STA286 – Term Assignment

Analysis of Typing Performance on Hard Keyboard and Software Keyboard

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I. Introduction

Efficiency has always been a key design factor in input devices. As technology advanced, hardware keyboard is no longer the dominant input method. With the increase popularity of mobile device, soft keyboard has become one of the primary input methods, especially the QWERTY type. The goal of this research is to examine the performance of soft-keyboard compared to the traditional hardware keyboard, based on input speed and accuracy.

II. Background

a. Hard Keyboard

This paper refers "Hard Keyboard" to those used on desktop or laptop, which contain 101 to 104 keys depending on specific design.

b. Soft Keyboard

"Soft Keyboard", sometimes called "Onscreen Keyboard", "is a system that replaces the hardware keyboard on a computing device with an on-screen image map"[1]. It is commonly seen on touch-screen devices.

c. Layout

For both hard and soft keyboard, this research focuses on the QWERTY layout, invented by Christopher Sholes. It is shown in Figure 1. This type is one of the most widespread and popular layout in North America in particular.

Figure 1 – QWERTY

The reason for such layout of letters can be traced back to the era of typewriter. Type Writers were easily susceptible to jam when two neighboring keys are pressed at the same time or in rapid succession. The design of QWERTY spaced out commonly used pair of letter, such as “th” or “st” as far as possible to decrease the chance of jamming. Counter to popular beliefs, the QWERTY design does not intend to slow down typist speed, but in fact increase it through prevention of jamming# [3][4]

III. Experimental Method

In order to facilitate the data collection process, a website has been constructed by the team in PHP at http://typingtest.site11.com/. In particular, each participant is asked to enter the following paragraph character-by-character:

> *The term "design of experiments" derives from early statistical work performed by Sir Ronald Fisher. He was described as "a genius who almost single-handedly created the foundations for modern statistical science." Fisher initiated the principles of design of experiments and elaborated on his studies of "analysis of variance". Perhaps even more important, Fisher began his systematic approach to the analysis of real data as the springboard for the development of new statistical methods. He began to pay particular attention to the labour involved in the necessary computations performed by hand, and developed methods that were as practical as they were founded in rigour. In 1925, this work culminated in the publication of his first book, Statistical Methods for Research Workers.#[5]*

The website will measure the elapsed time and number of wrong words entered automatically, and it will then calculate the average typing speed in unit of word-per-second as well as error rate per-word in unit of accordingly.

a. Independent and Dependent Variables

Based on our study interest, typing speed and accuracy are the dependent variables, while entry method (hard keyboard vs soft keyboard) is the independent variables in

this experiment. In particular, two different types of entry methods are being the interests of study: the hard keyboard with QWERTY layout and soft keyboard with screen size less than 5 inches.

b. Controlled Variables:

One of the controlled variables is the entry text as shown above. This is to ensure all participants type out same amount of words to calculate the average more accurately.

Age and occupation are two other controlled variables. The data of interest is the ones from students aged between 13 ~ 24.

Another controlled variable is the automation text entry such as “autocorrect” in most mobile device or “suggestion” in mobile devices that use T9 entry method. For this experiment, all participants are asked to turn of their autocorrect by forcing them to input the paragraph character-by-character.

Another controlled variable in this experiment is the so called “counter-balancing”. Half of the participant is asked to enter the text on hard keyboard first then proceed to soft keyboard, while the other half do the exact opposite (soft -> hard). This is to reduce any other effect that may occur due to the order of tasks, such as familiarity to the entry text.

c. Explanatory Variables:

There are some other variables that may pose an effect onto the performance, and the team chooses to record them for reference. They include:

- Gender
- Usage frequency of device (hours per day)

- Length being using the type of input device

Their effect (if any) on the performance of typing will be elaborated later in this report.

IV. Analysis Method

Two Sample Hypothesis Testing is used to analyze the collected data. The null hypotheses are that the average typing speed and typing errors are identical between two different input method. Alternative hypothesis for speed is that hard keyboard has a higher average typing speed than soft keyboard. Alternative hypothesis for accuracy is that hard keyboard results in fewer errors than soft keyboard.

Since the team has successfully collected data from 100 people, it is reasonable to assume the test statistic follows normal distribution. The way to calculate test statistic Z is:

$$z = \frac{\mu_x - \mu_y}{\sqrt{\frac{\sigma_x^2}{N_x} - \frac{\sigma_y^2}{N_y}}}$$

The next step is to calculate the p-value and compare it to the significance level. P-value is essentially the area on standard normal distribution larger/smaller than the test statistic. For an alternative hypothesis suggesting $\mu_x > \mu_y$, p-value will be the area on the right tail, while the left tail is used for $\mu_x < \mu_y$. Significance Level is chosen as 5% by the team. The relationship between test statistic and significance level will either reject or fail to reject the null hypotheses.

