How to Optimize the Input Efficiency of Keyboard Buttons in Large Smartphone? A Comparison of Curved Keyboard and Keyboard Area Size

Yincheng Wang[1], Hailin Ai[1], Qiongdan Liang[1], Wenjie Chang[2], and Jibo He[1](✉)

[1] Tsinghua University, Beijing, People's Republic of China
{wang-yc18, ahl16, lqd18}@mails.tsinghua.edu.cn,
hejibo666@mail.tsinghua.edu.cn

[2] Wuhan University of Technology, Wuhan, People's Republic of China
narcissusc@live.com

Abstract. Smartphone has been constantly optimizing the user experience of viewing content by increasing screen size. However, larger screen brings about unsatisfactory input issue, especially for one-handed users. Curved QWERTY keyboard and reduced soft keyboard area are proposed to solve the input inefficiency issue of application design in the large smartphones. Following the design of existing curved keyboards, we designed a keyboard application, which could collect all the usage data, to test whether the curved keyboard or reduced-area keyboard could indeed solve the input inefficiency issue. By using within-subject design. we compared 2 screen sizes (5.0 in. vs. 6.5 in.), 2 area sizes (small-area: letter key area is 4.9 mm × 7 mm vs. large-area: letter key area is 6.3 mm × 9 mm), and 2 keyboard layouts (curved QWERTY vs. traditional QWERTY). The results show that the large-area keyboard is significantly better in terms of pairs per minute and reaction time between two keys, at the same time, the curved keyboard performs worse than the traditional keyboard. It indicates that the two design elements are not a common practice.

Keywords: Curved QWERTY keyboard · Reduced input area · Input efficiency · Reachability

1 Introduction

1.1 Input Efficiency Issue

The large screen smartphone is everywhere. Although Steve Jobs insisted that 3.5 in. is the perfect mobile phone size, smartphone designers have been increasing the phone screen sizes to optimize the user experience. From 2007 to 2019, the size of the Apple mobile phone increased from 3.5 in. (iPhone 4) to 6.5 in. (iPhone XS Max), and the similar increases in sizes for the Android smartphone. Among 3774 different kinds of smartphones, 6.5-in. smartphone (e.g., Honor 8X, iPhone XS Max) is larger than

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95.62% smartphones [1], while 5-in. smartphone (e.g., Huawei Changxiang 6S, nova 2) is larger than 13.46% smartphones [2].

Reachability refers to the difficulty and efficiency of touching with a finger for a point on the screen. The increase in the screen of the mobile phone has changed the center of gravity of the smartphone. In order to accomplish the input task, users have to continuously change their hand-grip posture and rapidly flex their fingers to reach the buttons which include some hard-to-reach keys. These hand-grip and reachability issues bring about finger fatigue and joint pain which leads to unsatisfactory input efficiency and experience. People sometimes have to use a phone with one hand (some people are originally one-handed users), such as in a meeting, or being busy with a variety of things, etc., and one-handed operation can improve the convenience of using the mobile phone to a certain extent. In the large smartphone, the above issues exist in different operation styles, however, they are more prominent in one-handed operation posture [3–6].

1.2 Curved Keyboard and Reduced Input Area

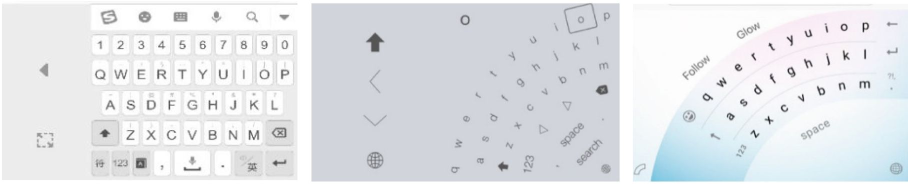
Three kinds of approaches were used to optimize the keyboard layout to improve input efficiency, including adaptive keyboards [7, 8], dynamic and static key resizing [9–11], and keyboard optimization [12–16], e.g., IJQWERTY, Quasi-QWERTY, etc. Although several of these approaches have shown some benefits, they all have failed to be widely accepted and have not proven to well solve input inefficiency issue in large smartphones [17, 18].

