DEA 325

Homework 3: Applying Ergonomic Design Principles "Redesigning the Smartphone"

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Introduction to Smartphones

Smartphones are a popular necessity in today's technology obsessed culture. The modern generation is all too familiar with hand-held devices like the RIM Blackberry™, the Palm Pilot™, and the newly released Apple iPhone. What is a smartphone? Technically, it is a mobile phone that goes beyond the functions of a simple portable phone and phone book. Smartphones are like compact computers that can support and run complete PC-like operating systems with advanced communication options including voice calling, text messaging, emailing, and even video conferencing. Popular manufacturers including Samsung, Motorola, and Nokia are producing tiny phones that are decreasing in size and weight but increasing in usable memory and functional applications.

Smartphones have created a new industry in electronics. What began as a simple mobile phone, has now expanded its uses to include functions like portable music players, video games, Internet capabilities, global positioning systems (GPS), and movie/television players. They have become essential accessories in day-to-day life, which brings up the importance of smartphone design and hand health.

Glance at Smartphone History

The first smartphone was conceived in 1994. Computer manufacturer, IBM, and telecommunications company, Bellsouth, created "Simon", the first personal communicator. Since this time, the dominant revolution observed in the mobile phone industry is growing public desire for smaller phones. People want miniaturized, thin, ultra-portable cellular phones – all while maintaining full functionality as a telephone, organizer, gaming device, and more. When the Palm Pilot was introduced in 1996, it was launched as a Personal Digital Assistant (PDA), not a phone. Capable of full grip in the palm of a hand, the Palm Pilot drew much attention by men and women who were looking for an alternative electronic organizer from mini cell phones that had numeric keys that were too small to control. An increase in demand for larger, yet distinctive, and sleek phones with PDA capabilities soared. The "smartphone" began its boom with Palm's QUALCOMM model in 1999.

Current Designs and Specifications to Consider

Small, sleek, shiny objects are sure to draw public attention, especially if they play hit music, allow international communication, and come in an assortment of colors that are user-customizable[1]. But the incredible shrinking size and sometimes-bizarre shape of many smartphones are pushing the extremes for many people. Ergonomically, the dimensions of new phones are best suited for the hands of children, not the adults who really depend on them. Although miniaturized phones are aesthetically cute and pleasing, the breadth of possible features in these expensive phones become virtually useless if the tiny buttons limit its function.

Keypad Layout

Almost all smartphones utilize a full QWERTY keypad to increase the mode by which information can be recorded and transmitted. Although the QWERTY layout is was designed to slow the typing speed of its users, it has become the internationally acknowledged arrangement for the English alphabet This familiarity is important to maintain in order to consistently imitate PC-like conventions that smartphones try to capture. To accommodate the QWERTY keypad, however, smartphones must be approximately 13-15mm longer in width than conventional and simple flip-cellular phones[2]. This increased size usually does not pose an immediate threat to sales, but it can cause the price of manufacturing. However, since smartphones require more bulk size in order to fit its assortment of electronic and digital chips and devices, this does not become a two-sided problem. In fact, the focus for most manufacturers is still to pursue minimizing the size of their phones. When creating future smartphones, I would maintain the QWERTY layout for phones that occupy

[1] See Appendix, Figure 3
[2] Motorola RAZR™ (53mm x 15mm x 104mm) *versus* Motorola Q9h™ (66mm x 13mm x 117mm) [WxDxH].

the full-keyboard layout. It will increase user-familiarity and will demand less time for users to adapt to their control pad.