V. Result and Discussion

a) Normality of data

A quartile-quartile plot is used to analyze the normality of data. Data collected is plotted against a set of normally distributed theoretical data. Refer to figure 1 and 2, the Q-Q plot of both mobile data and desktop/laptop data are concave, indicates a positive skew, meaning that the data is head-heavy and more participants tend to have slower typing speeds. It is also observed from figure 3 and 4 that the distribution is head-heavy, meaning that there tends to be fewer participants with fast typing speed while the majority of the participants had slow typing speed. Note that the distribution of mobile typing speed is narrower than the distribution of desktop/laptop typing speed (0.2 - 1.4 words/second compared to 0.5 - 2.5 words/second). Refer to figure 5, a “S” shaped Q-Q plot indicates that the data is nearly normally distributed with fat tails, meaning that data collected is more closely centered around the mean. Refer to figure 6, linear Q-Q plot indicates that the data is normally distributed, ie error for desktop/laptop users is normally distributed. These statements are also supported by the histograms provided as figure 7 and 8.

Figure 1 – Q-Q Plot for Soft Keyboard

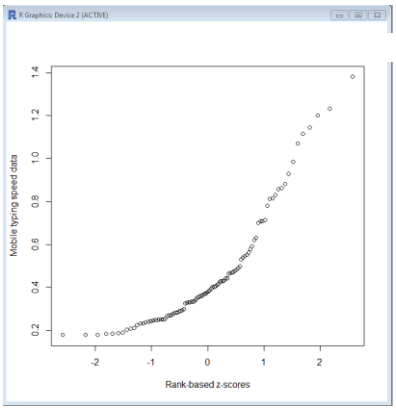


Figure 2 – Q-Q Plot for Hard Keyboard (SPEED)

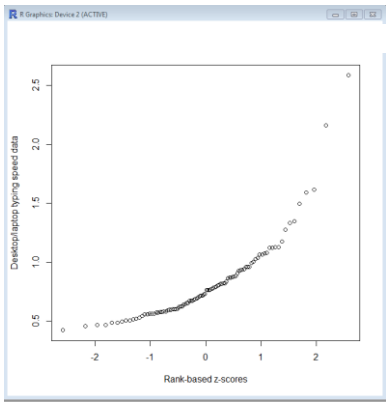


Figure 3 – Histogram for Soft Keyboard

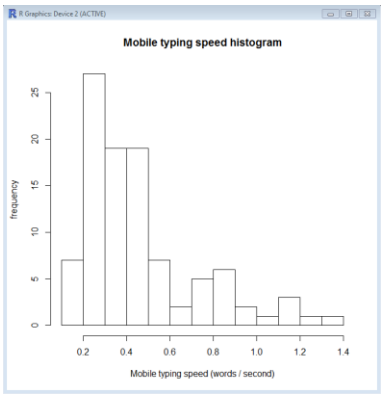


Figure 4 – Histogram for Hard Keyboard (SPEED)

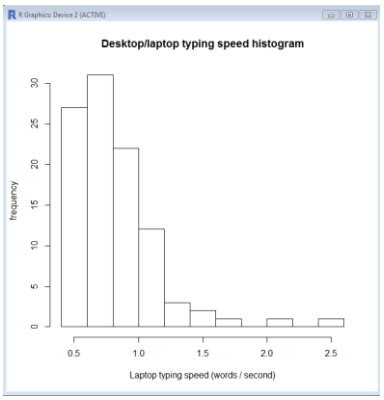


Figure 5 – Q-Q Plot for Soft Keyboard

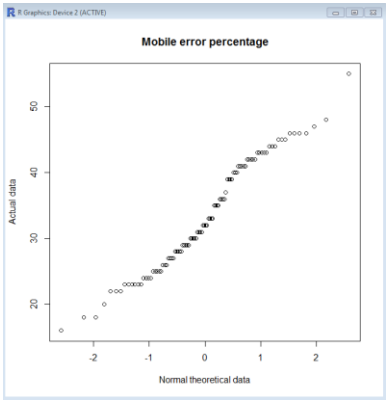


Figure 6 – Q-Q Plot for Hard Keyboard (ERROR)