Researchers found that curved QWERTYand reduced-area keyboards may be useful and helpful. Trudeau, Sunderland, Jindrich, and Dennerlein found that the user performance with soft QWERTY keyboard could be improved by changing its radius of curvature, orientation, and vertical location on the screen [19]. Also, Fitts' Law shows that distance, area, and space are important factors for efficiency [20, 21]. Users have to frequently change their hand posture and move their fingers to reach all necessary regions of the phone screen relevant to their tasks, and the regions were defined as the "functional area" [22]. It indicated increasing the number of buttons in the functional area of the user's thumb could improve the one-handed input efficiency. Based on the above, curved QWERTY keyboard and reduced-area (small-area) keyboard are designed to solve the input inefficiency issue, e.g., Sogou Keyboard, ThumbFan, and WordFlow, etc. (Fig. 1).

Therefore, following the design of existing curved keyboards, we designed a one-handed keyboard application to test whether the curved keyboard or reduced input area could indeed solve the input inefficiency issue on different screen sizes.

2 Method

By using within-subject design, we compared 2 screen sizes (5.0 in. vs. 6.5 in.), 2 area sizes (small-area: letter key area is 4.9 mm × 7 mm vs. large-area: letter key area is 6.3 mm × 9 mm), and 2 keyboard layouts (curved QWERTY vs. traditional



(a) Sogou Keyboard (b) ThumbFan (c) WordFlow

Fig. 1. Existing reduced-area keyboard: (a) Sogou Keyboard. Existing curved QWERTY keyboards: (b) ThumbFan, and (c) WordFlow.

QWERTY), and the apparatus are Honor 8X (6.5-in. screen) and Huawei Changxiang 6S (5.0-in. screen) (Fig. 2).

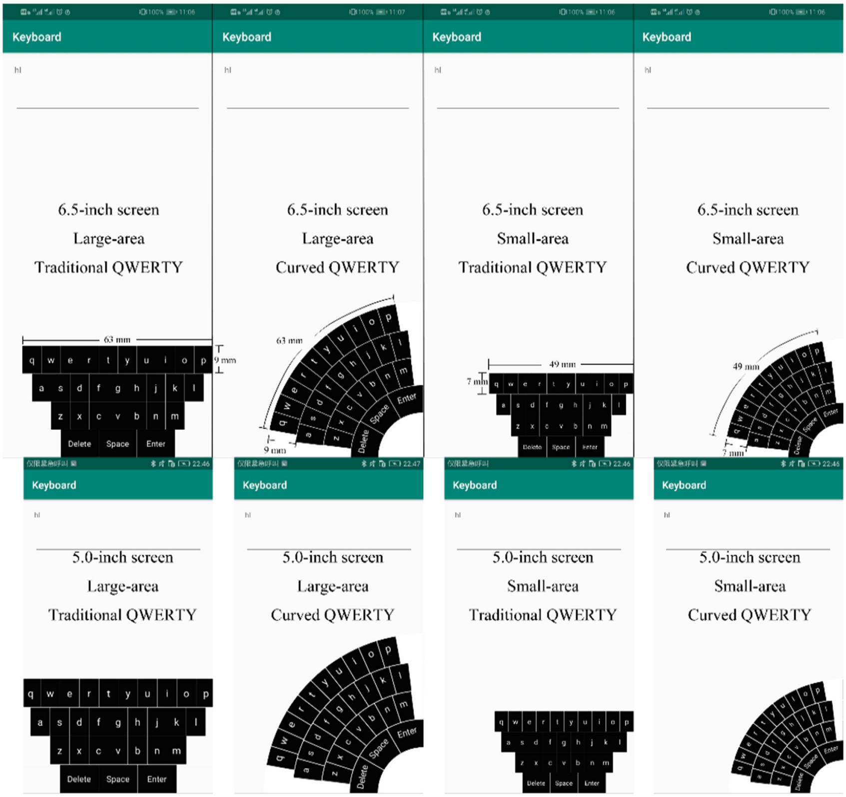


Fig. 2. All the conditions and application interfaces. In each keyboard, the length and width of each letter key are the same, while the functional keys (Space, Delete, and Enter) are twice as wide as the letter key. The parameters of the small-area keyboard depend on iPhone 4 s screen size (3.5 in.). Large-area keyboard, which is 1.3 times of small-area (reduced-area) keyboard, is covered with the width of the screen of the 5-in. smartphone.

Thirty-two right-handed college students (*M* = 22.41 years, *SD* = 2.70 years, 16 females) were recruited to finish an input task (two characters are randomly paired together as input materials) by only using their right hand. Pair per minute, pair error rate, and reaction time between two characters are collected by the application to evaluate typing performance.

