The Effect of Language and Keyboard Type on Typing Speed

William Chon
Tyler Hays
Raymond Jiang
Daniel Kim

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1 Introduction

The student body at U.C. Berkeley contains a significant international contingent. However, for many of these students, English is a secondary language. These students may be at a disadvantage when tasked with writing assignments, especially when these assignments must be typed. It is not uncommon for essays and research papers to be more than twenty pages, requiring a good deal of typing. Because time is such a precious resource in college, we wanted to measure if non-native English speakers would be at a disadvantage by having a slower typing speed when compared to native English speakers. That is, we wanted to measure if non-native English speakers are capable of typing English passages at a similar pace to native English speakers.

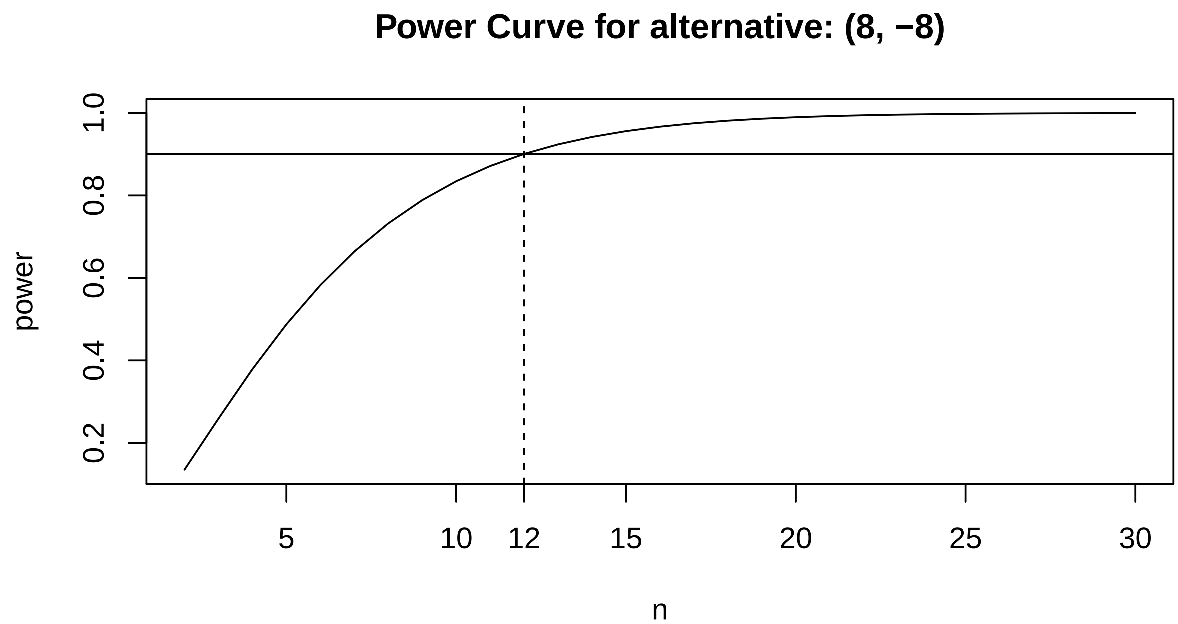
In addition to measuring how having English as a first language vs. a secondary language affects typing speed, we also wanted to measure how the type of keyboard affects typing speed. In particular, there are two main types of keyboards that are in use nowadays: modern rubber membrane keyboards which are activated by electrical signals, and mechanical keyboards which operate on a systems of switches, which are commonly found in the libraries on campus. We wanted to see how these keyboards stack up against each other, especially because mechanical keyboards are priced at a premium and claim to increase typing speed.

We determined that a split-plot/repeated measures experiment best suited to measure how keyboard type and native language affects typing speed while respecting our constraints. By analyzing how words per minute (WPM) varies, we found that both keyboard and native language both have a significant effect on one's typing speed.

2 Methodology

Because we used a split plot/repeated measures design, we had two units of different sizes: blocks for the between-blocks treatments, and subplots for the within-blocks treatments. In this case, we had students be the units for the between-blocks treatments, and the time slots within each student be the within-blocks unit.

We split our blocks into two groups: primary English speaker or secondary English speaker. Once assigned into one of these two groups, the students were then randomly assigned to take the typing tests in one of two orders (mechanical keyboard first and normal keyboard second versus normal keyboard first and mechanical keyboard second) , which allowed us to control for difficulty within the passages. From our power calculations, we found that we needed twelve students from each group to participate in our experiment, as can be seen in the below power plot for detecting a 16 WPM difference.



We ran a balanced test, so half of the students took the test with the mechanical keyboard first, and the other half used the normal keyboard first. We randomly selected which order each student uses the keyboard through a random permutation of an equal amount of 0s and 1s, and assigning those 0s and 1s to the students in the order in which they partook in our experiment.

We also realized that there may be differences in accuracy of typing among our test subjects. To combat this, we told our test subjects that they should be typing with minimal errors as we were going to be measuring accuracy. In addition to that, our responses were measured through corrected words per minute, in order to further control for differences in. In this case, corrected WPM is equal to raw WPM minus the number of errors within one minute. For example, if one of our subjects were to type a passage at a raw WPM of 100 words per minute with 10 errors, they would have a final corrected WPM of 90, which would be the response that we recorded.