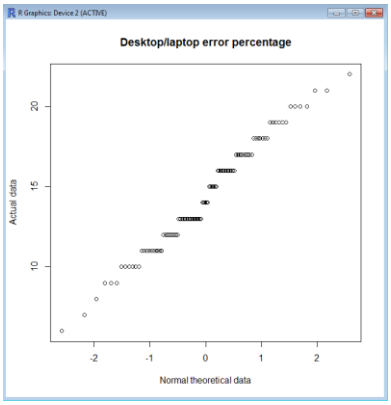


Figure 7 – Histogram for Soft Keyboard

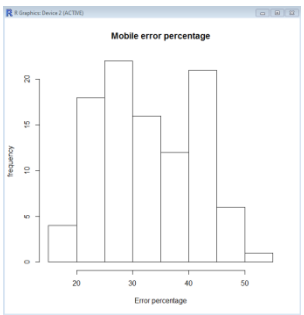
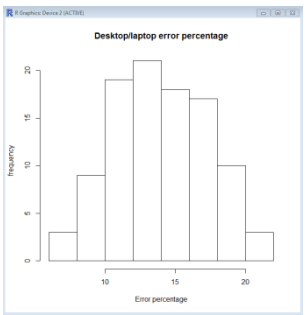


Figure 8 – Histogram for Hard Keyboard (ERRORS)



b) Typing Speed

Null hypothesis is such that two typing methods result in the same typing speed, while the alternative hypothesis is that hard keyboard has a higher average speed. Hence, for us to reject the null hypothesis, the p-value calculated will need to be lower than the chosen significance level. Table 1 summarizes the values of each mean, Z, and p scores.

The data collected result in a Z-score of 8.30, which correspond to extremely small p-value (<0.00005)[6], hence the null hypothesis is rejected, and there is enough evidence to suggest that hard keyboard result in a faster typing speed than soft keyboard.

c) Typing Accuracy

Null hypothesis for accuracy is defined as two method result in same amount of error input per paragraph typed. Alternative hypothesis is that hard keyboard result in a lower error per paragraph. Hence the p-value needs to be lower than the significance level for us to reject the null hypothesis.

A Z-score of -3.70 resulted from the error data. P-value calculated by left side tail of standard normal curve turns out to be 0.011%, which is much lower than the chosen significance level of 5%. Hence the null hypothesis is rejected, and there is enough evidence to suggest that hard keyboard result in a lower error percentage than soft keyboard. See table 1 for detailed values of each variables.

Table 1 – Two Sample Hypothesis Testing

	Speed		Error	
	Mean	Standard Deviation	Mean	Standard Deviation
Hard	0.819	0.337	23.85	11.44
Soft	0.462	0.267	29.56	10.40
Z	8.30		-3.70	
P	small		0.00011	

d) Relation with Other Variables

In this study, gender is considered as one explanatory variable in order to analyze typing speed and accuracy difference between male and female population. The laptop typing speed average for the 63 male participants is calculated to be 0.82 words/s with an error percentage of 14.9% and that for the 36 female participants is determined to be 0.76 words/s with error percentage of 13.9%. The differences of both measurements between male and female are significant smaller than the standard deviations. Therefore, it can be concluded that gender has negligible effect on both typing speed and accuracy according to the sample being analyzed.

Usage of device has relatively low effect on the typing performance. This is somewhat expected as most of the testing participants have more than 2 years of experience with the device. Once one is familiar with the type of keyboards the typing performance can hardly alter.

VI. Conclusion

Data collected from the experiment has shown that typing performance is better on hard keyboard than that of soft keyboard. Hard keyboard results in a faster typing speed and lower error percentage. This is verified using two sample hypothesis testing with Z statistic. It is also observed that the general trend of data follows a skew

normal distribution as evident by Q-Q plot. Gender has limiting effect on the performance, with females perform slightly better (higher speed, lower error rate) than males.. Usage of device appears to be irrelevant on the performance.

VII. Reference

[1] WhatIs.com, "Soft Keyboard", Apr 10, 2013, available: http://whatis.techtarget.com/definition/soft-keyboard-onscreen-keyboard-or-software-keyboard

[2] ComputerHope, "QWERTY Keyboard", Apr 10, 2013, available: http://www.computerhope.com/jargon/q/qwerty.htm

[3] Straight Dope, "Was the QWERTY keyboard purposely designed to slow typists?", Oct 30, 1981, available: http://www.straightdope.com/columns/read/221/was-the-qwerty-keyboard-purposely-designed-to-slow-typists

[4] Nick Baker, "Why do we all use Qwerty keyboards?", Aug 11, 2010, available: http://www.bbc.co.uk/news/technology-10925456

[5] Wikipedia, "History of Statistic", Available http://en.wikipedia.org/wiki/History_of_statistics

[6] Standard Normal Distribution Table, available http://www.stat.tamu.edu/~lzhou/stat302/standardnormaltable.pdf

