Shift+Tap or Tap+LongPress? The Upper Bound of Typing Speed on InScript

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ABSTRACT
This paper presents the results of a within-subject longitudinal evaluation on Inscript keyboard, which is the national standard layout for Indian scripts. We studied the practical upper bound speed and accuracy as well as the effect of practice. Through longitudinal transcription task of 400 repeated attempts, we observed typing speeds for highly experienced users consistently peak close to 120 cpm i.e. 2.5 times that of fastest speeds reported in literature. Our analysis compared the lower bound times for Tap, Tap+LongPress and Shift+Tap, the three text input mechanisms in this keyboard. Among the two alternative methods, our findings established Tap+LongPress method to be faster than Shift+Tap method and almost equally accurate. Also, we derived a model which explains the influence of corrected errors and number of practice attempts on the typing speed.

Author Keywords
Text Input in Indian Language; Virtual Keyboards; Performance Modelling; Error Analysis.

ACM Classification Keywords
H.5.2. User Interfaces: Input devices and strategies (e.g., mouse, touchscreen)

INTRODUCTION
Challenges in text entry for Indian language keyboards are different from those of English language keyboards. A significant amount of research work has been done for English language keyboards. Indic scripts belong to the abugida family. Abugida or alphasyllabary is segmental writing system where a consonant-vowel forms a unit [15]. Most Indic scripts typically have more than 60 Unicode characters. To accommodate so many characters on the 47 character keys that are typically available on QWERTY, these keyboards map two characters on many keys. The frequent characters are usually placed on the first layer of the keyboard and are accessed by tapping on the key. The infrequent characters are placed on the shifted layer of the keyboard and are input either by a “long-press” on the key (Tap+LongPress), or by using shift key to access the second layer (Shift+Tap), similar to the capital letters in the Roman script. Which among these two input methods is faster? And would the results hold after extensive practice?

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The fastest average novice typing speeds on touch-screen mobile phones are reported to be less than 45 characters per minute (cpm) after about 5 hours of practice [3]. We could say four things about it. Firstly, speeds are obviously very low, and do not amount to even one third of the speeds reported for English keyboards [8] [11]. This could be due to the large character set which leads to larger scanning time [5] [7], the complexity of the script, or the script rules. Secondly, a single average typing speed for Indic text input may hide a lot of data. Indic script consists of characters which impose different levels of typing complexities. The speed will vary depending on the complexity of the character and typing rules of a given keyboard. Thirdly, prior work on Indic keyboards has not considered the effect of errors on typing speeds. Indic text input tends to have a lot of corrected and uncorrected errors due to small key sizes, and phonetic and visual confusion among characters. Fourthly, studies have been typically done on novice users who were not familiar with the text input mechanism at the beginning of the study, and whose speed may not have reached a peak at the end of the study. Experience from our earlier evaluation [3] showed that user’s speeds kept improving even after 300 minutes of typing practice. It is not clear what the effect of extensive practice will be on typing speeds. In this study we attempted to investigate following research questions:

RQ1. What is the upper bound typing speed possible on the InScript keyboard after extensive practice?

RQ2. How does speed vary between Tap+LongPress and Shift+Tap input methods?

RQ3. What is the effect of errors in the speed of typing?

BACKGROUND
Several prior reported longitudinal studies on English keyboards have evaluated user’s peak typing performance through long duration trials and empirical predictions [9] [8] [6] [11]. Of particular relevance to RQ1 is literature that

looks at effects of extensive typing. Prediction of 'peak performance' has been modelled by using Power Law of Learning [8] [2] and Fitts' Finger Movement [12] [17] [18]. Further, McMulkin [10] conducted a 12 hours of short repetitive typing task with users to establish 50 repetitive trials are enough for long term learning behaviour to emerge substantially in English on Chord keyboard. On the other hand, Gopher et al. reported that even after 35 hours of training on two hand chord keyboard performance saturation was not observed among novice users [20]. Similarly, Lyons et al. [21] reported continuous improvement of performance even after 400 minutes of practice on Twiddler keyboard. While useful as guides, these results may not be directly applicable to Indic typing due to the differences in input methods. The effect of practice on Tap+LongPress and Shift+Tap, which feature in many popular Indic keyboards, has never been evaluated.

Prior work on analysis of typing errors for English keyboards has established categories of errors made while typing, frequencies of the errors[13] [4] and probabilities of them being corrected or being left uncorrected [16]. We investigated how much impact error correction has on the typing speeds of expert users during fast typing. As speed exhibits trade-off with accuracy [1], we attempted to relate the error correction back to the speed of typing.

METHOD

Our study was done in Marathi, a language spoken by 90 million users and the 19th most widely spoken language in the world [14]. We chose InScript keyboard (short for Indian Script) which is the national standard keyboard layout for Indian scripts [19]. It has a common layout for 22 Indic languages. Fig.1. shows the InScript Marathi layout.