Keypad Force and Feel

The force and push strength required to manipulate most smartphone buttons is fairly resistant, but gives an appearance of being light to the touch. Some phones (i.e. flip-cover phones and typical cellular phones) have keys that do not rise above the main surface of the phone (See Appendix, Figure 1). Others (most smartphones) distinctly have keys raised above the surface of the main body (Fig. 2). Smartphones that do not have a flip (or slide) cover, are usually designed with keys that lie raised from the surface, which gives a closer resemblance to the QWERTY computer keyboard feel. A raised keypad has many benefits compared to its flatter counterpart. It allows the user to actually feel his or her finger force changing the surface position of the controls. Ergonomic studies have shown that a keyboard's *feel* is an important parameter that alters a typist's performance and preference for a certain product. Similarly, the same idea applies to the smartphone keypad. Phones that employ physical controls requiring touch force (i.e. excluding touch-screen devices), must be comfortable for frequent use by men and women of a range of ages, sizes, and strengths. Anthropometric hand data from a study for the British Government's Department of Trade and Industry (posted July 2007) show that the force of the thumb by men and women vary significantly from each other and also by age (See Table 1). For females aged 11-15, maximum thumb force may be as little as 39.10 N, while a healthy male adult aged 21-30 can exert a thumb force up to 290.10 N. The downwards thumb force of the elderly (ages 71-80) lies within this range at 61.50N (lowest, female) to 211.80N (highest, male). In this case, the weakest finger push strength must influence the force required to elicit a response by the phone's controls. A redesigned smartphone must still retain some restraint in its keys, but must have a light *feel* that will accommodate the finger downward finger strength of all users. Some keypad resistance (no more than 23N[3]) is necessary because it will provide tactile feedback when the controls are pressed. Approximately 25N of control resistance would be built into the keypad of a redesigned smartphone.

Keypad Button Size

Some smartphones, like the Blackberry 8800 (Fig. 4) and the Motorola Q9M (Fig. 5), have keys that lack spaces between each individual button on top, bottom, and to the sides. This greatly diminishes tactile control recognition by the fingertips. Accordingly, this causes difficulties when using the extended QWERTY layout. When designing the size of the phone's keypad, the most important consideration is for the buttons to be easily maneuverable and distinctly detectable by all users. Anthropometric data show that there is a difference between thumb and index finger sizes that must be considered when designing smartphone keys. On average, men have index and thumb sizes of 0.72 in. and 0.79 in., respectively. Women have index and thumb sizes of 0.60 in. and 0.66 in., respectively. The mean measurements of men and women span from 0.60 in. to 0.72 in., a 0.12-inch difference. In this case, the largest finger size becomes the major determinant in desired control size. Many men have difficulty pressing the keys on Blackberry models because of their restricted sizes and spacing, and therefore, mistakenly press the wrong letters/numbers or press more than one key with one touch.

Unfortunately, the balance between key size and phone size is difficult. By increasing key size on a QWERTY keypad, a phone's overall dimensions may be forced to increase, which would then decrease the appeal and sales of the phone. To avoid this, I would propose that a redesigned phone keep button sizes that are functionally the same as the popular Palm Treo models. The alphanumeric keys on the Treo are 1.8 mm x 2.0 mm and rise above the main surface of smartphone body (Fig. 7). The buttons are distinctive to the touch and are separated by enough distance (i.e. less

[3] This force value was obtained by calculating 25% of the weakest mean thumb force from anthropometric data of women ages 71-80 years old.

than 1 mm.) for it to avoid being a "membrane keyboard" that Sanders and McCormick's textbook[4] criticizes. There is a critical fault in the keypads of some of today's popular cellular phones, like the Motorola SLVR L7 (Fig. 1), where the keypad presents some problems in human factors. Like Sanders and McCormick discuss, the Motorola SLVR has a virtually nonexistent key travel distance. Activation of the buttons lacks any significant depression of the keys and familiar keystroke feedback found in PC keyboards is absent. Also, the actual active contact areas of each key are often difficult to locate. Numbers, letters, and icons are engraved into the keypad, but accurate pressure on the correct location of the membrane keys becomes difficult for people who have fingertips that are too small, or too large.

A redesigned smartphone would avoid this characteristic.