To conduct our typing tests we used the utilized the website http://www.typingtest.com/. From this site, we used the same two passages – ”Test Instructions” and ”Aesop’s Fable” – for every subject to measure their typing speed in corrected WPM. The passages were chosen for their simple grammar and vocabulary. As a result, both primary and secondary English speakers were able to understand the passage they were copying. Each trial was strictly 60 seconds and after the first typing test our subjects were required to take a 60 second break to rest their hands before taking the second typing test.

One of our greatest concerns about the experiment was that our sampling population is relatively small. When looking at our class, we can see that it is definitely not representative of the demographics of the college's student body. Furthermore, while running the tests, we felt that some of our subjects may have felt pressured while taking the typing test because we were watching them. For some students, being watched by others will tend to make them type less accurately and slower. On the other hand, being under pressure may compel some students to type faster. On a whole, we do not believe these overwhelmingly harm the validity of our response in answering our question of how one's language and the type of keyboard affects one's typing speed.

The end product of the experiment is represented in the following table, where each column represents a subject's performance and each row represents which keyboard type was used.

English Native Language Adjusted Typing Speed (wpm)

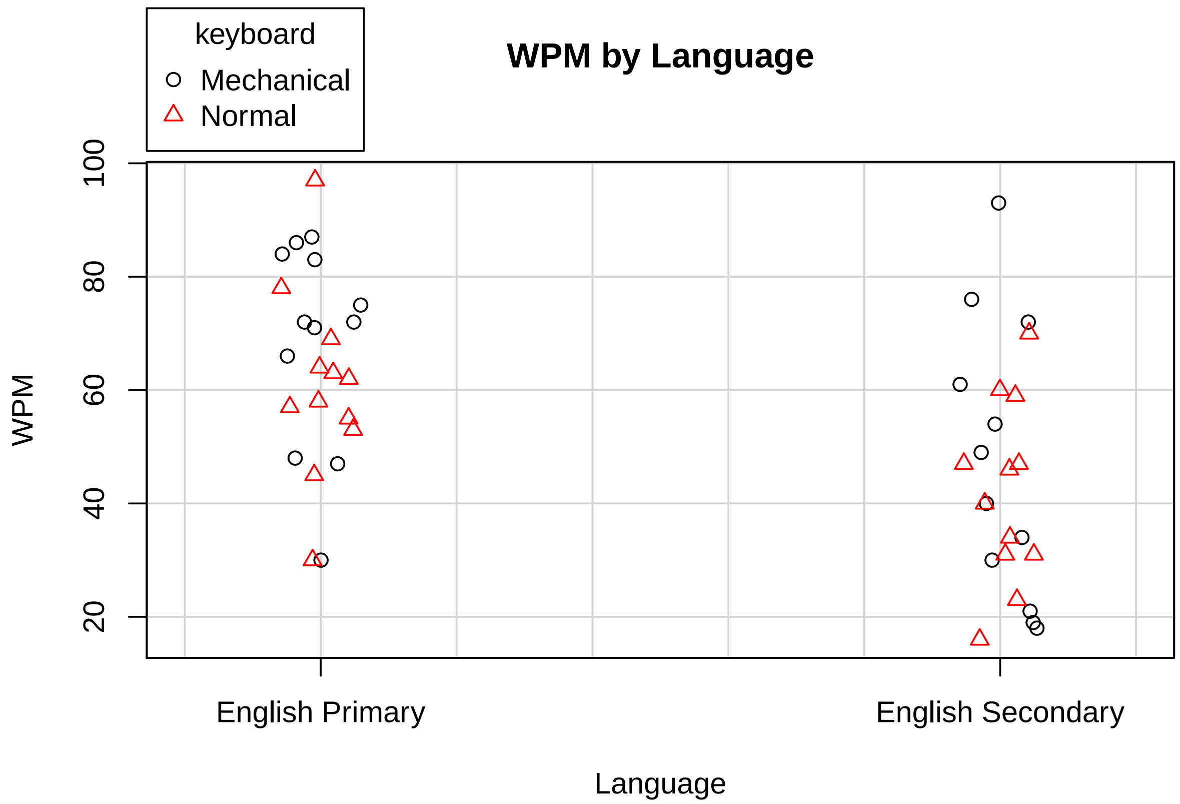
	1	2	3	4	5	6	7	8	9	10	11	12
Normal	97	63	53	58	62	78	57	45	69	30	55	64
Mechanical	87	72	72	71	83	84	75	47	86	48	30	66

English Second Language Adjusted Typing Speed (wpm)

	1	2	3	4	5	6	7	8	9	10	11	12
Normal	31	16	47	59	70	31	60	46	23	40	34	47
Mechanical	30	19	61	54	93	18	72	76	21	34	49	40

