning.

When 4.2 and 4.5 inch screens were used, a significant difference in the frequency of errors was found between non-dominant and dominant hand users, but not when 5.6 inch screens were used. This was considered because thumb movement

Table 3. The usability according to the size of smartphone and comparison between dominant and non-dominant hand user group

		4.2 inch	4.5 inch	5.6 inch
1–3	Total	1.38±0.51	1.38±0.51	1.92±0.95
	Non-dominant	1.80±0.45*	1.60±0.55	2.60±0.89*
	Dominant	1.13±0.35*	1.25±0.46	1.50±0.76*
5–7	Total	1.38±0.51	1.54±0.52	2.00±1.22
	Non-dominant	1.50±0.45*	2.00±0.00*	3.00±1.22*
	Dominant	1.13±0.35*	1.25±0.46*	1.37±0.74*
9–11	Total	1.38±0.51	1.54±0.52	2.00±1.22
	Non-dominant	1.80±0.45	2.00±0.00*	3.40±1.34*
	Dominant	2.37±1.06	1.37±0.52*	2.00±0.75*
2–10	Total	1.85±0.90	2.15±1.21	3.77±0.44
	Non-dominant	2.80±0.45*	3.20±0.84*	3.80±0.45
	Dominant[bc]	1.25±0.46*	1.50±0.93*	3.75±0.46
1–9	Total	2.92±1.12	3.38±1.12	3.85±0.38
	Non-dominant	3.80±0.45*	3.80±0.45	4.00±0.00
	Dominant	2.37±1.06*	3.12±1.36	3.75±0.46
3–11	Total	2.38±1.26	2.23±1.09	3.46±0.52
	Non-dominant	3.60±0.89*	3.20±0.84*	3.80±0.45
	Dominant[bc]	1.63±0.74*	1.63±0.74*	3.25±0.46
1–11	Total	2.54±0.97	2.31±0.95	3.69±0.48
	Non-dominant	3.40±0.55*	2.80±1.09	4.00±0.00
	Dominant[bc]	2.00±0.75*	2.00±0.75	3.50±0.53
3–9	Total	3.08±0.86	3.00±1.00	3.85±0.38
	Non-dominant	3.60±0.89	3.60±0.89	4.00±0.00
	Dominant	2.75±0.71	2.63±0.92	3.75±0.46

[a] Significant difference at 0.016 between 4.2 and 4.5 inch
[b] Significant difference at 0.016 between 4.5 and 5.6 inch
[c] Significant difference at 0.016 between 4.2 and 5.6 inch
*Significant difference at 0.05 between dominant hand use group and non-dominant hand use group

Table 4. The functionality according to the size of smartphone

		4.2 inch	4.5 inch	5.6 inch
Time (sec.)	Total[b]	8.37±3.98	7.45±3.04	10.06±4.87
	Non-dominant	11.27±3.22*	10.60±2.72*	14.16±5.30*
	Dominant[bc]	7.50±2.24*	5.50±0.48*	5.31±0.42*
Number of errors	Total	1.15±1.19	0.76±1.09	1.23±1.16
	Non-dominant	2.80±2.95*	1.60±1.34*	2.40±3.29
	Dominant	0.13±0.35*	0.25±0.46*	0.50±0.53

[a] Significant difference at 0.016 between 4.2 and 4.5 inch
[b] Significant difference at 0.016 between 4.5 and 5.6 inch
[c] Significant difference at 0.016 between 4.2 and 5.6 inch
*Significant difference at 0.05 between dominant hand use group and non-dominant hand use group

involved flexibility and sensitivity[11].

This study has some limitations. It assessed functionality and usability while the smartphone was being held in the vertical position; horizontal position was not considered. Many variables such as flexibility of the thumb, smartphone grip patterns, and smartphone weight[6], were not considered in this study. In the future, studies on smartphone functionality and usability of patients with stroke using only pre-non dominant hand need to be conducted.

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