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Hand Anthropometry and SMS Satisfaction

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Abstract: The effect of hand anthropometry on Short Message Service (SMS) satisfaction was investigated using structured questionnaire interviews with 110 subjects, aged between 17-25 years old. Hand size was measured to assess its effect on mobile phone design factors satisfaction whereas thumb circumference and length were measured for keypad design factors. Small hand-sized subjects were found to be more satisfied with mobile phone dimensions than large hand-sized subjects. Thumb circumference significantly affects users' satisfaction towards key size and space between keys whereas thumb length significantly affects keypad layout satisfaction. Both thumb circumference and length significantly correlate negatively with the corresponding keypad design factors. Results confirm that hand anthropometry do affect users messaging satisfaction. These findings should prove useful to mobile phone designers who could look into the possibility of designing customized mobile phones that cater to large hand and thumb sized users, so as to increase their subjective satisfaction.

Key words: Hand-size, thumb length, thumb circumference, mobile phone design, keypad design

INTRODUCTION

Short Message Service or popularly known as SMS allows the sending of short messages (160 characters or few) between mobile phone subscribers. SMS has been a tremendous success in most of the countries, including Asian countries like Singapore, Philippines and Malaysia. Malaysians, for example, were found to have sent 11.7 billion messages in the first three months of 2007, compared to only 7.4 billion in 2006 (The Star, 2007a). Moreover, a survey among 1,004 mobile phone users revealed that Malaysians send an average of 17 SMS in a day and spend an average of RM 101.50 per month to send SMS (The Star, 2007b). SMS is popular as it is fast, easy and most importantly cheap.

The popularity of SMS has heightened the interest in mobile phone research. A lot of studies have been done on the adoption of mobile phone and SMS in certain countries (Faulkner and Culwin, 2005; Ling, 2005; Höflich and Rössler, 2002). Social and psychological effects of SMS messaging were also studied to examine the underlying motivations of using SMS (Reid and Reid, 2004). Some researchers have done usability studies of mobile phones (Soriano *et al*., 2005; Balakrishnan *et al*., 2005) and some have compared the performance of the text entry methods (James and Reischel, 2001; Friedman *et al*., 2001). Although numerous studies have been conducted related to SMS, however very few were related to SMS users' subjective satisfaction (Yun *et al*., 2003; Han *et al*., 2004).

User satisfaction should be the main priority in any product designs. In Japan, cars, houses and costumes have been designed based on Kansei engineering, which is a product development technique that takes into account the desirable features of products as perceived by the end users (Nagamachi, 2002; Miyazaki *et al*., 2003; Kashiwagi *et al*., 1994). Overall satisfaction was also used as one of the usability factors to evaluate the look-and-feel of mobile phone designs (Yun *et al*., 2003). One can conclude that the success or failure of any product is heavily dependent on the end users' satisfaction. Literature reviews revealed no studies investigated the effect of hand anthropometry (physical measurements of the hand) on SMS users' satisfaction. Some users with large fingers have commented about the difficulty of using mobile phones to SMS (Axup *et al*., 2005; Faulkner and Culwin, 2005) and many have reported about the shrinking size of the mobile phones (Ergonomics Today, 2005; Anderson, 2005). These suggest that varying hand and finger sizes might affect users' satisfaction in using mobile phones to SMS, thus this study aims to investigate if hand anthropometry affects users' SMS satisfaction, focusing on mobile phone and keypad design factors.

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MATERIALS AND METHODS

Text entry on mobile phones: The standard keypad layout on many mobile phones consists between 12-15 keys that are overloaded (Fig. 1). These keys are used to enter text, symbols, numbers and punctuation. Each key is mapped to between three to four characters, resulting in the users having to make repetitive key presses for text input. The most popular forms of text input on a standard 12-key mobile phone are either multitap or predictive text entry.

Multitap: Successive key presses are made on different or the same keys to determine the intended letters. For example, to enter SMS, the user would press 7777 (to get the fourth letter on key-7), then 6 and finally 7777. The break between two letters entered with the same key is normally indicated by a pause (1-2 sec). Multitap is simple and unambiguous; however it can be slow (Mackenzie, 2002).