(a) (b)

Figure 1.InScript keyboard (a) front layout (b) shifted layout.

It may not be practical to investigate RQ1 by testing with novice users in an experimental setup. Hence, we involved 4 expert users in this study, who had more than 1500 minutes each of recorded typing experience of Marathi text on InScript keyboard. Their initial typing speeds on InScript keyboard were 60 cpm or more. Two of them were female and all of them were right handed adult native Marathi speakers. As a test device, we used "Samsung Galaxy Star Advance" smartphone for the experiment that has a 4.3 inches display. We used an app that displayed transcription phrases and recorded typed keystrokes. Each participant was given a test device for the test duration of 4 weeks during which each of them typed 800 phrases. A set of 10 phrases was deemed a session. Each sitting consisted of typing at most 4 sessions, i.e. 40 phrases, with a gap of at least a few hours between two sittings. They were allowed to attempt up to 8 sessions in a day. The user logs were periodically synched and progress sessions for each participant was managed using a central server.

The evaluation involved alternately typing two phrases Ph1 and Ph2 described in Table 1. We selectively picked the two phrases to include different syllable compositions including consonants, vowels, vowel modifiers, conjuncts, diacritic marks, characters typed using Tap+LongPress or Shift+Tap and characters mapped to keys that required longer and shorter finger movement. High repetitions of the two phrases enabled the expert upper bound speeds to emerge out quickly. After several trials participants were no longer reading the test phrases or searching the keys. The typing sequence rather got inbuilt in their muscle memory.

Ph1: शिक्षकांनी प्रयत्नपूर्वक मुलगा अचूक निवडावा			
Unicodes	Shift+Tap/Tap+ LP	Tap-Space	Taps
43	5	4	30
Ph-2: गणित व इंग्रजी ह्यांच्यापेक्षा चित्र काढणे सोपे वाटायचे			
Unicodes	Shift+Tap/Tap+ LP	Tap-Space	Taps
55	7	7	36

Table 1. Description of the two transcription phrases.

All participants first completed 400 instances (200 for each phrase) of typing using Tap+LongPress and then 400 instances of typing using Shift+Tap. Thus, we had a data log of 4,000 phrases (2 phrases x 200 repetitions x 2 input methods x 4 participants). Participants were encouraged to type as fast and as accurately as possible. The app gave feedback on speed and errors after each phrase were typed. If the user realised that she had made an error just after typing a character, she was allowed to correct the same by pressing the backspace key. However, if she realised that she had made an error while reviewing the completed phrase, she was asked not to correct such an error. This was done to maintain consistency of error correction mechanism so that the effect is comparable across users and phrases.

In order to keep the participants engaged and competitive they were periodically shown their speed progress plots. All participants were briefed about the experiment protocol as they performed initial attempts in presence of a moderator. Typing was performed only using index finger of dominant hand by holding the device in the palm of other in a quiet environment. In case of unforeseen disturbance users were instructed to restart the phrase being typed.

RESULTS AND DISCUSSION

Typing speeds for all 4 expert users were observed to have low within-subject variations. Difference in the average speed for the fastest and the slowest participants in their last 100 phrase attempts was only 10%. Hence analysis on typing speeds considers the average of all participants.

Expert Peak Performance

Fig.2. plots the session wise typing speed (measured in cpm) for both the phrases, attempt no 1-200 with LongPress and attempt no 201-400 with Shift+Tap. As expected, speed for Ph2, which involved more instances of shifted characters, was consistently lower than that of Ph1. This validates that the complexity of keystrokes especially the shifted characters influences speed. Performance trend lines were observed to have asymptotic pattern following Power Law of Learning [8] [17]. With repeated attempts, the rate of increase of speed reduced. All participants completed 200 set of repetitions for both phrases with Tap+LongPress (1-200 trials) followed by that with Shift+Tap method (201-400 trials). Fig.2. compares the performance of Shift+Tap (201 - 400 trials) with that of Tap+LongPress extrapolated (201 - 400 trials) using Power Law of Practice.

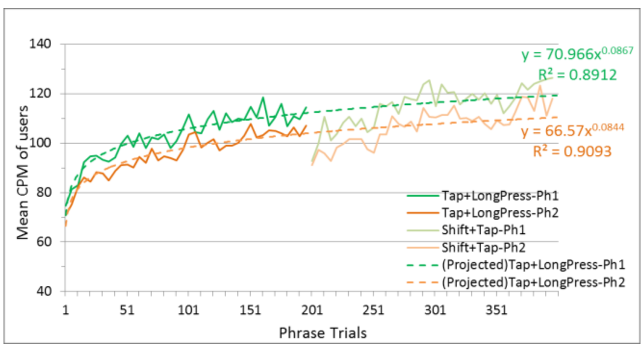

Figure 2.Typing speeds with 400 trials on LongPress and Shift.