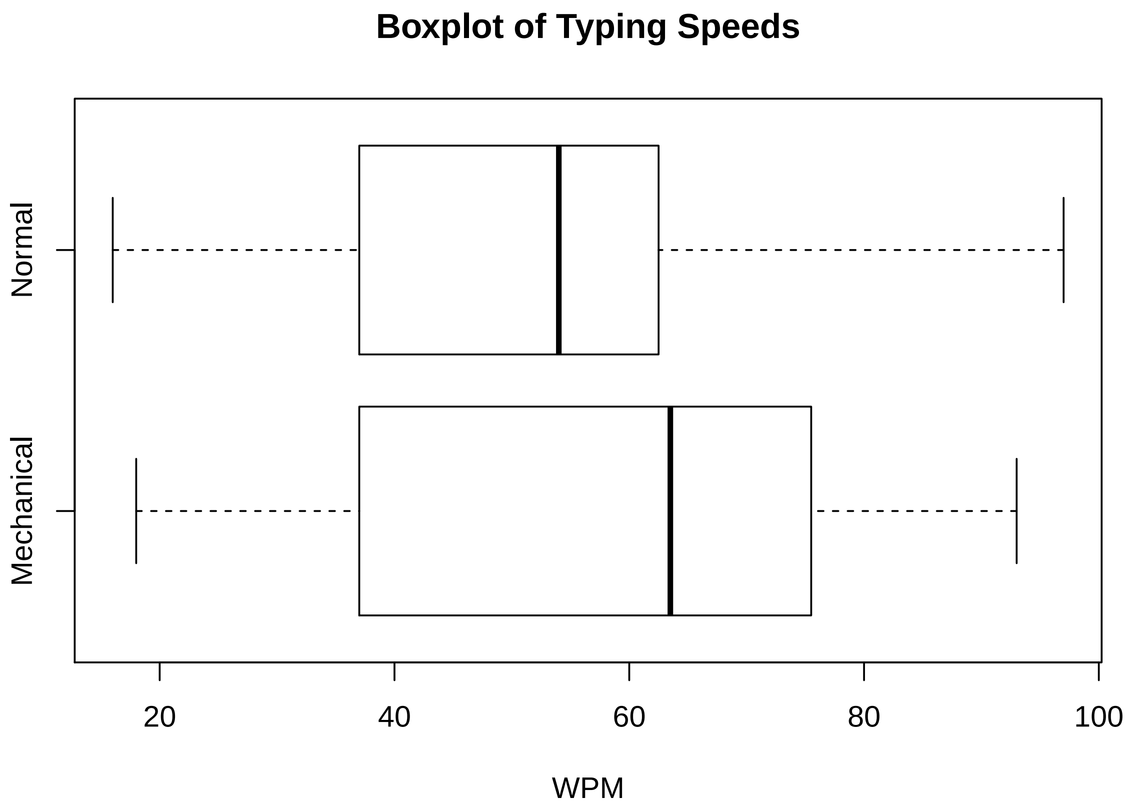
3 Results

Informal analysis of our data suggests a considerable difference in typing speed between native English speakers and secondary English speakers. Looking at the strip plot below, we see that median typing speed for native speakers is about 20 wpm higher than that of non-native speakers.

