The Effects of Virtual Keyboard Key Sizes on Typing Productivity and Physical Exposures

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The Effects of Virtual Keyboard Key Sizes on Typing Productivity and Physical Exposures

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With mobile devices including tablet PCs, gravitating towards smaller sizes, the keyboard key sizes on these devices often have to be smaller than recommended key sizes and spacing (18 to 20 mm) for notebook and desktop keyboards. Currently, there is limited research into how key sizes can affect typing proficiency and physical exposures during virtual keyboard use. Therefore, the present study investigated how different virtual keyboard key sizes affected muscle activity, wrist posture, and typing productivity. A total of 21 subjects (12 males and 9 females) participated in a repeated-measures laboratory experiment where typing speed, accuracy, muscle activity, wrist posture, and subjective discomfort were compared between four different virtual keyboards with key sizes (width x height) of 13x13, 16x16, 19x19, and 22x22 mm with a 2-mm gutter surrounding each key. The results showed that the keyboard with the 13x13 mm keys (15 mm center-to-center key spacing) had a 15% slower typing speed ($p < 0.0001$), higher static (10^{th} $^{\%tile}$) shoulder muscle activity (2% MVC, $p = 0.01$), and greater wrist extension in both hands (2° - 3°, p's < 0.01). The study findings indicate that 13x13 mm key size may not be optimal for touch typing on a virtual keyboard.

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INTRODUCTION

With the increasingly prevalent use of tablet PCs, touch screen virtual keyboards are starting to compliment traditional computer input devices such as a keyboard and mouse (Kim et al. 2012). However, as tablets gravitate towards smaller sizes for better portability, the virtual keyboard key sizes often end up being smaller than the 18 to 20 mm key sizes (center-to-center key spacing) recommended for notebook and desktop keyboards (ANSI/HFES 100-2007, ISO 9241-410, 2008). The research on the effect of these smaller virtual keyboard key sizes has been limited, and there has been a lack of consistent recommendations for key sizes on touch screen virtual keyboards (Sesto et al. 2012).

Previous studies have shown that computer keyboard geometry including key spacing (center-to-center distance) and key size could affect typing performance, usability, and physical risk factors associated with computer-related musculoskeletal disorders (Hoffmann et al. 1995, Yoshitake 1995, Jindrich et al. 2004, Balakrishnan et al. 2006, Rempel et al. 2009, Pereira et al. 2012). These studies found that inappropriate key sizes and/or spacing may adversely affect typing productivity and physical exposures. Some of these studies on conventional notebook and desktop keyboards showed that smaller keyboard sizes and key spacing affected typing productivity and usability. However, given substantial differences in keyboard characteristics between a conventional and virtual keyboard (Kim et al. 2012), it may be difficult to generalize the previous findings on conventional keyboards to predict typing productivity and physical exposures during virtual keyboard use.

Some research has explored the effects of virtual keyboard geometry on usability (Kwon et al. 2009, Sesto et al. 2012) and these studies have found that key size significantly affects usability and subjective preferences. However, since most previous research has focused on virtual keyboard usability and productivity (Kwon et al. 2009, Park and Han 2010), biomechanical research on virtual keyboards has been limited. As a result, the effects of virtual keyboard key sizes on physical exposures are not well understood.

Therefore, the goal of the present study was to determine how virtual keyboard key size affects not only typing productivity but also biomechanical exposures including muscle activity and wrist posture. Based on the current body of literature, we hypothesized that smaller key sizes will decrease typing productivity. We also hypothesized that smaller key sizes may increase visual demand to locate the keys and therefore increase shoulder muscle activity when compared to larger key sizes.

METHODS

Subjects

Twenty-one subjects (12 male and 9 female) with an average age of 24.5 years (range 18-49 years) were recruited to participate in the study through e-mail solicitations. All subjects were experienced touch typists with no history of upper extremity musculoskeletal disorders and 19 subjects were right hand dominant. The experimental protocol was approved by the University's Human Subjects Committee and all subjects gave their written consent prior to their participation in the study.

Experimental design

Before starting the typing task, the chair, table, and monitor were adjusted to each subject's anthropometry in accordance with ANSI/HFES 100-2007. The chair was adjusted so the subject's feet rested firmly on the floor. With subjects relaxing their shoulders, resting their arms comfortably at their side and forming roughly a 90 degree angle at the elbow, the height of the workstation was adjusted so the table height was set at approximately 2 cm below elbow height. Finally, the virtual keyboard was placed so the spacebar centered on the subject's body and 7 cm from the front edge of the worksurface.