Variations of the user's speeds even for subsequent attempts in the same session were observed to be as high as +/-5%. Average speeds for trial numbers for last few trials, 301-400 for both the phrases using Tap+LongPress (LP) (projected values) and Shift+Tap (SH) may be considered as upper bound peak speeds. At this stage asymptotic speed improvement for further 200 trials would be below 10%. In other words, had the user continued to type 200 more trials for both the phrases (i.e. till 800 trials), the speed improvement would have been below 10%. This peak performance phase (PPP) data is considered for further keystroke level analysis. We observed that the mean typing speeds of users during peak performance were higher for phrases typed using Tap+LongPress than those typed using Shift+Tap. However, by performing analysis at phrase level it can't be inferred whether this difference is due to Tap+LongPress being faster than Shift+Tap or due to effect of learning or due to variations in the errors committed. So, further we continued with analysis at keystroke level.

Keystroke Speeds for Input Methods

All keystrokes performed by the users in the experiment fall into four categories as mentioned earlier in Table 1, viz. (i) Tap+LongPress, (ii) Shift+Tap, (iii) Tap-Space (pressing spacebar key) and (iv)Taps. Fig.3. shows that the average typing times for four types of keystrokes consistently reduced with practice. Tap+LongPress keystroke projected time data for PPP was derived by fitting Power law of learning curve ($T_{Sn} = 1810.6T_{S1}^{0.102}$; R^2=0.866) and is represented as 'Power (Tap-LongPress)'. For expert users in their peak performance, the reaction time component of the total time is assumed to be negligible [12]. Thus, all the times plotted in fig.3. during PPP is the finger movement times (MT). It is clearly evident as mean time for Taps on any character key (595ms) during peak performance trials is longer than that for Tap-Space (207ms). Of course this is primarily due to the larger size of the space key. It may also be due to user's very high practice in using the space key as it being the most frequently tapped key.

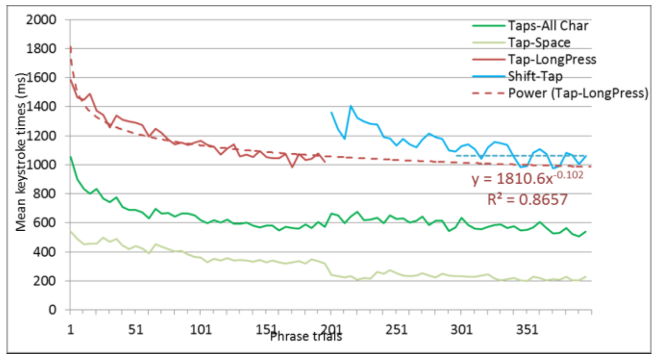

Figure 3. Times for Tap, Tap-Space, Tap+LongPress and Shift+Tap, and their improvements with practice.

Time for Tap+LongPress Vs. Time for Shift+Tap

Each instance of Shift+$Tap_{i\rightarrow j}$ between adjacent bigram pairs (i, j) involves two finger movement keystrokes between i to Shift ($Shift_{i\rightarrow Shift}$) and Shift to j ($Tap_{Shift\rightarrow j}$). Thus keystroke times of Shift+Tap instances (mean time=1051ms in PPP) were approximately twice that of Taps. On the other hand, every LongPress instance involves a Tap keystroke and a constant wait time before a character gets registered. Default LongPress duration in this keyboard was 450ms. It may be due to this additional LongPress duration that keystroke times of Tap+LongPress instances (mean time=1000ms in PPP) were approximately 450ms more than that of Tap, as evident from fig.3. plot. We can thus infer that user's performance using Tap+LongPress is slightly superior to that using Shift+Tap.

Plot in fig.3.also shows that with practice the rate of speed improvement for Shift+Tap was higher than that of Tap+LongPress. This speed improvement may be due to improvements in each of the two finger movement keystrokes involved in Shift+Tap. Comparatively speed improvement rate for Tap+LongPress was low because its every instance involved a default wait time which did not improve with practice. For Tap+LongPress there could be a scope for improving the speed of typing by reducing the LongPress wait time as users start to type faster with practice. This is not supported in the keyboard yet.

Error Rates

Corrected and Un-corrected Error rate Analysis

The purpose of performing error rate analysis was to observe any variations in the pattern of errors while using Tap+LongPress and Shift+Tap methods. Since our study involved expert users and had high phrase repetitions, as expected the overall the errors observed were much lower than those reported in prior literature [3]. Fig.4. shows consolidated errors for set of 5 sessions. Corrected error rates (CER) largely outnumbered the uncorrected error rates (UER), as expected. We were interested in observing the variation in error rates w.r.t. the amount of practice. Unlike reported in one of our earlier work [3], we did not observe the error rates going down as the users advance their trials. Sessions with Shift+Tap method had lower UER perhaps due to the users' higher familiarity with phrases while attempting Shift+Tap later in the sequence. In any case, the ratio of UER to the CER is very low, so the uncorrected errors may not be of much interest. For further analysis on effects of errors on typing speed, we considered only the phrases without errors as well as those with corrected errors and ignored the ones with uncorrected errors.