Predictive text entry: With predictive text entry, the mobile phone displays the most likely word for the sequence of keys pressed since the last space character. If the predicted word is incorrect, the user will have to scroll through the alternative words. However, if the word is not recognized at all, then the user must delete their input and enter the word via multitap. This can be quite frustrating. Moreover, it is also impossible to enter numerals, acronyms or any combinations of letters and numerals (e.g., l8r for later). Users also have to visually monitor the display to resolve ambiguities, unlike multitap that can be operated eyes free by experts (Mackenzie *et al*., 2001).

Design of study: Figure 2 shows the theoretical framework used in this study. SMS satisfaction acts as the dependent variable whereas mobile phone and keypad design factors are the independent variables, tested against hand anthropometry.

Both the independent variables were chosen as they represent the physical aspects of a mobile phone that directly relate to hand anthropometry. A mobile phone is held in one or two hands and messages are entered via the keypads using one or two thumbs. Moreover, a lot of work has identified these two factors as some of the usability issues of mobile phones (Axup *et al*., 2005; Soriano *et al*., 2005; Balakrishnan *et al*., 2005). Table 1 and 2 show the different factors tested for the independent variables.

All the design factors for mobile phone and keypad were identified from studies conducted to determine some of the critical mobile phone design features to users' satisfaction (Ling *et al*., 2007; Han *et al*., 2004; Yun *et al*., 2003). Other studies that have reported on issues related to some of these features are: problems related to tiny keys (Soriano *et al*., 2005; Kurniawan *et al*., 2006), problems related to key size and space between keys (Balakrishnan *et al*., 2005; Ornella and Stephanie, 2006) and issues on the shrinking size of mobile phones (Anderson, 2005; Croasmun, 2002). None of these studies, however, took hand anthropometry into consideration.

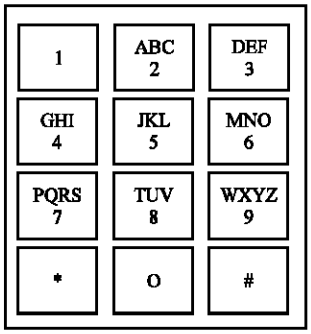

Fig. 1: Standard ISO 12-key keypad design

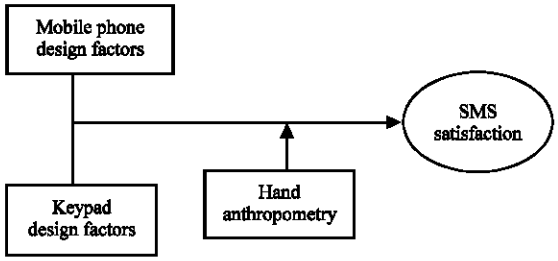

Fig. 2: Theoretical framework

Table 1: Mobile phone design factors

Mobile phone design factors	Definition
Weight	Weight of the mobile phone
Design	Shape of the mobile phone
Dimension	Size of the mobile phone (Length×Width×Thickness)
Feel	Tactual satisfaction while holding the mobile phone

Table 2: Keypad design factors

Keypad design factors	Definition
Size	Size of the keys
Simplicity	Simplicity of keypad design
Space	Existing space between the keys
Shape	Shape of the keys (square, rectangle, oval etc.)
Layout	Arrangement of keys (4×3 etc.)
Texture	Tactual satisfaction related to key texture/material (e.g. soft, hard, coarse etc.)

Subjects: One hundred and ten youth ranging between 17-25 years old were interviewed (mean = 21.5 years,

SD = 1.64). The majority of them (84/110) were recruited from a local university and the rest were selected from public places (mall, public library etc.). All the subjects had some experience in using SMS, with an average of 3.8 years and SD = 1.19. All the subjects also used their thumbs to compose messages. 80.9% (89/110) of the subjects used multitap for text entry, 11.8% (13/110) used both multitap and predictive text entry interchangeably and only 7.3% (8/110) used predictive text entry. The mobile phones used in this study were by some of the popular brands, namely Nokia with 66.4% of the subjects owning this phone. This was followed by Samsung (12.7%), Motorola (9.1%), Sony Erickson (8.2%), Siemens (1.8%) and Alcatel (1.8%).