During the repeated-measures laboratory experiment, subjects typed for two five-minute sessions on a touch screen virtual keyboard (Iconia, Acer Inc., Taiwan) with the four different key sizes (shown in Fig. 1): 13×13 mm, 16×16 mm, 19×19 mm, and 22×22 mm (Width × Height). The gutter size surrounding the keys was kept at fixed size of 2.0 mm; accordingly, the center-to-center key spacing for these four keyboard was 15x15, 18x18, 21x21, 24x24 mm (Vertical x Horizontal). The presentation of the key sizes was randomized to minimize potential confounding effects with order.

During the typing sessions, typing productivity including typing speed (words per minute) and accuracy (% key correctly typed) were recorded using a program developed in LabVIEW (Ver. 2009; National Instruments; Austin, TX, USA). A data logger (Mega ME6000; Mega Electronics; Kupio, Finland) recorded muscle activity from the right extensor digitorum communis (EDC), flexor digitorum superficialis (FDS), and the right trapezius (TRAP) at a sample rate of 1000 Hz (Fig. 2). The EDC muscle activity was measured by placing the EMG electrodes (Blue Sensor N-00-S; Ambu; Ballerup, Denmark) over the muscle belly one-third of the distance from its origin at the lateral epicondyle (Cram et al. 1998). Similarly, the FDS muscle activity was measured by placing the EMG electrodes over the muscle belly one-third of the distance from its origin on the medial epicondyle. The electrodes for the TRAP were placed 1 cm laterally from halfway between C7 and the right acromium process and the ground electrode was placed on C7 (Onishi et al. 2000). At the end of the experiment three Maximum Voluntary Contractions (MVCs) were recorded, each of which lasted for three seconds in duration with 3 to 5 seconds of rest between each MVC (Soderberg and Knutson 2000).

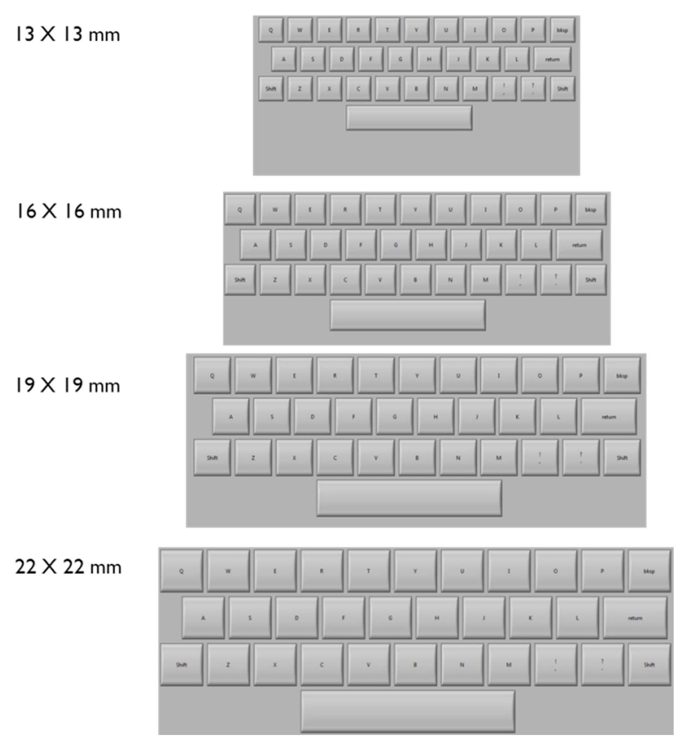

Figure 1. Four key sizes tested in the study

After the EMG data was band pass filtered (10-350 Hz), each muscle's EMG data was normalized using the highest 1 second RMS signal from the three MVCs. From the normalized EMG data, the amplitude probability density function (APDF) was calculated for each muscle. The $10^{th\ \%tile}$ EMG was used to indicate static muscle loads; the $90^{th\ \%tile}$ indicated peak muscle loads; and the $50^{th\ \%tile}$ provided a measure of the central tendency of the muscle activity.

Lastly, using the same aforementioned data logger, wrist postures including flexion/extension and radial/ulnar deviation were synchronously measured at 1000 Hz from both hands using biaxial electrogoniometers (Model SG-75; Biometrics Ltd; Newport, UK). The attachment and calibration of the electrogoniometers were performed using the methods prescribed by (Johnson et al. 2002). From the raw goniometer data, the 5^{th}, 50^{th}, and 95^{th} percentile values were calculated for the flexion/extension and radial/ulnar deviation. The 5th and $95^{th\ \%tile}$ represent the extreme wrist postures while the $50^{th\ \%tile}$ represents the central tendency of the wrist postures (Blackstone et al. 2008).