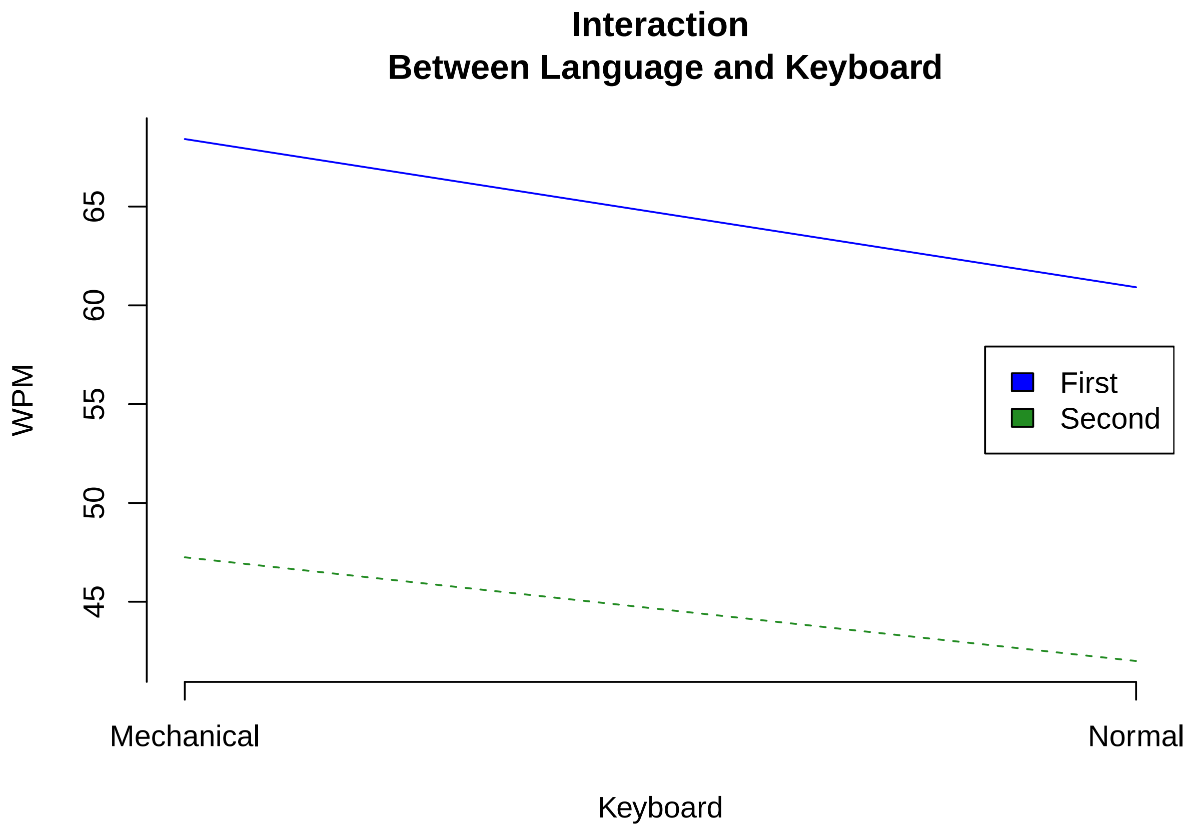


We also see that the spreads are similar for both language classes and variance is not significantly different between the two groups. While there is one response that looks like it could be an outlier within the Secondary English group of responses, it is not an outlier with respect to all the data and, even within its own class, is not significantly far away from the rest of the responses. Thus we do not have any concerns about the spread and skewness of the groups, nor do we have any concerns about variance being significantly difference between language groups.

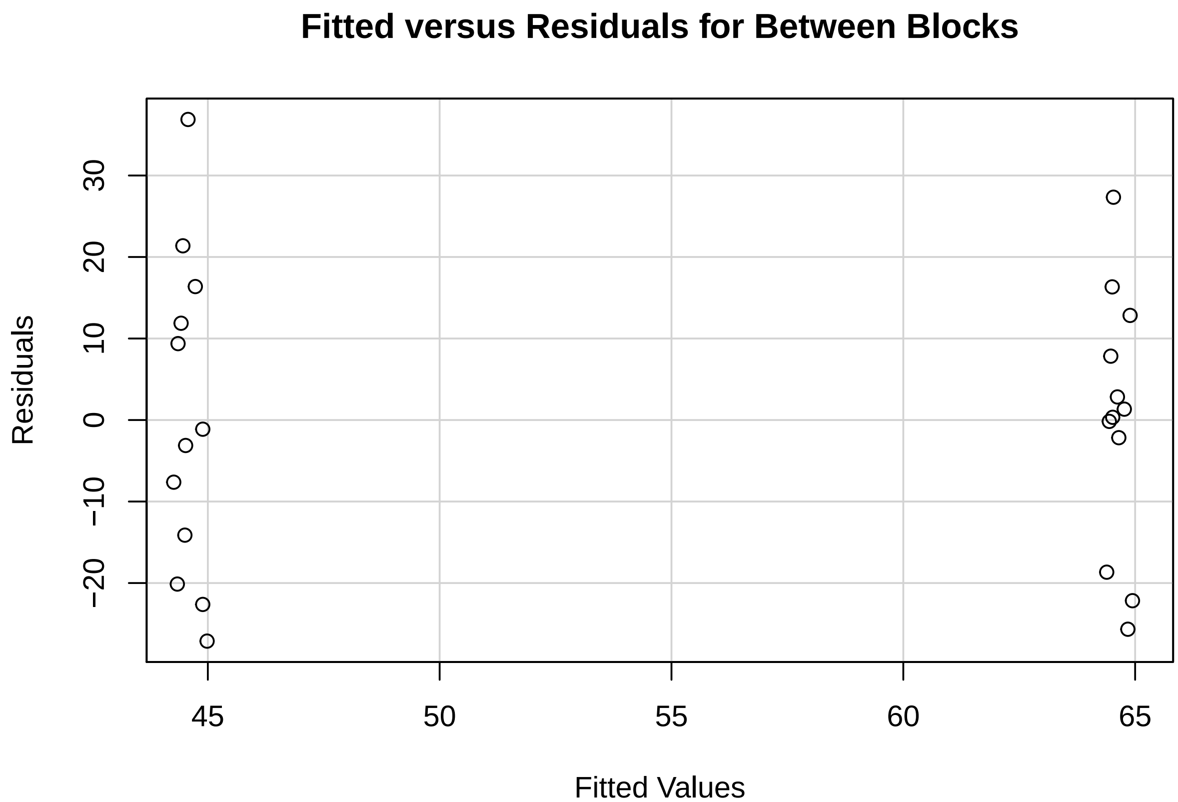
On the other hand, the difference in typing speed between the mechanical and normal keyboards is not obvious. The difference between the median typing speeds is only about 10 WPM in favor of the mechanical keyboard. As one can see in the below boxplot, the main spread of the mechanical responses is wider than that of the normal responses and the mean in in fact larger. This suggests overall that mechanical keyboards have a positive effect on one's typing speed.



Lastly, our informal analysis suggests there is little if any interaction between language and keyboard, as evident from the interaction plot below. This fits with the intuition that keyboards in the home countries of our English-as-a-secondary-language subjects, who predominantly come from East Asian countries, are not entirely dissimilar to those in the United States, when it comes to the mechanics of the keyboard. As such, we would not expect that native English speakers would be any better or worse at one kind of keyboard specifically because of their native language and all that that implies.