Keypad Composition

The majority of smartphones are made of synthetic plastics that are smooth, durable, and stainless. The keys are always smooth to the touch, although some critics say that several smartphones have keypads that are "slippery", like the RIM Blackberry 8800 (Fig. 4). Personal experience, however, has proved that this slip can be avoided by separating the keys, as seen in the Motorola MOTO Q (Fig. 2), and keeping away from membrane keypads. Nevertheless, the RIM Blackberry 8800 does present a very desirable feature: a trackball navigation system. The latest Blackberry models include a small and unique rolling control that replaces the four-arrow coded keys that almost all other phones use to control up-down-left-right navigation. Future smartphones should take advantage of this method of information input. It eliminates fingertip control problems for users who have difficulty with hard-to-discriminate arrows buttons. It also helps people with fingertips and thumbs that may be too large to properly press desired navigation keys. The small trackball (Fig. 6) rolls freely and is made of a smooth but "rubbery" material that provides some

[4] Sanders, M.S. and McCormick, E.J., *Human Factors in Engineering and Design, 7th Ed:* Chapter 11.

traction and grip when you use your thumb to control the ball in any spherical direction. This trackball is small, but is easily accessible by any size thumb or fingertip because of its shape, and because it avoids being another tiny button to press. In this sense, it helps remove forces that must be applied by the fingers to elicit a control-display response by the smartphone. In terms of hand health, this removes an unnecessary stress and pressure-induced movement by the fingertips that could lead to arthritic problems with the fingers and hand joints with consistent use.

Alphanumeric Font

The font imprinted onto the smartphone's keypad must be in Sans Serif fonts that are capitalized. Currently, all phones with alphanumeric buttons are made using this type of font and future models should continue doing so. It is the most legible and easiest to recognize to enhance user-recognition and therefore, typing speed.

Handling and Grip

Since many smartphones sport full QWERTY layouts, they require more horizontal width than just simple numeric telephone keypads (Fig. 8). By designing a phone that has greater horizontal length than can be held in the palm of one hand, the user is forced to use both hands and at least two fingers to manipulate the phone's controls. Older smartphones attempted this design. The Nokia 6820 is a good example (Fig. 9). But today's on-the-go people want the best of both worlds: QWERTY layout and one-handed design. Most smartphones now have a vertically upright shape that gripped within the palm of one hand. The screen:keypad ratio is usually 1:1, where the screen can be larger (important for users with needs of a clearer and wider display) and the keypad spans below the screen, never *over* the screen. This relative ratio should be maintained when future smartphones are designed. Maximizing the size of the screen and balancing its dimensions with the space taken by the keypad will help users who use certain applications in the smartphone (document viewers, internet browsing) that demand more space to display contents. A larger screen will also relieve some eye strain that people suffer when viewing information through miniature screens. A larger screen will provide space for larger fonts, which becomes more legible and easier to read. The physical dimensions of several popular smartphones can be found in Table 2.

Smartphone Dimensions

Table 2 shows that many popular smartphones from various manufacturers share very similar dimensions. When the measurements of the nine smartphones in Table 2 are averaged, the height x length x depth (mm) is 112.3 x 60.6 x 15.8. A redesigned smartphone must consider the bottom 5%ile size of a woman's hand and correspondingly, the top 95%ile size of a man's hand. Anthropometric data show that the bottom 5% palm length of a woman is 86 mm; the top 95% palm length of a man is 114 mm. Palm length is very important because the phone should fit comfortably in the grip of a user's palm (i.e. think of how Palm Pilots obtained their name). The Nokia E62 has the greatest length at 71.1 mm. This may be ideal for the larger hands, but for users with a narrow palm length, they will be unable to grip the phone in one hand, thus, dropping sales. Overall, many phones are still too wide for many hands to grip in one hand. A redesigned smartphone should aim to decrease the current *average* length (60.6 mm) to better accommodate those who cannot grasp the phone in their hands. The height of the phone should not dramatically alter the grip of the phone because it can extend below and/or above the grip width of the hand. A redesigned phone should aim to for the current *average* height of popular smartphones (112.3 mm). The depth of the phone is also important in terms of proper grip. The depth will also affect the movement of the thumb in order to press the keypad. If the phone is too thick, it will be very difficult for those with smaller hands (mostly women) to hold the phone and to operate it. The length and thickness of the thumb must be considered. The bottom 5% woman has a thumb length and thickness of 44 mm and 15 mm, respectively; while the top 95% man measures 69 mm and 24 mm, respectively. The current *average* depth of smartphones is about 16 mm. Many users critique the

Blackberry models of being too thick and demand that they slim down. Personal experience has taught me that the Palm Centro is too thick for me to comfortably maneuver using my thumb, while the new Motorola Q is much thinner (although it is slightly taller). Users will put preference on phones that are thin and sleek, not bulky. A redesigned smartphone should be no thicker than the Motorola Q9h (12.7 mm), which will better accommodate users with less thumb reach than others. This dimensional variable is also an important factor in hand health. Many users who are constantly using applications by typing using only their thumbs will tend to damage and evoke injuries on the radial nerves of their hands. If the thumb is strained because of the smartphone, users will be dissatisfied and possibly injured. A small diagram of the thumb in relation to the radial nerve can be found in Figure 10.