Hand anthropometry: Different hand anthropometries were measured for mobile phone and keypad design factors. Users with small hands might find it difficult to hold large mobile phones and users with large hands might find it difficult to hold small mobile phones, thus hand breadth was measured to test if it affects users' satisfaction towards mobile phone design factors. Hand breadth was measured at the distal ends of the metacarpal bones (the joints of index finger to the little finger) with the hand held straight and flat (Fig. 3a). Thumb length might affect users' reachability of the keys whereas users with large thumbs might find it cumbersome keying in messages via the tiny keys. Thumb length was measured from the second joint of the thumb to the tip of the thumb whereas thumb circumference was measured at the widest point of the thumb (Fig. 3b). These measurements were taken based on the physical definitions used by Vasu and Mital (2000). Measurement tapes were used and all the readings were taken twice to obtain the average measurements.

Questionnaire: An interview questionnaire was developed in English with two major sections: Section A to obtain the demographic profile of the subjects (gender, hand measurements, hand used to text etc.) whereas Section B is for the subjects to rate their satisfaction/dissatisfaction levels to statements using Likert's five-point scale, whereby 1 means Strongly dissatisfied, 2 means Dissatisfied, 3 means Neutral, 4 means Satisfied and 5 means Strongly Satisfied.

Interviews: Face-to-face interviews were conducted using the above questionnaire on a one-to-one basis, beginning with the subjects filling in their background information, which includes their age, gender, finger(s) used in composing SMS and so forth. The interviewer then

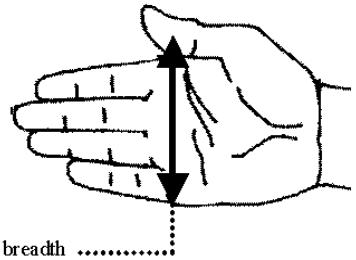

Fig. 3a: Hand breadth measurement

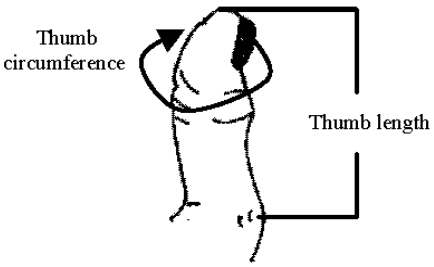

Fig. 3b: Thumb measurements

measured the hand and thumb sizes, based on the dominant hands. Subjects were encouraged to give comments, opinions and suggestions. All verbal comments were noted by the interviewer. Each interview session lasted for about 30 min. Two interviewers participated in these exercise that took almost eight weeks to complete.

Statistical tests: Statistical Package for the Social Sciences (SPSS) software was used to test the statistical significant difference(s) of the variables. Hand-size groups were tested against mobile phone design factors whereas thumb length and circumference were tested against keypad design factors. Analysis of variance (ANOVA), analysis of covariance (ANCOVA), Tukey Post-Hoc analysis and Pearson correlations were used to analyze the collected data.

RESULTS

The five-point Likert scale structured interview questionnaire has an acceptable level of internal consistency with a Cronbach's alpha value of 0.73.

Table 3 shows the summary of hand anthropometry statistics based on gender. Three hand-size groups (small, medium and large) were defined based on the hand breadth: for males, <8.8 cm is small, 8.8-9.2 cm is medium and >9.2 cm is large; for females, <7.3 cm is small, 7.3-7.7 cm is medium and >7.7 cm is large (You *et al.*,

Table 3: Hand anthropometry statistics

Measurements (cm)	Male (N = 55) Mean±SD (Min-Max)	Female (N = 55) Mean±SD (Min-Max)
Hand breadth	9.0±0.5 (8.0-9.4)	7.3±0.4 (6.0-8.2)
Thumb length	6.4±0.8 (4.8-7.0)	5.4±0.65 (4.2-6.5)
Thumb circumference	5.8±0.75 (4.5-7.8)	5.4±0.58 (4.5-7.2)

Note: Dominant hand measurements only

Table 4: Mobile phone design factors satisfaction, based on hand-size

Mobile phone design factors	Hand-size F-ratio (p-value)
Weight	0.334 (0.717)
Design	2.247 (0.111)
Dimension	7.415 (0.001*)
Feel	0.129 (0.879)

*: Significant at $p<0.05$

Table 5: Keypad design factors satisfaction, based on thumb circumference and length

Keypad design factors	Thumb circumference F-ratio (p-value)	Thumb length F-ratio (p-value)
Size	11.411 (0.001*)	3.111 (0.079)
Simplicity	0.189 (0.665)	3.255 (0.074)
Space	8.608 (0.004*)	3.989 (0.059)
Shape	0.046 (0.831)	1.956 (0.165)
Layout	2.439 (0.121)	4.235 (0.042*)
Texture	0.696 (0.406)	3.123 (0.080)

*: Significant at $p<0.05$

2005). The overall number of subjects for each hand-size groups is: 28 small, 43 medium and 39 large.