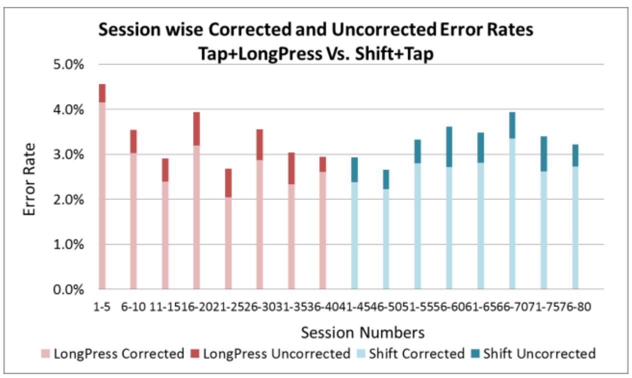

Figure 4. Rate of Corrected and Uncorrected Errors during sessions with Tap+LongPress method and Shift+Tap method.

Impact of Error on Upper bound Speed

We considered the cpm (typing speed in character per minute) for phrase attempts by all users during their peak performance sessions and related the same with the number of errors committed. Interestingly, we observed that 77% of these phrases were correctly typed, 34% with no correction (CER = 0) and 43% with some error correction (CER > 0). So we have to assume that some error correction is to be expected even for expert users. Table 2 shows the mean cpm for the two conditions - CER=0 and CER>0 for the 4 users (U1-U4). Paired samples t-test was found significant (n=4, $p<0.05$, t=7.304) indicating that error correction significantly affects speed. Therefore investigating the effect of corrected error rate on speed is of some interest.

		U1	U2	U3	U4	Overall
Mean CPM	CER=0	106	117	118	121	115
	CER>0	96	99	107	106	101

Table 2. Mean CPM for attempts 100-200 for Ph-1and Ph-2

The typing speed of a given attempt is dependent on several factors including the corrected error rate, the phrase being typed and its complexity, the input method (Tap+LongPress or Shift+Tap), the amount of practice the user has had on that phrase, and the user. To eliminate the effect of other variables, we performed a multiple regression using the stepwise method. We assume the CPMs of attempt numbers 101 to 200 for both phrases with UER=0 as the criterion variable and the CER (%), the attempt number, and dummy variables for Ph-1 or Ph-2, the input method (Tap+LongPress or Shift+Tap) and users (U1-U4) as predictor variables. The most significant model returned these values: R = 0.799, R^2 = 0.638, adjusted R^2 = 0.637, F = 360.335, $p < 0.0005$. The corrected error rate emerged as a significant predictor ($p < 0.0005$) with each additional percentage point of corrected error rate reducing the CPM by 2.68 (95% CI from 2.84 to 2.51). The attempt number also emerged as one of the significant predictors ($p < 0.005$) increasing the CPM per attempt by 0.056 (95% CI from 0.038 to 0.072). The variance inflation factors (VIFs) of all predictor variables are well below 2, indicating that there is no multi-collinearity among the predictor variables of the model, as expected. The distributions of the criterion variable and the z residuals were found to be normal.

LIMITATION OF THE STUDY

The objective of this study was to observe the 'upper bound typing speeds' of expert users with extensive repeated trials. Thus the results should not be directly inferred to assess regular keyboard usage. In the experiment design, ideally the sequence of two conditions (Shift+Tap and Tap+LongPress) should have been counter-balanced. However, due to small number of expert users counter balancing was not done to avoid influence of within subject variations in very small groups. Exhaustive number of trials did mitigate this to some extent. Additionally to mitigate this, we compared Tap+LongPress performance, which all users attempted first, by extrapolating the values to the peak performance sessions using Power Law of Practice.

CONCLUSION

This study contributes in establishing the upper bound of typing speed for InScript keyboard with extensive practice. We empirically established the absolute mean finger movement times for the four types of keystrokes, i.e. Tap+LongPress, Shift+Tap, Tap and Tap-Space. Tap+LongPress method was found more efficient than Shift+Tap method for expert users as the later involves additional finger movement for the Shift key. It was interesting to note that even after extensive practice the expert users continued to make errors. A paired t-test between phrases with no error correction and some error correction showed that the time invested in error correction significantly brings down the speed of typing. A regression analysis that accounted for all other measurable factors showed that every 1% increase in the corrected error rate reduces the typing speed by about 2.68 cpm.

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