VIII. Appendix

a) Raw Data Table

startTime	time Elapsed (s)	age	occupation	gender	usingHrs	typingMethod	usageAge	errPercentage	typing_speed
2013/4/11 12:59	120	16	student	Famale	2	laptop	6-14 months	13	0.996659
2013/4/11 12:59	278	16	student	Famale	1	touchscreen	2-5 yrs	37	0.431818
2013/4/11 12:59	219	19	student	Famale	3	laptop	5-10 yrs	12	0.546777
2013/4/11 12:59	144	19	student	Famale	2	touchscreen	2-5 yrs	30	0.831189
2013/4/11 12:59	137	21	student	Male	2	laptop	5-10 yrs	13	0.877186
2013/4/11 12:59	483	21	student	Male	2	touchscreen	2-5 yrs	41	0.248378
2013/4/11 12:59	192	17	student	Famale	4	laptop	2-5 yrs	12	0.626429
2013/4/11 12:59	334	17	student	Famale	2	touchscreen	5-10 yrs	33	0.359678
2013/4/11 12:59	199	17	student	Male	5	laptop	>10 yrs	10	0.602601
2013/4/11 12:59	251	17	student	Male	4	touchscreen	2-5 yrs	29	0.477435
2013/4/11 12:59	138	22	student	Male	11	laptop	5-10 yrs	19	0.872359
2013/4/11 12:59	168	22	student	Male	1	touchscreen	2-5 yrs	20	0.713972
2013/4/11 12:59	210	16	student	Male	1	laptop	1-6 months	15	0.571957
2013/4/11 12:59	208	16	student	Male	2	touchscreen	2-5 yrs	35	0.577747
2013/4/11 12:59	201	19	student	Famale	6	laptop	2-5 yrs	17	0.595767
2013/4/11 12:59	280	19	student	Famale	3	touchscreen	5-10 yrs	30	0.428588
2013/4/11 12:59	200	21	student	Famale	5	laptop	>10 yrs	16	0.601103
2013/4/11 12:59	369	21	student	Famale	1	touchscreen	2-5 yrs	24	0.32534
2013/4/11 12:59	120	17	student	Famale	8	laptop	>10 yrs	19	1.003492

2013/4/11 12:59	575	17	student	Famale	2	touchscreen	2-5 yrs	33	0.208602
2013/4/11 12:59	150	16	student	Male	1	laptop	6-14 months	13	0.802656
2013/4/11 12:59	87	16	student	Male	3	touchscreen	2-5 yrs	47	1.380604
2013/4/11 12:59	215	16	student	Male	0	laptop	5-10 yrs	17	0.557791
2013/4/11 12:59	288	16	student	Male	3	touchscreen	2-5 yrs	31	0.416189
2013/4/11 12:59	136	18	student	Famale	5	laptop	5-10 yrs	9	0.884742
2013/4/11 12:59	475	18	student	Famale	3	touchscreen	2-5 yrs	36	0.25245
2013/4/11 12:59	46	18	student	Famale	4	laptop	>10 yrs	12	2.586673
2013/4/11 12:59	169	18	student	Famale	1	touchscreen	5-10 yrs	46	0.708217
2013/4/11 12:59	156	22	student	Male	1	laptop	>10 yrs	11	0.771234
2013/4/11 12:59	445	22	student	Male	2	touchscreen	5-10 yrs	35	0.269447
2013/4/11 12:59	283	19	student	Male	3	laptop	5-10 yrs	21	0.423338
2013/4/11 12:59	315	19	student	Male	0	touchscreen	2-5 yrs	46	0.380643
2013/4/11 12:59	147	18	student	Famale	2	laptop	>10 yrs	15	0.817514
2013/4/11 12:59	478	18	student	Famale	0	touchscreen	NULL	42	0.251173
2013/4/11 12:59	261	15	student	Famale	6	laptop	5-10 yrs	9	0.46031
2013/4/11 12:59	248	15	student	Famale	4	touchscreen	2-5 yrs	30	0.482914
2013/4/11 12:59	207	19	student	Male	9	laptop	2-5 yrs	13	0.579806
2013/4/11 12:59	592	19	student	Male	2	touchscreen	5-10 yrs	45	0.202701
2013/4/11 12:59	80	18	student	Famale	3	laptop	5-10 yrs	14	1.496757
2013/4/11 12:59	668	18	student	Famale	1	touchscreen	2-5 yrs	28	0.179746
2013/4/11 12:59	167	19	student	Male	4	laptop	2-5 yrs	16	0.716792

