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A Comparative Evaluation of the Effectiveness of Touchscreen and Keypad Input Styles on Mobile Phones

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Abstract

Mobile phones have become a vital part of our everyday activities for personal, business and educational purposes. A lot of interaction with the mobile phone is a via text input. This research presents an empirical evaluation of the effectiveness of the touchscreen and keypad interactive styles for text input on mobile phones. An experiment was setup to investigate any differences between four mobile input styles: Touchscreen QWERTY, Touch screen Multi-press, Keypad QWERTY and Keypad Multi-press. The research found no significant difference between the touchscreen keyboards. However, there was a significant difference (p=0.016 at 95% confidence) between the physical keyboards. Keypad QWERTY was the fastest (27.5WPM) while Keypad multi-press was the slowest (18.1WPM). Results from post-experiment questionnaires showed no difference in learnability between the four methods but, differences occurred in error rate and efficiency. It is also shown that results of our experiment are comparable to those presented by earlier research which developed a predictive model based on Fitt's law.

Keywords* – *Mobile interaction, Mobile text input, Mobile touchscreen, Keypad multi-press, Mobile keypad, QWERTY keyboard.

I INTRODUCTION

Mobile devices have become the defacto devices for communication today. Indeed mobile devices have become powerful computers that fit in the palm of the hand. Mobile devices are no longer simply used for communication – calls and texting, only. Today, complex tasks such as emailing, word processing are being carried out on mobile devices. Tens of productivity applications (apps) that we rely on for daily functions also exist on mobile platforms. Asynchronous chat applications such as WhatsApp, Twitter, Skype have become extremely popular for communication and information dissemination even at organizational levels. Many academic activities such as student supervision and class coordination are carried on mobile devices through social media, synchronous and asynchronous messaging and voice apps. Research in the field of mobile learning investigates the effect of mobile devices in education [1], [2]. Some researchers have discussed the importance and usefulness of mobile devices for academic purposes with interesting results[1]–[4].

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The following section presents the background and related literature. The details of the experiment conducted are presented and results discussed. Finally, conclusions are made.

Objective
To compare text input speed using four (4) mobile text input styles

Hypothesis
Ho: There is no significant difference in the effectiveness of different mobile text input styles

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H1: There is a significant difference in effectiveness of mobile text input styles.

Research Question
This research set out to answer the following questions:
1. Is there any difference in the efficiency of text-input on mobile devices based on input style?

2. Which input style is fasted on mobile devices?

II LITERATURE REVIEW

A Background

Mobile computing devices have been proliferating over the recent past. In 2016, the use of mobile devices was reported to have surpassed that of desktop computers in the UK[5]. Similar trends are witnessed worldwide as the number of mobile devices continues to rise steadily from 2013 as reported by Statista Inc[6]. Mobile phones are particularly popular because of their portability: fitting into the palm of the hand. Mobile phones have evolved over the years from simple devices used solely for voice and text communication to powerful computing devices capable of almost any computing task from word processing to graphics creation and even writing and compiling computer programmes.

B Mobile Interaction model

Text input styles

The main interaction style for mobile devices is text input. Many smart phones feature the ability for voice input but this has limited use when compared to the number of activities that can be performed on the smart phone. For this reason, most research has focused on text input. Three styles are discussed in the literature: Keyboard based, Finger based and Stylus based[7].

Mobile Keyboard Layouts

The keyboard input style remains the most popular mobile text input method. This could be attributed to the legacy carried over from well established use of the keyboard on the telephone, typewriter and desktop computer over the years[7]. A lot of research has gone into the development of mobile keyboards. Owing to the size of mobile devices, it is not possible to feature a full sized keyboard as existed on the desktop computer. The space constraint provided a fertile ground for research: The literature is replete with several evolutions of mobile keyboards including Dvorak, Opti, ABC, Half Qwerty, Phone, Five-key pages, Less Tap,SureType, Fast Tap,TiltText, Qwerty [7]–[11]. Of all these the phone and qwerty layouts form the highest percentage of keyboard layouts on mobile devices for everyday use.

