Bryant University

HONORS THESIS

Does Being Bilingual Make You Better At Math?

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Does Being Bilingual Make You Better At Math?
Senior Capstone Project for Enxhi Elezi

ABSTRACT

The purpose of this study is to examine if there is any relationship between being bilingual, defined as speaking your native language at home and another language in school, and your mathematical ability. Data from the National Longitudinal Study of Adolescent Health was used to compare the math grades of students who were not born in the US and speak English, Spanish, or Other at home. Also, data from the Bryant University first year students was used to test if students who speak a different language at home have a higher mathematical average than their monolingual peers. Results show that students who are classified as balanced bilinguals perform better at math than monolingual or one-dominant bilingual students.

INTRODUCTION

Prior to coming to the US, I was born and raised in Albania for 17 years. My studies in English began when I was seven years old, and now having been in the US for five years, I consider myself fluent in both Albanian and English, and by definition bilingual, able to speak and write fluently in both languages. English was the first foreign language that I learned, and given my desire to learn more languages, I started learning Italian a few years later. At the same time, mathematics is another one of my passions. I have always enjoyed it and it has come easy to me, which is why I decided to pursue a career that strongly uses mathematics. As I was about to decide on a topic to write my Honors thesis on, I wondered whether I could connect these two interests of mine. Naturally, the question that came to my mind was whether there is any relationship between being bilingual and mathematics. Essentially, does being fluent in a second language make one better at math compared to if he or she remained monolingual?

To answer this question, it is important to first define bilingualism and find a good sample with which to work. For the purpose of this research paper, I have defined bilingualism as speaking your native language at home, while speaking a different language in school. The best sample that fulfills that definition is the children of immigrants who speak English in school, but still speak their native language at home. Since they habitually use both languages, I have classified them as balanced bilinguals. There are two samples with which I will work.

The first sample is from the National Longitudinal Study of Adolescent Health conducted among 7th through 12th graders in the US during the 1994-95 academic year. The 6500 participants completed in-home interviews, as well as in-school questionnaires, and constitute a representative sample of adolescents in the US. This data has much information about the social, economic, psychological and physical well-being of the participants. However, only a few variables are relevant to my topic. These variables include the language students speak at home, country of origin, year they came to the US, their most recent grade in mathematics and English, and their gender. I will perform statistical analysis on these variables to see if there is any evidence that links the language the student speaks at home with their mathematical performance. If so, I will be looking more in detail if there is a particular foreign language that seems to be related to significantly higher mathematical grades.

The second sample will be the Bryant University first year students. Following the same definition for bilingualism, I will be testing whether the conclusions from the national database are true for the Bryant sample. The Admissions Office at Bryant has collected data from the 2018 student class in terms of what language they speak at home. At end of the first semester, data about which math class each student took and their final grade will be provided to me, keeping their names anonymous. This data will allow for the statistical analysis to be conducted and conclusions to be derived.

LITERATURE REVIEW

In today's global environment, being bilingual is perceived to be very beneficial, but this was not the case a few decades ago. Thus, it is important to first see how society has changed its view towards bilingualism; and then look at the main research done on this topic. In 1919, President Roosevelt associated monolingualism with loyalty to the US as he addressed that, "We have room for but one language here, and that is the English language, for we intend to see that the crucible turns our people out as Americans, of American nationality, and not as dwellers in a polyglot boarding house; and we have room for but one sole loyalty, and that is the loyalty to the American people." (Cited in Brumberg, 1986: 7). This statement comes from the need to unify the people in the US as one country and language is one of the ways to accomplish this goal. The same view grew even stronger in Nazi Germany, where bilingualism was seen as distorting to the attitudes conditioned by the language and culture of a country. Therefore, bilingualism was seen as the cause for speech errors and culture distortion.

It wasn't until the 1950s that Arsenian (1945), Haugen (1953, 1956), and Weinreich (1953) started promoting a more positive view of bilingualism, even though it was then seen as an "unusual" characteristic that belonged to the margins but did not affect society as a whole. Bilinguals have been in the focus of systematic research and findings only in the past few decades, and the results have switched the way society views bilingualism and its necessity in today's world. This literature review will highlight the cognitive benefits of bilingualism, including mathematics. These studies will provide a foundation and evidence for my own research in the field of bilingualism and mathematical ability.

One of the earliest studies on bilingualism that provided the theoretical basis for bilingual studies is that done by professor James Cummins in Canada in the 1970s. He develops his own theories about bilingualism, among which the *threshold hypothesis* and *developmental interdependence* hypothesis are the most central. The threshold hypothesis suggests that there are two types of learning environments when it comes to language acquisition. One can be a subtractive environment, where the native language of the student is not strong enough and is replaced by the acquisition of the second language. The second environment, the additive one, happens when the competency in the native language is strong enough for the second language skill to be added. Cummins argues that balanced bilinguals, individuals who have similar competency in both the native language and the second language, show cognitive acceleration compared to their monolingual peers (Cummins, 1976).