Table 4 shows that hand-size significantly affects users' satisfaction with respect to mobile phone dimensions. Tukey post-hoc analysis revealed that small hand-sized subjects are significantly more satisfied than large hand-sized subjects ($p = 0.001$).

Table 5 shows that thumb circumference significantly affects users' satisfaction towards key size and space between keys. A significant correlation was found between thumb circumference and key size ($p = 0.001$, $r = -0.309$) and with space between keys ($p = 0.004$, $r = -0.272$). Thumb length was found to be significant only for keypad layout, both also significantly correlated to each other ($p = 0.042$, $r = -0.194$).

DISCUSSION

According to the p-values in Table 4, hand-size significantly affects users' satisfaction towards mobile phone dimension. Smaller hand-sized subjects are more satisfied with the mobile phone dimension than large hand-sized subjects. A good and comfortable grip is necessary to enable one to compose messages in an efficient manner, however, this is not possible for users with large hands who have to struggle messaging while holding the small mobile phones. The users find it awkward pressing the keys while holding the small and slim mobile phones in their large hands. This statement is supported by Margaret Head, the President of Ergonomics Society of Australia who said that mobile phones are more suited to a young child than a grown adult (Croasmun, 2004). Nine large hand-sized subjects mentioned that they only use SMS to send very short messages; otherwise they prefer making calls as they can carry conversations by holding their phones (no fumbling with fingers and keys required) or by using hands-free gadgets. Mobile phone dimensions were also found as one the features impacting overall satisfactions of mobile phone users by Ling *et al.* (2007); however, no hand-size measurements were included.

In Table 5, thumb length significantly affects keypad layout satisfaction, negatively correlating with each other. This could be due to the 4×3 layout used by the mobile phones in this study and in most of the mobile phones in the market as well. It was found that subjects with longer thumbs find it difficult to reach key -3, 6, 9 and #, which are all placed at the right-most column of the keypad (Fig. 1). Eleven subjects commented that they have to practically bend their thumbs or readjust the placement of the phone on their palms in order to press these keys, especially for key # which is at the bottom corner of the phone. The motion of adjusting the hand and thumb to accommodate the keypad layout causes dissatisfaction among these users. When prodded further, four of them stated that continuously bending their thumb have caused discomfort at the first joint of their thumb, especially after continuously messaging. Increase in messaging may contribute to a rise in Repetitive Strain Injury (RSI) in thumbs, especially among the young users. Bronwyn Clifford, of the Association of Chartered Physiotherapists in Occupational Health and Ergonomics (ACPOHE) mentioned that too much messaging can result in pain and swelling of the tendons at the base of the thumb and wrist as the thumb is good at grasping but not good for repetitive movement (Cannon, 2005). The majority of the subjects (64/110) stated that the keys placed in the middle of the keypad (sweet spot) were the easiest to be accessed and most comfortable as well.

Thumb circumference was found to significantly affect users' satisfaction towards key size (Table 5). As mobile phones shrink in size, the key size shrinks as well. This further complicates the problem of messaging among users with large thumbs. Thumb circumference was also found to significantly correlate negatively to key size. This confirms that as users' thumb increases in size, their satisfaction decreases towards key size satisfaction. Large thumbed users find it difficult to make multiple key presses on the tiny keys. This is further aggravated by

the limited or no space between keys. These users tend to accidentally hit the wrong keys when entering messages. Having to correct the errors cause frustrations among these users, hence decreasing their satisfaction with respect to key size. This finding is consistent with Soriano *et al.* (2005) who reported that four out of five male participants in their study claimed that the size of the keys became an issue when messaging especially among those with larger fingers; however, the researchers did not take any finger measurements in their study. Small key sizes were also reported as one of the mobile phone usability problems by Axup *et al.* (2005) and Ornella and Stephanie (2006); however none took anthropometric details into consideration. Anderson (2005) reported that any tool that involves a struggle to be used earns a D or worse for usability. A common criticism is that mobile phones have become too small causing aim and accuracy to suffer when adult hands finger child-sized buttons.