The Phone (12-key) keyboard layout

The 12-key arrangement was the first to be implemented on mobile phones with several schemes for arranging and imputing the English alphabets. This layout features 12 keys on which the digits 0 – 9 and the English alphabets a – z are assigned consecutively in a 3 by 4 matrix. This layout is similar to the key layout on the telephone. The alphabets are assigned in 3s or 4s on each key and user uses one of several schemes to select with each group. The within group selection is made by pressing one or more times on the key till the desired character as shown on the screen as shown in Figure 1

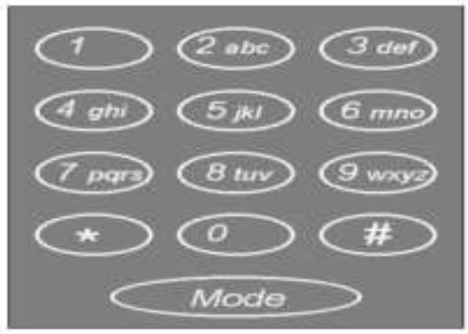

Figure 1: 12-key keypad layout

i. **Multi-press (multiTap) with timeout** – A short resting time was set to signify the end of selection within a particular group. This was useful to allow users enter words that required successive multiple instances of the same letter or within group selection. This method tended to slow down text input as the user needed to wait out the time out.

ii. **Multi-press with next button** – This was a new modifications allowed the user to cut short the timeout by pressing a neutral key. This was an improvement on the speed of text input but it increased the users keystroke per character (KSPC).

iii. **Pressure Text**: This method aimed to reduce the KSPC. It required the user to apply a certain amount of pressure on the key to make within group selection [12], [13].

iv. **T9 predictive input** – Predictive text input consists using list of dictionary words to predict the word intended by the user to be typed. The algorithm tries to compute word suggestions by combining characters from successive key presses and matching them with the possible dictionary words. The accuracy of prediction depends to the number of words available in the dictionary.

The popular variations today use Multi-press and T9 predictive texting simultaneously.

Qwertykeyboard layout

The qwerty keyboard arrangement was originally created for typewriters by Chistopher Latman Scholes [14] in the 1870s. Blackberry was one of the most popular mobile phones to come out with the QWERTY keyboard. This layout reduced the KSPC drastically. Variations of this keyboard layout include the half qwerty, Octopus, Curve and T+ [9]. This keyboard layout is now popular on mobile devices especially on the virtual keypads available on touch screen devices as shown in Figure 2.

Figure 2: Qwerty Keypad layout

C Keyboard Formats

Mobile keyboards come in two formats:

1. **Physical Keyboards:** This type of keyboard is usually made of plastic keys which are fitted to the body of the mobile device. Bearing in mind the number of keys needed, the limit to the physical size of the mobile device and the limit to minimum size of the keys, the physical keyboard takes up a large percentage of the mobile device surface thereby limiting the screen size. Physical keyboards come in either Phone or qwerty layout.

2. **Virtual (Soft) keyboards:** These are software based keyboards that come as part of the operating system or can be downloaded and installed. They come with a lot of advantages over the physical keyboards. The keyboard is viewed on apportion of the screen when text input is to made after which, the keyboard can be 'closed' allowing a much larger screen space to the user. Devices that come with virtual keyboards can usually swap between the Phone and the QWERTY arrangement. The keyboard can also be viewed in portrait or landscape orientation.

D Related works

Research into the effectiveness of mobile text input methods has been ongoing for a while. A number of researchers have contributed immensely to the field. [10]made a comparison of three text input methods to discover if there were any significant differences in input speeds. They conducted an experiment in which they simulated three text input methods namely: Multi-press with timeout, Multi-press with next and two-key. The use of mobile phones was still in its infancy at the time of the research. They however came up with finding that indicated Multi-press with next button method provided the fasted experience with text input.

Oniszczak& Mackenzie [15] carried out a comparison between MultiTap (also known as Multi-press) and an innovative RollPad text input method. They found no difference in error rates and input speed. However, they reported a significant difference in Keystrokes per character (KSPC), with RollPad doing better than Multi-press.

Curran and colleagues [16] investigated the preference of a range of devices among a target segment of participants. Their research revealed that the users preferred larger keyboards to smaller ones. They also discovered that female users seemed to sacrifice accuracy for speed. Older users were also found to be faster and more accurate that younger users. The QWERTY keyboard was also preferred for speed and accuracy and older users commented on their difficulty in using small screens and small keypads.