3 Results

3.1 Reaction Time (RT)

Using reaction time between two characters as a dependent variable, a 2 (screen size: 5.0-in. screen and 6.5-in. screen) × 2 (area size: small-area and large-area) × 2 (keyboard layout: Curved QWERTY and Traditional QWERTY) repeated measures ANOVA was applied, and it was consequently found that the three-way interaction was not significant, $F(1,31) = 0.151$, $p = .701$, $\eta_p^2 = .005$).

The main effect of area size was significant, $F(1,31) = 15.362$, $p < .001$, $\eta_p^2 = .331$, and RT of small-area is longer than that of the large-area ($p < .001$). The main effect of keyboard layout was significant, $F(1,31) = 79.384$, $p < .001$, $\eta_p^2 = .719$, and reaction time of traditional QWERTY is shorter than that of the curved QWERTY ($p < .001$). The main effect of screen size was not significant, $F(1,31) = 0.815$, $p = .374$, $\eta_p^2 = .026$.

The interaction between keyboard layout and area size was significant, $F(1,31) = 5.733$, $p = .023$, $\eta_p^2 = .156$. In particular, simple-effect analysis returned the following result (Figs. 3 and 4): In the curved QWERTY, the small-area's reaction time is longer than that of the large-area ($p = .001$), while in the traditional QWERTY, there is no significant difference between the reaction time of the small-area and that of the large-area ($p = .442$). In the small-area, the reaction time of the curved QWERTY is longer than that of the traditional QWERTY ($p < .001$), while in the large-area, the reaction time of the curved QWERTY is longer than that of the traditional QWERTY ($p < .001$).

3.2 Pair Per Minute (PPM)

Using pair per minute as a dependent variable, a 2 (screen size: 5.0-in. screen and 6.5-in. screen) × 2 (area size: small-area and large-area) × 2 (keyboard layout: Curved QWERTY and Traditional QWERTY) repeated measures ANOVA was applied, and it was consequently found that the interaction between the three was not significant, $F(1,31) = 0.206$, $p = .653$, $\eta_p^2 = .007$.

The main effect of area size was significant, $F(1,31) = 23.816$, $p < .001$, $\eta_p^2 = .434$, and the pair per minute of small-area is shorter than that of the large-area ($p < .001$). The main effect of screen size was significant, $F(1,31) = 7.402$, $p = .011$, $\eta_p^2 = .193$, and the pair per minute of 5.0-in. screen is longer than that of the 6.5-in. screen ($p = .011$). The main effect of keyboard layout was significant, $F(1,31) = 117.422$,

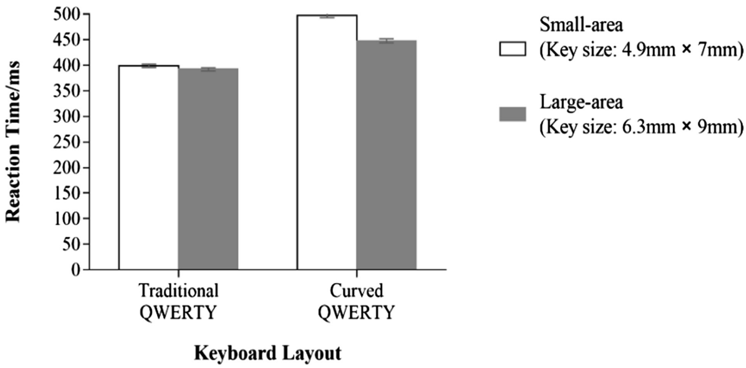


Fig. 3. Difference of reaction time between keyboard layout and keyboard area size. Error bar represents Standard Error of Mean. (Keyboard layout)

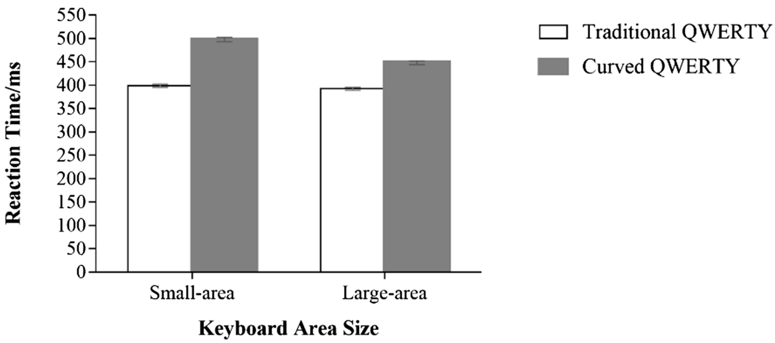


Fig. 4. Difference of reaction time between keyboard layout and keyboard area size. Error bar represents Standard Error of Mean. (Keyboard area size)

$p < .001$, $\eta_p^2 = .791$, and the pair per minute of traditional QWERTY is longer than that of the curved QWERTY ($p < .001$).