Concluding Comments

A newly redesigned smartphone will use many of the current designs, features and measurements; however, they will be specifically pulled from certain phones. Although many manufacturers continue to only "enhance" their current models, it would be interesting to see several smartphone designers and manufacturers share their innovative ideas and create one smartphone. The above critiques have been merged into a future smartphone idea (below).

Data

Table 1:

Hand Anthropometric Data (Index Finger)

			Pushing Downwards (N)		
Age (Years)	**Sex**	**No.**	**Mean**	**Standard Dev.**	**Range**
2-5	M F	9 8	21.82 24.49	7.01 8.07	14.70-35.00 12.40-35.10
6-10	M F	5 10	43.32 42.00	16.58 17.20	15.30-57.10 22.80-76.80
11-15	M F	12 5	66.65 32.02	22.56 19.44	35.90-102.70 31.00-78.40
16-20	M F	6 8	113.93 76.12	38.49 22.18	60.90-162.60 53.60-115.90
21-30	M F	10 7	111.29 76.47	26.19 15.57	71.70-142.50 61.90-106.60
31-50	M F	7 16	127.64 85.95	28.70 18.62	98.20-176.80 62.90-119.00
51-60	M F	5 6	105.28 74.33	23.74 9.26	71.20-124.80 58.00-84.70
61-70	M F	3 8	122.10 65.45	48.59 8.17	93.00-178.20 55.00-75.10
71-80	M F	8 11	90.00 62.03	17.64 12.40	64.70-118.20 37.50-79.20
81-90	F	4	54.25	7.05	44.40-60.70

Hand Anthropometric Data (Thumb)

			Pushing Downwards (N)		
Age (Years)	**Sex**	**No.**	**Mean**	**Standard Dev.**	**Range**
2-5	M F	9 8	26.920 34.40	18.85 14.59	23.50-53.80 13.60-53.90
6-10	M F	5 10	85.08 71.14	34.18 33.56	51.40-132.10 27.80-119.50
11-15	M F	12 5	115.09 94.34	40.01 36.16	67.90-209.10 39.10-139.60
16-20	M F	6 8	195.78 125.46	51.50 24.26	113.90-247.50 86.20-161.40
21-30	M F	10 7	184.14 135.17	52.19 30.35	109.30-290.10 84.70-180.70
31-50	M F	7 16	201.40 133.36	23.54 29.36	178.70-242.20 86.90-187.20
51-60	M F	5 6	168.34 124.48	61.27 26.78	76.30-248.70 85.60-142.80
61-70	M F	3 8	172.73 94.53	67.13 13.97	103.80-237.90 72.80-119.30
71-80	M F	8 11	145.45 89.83	46.89 18.94	91.60-211.80 61.50-123.30
81-90	F	4	80.87	25.37	56.50-109.90

Table 2: Smartphone Specifications and Dimensions

Brand and Model No.	Dimensions (mm)	Weight (g)
RIM Blackberry Pearl 8100	107 x 50 x 14.5	89
RIM Blackberry 8800	114 x 66 x 14	134
RIM Blackberry Curve 8310	107 x 60 x 15.5	110
Palm Treo 755p	113 x 59.3 x 21.3	160
Palm Centro	107.2 x 53.6 x 18.5	119
Motorola Q9h	116.8 x 66.0 x 12.7	133
Nokia E62	116.8 x 71.1 x 15.2	145
Samsung Blackjack SGH i607	111.8 x 58.4 x 12.7	99
Apple iPhone	116.8 x 60.9 x 17.8	136