2013/4/11 12:59	348	19	student	Male	3	touchscreen	5-10 yrs	25	0.344621
2013/4/11 12:59	232	20	student	Male	1	laptop	5-10 yrs	11	0.516373
2013/4/11 12:59	226	20	student	Male	2	touchscreen	5-10 yrs	36	0.531083
2013/4/11 12:59	146	17	student	Male	10	laptop	6-14 months	18	0.820396
2013/4/11 12:59	136	17	student	Male	1	touchscreen	5-10 yrs	46	0.880332
2013/4/11 12:59	175	17	student	Male	9	laptop	2-5 yrs	13	0.685738
2013/4/11 12:59	97	17	student	Male	3	touchscreen	5-10 yrs	28	1.232043
2013/4/11 12:59	157	19	student	Male	11	laptop	1-6 months	13	0.764179
2013/4/11 12:59	360	19	student	Male	1	touchscreen	NULL	26	0.333544
2013/4/11 12:59	173	18	student	Famale	7	laptop	2-5 yrs	10	0.693793
2013/4/11 12:59	500	18	student	Famale	2	touchscreen	NULL	29	0.240209
2013/4/11 12:59	209	17	student	Male	8	laptop	5-10 yrs	18	0.574464
2013/4/11 12:59	223	17	student	Male	2	touchscreen	2-5 yrs	22	0.538555
2013/4/11 12:59	212	20	student	Male	4	laptop	>10 yrs	17	0.5648
2013/4/11 12:59	257	20	student	Male	1	touchscreen	2-5 yrs	23	0.466476
2013/4/11 12:59	94	20	student	Male	2	laptop	>10 yrs	13	1.278589
2013/4/11 12:59	437	20	student	Male	1	touchscreen	5-10 yrs	28	0.274435
2013/4/11 12:59	257	16	student	Famale	2	laptop	>10 yrs	13	0.466369
2013/4/11 12:59	324	16	student	Famale	2	touchscreen	2-5 yrs	43	0.370443
2013/4/11 12:59	213	17	student	Male	8	laptop	5-10 yrs	18	0.563629
2013/4/11 12:59	280	17	student	Male	2	touchscreen	2-5 yrs	41	0.429314
2013/4/11 12:59	107	20	student	Male	6	laptop	5-10 yrs	20	1.124906

2013/4/11 12:59	171	20	student	Male	3	touchscreen	5-10 yrs	27	0.70032
2013/4/11 12:59	226	18	student	Famale	6	laptop	>10 yrs	11	0.531915
2013/4/11 12:59	260	18	student	Famale	1	touchscreen	2-5 yrs	39	0.462411
2013/4/11 12:59	178	21	student	Male	9	laptop	1-6 months	16	0.673011
2013/4/11 12:59	476	21	student	Male	0	touchscreen	2-5 yrs	40	0.251918
2013/4/11 12:59	112	17	student	Male	3	laptop	5-10 yrs	11	1.075627
2013/4/11 12:59	100	17	student	Male	4	touchscreen	5-10 yrs	40	1.199952
2013/4/11 12:59	245	19	student	Male	2	laptop	>10 yrs	18	0.489564
2013/4/11 12:59	358	19	student	Male	4	touchscreen	2-5 yrs	25	0.335218
2013/4/11 12:59	75	20	student	Male	7	laptop	5-10 yrs	11	1.594971
2013/4/11 12:59	514	20	student	Male	3	touchscreen	2-5 yrs	18	0.233325
2013/4/11 12:59	193	20	student	Famale	6	laptop	5-10 yrs	17	0.621971
2013/4/11 12:59	413	20	student	Famale	3	touchscreen	2-5 yrs	31	0.290567
2013/4/11 12:59	240	20	student	Male	3	laptop	5-10 yrs	13	0.499096
2013/4/11 12:59	339	20	student	Male	2	touchscreen	2-5 yrs	16	0.35411
2013/4/11 12:59	200	14	student	Famale	3	laptop	5-10 yrs	13	0.600958
2013/4/11 12:59	409	14	student	Famale	2	touchscreen	2-5 yrs	23	0.293746
2013/4/11 12:59	237	20	student	Male	6	laptop	1-6 months	20	0.50685
2013/4/11 12:59	108	20	student	Male	5	touchscreen	2-5 yrs	32	1.114242
2013/4/11 12:59	90	13	student	Famale	12	laptop	>10 yrs	17	1.335107
2013/4/11 12:59	342	13	student	Famale	1	touchscreen	2-5 yrs	32	0.351164
2013/4/11 12:59	203	19	student	Male	8	laptop	5-10 yrs	14	0.592233