McCullam et al. [13] presented a novel text input method called PressureText. There experiment showed that PressureText produced similar results as multiTap while expert users gained 5% speed on average. [12]also describe the design of a touchscreen based pressure keyboard that used pressure to transit between letter case They report an experiment comparing two variants of the Pressure based input – Dwell and Quick Release with the shift-key keyboard design and found Quick release to be the fastest while Dwell was more accurate.

Sears &Zha [17] researched the effect of soft keyboard size on user tasks. They discovered that keyboard size had no significant effect on performance.

Several researchers have compared different input styles, but none has focused solely on commonly used mobile input styles. Silfverberg et.al [18] discussed a predictive model for text-input speed based on Fitt's Law, which predicts speed of rapid aimed movements by relating the distance to be moved between points with the size of the target . Applying this law to mobile phone keyboards, they obtained predicted expert input speeds as shown in Table 6 **Error! Reference source not found.**. This served as a benchmark for this work too.

III METHODOLOGY

An empirical evaluation of the available mobile input styles was carried out. The plan included recruiting subjects from our immediate community which was our university, Salem University, Lokoja, Nigeria.

A Experimental Design:

The experiment was setup to investigate the effectiveness of the four keyboard input styles outlined. Following similar experimental set up used in previous research, we set out to discover any significant differences in speed and accuracy of the input styles.

B Subjects:

The experiment followed the completely randomized design (CDR). 30 undergraduate students were randomly selected from the student population. The subjects were allowed to randomly select one of the four available devices for use in the experiment. There was no incentive given.

C Tools

The following tools were used for the experiment.

- Blackberry z10 (Touch screen QWERTY phone)
- Blackberry Q10 (QWERTY keypad phone)
- Nokia C1(Multi-press keypad)
- Nokia Lumia (Touch screen Multi-press keypad)
- Stopwatch

D Experiment Procedure

The participants were sited in a classroom and briefed on the experimental procedure. The participants were trained briefly on each of the four input interfaces to be used. They were then presented with the sentences to be typed on a piece of paper and were allowed to select any phone of their choice (there were four phones each with one of the four input interfaces to be tested).

Each participant was timed as they typed each sentence using a stopwatch. The times were recorded on record sheet provided for each participant.

Table 1: Five Sentences used for experiment [10]

s/n	Sentences	No. of characters
1	Hi Joe how are you want to meet tonight	39
2	Want to go to the movies with Sue and me	40
3	What show do you want to see	28
4	We are meeting at the front of the theatre at eight	47
5	Let me know if we should wait	29

After the experiment, the participants were asked to answer three questions with respect to their learnability, efficiency and error rate as shown in Table 5 (see below for discussion) using the likert scale (1:strongly disagree, 5:strongly agree).

E Metrics

Two main performance metrics in mobile input: Entry rate and Error rate.

1. **Entry Rate:** This metric is measured in words per minute (WPM). The word count is benchmarked to 5.98 characters per word based on previous research. We modified the equations from [9] shown below

   $$WPM = (S/5.98) / (T/60) \text{ -------(1)}$$

   S= Number of characters in input text T= Total input time

2. **Error Rate:**We applied the ‘forced’ error correction condition [19]. Therefore, although we did not calculate error rate, participants were asked to correct all errors. This meant that only correct text were submitted. Also, [19] already reported that error correction condition did not have any effect on input speed in WPM.

IV RESULTS

Four input styles were studied: Mobile Touchscreen qwerty (TSQ), Mobile Touchscreen Multi-press (TSM), Mobile Keypad Qwerty(KPQ) and Mobile Keypad Multi-press (KPM). Analysis were conducted using SPSS v.21 and minitab.

A Experiment Result Analysis

The experiment was carried out with a total of 30 participants which were asked to write out 5 different sentences (see Table 1) and the time taken to input each sentence was recorded. ANOVA was used to analyse the results.