Thumb circumference also significantly affects users' satisfaction with respect to space between keys (Table 5) and both correlating negatively to each other. Large thumbed users are more dissatisfied with the limited space between the keys. Miniaturization of the mobile phones also causes the keys to be placed closely together; hence limiting the space between the keys. Large thumbed users find messaging a tedious task due to the close placement of the keys, which is further aggravated by the tiny key size. Thirty two subjects commented that they tend to hit the neighbouring keys accidentally while messaging, especially when it is done in a hurry or while in motion (e.g., walking, talking etc.). It can be a frustrating task as they have to waste their time correcting the errors instead of messaging efficiently. Moreover, they also mentioned that they need to constantly focus on the screen to make sure they have pressed the correct key; hence eliminating the possibility of 'eyes-free' input among the large thumbed users. Frequently having to correct their errors hinders these users from adopting SMS at times or to use it only when it is deemed necessary, for example to send simple and short messages, especially single line messages. This is especially true among the male users, who generally have larger thumbs than females (Table 3). Ornella and Stephanie (2006) also found limited spaces between the keys to be a problem among the elderly mobile phone users (60-80 years old); however no anthropometric measurements were taken into consideration. Soriano *et al.* (2005) found that spacing between the keys became an issue especially for participants with large fingers, based on their survey among middle aged-users. Moreover, subjects with larger thumbs tend to be more careful when making key presses to avoid making unwanted errors and this increases the time spent on composing a message. Due to this, subjects tend to make phone calls that are faster instead of making slow key presses to message.

Key size and space between keys seem to be the major obstacles among users with large thumbs. The problem is further complicated for large hand-sized users who also have to struggle holding the small mobile phones while sending SMS. This shows that mobile phone users are not satisfied with the mobile phone and keypad designs. Interestingly, the dissatisfaction towards key size and space between keys exists regardless of the text entry method used as both require users to make key presses via the keypads. Multitap technique is often criticized for being slow. An experiment using a mobile phone found that experts and novices reached about 8 words per minute (wpm) with multitap (James and Reischel, 2001). In 2003, the world's fastest mobile texter typed 29 wpm using multitap technique, which is more than six times slower than the Guinness record of 192 wpm for the desktop QWERTY keyboard (Starner, 2004). Multitap requires users to make successive key presses to enter characters and numbers. This complicates the task of messaging as users with large thumbs find it cumbersome to make key presses on the closely arranged tiny keys. On the other hand, the predictive text entry requires users to cycle through possible words as they are predicted by the mobile phone. Apart from having to make key presses, users also have to visually monitor the screen to select the desired word. Moreover, users still need to switch to multitap to enter numerals. These text entry problems coupled with poor design of keypads greatly cause dissatisfaction among mobile phone users to SMS, especially among users with larger thumbs.

CONCLUSION

The effect of hand anthropometry on SMS satisfaction was studied based on hand-size, thumb length and circumference measurements. These measurements were tested against mobile phone and keypad design factors. The following results were drawn:

- Smaller hand-sized users are more satisfied with the mobile phone dimensions than larger hand-sized users, with regards to holding the mobile phone and messaging at the same time,
- The increase of thumb circumference decreases users' satisfactions towards key size and space between keys as messaging becomes tedious due to accidentally hitting the wrong keys,

- The increase of thumb length decreases users' satisfactions towards keypad layout as accessing some of the keys becomes difficult and sometimes causes pain in the thumbs,
- All the above problems were reported regardless of the text entry method used to enter text.

It can be concluded that hand anthropometry definitely affects mobile phone users' SMS satisfaction. Customized mobile phones have been designed to suit the elder people (Croasmun, 2005) and also kids (Budnick, 2005) to improve usability and increase satisfactions. With this in mind, the results from this study can be used to design customized mobile phones that suit users with larger hands and thumbs or even enhance the current designs to increase the satisfaction among all mobile phone users.

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