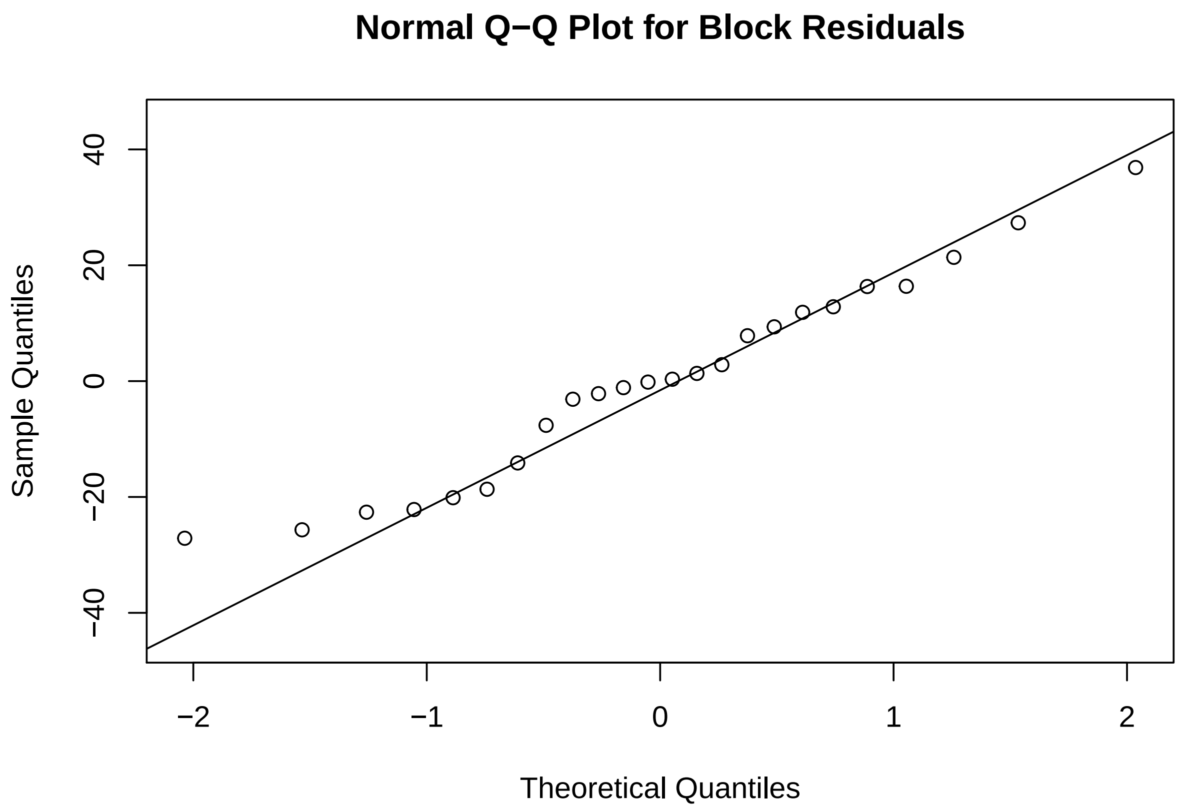
To make sure that we can use analysis of variance, we fit a model to this data and inspect its residuals to see if they conform to the assumptions of ANOVA. That is, we wish to see if the residuals are in fact independent, identically distributed normal random variables with mean 0 and constant variance. With this, we need to inspect both sources of errors: the subjects, which are our between block error source, and the run-of-the-mill residuals, our within block errors. We begin with the blocks.



This plot gives us some cause for concern. Clearly, we have two fitted values (the points are jittered for clarity) and the variance appears to be somewhat smaller in the group of residuals that pair with the higher fitted value. We turn to Cobb's rule of thumb to detect if there is a problem, however, by dividing the largest standard deviation of the responses (when grouped by language) by the smallest standard deviation of the responses and noting that the resulting value is less than 3. This works similarly for dividing the largest deviation of the residuals when grouped by fitted value by the smallest standard deviation of the residuals. We conclude that the assumption of constant variance is sufficiently satisfied.