Appendix

Figure 1. Motorola SLVR L7

Figure 2. Motorola MOTO Q

Figure 3. Palm Treo 680

Figure 4. RIM Blackberry 8800

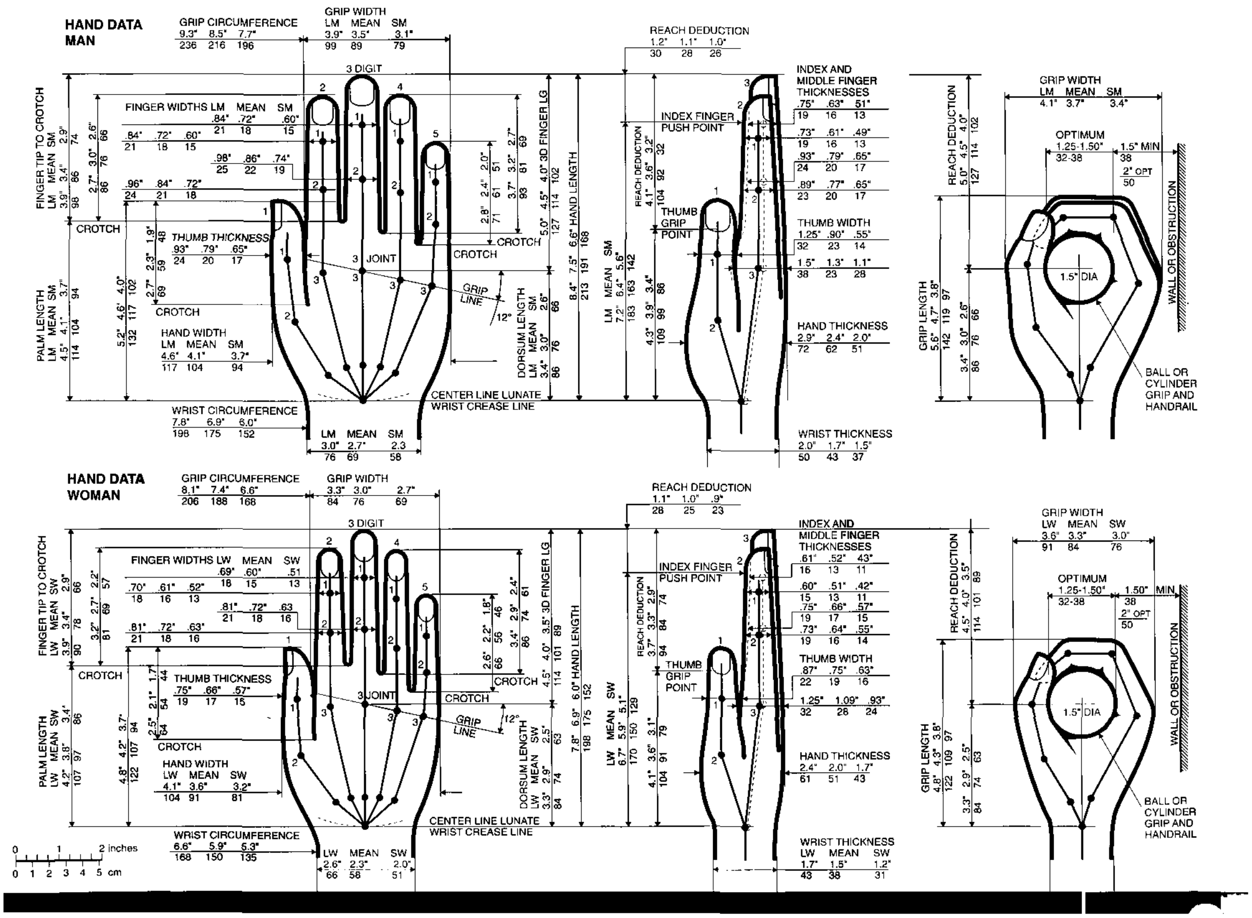
Figure 5. Motorola Q9m

Figure 6. RIM Blackberry Pearl 8100 Navigation Trackball view

Figure 7. Palm Treo 700p Keypad view

Figure 8. Simple Numeric Keypad

Figure 9. Nokia 6820 Two-Handed Grip



Hand Anthropometric Data