There was a significant interaction between screen size and area size, $F(1,31) = 5.704$, $p = .023$, $\eta_p^2 = .155$. In particular, simple-effect analysis returned the following result (Fig. 5): In the 5.0-in. screen smartphone, the small-area's pair per minute is shorter than that of the large-area ($p = .026$), while in the 6.5-in. screen smartphone, the difference between the small-area and the large-area was not significant in terms of pair per minute ($p = .197$). In the small-area, there is no significant difference between the 5.0-in. screen and the 6.5-in. screen smartphone in terms of pair per minute ($p = .991$), while in the large-area, there is no significant difference between the 5.0-in. screen and the 6.5-in. screen smartphone in terms of the pair per minute ($p = .561$).

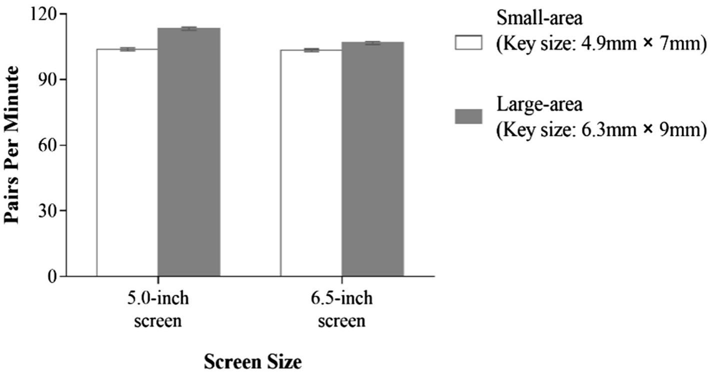


Fig. 5. Difference of pair per minute between screen size and keyboard area size. Error bar represents Standard Error of Mean.

3.3 Pair Error Rate (PER)

Using pair error rate as a dependent variable, a 2 (screen size: 5.0-in. screen and 6.5-in. screen) × 2 (area size: small-area and large-area) × 2 (keyboard layout: Curved QWERTY and Traditional QWERTY) repeated measures ANOVA was applied, and it was consequently found that the interaction between the three was not significant ($F(1,31) = 1.545$, $p = .223$, $\eta_p^2 = .047$).

The main effect of area size was significant, $F(1,31) = 55.269$, $p < .001$, $\eta_p^2 = .641$, and pair error rate of small-area is shorter than that of the large-area ($p < .001$). The main effect of keyboard layout was significant, $F(1,31) = 31.778$, $p < .001$, $\eta_p^2 = .506$, and pair error rate of traditional QWERTY is longer than that of the curved QWERTY ($p < .001$). The main effect of screen size was not significant, $F(1,31) = 0.017$, $p = .896$, $\eta_p^2 = .001$. At the same time, we didn't find other significant two-way interaction.

4 Discussion and Application

Based on the results, we found that the large-area keyboard is significantly better in terms of pair per minute and reaction time. The curved keyboard performs worse than the traditional keyboard in terms of longer reaction time.

In this study, we designed a keyboard application to test whether curved QWERTY keyboard and reduced-area keyboard could optimize input efficiency in large smartphones. The results showed that in the aspect of reaction time between two characters, the traditional QWERTY keyboard is significantly better than the curved QWERTY keyboard, and the large-area keyboard is significantly better in the aspect of pair per minute and reaction time. It means that curved QWERTY keyboard and reduced-area keyboard both perform worse than traditional QWERTY keyboard and large-area keyboard in terms of reachability and input efficiency issue. The reasons might be unfamiliarity with the keyboard, rotation of keyboard letters, and that large area was not covered with the width of the screen of 6.5-in. smartphone, etc. Besides, it indicated that 3.5-in. keyboard is not perfect in the large smartphone, and functional area could be more precisely redefined to enlighten keyboard designers.

In conclusion, although many designers intuitively believed that small-area (reduced-area) keyboard and curved keyboard can solve the reachability and input inefficiency issues of the large smartphone, our data showed no benefits of both small-area keyboard and curved QWERTY keyboard. Perhaps that is why the two design elements are not a common practice.

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