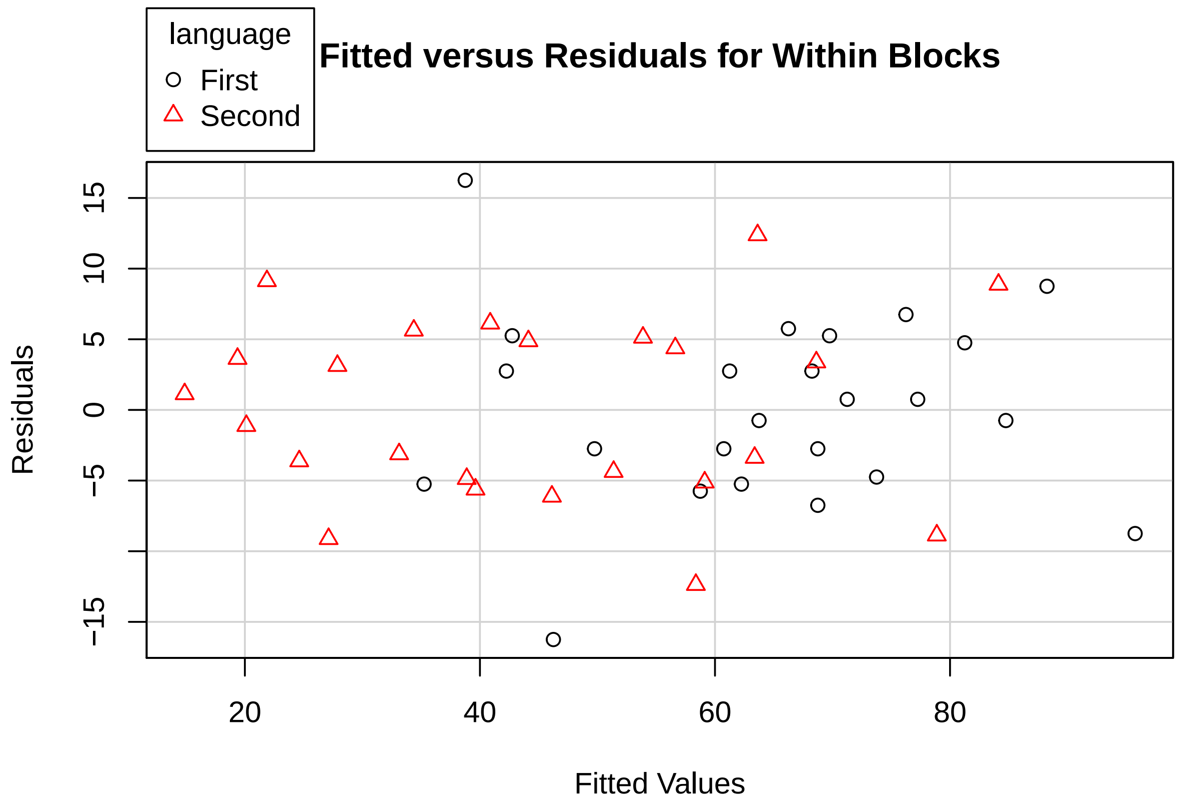
$$SD_{\max}/SD_{\min} = 20.44465/17.30209 = 1.181629 < 3$$
$$SD^{res}_{\max}/SD^{res}_{\min} = 19.62156/15.82049 = 1.240263 < 3$$

Now we consider the assumption of normal residuals. First, recall the scatter plot from above. Notice that there were not significant outliers, i.e. no residuals more than three standard deviations from 0. There is some lumpiness in the middle of the higher fitted valued residuals, but otherwise the distribution is pretty even. We are not too unhappy about the symmetry and skewness seen in the residuals, though we acknowledge there is some skewness in the higher fitted valued residuals. To examine the tails of the residuals, we look at a normal QQ plot:

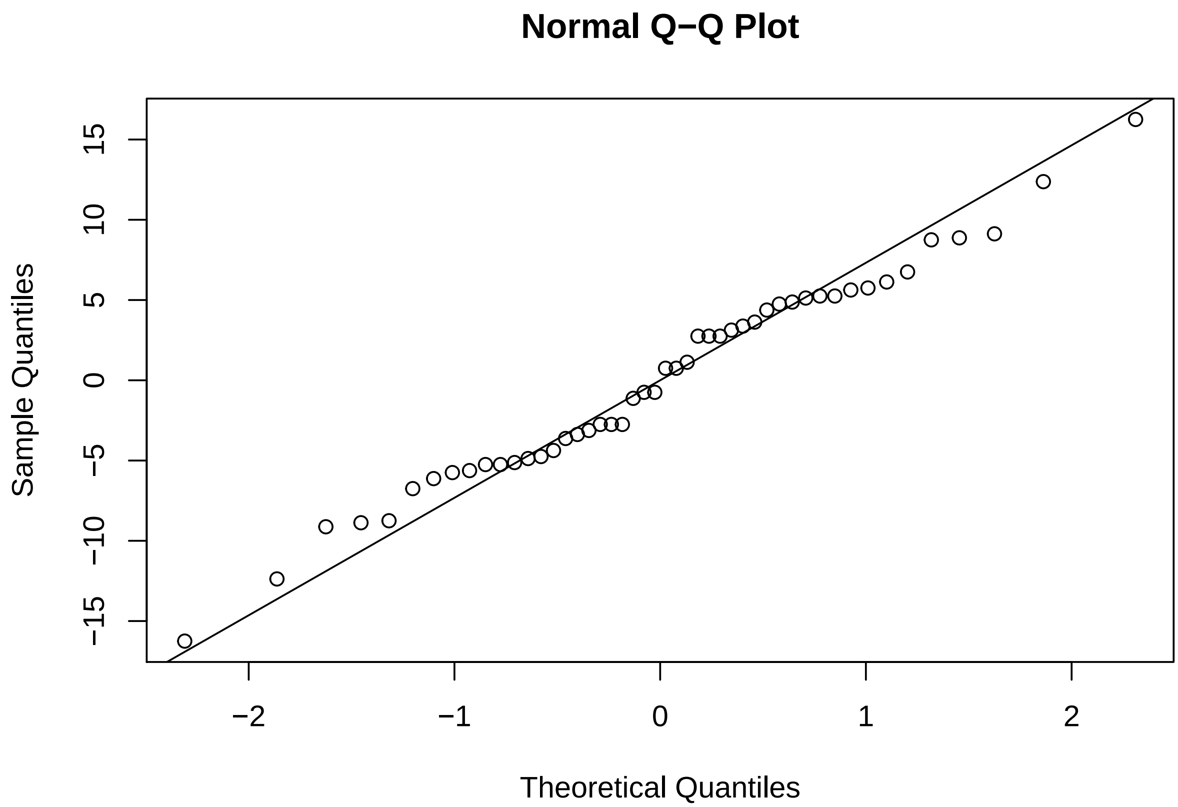


There is a heavy left tail, but these residuals do not look exceeedingly abnormal. Additionally, removing the outlier in the lower left hand side of the above plot does not have a significant effect on the analysis and makes the analysis more difficult and require methods beyond those covered in the course. As such, we will leave the data as is.