Table 2: ANOVA Results

Factor Information
Factor Levels Values
IM 4 1, 2, 3, 4
Analysis of Variance
Source DF Adj SS Adj MS F-Value P-Value
IM 3 480.3 160.11 4.15 0.016
Error 26 1002.2 38.55
Total 29 1482.5
Model Summary
S R-sq R-sq(adj) R-sq(pred)
6.20853 32.40% 24.60% 10.21%

Table 3: Analysis of means

Analysis of Means

	N	Mean	Std. Deviation	Std. Error Mean
TSQ (1)	6	25.4436	6.00301	2.45072
TSM (2)	6	20.0032	6.27305	2.56096
KPQ (3)	10	27.4811	6.63010	2.09662
KPM (4)	8	18.1261	5.72751	2.02498

ANOVA using a confidence interval of 95%. The p-value = 0.016. p-value<0.05. Reject Ho. There is enough evidence to show a difference between the mean words per minute of the four methods.

Table 4: Tukey Pairwise Comparisons

IM	N	Mean	Grouping
3	10	27.48	A
1	6	25.44	AB
2	6	20.00	AB
4	8	18.13	B

Grouping Information Using the Tukey Method and 95% Confidence. The p-value = 0.016. p-value<0.05. Reject Ho. There is enough evidence to show a difference between the mean words per minute of the four methods.

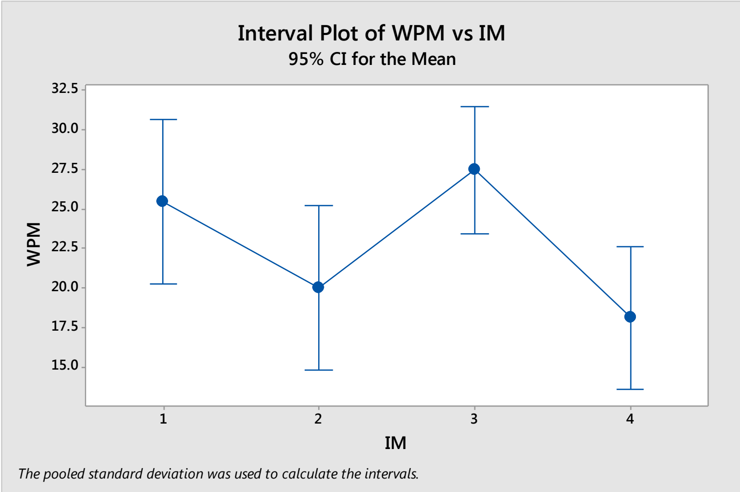

Figure 3: Interval plot for WPM vs IM (input method)

IM key: 1=TSQ, 2=TSM, 3= KPQ, 4 =KPM

For the validity of the ANOVA a normality test is done on the residuals

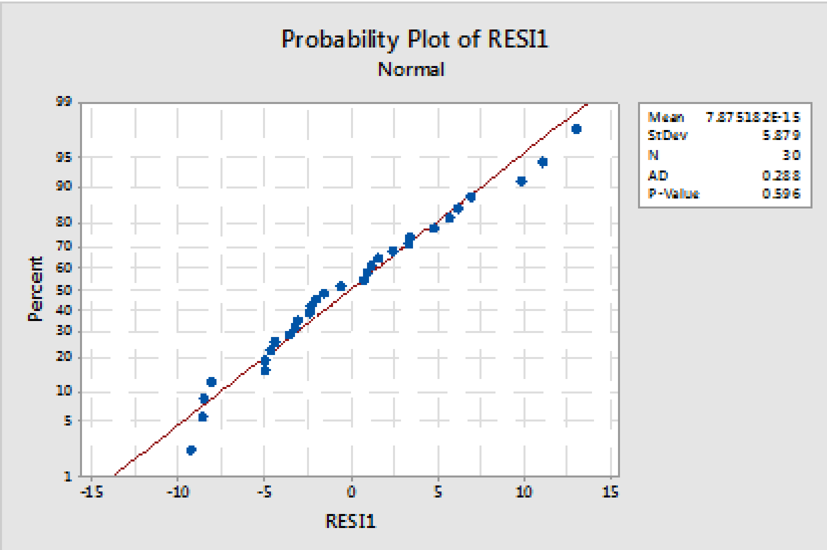

Figure 4: Probability plot of RESI1

The Turkey Pairwise comparison shows a difference between KPQ and KPM. This is further shown in the interval plot in Figure 3. The mean WPM for KPQ is significantly higher than that of KPM p-value> 0.05 and points are reasonably close to the straight line, it is reasonable to assume that the residuals are normally distributed. Therefore ANOVA is valid.