A study that uses Cummins' theory as a guide to test the relationship between bilingualism and mathematical performance is done by P.C Clarkson and Peter Galbraith (1991). The authors take a sample of 227 6^{th} grade students from five different urban schools in Papua New Guinea. There, English is the official language, with Melanesian Pidgin as the most common language for general communication. The students examined in the study regarded Pidgin as their mother tongue with different degrees of competencies in English. The study tries to answer the question as to whether students who show a high competence in both English and Pidgin do better in math than other students. At the same time they looked into whether the opposite is true for students with lower competence in both languages.

Clarkson and Galbraith conduct three mathematical tests: a general mathematics test, a word problem math test, as well as a number competence test. Another variable called Language was created, which grouped students as *high/high* if they scored as high competence in reading comprehension tests for both English and Pidgin, *low/low* if they were in the lower threshold for both languages, and *one dominant* if they scored high competence in only one language. Mathematical competence was the dependent variable with Language as the independent variable, as well as cognitive ability and home background as co-variants. The results showed that the performance of *high/high* and *one dominant* groups were significantly higher than the *low/low* group for all the three tests, with a level of significance of 0.05. Also, only for the general mathematics test there was a significantly higher performance from the *high/high* group compared to the *one dominant* group. In the other two tests, these groups were not significantly different in performance and were higher than the *low/low* group. This study supports Cummins threshold hypothesis, as well as gives some evidence that bilingualism affects one's mathematical performance.

Another study that examines the direct relationship between levels of bilingualism and mathematical performance is conducted by John Jean (1998). There were 125 students chosen, from which 70 were in the 7th grade and 55 in the 8th grade. Students were chosen from two urban schools and were tested for their language performance in English and Haitian, as well as their performance in mathematical word problems. Essay writing and self-evaluation were used to classify the subjects as balanced bilinguals, if they showed high performance in both languages. They would be classified as Haitian-dominant if they showed high performance only in Haitian and English-dominant, if they showed high language skills only in English. Also, students were classified as limited bilinguals if they showed poor performance in both languages.

Jean notes that to evaluate their mathematical abilities, the students were given a word problem test with half the questions in English and the other half in Haitian. The test had consistent and inconsistent addition, subtraction, multiplication and division problems. A consistent math problem has the unknown variable as the subject of the sentence, whereas in an inconsistent problem, the unknown variable is the object of the sentence. The study was trying to capture the difference in the reversal errors based on bilingualism, with reversal errors being classified as, "a problem solver's mis-representation of an inconsistent language problem" (Jean, pg 7). The results showed that balanced bilinguals were less likely to generate reversal errors compared to both Haitian-dominant and English-dominant bilinguals. Different from the previous study, these results support the theory that being a balanced bilingual provides mathematical advantage not only compared to monolinguals, but to one-dominant bilinguals as well.

Similarly, Sarah Howie examined the relationship between English proficiency and mathematical performance among 8,000 secondary school students from 200 different schools in South Africa (2005). In the Third International Mathematics and Science Study in 1995 and 1999, she noted that South African students scored extremely low compared to students from other countries in the study. This study tried to explain the achievement of South African students in mathematics, by taking into account their English proficiency, language usage and other background factors. The results of the study showed that high proficiency in English was the most significant factor in explaining the differences in students' mathematical scores, with socio-economic status to be less significant and the students' home language not to be significant in their mathematical performance .

Another sample of bilingual students is that of children of immigrants. These students are faced with the inevitable choice of assimilation when arriving to the US, whether it means forgetting their native language and culture altogether or adopting the American one in addition to their own. Tanya Golash-Boza examines the effects of bilingualism in the educational outcomes for the children of immigrants (2005). She uses data from the 1992-1993 Children of Immigrants Longitudinal Study, which includes 8^{th} and 9^{th} grade students among 42 schools in Miami, Florida and San Diego, California.

Golash-Boza uses Stanford math and reading tests to measure the students' academic performance, as well as their self-reported language ability. The bilingual samples used in the study were Hispanics, Vietnamese, or Filipinos. The results suggested that balanced bilingual Latinos in Miami have a significant advantage over English-dominant Latinos in Miami on all of the measures of academic success. The same is true even when their parents were proficient in English and they spoke English at home. The balanced bilingual Latinos in San Diego, on the other hand, did not perform statistically higher than English-dominant students on the standardized tests, but they had higher GPAs overall. It is important to mention that the difference between the Latinos in the two regions was the fact that the socio-economic level of the Latinos in Miami is higher than those in San Diego, which translates to more resources and opportunities for the Latino students to succeed. Therefore, this article provides evidence that the socio-economic level can have an impact in the degree of influence that bilingualism plays in one's academic performance, including math scores, but there is, nonetheless, an advantage to being a bilingual student.