We conclude that the assumptions that ANOVA rely on are sufficiently satisfied by the between block residuals. Now we investigate the within block residuals.



From this scatterplot, we see that there is no strong relationship between residuals and fitted values, and from this, we conclude that there is no sign for concern that variance is not constant. We do not see any significant outliers, gapping, asymmetry, nor skewness. There is some lumpiness, in that the distribution of residuals seems clustered in the middle, i.e. close to 0. To examine the tails of the residuals, we turn to the normal QQ plot:



We see that the tails are not very heavy, but we also see a reminder of the lumpiness of the residuals towards the center. Overall, these residuals do not look exceedingly abnormal. Thus we conclude that these residuals are well behaved for ANOVA analysis.

With that, we give the ANOVA table for our analysis.

Error: Subject

Source	df	SS	MS	F	p-value
Language	1	4820	4820	7.587	0.0116
Residuals	22	13976	635		

Error: Within

Source	df	SS	MS	F	p-value
Keyboard	1	487.7	487.7	5.312	0.031
Keyboard:Language	1	15.2	15.2	0.165	0.688
Residuals	22	2019.6	91.8		

The ANOVA table tells us that there is a significant difference in typing speed depending on the type of keyboard (p = 0.031), and first language is also a significant factor with respect to typing speed (p = 0.0116). Also, there is no significant interaction between keyboard and language (p = 0.688), so the effect of the keyboard is consistent throughout both language groups.

4 Discussion/Conclusion

To answer our initial question, we can conclude that native English speakers have faster typing speeds than non-native speakers. We can also conclude that there is a significant difference between the typing speeds for mechanical and rubber membrane keyboards. However, there is no significant interaction between keyboards and the subjects first language, given that these are independent factors.

Given our results, we can conclude that it may be helpful for non-native speakers to use mechanical keyboards to improve their typing speed. In the context of schoolwork, native speakers have a clear advantage in writing assignments given that English is their first language and that they are more comfortable with QWERTY keyboards. Thus, it may be strategic for non-native speakers to adopt mechanical keyboards to type more efficiently.

An interesting question to address would be if we would expect similar results if we did not sample in a statistics course at Cal. The majority of the students in the Statistics department are of Asian-American descent, so naturally our sample encompassed mainly Asian Americans as both native and non-native speakers. An interesting experiment would be to sample subjects from a classroom that is more representative of the population at Cal, such as Nutritional Science 10 or Undergraduate Business Administration 10. This would broaden our sample of native and non-native speakers to encapsulate students from European, African, South American and Middle-Eastern descent.

If we were to develop our current experiment further, it would be interesting to observe the amount of error in the typing tests. Every misspelled words was factored as a deduction in the raw score, so a subject who typed 50 words perfectly and another subject who typed 80 words perfectly and 30 incorrectly would receive the same score; this does not necessarily imply that their typing abilities are identical. In our experiment, we observed that non-native speakers were meticulous with the typing portion, frequently using the backspace to correct misspelled words. Given the high WPM of native-speakers, many subjects breezed through misspelled words but still produced high WPM. This may be due to the fact that Asian languages such as Chinese and Japanese contain many more characters and strokes than English, causing accuracy to be more important than efficiency.

In conclusion: through our SP/RM design experiment, our team was able to observe significant differences in typing speeds between native and non-native speakers, as well as the improved efficiency of typing with mechanical keyboards over rubber keyboards.

5 Appendix

English First Language				
			WPM	
Run #	Name	Mechanical First? (y/n)	Normal	Mechanical
1	Jessica Chen	y	97	87
2	Brian Qiu	y	63	72
3	Connie Fee	y	53	72
4	Wendy Tang	n	58	71
5	Timothy Lee	n	62	83
6	Alex Chao	n	78	84
7	Russell Mays	n	57	75
8	Theresa Andrasfay	y	45	47
9	Divya Narayanan	n	69	86
10	Cerys Morgan	y	30	48
11	Jane Luo	n	55	30
12	Sydney Wong	y	64	66