2013/4/11 12:59	320	19	student	Male	2	touchscreen	2-5 yrs	33	0.374843
2013/4/11 12:59	127	19	student	Famale	1	laptop	2-5 yrs	16	0.943804
2013/4/11 12:59	190	19	student	Famale	2	touchscreen	5-10 yrs	27	0.632122
2013/4/11 12:59	112	19	student	Famale	13	laptop	>10 yrs	11	1.067994
2013/4/11 12:59	508	19	student	Famale	1	touchscreen	5-10 yrs	27	0.236277
2013/4/11 12:59	143	20	student	Male	9	laptop	5-10 yrs	12	0.837327
2013/4/11 12:59	282	20	student	Male	5	touchscreen	2-5 yrs	39	0.425067
2013/4/11 12:59	167	24	student	Famale	3	laptop	>10 yrs	15	0.717755
2013/4/11 12:59	240	24	student	Famale	1	touchscreen	2-5 yrs	42	0.499132
2013/4/11 12:59	102	19	student	Male	12	laptop	1-6 months	11	1.176582
2013/4/11 12:59	415	19	student	Male	1	touchscreen	5-10 yrs	26	0.289237
2013/4/11 12:59	153	18	student	Male	9	laptop	5-10 yrs	11	0.782799
2013/4/11 12:59	220	18	student	Male	1	touchscreen	2-5 yrs	27	0.546227
2013/4/11 12:59	111	19	student	Famale	5	laptop	5-10 yrs	13	1.082231
2013/4/11 12:59	481	19	student	Famale	2	touchscreen	2-5 yrs	29	0.249632
2013/4/11 12:59	112	17	student	Male	4	laptop	5-10 yrs	15	1.067675
2013/4/11 12:59	256	17	student	Male	4	touchscreen	5-10 yrs	23	0.468102
2013/4/11 12:59	213	21	student	Male	5	laptop	5-10 yrs	20	0.564122
2013/4/11 12:59	631	21	student	Male	3	touchscreen	2-5 yrs	43	0.190134
2013/4/11 12:59	117	18	student	Famale	7	laptop	2-5 yrs	10	1.027253
2013/4/11 12:59	492	18	student	Famale	1	touchscreen	2-5 yrs	41	0.244002
2013/4/11 12:59	157	22	student	Male	8	laptop	2-5 yrs	13	0.763909

2013/4/11 12:59	304	22	student	Male	6	touchscreen	2-5 yrs	43	0.394195
2013/4/11 12:59	157	19	student	Male	4	laptop	>10 yrs	16	0.765912
2013/4/11 12:59	105	19	student	Male	1	touchscreen	2-5 yrs	39	1.145766
2013/4/11 12:59	138	18	student	Male	3	laptop	6-14 months	16	0.866602
2013/4/11 12:59	292	18	student	Male	1	touchscreen	5-10 yrs	24	0.411493
2013/4/11 12:59	191	17	student	Famale	7	laptop	6-14 months	10	0.628134
2013/4/11 12:59	362	17	student	Famale	2	touchscreen	2-5 yrs	33	0.331587
2013/4/11 12:59	198	21	student	Famale	0	laptop	5-10 yrs	16	0.605672
2013/4/11 12:59	122	21	student	Famale	1	touchscreen	2-5 yrs	30	0.985392
2013/4/11 12:59	177	15	student	Famale	6	laptop	>10 yrs	10	0.676527
2013/4/11 12:59	213	15	student	Famale	3	touchscreen	2-5 yrs	25	0.562387
2013/4/11 12:59	125	19	student	Male	3	laptop	>10 yrs	13	0.959887
2013/4/11 12:59	485	19	student	Male	2	touchscreen	2-5 yrs	48	0.247348
2013/4/11 12:59	151	20	student	Male	5	laptop	5-10 yrs	19	0.792616
2013/4/11 12:59	218	20	student	Male	2	touchscreen	5-10 yrs	31	0.550367
2013/4/11 12:59	205	21	student	Male	11	laptop	2-5 yrs	17	0.585583
2013/4/11 12:59	311	21	student	Male	0	touchscreen	2-5 yrs	35	0.38644
2013/4/11 12:59	164	20	student	Male	8	laptop	>10 yrs	17	0.732162
2013/4/11 12:59	112	20	student	Male	1	touchscreen	5-10 yrs	29	1.07031
2013/4/11 12:59	125	20	student	Famale	6	laptop	6-14 months	17	0.96303
2013/4/11 12:59	271	20	student	Famale	3	touchscreen	5-10 yrs	22	0.442532
2013/4/11 12:59	129	15	student	Male	11	laptop	5-10 yrs	14	0.933321