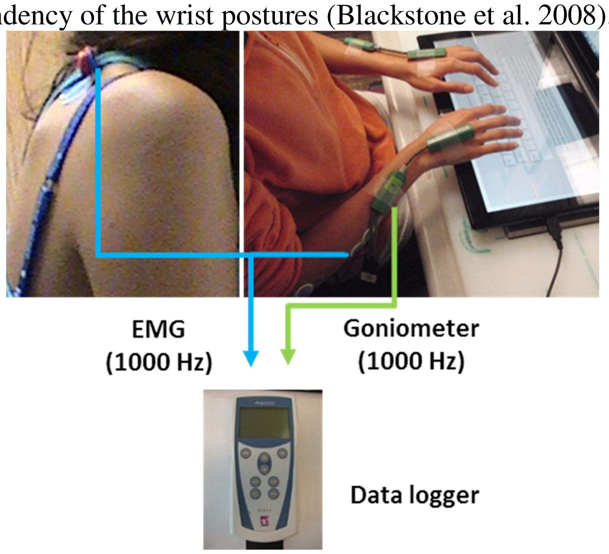

Figure 1. Experiment setup.

Data analysis

Statistical analysis was conducted in JMP (Version 9; SAS Institute Inc., USA). A *mixed model* with *restricted maximum likelihood estimation* (REML) was used to determine whether there were any differences in typing productivity, muscle activity, and wrist posture between the virtual keyboards with different key sizes. Any statistical significance was followed by the *Tukey-Kramer* method to determine whether there were differences between the virtual key sizes tested. All data are presented as mean and standard error; and significance was noted when Type I error was less than 0.05.

RESULTS

Typing productivity

As shown in Table 1, net typing speed on the virtual keyboard with 13mm keys (15 mm center-to-center spacing) was approximately 15% slower than the other virtual keyboards ($p < 0.0001$) while typing accuracy with the 13 mm keys was 4.5% higher compared to the other virtual keyboards ($p = 0.004$).

Table 1. Mean (SE) typing speed in word per minute (WPM) and percent accuracy (%) compared across the four keyboards [n = 21]. Across rows, different letters indicate significant differences.

	Key Size				
	13 mm	16 mm	19 mm	22 mm	p-value
Typing Speed (WPM)	23.3 [a] (1.0)	27.0 [b] (1.0)	27.0 [b] (1.0)	27.5 [b] (1.0)	**<0.0001**
Typing Accuracy (%)	92.3 [a] (1.0)	90.3 [b] (1.0)	88.7 [b] (1.0)	88.9 [b] (1.0)	**0.004**

Muscle Activity

Due to technical difficulties, muscle activity was collected from 19 of 21 subjects. Table 2 compares the static (10th $^{\%tile}$), median (50th $^{\%tile}$), and peak (90th $^{\%tile}$) muscle activity levels between the virtual keyboards with the different key sizes. The results indicated that virtual key size had little effect on EDC and FDS muscle activity whereas, when expressed at a %MVC, the static (10th $^{\%tile}$) TRAP muscle activity on the virtual keyboard with the 13 mm keys was 2.5% higher as compared to the virtual keyboards with the 19 and 22 mm keys ($p = 0.01$).

Table 2. Differences in muscle activity (%MVC) compared across the four keyboards [n=19]. Rows with different superscripts indicate significant differences in muscle activity between key sizes.

	Percentile	Key Size				
		13 mm	16 mm	19 mm	22 mm	p-value
EDC	10th	6.9 (0.5)	6.6 (0.5)	6.6 (0.5)	6.5 (0.5)	0.26
	50th	11.0 (0.9)	11.0 (0.9)	11.0 (0.9)	10.9 (0.9)	0.99
	90th	18.8 (2.4)	19.0 (2.2)	19.2 (2.2)	19.1 (2.1)	0.81
FDS	10th	2.3 (0.3)	2.2 (0.2)	2.3 (0.3)	2.3 (0.3)	0.57
	50th	4.0 (0.4)	3.8 (0.3)	4.0 (0.4)	4.1 (0.5)	0.71
	90th	13.4 (1.7)	13.7 (1.6)	15.3 (2.2)	14.9 (2.1)	0.19
TRAP	10th	12.6 (2.5) [a]	11.3 (2.2) [a,b]	9.9 (2.0) [b]	10.3 (2.1) [b]	**0.01**
	50th	16.7 (3.2)	15.7 (2.9)	14.7 (2.6)	14.4 (2.8)	0.06
	90th	21.9 (4.0)	21.6 (3.7)	21.1 (3.5)	19.7 (3.7)	0.16

EDC = extensor digitorum commonis; FDS = flexor digitorum superficialis; TRAP = trapezius.