English Second Language				
			WPM	
Run #	Name	Mechanical First? (y/n)	Normal	Mechanical
1	Xiying He	n	31	30
2	Yujia Zhang	y	16	19
3	Shanna Su	n	47	61
4	Samuel Lin	n	59	54
5	Sung Bae	n	70	93
6	August Zhan	y	31	18
7	Yeeun Sung	y	60	72
8	Luyi Zhang	y	46	76
9	Jay Park	n	23	21
10	Aaron Ma	n	40	34
11	Shichen Wang	y	34	49
12	Jiayu Tan	y	47	40

```
#######################
### Experiment Data ###
#######################
response = c(97, 63, 53, 58, 62, 78, 57, 45, 69, 30, 55, 64,
             87, 72, 72, 71, 83, 84, 75, 47, 86, 48, 30, 66,
             31, 16, 47, 59, 70, 31, 60, 46, 23, 40, 34, 47,
             30, 19, 61, 54, 93, 18, 72, 76, 21, 34, 49, 40)
keyboard = as.factor(rep(rep(c("Normal", "Mechanical"), each=12), 2))
language = as.factor(rep(c("First", "Second"), each=24))
subject = as.factor(c(rep(1:12,2),rep(13:24, 2)))
# What the mechanical keyboard done first? y = yes.
note = as.factor(rep(c('y','y','y','n','n','n','n','y','n','y','n','y',
                       'n','y','n','n','n','y','y','y','n','n','y','y'),
                     each=2))
dat = data.frame(response, keyboard, language, subject)
dat.aov = aov(response ~ keyboard * language + Error(subject), data=dat)

#############################
### ANOVA table (in text) ###
#############################
summary(dat.aov)

#########################################
### Functions for analyzing residuals ###
#########################################

getBlockResFit = function(resp) {
  dat.aov = aov(resp ~ language * keyboard + Error(subject))
  aovProj = proj(dat.aov)
  allTerms = do.call("cbind",lapply(aovProj[1:3],function(x){x}))
  colnames(allTerms)[3] = "subject"
  datFitAOV = rowSums(allTerms[,1:2])
  datResAOV = aovProj[["subject"]][,"Residuals"]
  datFitAOV = round(tapply(datFitAOV,dat$subject,
                         function(x){unique(round(x,4))}),4)
  datResAOV = round(tapply(datResAOV,dat$subject,
                         function(x){unique(round(x,4))}),4)
  return(list("Res"=datResAOV, "Fit"=datFitAOV))
}
```

```
getWithinResFit = function(resp) {
  dat.aov = aov(resp ~ language * keyboard + Error(subject))
  aovProj = proj(dat.aov)
  allTerms = do.call("cbind",lapply(aovProj[1:3],function(x){x}))
  colnames(allTerms)[3] = "subject"
  subunitFitAOV = rowSums(allTerms[,-ncol(allTerms)])
  subunitResAOV = allTerms[,ncol(allTerms)]
  return(list("Res"=subunitResAOV, "Fit"=subunitFitAOV))
}

block.dat = getBlockResFit(response)
within.dat = getWithinResFit(response)

### Code for plots in order of appearance

##################
### Power Plot ###
##################
measures = list(c(101, 87),c(93,85),c(92,102),
                c(95,88),c(91,83),c(89,91),
                c(95,99),c(101,102),c(89,105),
                c(119,109),c(120,117),c(126,114))
nseq = 2:30
groupmeans = c(8,-8)
sigmasq = var(sapply(measures, mean))
power = sapply(nseq,function(n){
  ncpseq = n*var(groupmeans)/sigmasq
  fcutoff = qf(1-0.05,df=1,df2=2*n-2)
  1-pf(fcutoff,df1=1,df2=2*n-2,ncp=ncpseq)
})
plot(nseq,power,type="l",xlab="n",
     main="Power Curve for alternative: (8, -8)")
abline(h=0.9)
abline(v=12, lty=2)
axis(1, at=12, label="12")

######################################
### Stripchart for WPM by language ###
######################################
```

```
scatterplot(x=as.numeric(language),
     response, ylab="WPM", xlab="Language",
     main="WPM by Language", xlim=c(0.8,2.2), xaxt = "n",
     reg.line=F, groups=keyboard, jitter=list(x=.3), smooth=F)
axis(1, at=c(1,2), labels=c("English Primary", "English Secondary"))

###################################
### Boxplot for WPM by keyboard ###
###################################
boxplot(dat$response ~ dat$keyboard, horizontal = TRUE,
        main = "Boxplot of Typing Speeds", xlab = "WPM")

########################
### Interaction Plot ###
########################
treatMeanFac = factor(dat$language:dat$keyboard)
treatMeans = tapply(dat$response,treatMeanFac,mean)
treatMat = matplot(c(0, 1),
                   matrix(treatMeans,nrow=2,byrow=FALSE),
                   col = c("blue", "forest green"),type="l",
                   main="Interaction\n Between Language and Keyboard",
                   axes = F, ylab="WPM", xlab="Keyboard")
axis(side = 1, at = c(0, 1), labels = c("Mechanical", "Normal"))
axis(side = 2, at = seq(35, 70, by = 5))
legend("right", levels(dat$language), fill=c("blue", "forest green"))

##########################################
### Fitted vs. Residuals, Between Block ###
##########################################
scatterplot(y=block.dat$Res, x=block.dat$Fit, smooth=F, reg.line=F,
            jitter=list(x=0.1), boxplot="", xlim=c(44.5,65),
            xlab="Fitted Values", ylab="Residuals",
            main="Fitted versus Residuals for Between Blocks")

################################################
### Q-Q Normal Plot, Between Block Residuals ###
################################################
qqnorm(block.dat$Res, main="Normal Q-Q Plot for Block Residuals",
       ylim=c(-45,45))
```

```
qqline(block.dat$Res)

##########################################
### Fitted vs. Residuals, Within Block ###
##########################################
scatterplot(y=within.dat$Res, x=within.dat$Fit, smooth=F, reg.line=F,
            boxplot="", xlab="Fitted Values", ylab="Residuals",
            main="Fitted versus Residuals for Within Blocks",
            group=language)

###############################################
### Q-Q Normal Plot, Within Block Residuals ###
###############################################
qqnorm(within.dat$Res); qqline(within.dat$Res)
```