2013/4/11 12:59	299	15	student	Male	1	touchscreen	5-10 yrs	25	0.401057
2013/4/11 12:59	106	19	student	Male	6	laptop	5-10 yrs	16	1.130183
2013/4/11 12:59	295	19	student	Male	1	touchscreen	2-5 yrs	26	0.406231
2013/4/11 12:59	236	21	student	Male	8	laptop	5-10 yrs	12	0.507594
2013/4/11 12:59	140	21	student	Male	3	touchscreen	2-5 yrs	44	0.857312
2013/4/11 12:59	184	17	student	Famale	6	laptop	5-10 yrs	11	0.653451
2013/4/11 12:59	299	17	student	Famale	5	touchscreen	5-10 yrs	44	0.401019
2013/4/11 12:59	205	19	student	Male	3	laptop	5-10 yrs	19	0.584845
2013/4/11 12:59	452	19	student	Male	1	touchscreen	2-5 yrs	42	0.26532
2013/4/11 12:59	215	19	student	Famale	1	laptop	>10 yrs	22	0.55743
2013/4/11 12:59	245	19	student	Famale	2	touchscreen	2-5 yrs	41	0.489256
2013/4/11 12:59	74	17	student	Male	2	laptop	>10 yrs	8	1.614715
2013/4/11 12:59	668	17	student	Male	2	touchscreen	5-10 yrs	36	0.179702
2013/4/11 12:59	128	18	student	Male	9	laptop	5-10 yrs	15	0.937797
2013/4/11 12:59	491	18	student	Male	2	touchscreen	2-5 yrs	23	0.244475
2013/4/11 12:59	137	17	student	Famale	6	laptop	2-5 yrs	17	0.878773
2013/4/11 12:59	169	17	student	Famale	0	touchscreen	5-10 yrs	35	0.708291
2013/4/11 12:59	168	16	student	Famale	0	laptop	5-10 yrs	13	0.714161
2013/4/11 12:59	363	16	student	Famale	2	touchscreen	2-5 yrs	31	0.330497
2013/4/11 12:59	186	20	student	Famale	7	laptop	5-10 yrs	12	0.646072
2013/4/11 12:59	139	20	student	Famale	2	touchscreen	2-5 yrs	44	0.861438
2013/4/11 12:59	207	21	student	Famale	7	laptop	5-10 yrs	18	0.580756

2013/4/11 12:59	154	21	student	Famale	1	touchscreen	2-5 yrs	18	0.780333
2013/4/11 12:59	175	17	student	Male	1	laptop	2-5 yrs	18	0.687347
2013/4/11 12:59	361	17	student	Male	2	touchscreen	2-5 yrs	39	0.33275
2013/4/11 12:59	89	23	student	Male	0	laptop	>10 yrs	10	1.349085
2013/4/11 12:59	148	23	student	Male	1	touchscreen	2-5 yrs	23	0.81283
2013/4/11 12:59	132	17	student	Famale	2	laptop	5-10 yrs	16	0.910385
2013/4/11 12:59	366	17	student	Famale	2	touchscreen	5-10 yrs	45	0.327899
2013/4/11 12:59	201	16	student	Male	9	laptop	>10 yrs	16	0.595673
2013/4/11 12:59	147	16	student	Male	6	touchscreen	5-10 yrs	24	0.815873
2013/4/11 12:59	246	21	student	Famale	2	laptop	5-10 yrs	21	0.488566
2013/4/11 12:59	520	21	student	Famale	2	touchscreen	2-5 yrs	24	0.230953
2013/4/11 12:59	170	17	student	Male	3	laptop	6-14 months	7	0.704053
2013/4/11 12:59	255	17	student	Male	1	touchscreen	2-5 yrs	28	0.470748
2013/4/11 12:59	165	20	student	Male	14	laptop	5-10 yrs	17	0.726201
2013/4/11 12:59	651	20	student	Male	2	touchscreen	2-5 yrs	28	0.184265
2013/4/11 12:59	155	20	student	Male	2	laptop	6-14 months	14	0.772564
2013/4/11 12:59	129	20	student	Male	3	touchscreen	2-5 yrs	32	0.928476
2013/4/11 12:59	130	24	student	Male	8	laptop	>10 yrs	6	0.926391
2013/4/11 12:59	656	24	student	Male	3	touchscreen	5-10 yrs	30	0.182943
2013/4/11 12:59	106	18	student	Male	4	laptop	6-14 months	16	1.12868
2013/4/11 12:59	425	18	student	Male	3	touchscreen	2-5 yrs	41	0.282107
2013/4/11 12:59	187	17	student	Male	3	laptop	5-10 yrs	19	0.64029