Wrist Posture

Similar to the EMG data, the electrogoniometer data from two subjects were not recorded due to technical difficulties; therefore, the wrist posture results are also based on 19 subjects. The results showed that key size affected wrist extension and flexion whereas wrist postures on the ulnar/radial deviation plane were not affected by the different key sizes (Table 3). In both wrists, the 50th $^{\%tile}$ percentile values showed that typing on the virtual keyboards with the smaller keys resulted in greater wrist extension (2° to 3°) compared to the larger keys (p's < 0.01).

DISCUSSION

The present study investigated whether different virtual keyboard key sizes would affect typing speed, accuracy, muscle activity, and wrist postures. This study found that the virtual keyboard with a key size of 13 mm (15 mm center-to-center key spacing) may be less optimal for touch typing on a virtual keyboard, given that these smaller keys had slower typing speed, higher static shoulder muscle activity, and more wrist extension as compared to other key sizes.

Table 3. Differences in wrist postures between different key sizes [n=19]. Rows with different superscripts indicate key sizes which are significantly different.

percentile		Wrist	Key sizes 13 mm	16 mm	19 mm	22 mm	p-value
F/E (°)	5th	Left	-4.3(1.6)^{a}	-6.2(1.6)^{b}	-8.0(1.6)^{c}	-8.1(1.6)^{c}	**<0.0001**
		Right	-3.0 (3.1)^{a}	-3.6(3.1)^{a}	-6.9(3.1)^{b}	-6.6(3.1)^{b}	**<0.0001**
	50th	Left	5.2(1.7)^{a}	3.5(1.7)^{a,b}	2.0(1.7)^{b}	2.7(1.7)^{b}	**0.003**
		Right	6.4(3.1)^{a,b}	6.8(3.1)^{a}	4.1(3.1)^{b}	4.6(3.1)^{a,b}	**0.01**
	95th	Left	13.9(1.8)^{a}	12.7(1.8)^{a,b}	10.9(1.8)^{b}	11.5(1.8)^{a,b}	**0.01**
		Right	15.5(3.3)	16.4(3.3)	14.9(3.3)	15.4(3.3)	0.47
R/U (°)	5th	Left	9.9(1.6)	10.0(1.6)	10.5(1.6)	10.3(1.6)	0.91
		Right	8.3(1.8)	6.4(1.8)	7.2(1.8)	6.8(1.8)	0.18
	50th	Left	16.9(1.5)	17.3(1.5)	17.4(1.5)	16.6(1.5)	0.53
		Right	13.0(1.7)	12.5(1.7)	12.6(1.7)	12.6(1.7)	0.70
	95th	Left	22.2(1.5)	22.8(1.5)	23.1(1.5)	22.5(1.5)	0.27
		Right	17.3(1.8)	17.2(1.8)	18.1(1.8)	18.5(1.8)	0.08

F/E = flexion/extension; R/U = radial/ulnar deviation. Positive F/E and R/U indicate extension and ulnar deviation, respectively.

The slower typing speed observed with the smaller, 13 mm key size was in line with those reported by previous studies (Yoshitake 1995, Hoffmann et al. 1995). Yoshitake (1995) showed that typing speed decreased when the key spacing was smaller than 16 mm. It is possible that greater difficulty seeing the keys and/or insufficient clearance between fingers due to the smaller key size and key spacing may have also slowed down typing speed.

As hypothesized, static (10th $^{\%tile}$) shoulder muscle activity during the use of the keyboard with 13 mm keys was higher when compared to the other larger keys. Previous studies suggested that virtual keyboard use could increase the visual demands to locate the keys and therefore increase shoulder muscle activity (Shin and Zhu 2011). Since visual demands are known to increase as a target size decreases, the smaller key size may have increased visual demand and perhaps some additional neck flexion to identify and locate the keys; and therefore increased shoulder muscle activity. In future studies, it may be beneficial to also measure neck and/or head flexion to objectively determine if there is increased head/neck flexion.

Virtual keyboard key size had no effect on radial/ulnar deviation whereas wrist extension was affected by the different key sizes, especially on the left wrist. The 50th and 95th percentile values showed that 13 mm keyboard caused more wrist extension during typing. Pereira et al. (2012) also found greater wrist extension with smaller key spacing. Although the differences in wrist extension between the key sizes were less than 5°, prolonged virtual keyboard use with less neutral wrist posture may increase biomechanical risks and/or discomfort.

In conclusion, this study demonstrated that virtual keyboard key size affected typing productivity, muscle activity, and wrist posture. The slower typing speed, higher shoulder muscle activity, and less-neutral wrist postures suggested that 13 mm key size for virtual keyboards may not be the optimal size for touch typing.

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