B Post Experiment Questionnaire Analysis

After the experiment participants were given questionnaires to gather information on their opinion about the experiment as regard to learnability, error rate and efficiency and LIKERT scale was used to analyse the information gathered. The rating is labelled from 1 to 5 representing strongly disagree, disagree, fairly agree, agree and strongly agree respectively.

Table 5: Mean (standard deviation) responses to 5-point Likert scale post experiment questions.

Question	TSQ	TSM	KPQ	KPM
1. I found this method easy to learn	3.50(2.12)	3.20(1.5)	4.6(0.55)	2.75(1.71)
2. I did not make many errors with this method	3.67(1.15)	2.4 (0.89)	4.00(0.71)	2.00(0)
3. I found this method efficient to use	4.00(0)	2.4(1.52)	4.8(0.45)	3.00(0.82)

Further analysis using Kruskal-Wallis Test showed that there was no significant difference in learnability (p = 0.27) while there was a difference in error rate (p=0.013) and efficiency (0.013) between the four input styles. The means show that KPQ was preferred overall.

C Threats to validity

Demography of subjects
Our subjects were undergraduate students. This population is known to be very active users of text input on mobile phones. Our results therefore may not generalize to older users.

Familiarity bias
There could have been some bias due to familiarity with a particular keyboard from daily personal use. Subjects were allowed to select keyboard styles at random so we believe this threat will be minimized.

Test Sentences
The sentences did not explore the full breadth of keys on the keyboard. However, they were typical sentences that users would expect. Notably, the need for 'radical abbreviation' [10] is no longer as strong. Also, they were chosen to allow for some level of comparability with previous research.

D Comparison with Previous Research

We show a comparison of results from previous research. It is notable to see the exponential increase in WPM from the early use of mobile phone to more recent times. Silfverberg et al., [18] predicted speeds of up to 22WPM for Multi-press in their proposed Fitt's law. This figure was thought to be 'unrealistic', and 'extremely optimistic'[10]. However, our work has shown that it is not so unrealistic after all. Our subjects were able to record an average speed of 18.1WPM for KPM compared to 6.4WPM and 4.8WPM recorded in previous research for Multi-press input method.

Table 6: Comparable results from previous research

	Input Method		
Paper	**MP – Timeout**	**MP – Next**	**Two-key**
Lee Butts & A. Cockburn [10]	6.4	7.2	5.5
Silfverberg et.al (2000) [18] Fitts Law	22.5	27.2	25.0
Andy Cockburn &A. Siresena [8]	4.8	N/A	N/A

Compared to results from this study,

Table 7: Comparable results from this study

This Study	**TSQ**	**TSM**	**KPQ**	**KPM**
number of words per minute	25.4	20.0	27.5	18.1

The WPM calculated from our results are much faster than the previous research. [10] as work because, at the time of the previous study, users were not conversant with text messaging and mobile phones and instead of using mobile phones for the experiment they used keyboards to type and this was one of their major drawbacks also for their experiment, they worked with three input methods while this work reported work with four input methods.

V CONCLUSION

We have described an experiment to determine the fastest input style on mobile devices using four input styles. The difference in the mean input speed was significant between the physical keyboards (keypad) but not with the virtual (touchscreen) keyboards. Our experiment results show that qwerty keyboard layout did better than their Multi-press counterparts for both touchscreen (by 21%) and physical keyboards (by 51,9%). Overall, we also showed that the physical QWERTY keyboard (KPQ) produced the fastest input rate, 27.5 WPM. Touchscreen QWERTY (TSQ) and touchscreen Multi-press (TSM) produced speeds of 25.4WPM and 20.0WPM respectively. Physical Multi-press keyboard (KPM) produced the slowest rates at 18.1WPM.Despite the increasing popularity of touchscreen keyboards, we show that the physical keyboard produces faster input speed. Subjective ratings of the four input styles also showed significant differences in error rates and efficiency but not in learnability. This result has implications for design designers to enable them produce usable gadgets and not just follow fads.

Furthermore, our results shown in **Error! Reference source not found. Error! Reference source not found.** show that Silfverberg et al.'s predictive model is not completely over ambitious as previously asserted by [10].

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