2013/4/11 12:59	676	17	student	Male	1	touchscreen	NULL	43	0.177517
2013/4/11 12:59	230	20	student	Male	5	laptop	5-10 yrs	19	0.522481
2013/4/11 12:59	430	20	student	Male	3	touchscreen	5-10 yrs	46	0.279117
2013/4/11 12:59	178	18	student	Male	7	laptop	>10 yrs	11	0.675428
2013/4/11 12:59	335	18	student	Male	2	touchscreen	2-5 yrs	42	0.358551
2013/4/11 12:59	107	20	student	Famale	5	laptop	5-10 yrs	9	1.126006
2013/4/11 12:59	203	20	student	Famale	1	touchscreen	2-5 yrs	43	0.592465
2013/4/11 12:59	116	20	student	Male	8	laptop	5-10 yrs	12	1.036704
2013/4/11 12:59	330	20	student	Male	2	touchscreen	5-10 yrs	40	0.364078
2013/4/11 12:59	146	20	student	Male	8	laptop	5-10 yrs	13	0.819549
2013/4/11 12:59	444	20	student	Male	2	touchscreen	2-5 yrs	29	0.270099
2013/4/11 12:59	152	19	student	Male	10	laptop	5-10 yrs	20	0.791296
2013/4/11 12:59	572	19	student	Male	2	touchscreen	2-5 yrs	36	0.209679
2013/4/11 12:59	125	19	student	Male	6	laptop	5-10 yrs	12	0.959932
2013/4/11 12:59	271	19	student	Male	1	touchscreen	2-5 yrs	25	0.443169
2013/4/11 12:59	148	19	student	Male	3	laptop	2-5 yrs	12	0.808224
2013/4/11 12:59	402	19	student	Male	1	touchscreen	2-5 yrs	45	0.298708
2013/4/11 12:59	138	17	student	Male	6	laptop	>10 yrs	18	0.870809
2013/4/11 12:59	193	17	student	Male	2	touchscreen	2-5 yrs	22	0.620661
2013/4/11 12:59	56	19	student	Famale	8	laptop	>10 yrs	13	2.160758
2013/4/11 12:59	646	19	student	Famale	3	touchscreen	2-5 yrs	42	0.185668
2013/4/11 12:59	146	20	student	Male	2	laptop	5-10 yrs	15	0.821195

2013/4/11 12:59	425	20	student	Male	2	touchscreen	2-5 yrs	32	0.282402
2013/4/11 12:59	183	15	student	Famale	11	laptop	>10 yrs	16	0.655572
2013/4/11 12:59	324	15	student	Famale	2	touchscreen	2-5 yrs	23	0.370785
2013/4/11 12:59	255	24	student	Male	4	laptop	2-5 yrs	14	0.470237
2013/4/11 12:59	535	24	student	Male	3	touchscreen	5-10 yrs	55	0.224389

b) R CODE

```
bandplot <- function( LST, INTV){
    len <- length(LST)
    cumulative_sum <- array(0, c(1, INTV))
    band_sum <- array(0, c(1, INTV - 1))
    check_points <- seq(min(LST), max(LST), length = INTV)
    middle_pts <- array(0, c(1, INTV - 1))

    for(i in 1:INTV - 1){
        middle_pts[1, i] <- (check_points[i+1] + check_points[i])/2
    }


    for(data in LST){
        for(j in 1:INTV){
            if(check_points[[j]] > data){
                cumulative_sum[1, j] <- cumulative_sum[1, j] + 1;
            }
        }
    }

    for(i in 1:INTV-1){
```

```
        band_sum[1, i] <- cumulative_sum[1, i+1] - cumulative_sum[1, i]
    }

    plot(middle_pts, band_sum)
    return()


}


hist (laptop, 10, main = "Desktop/laptop typing speed", ylab = "frequency", xlab = "Desktop/laptop typing speed (words/ second)")
hist (cell, 10, main = "Mobile typing speed", ylab = "frequency", xlab = "Mobile typing speed (words/ second)")


bandplot(laptop, 10)
bandplot(cell, 100


qqnorm(laptop, main = "Desktop/laptop typing speed", xlab = "Rank-based z-scores", ylab = "Desktop/laptop typing speed")
qqnorm(cell, main = "Mobile typing speed", xlab = "Rank-based z-scores", ylab = "Mobile typing speed")


laptop_mean <- mean(laptop)
```

```
laptop_stdev <- sd(laptop)


mobile_mean <- mean(cell)
mobile_stdev <- sd(cell)


ist(err_lap, main = "Desktop/laptop error percentage", xlab = "Error percentage", ylab = "frequency")
qqnorm(err_lap, main = "Desktop/laptop error percentage", xlab = "Normal theoretical data", ylab = "Actual data")


hist(err_cell, main = "Mobile error percentage", xlab = "Error percentage", ylab = "frequency")
qqnorm(err_cell, main = "Mobile error percentage", xlab = "Normal theoretical data", ylab = "Actual data")
```