Besides the benefits that learning a second language has in the enhancement of one's mathematical abilities, research has been done in the importance of the native language, or the language in which the students learn math. Miller, Kelly and Zhou explain some of the reasons why East Asian children outperform North American children in mathematics. The authors claim that substantial differences between the two groups already exists by the time children enter school. These differences can be explained by "differences in the consistency and transparency of the linguistic representation of number as well as differences in parental beliefs and practices" (Miller, 2005). The number names in most Asian languages are fully congruent with the base 10 numeration system, which makes short-term memory easier and speeds calculation. For example, instead of saying eleven for 11, they would say something that translates to one-ten. The hypothesis that memory plays a crucial role in mental arithmetic of adults is now universally accepted and gives the East Asian children a head start. This advantage is further enhanced by the parenting beliefs that mathematical ability is a result of the amount of effort one puts in and the teaching that one gets, in contrast to that of American parents that believe that math ability is innate. It is important to notice these differences in monolingual populations, as they may affect bilingual populations as well. For example, comparing Chinese-English bilingual students who learned mathematics in Chinese might not be the same as comparing English-French bilinguals who studied math in the US. These pre-existing differences make the effect of bilingualism among different samples harder to isolate.

The studies mentioned above give some evidence that bilingualism enhances one's mathematical abilities, but the equally important question is why do bilinguals perform better in math than their monolingual peers? Are there different brain areas involved in performing mathematics in these two populations? To answer these questions, it is important to look at the executive functions of the brain. As described by Lucy Cragg and Camila Gilmore, executive function describes “the group of processes that allow us to respond flexibly to our environment and engage in deliberate, goal-directed, thought and action” (Cragg 64). These skills start to develop in infancy, but are among the latest cognitive abilities to mature in late adolescence. There are three executive functions most commonly studied, “*inhibition*: suppressing distracting information and unwanted responses, *shifting*: flexibly switching between different tasks, and *updating* or *working memory*: monitoring and manipulating information in mind” (Cragg 64). This paper is a collection of different correlations, experimental, and learning studies that show the strong relationship between the three functions of the executive system and the main components of mathematical knowledge, such as facts, procedures and concepts.

Executive functions of the brain are not only related to mathematics but also to bilingualism. Through the paper *Reshaping the Mind: The Benefits of Bilingualism*, Bialystok explains this correlation as well the benefits of lifelong bilingualism (2011). To better understand the relationship, it is important to realize that both languages of a bilingual speaker are constantly active even in monolingual contexts that only require the use of one language. This means that bilinguals have an added attention problem, since they do not only need to go through the linguistic choices appropriate for the context, but they also need to select the correct language, a problem absent in monolingual speakers. Therefore, the bilingual brain uses the executive control functions to control language switching, a role that the executive function does not have in monolingual brains. The constant exercise of these functions results in a more efficient performance of executive functions in bilinguals. We can therefore conclude that these strengthened executive functions enhance the mathematical ability in bilinguals, and indirectly connect bilingualism with one’s mathematical performance.

Moreover, these benefits seem to last for a lifetime. A news release issued by the Society for Neuroscience in 2013, stated that when tested for their cognitive flexibility, “bilingual seniors were faster at completing the task than their monolingual peers despite expending less energy in the frontal cortex; an area known to be involved in task switching”. (*Study Shows Cognitive Benefit of Lifelong Bilingualism*, http://www.sfn.org/Press-Room/News-Release-Archives/2013/Study-Shows-Cognitive-Benefit-of-Lifelong-Bilingualism). Therefore, the bilingual brain seems to be more efficient at task-switching, involved in both speaking two languages and performing mathematics, and this efficiency remains throughout the whole life of the bilingual individual.

RESEARCH DESIGN

Most of the authors listed above use essay writing, reading comprehension and self-reported language skills to classify the students as balanced bilinguals, one-dominant, or monolingual. In terms of their mathematical abilities, word problems, general mathematical test and standardized tests are used. In my studies, I have tried to operate the same methods, within the context of my samples. The two samples I will be working with are the National Longitudinal Study of Adolescent Health and the Bryant University first year students.

Sample Subjects

1. National Longitudinal Study of Adolescent Health

The National Longitudinal Study of Adolescent Health was conducted during the 1994-1995 school year among 7^{th} through 12^{th} graders. The participants completed an in-school questionnaire and were also followed by home interviews. With 6500 participants, the study presents a nationally representative sample of adolescents in the US. The variables I used from the study include the language students speak at home, country of origin, year they came to the US, their most recent grade in mathematics, and their gender. The language spoken at home was classified as English, if the students speak English at home, Spanish if they speak Spanish at home, and Other, if they speak any other language at home. The most recent math grades of students were classified as A, B, C or D and recorded with numbers 1, 2,3, and 4 respectively , which means that a higher average indicates lower performance since the bigger numbers correspond to lower letter grades. Therefore, comparisons were made among the three language categories and the students' average math grades.

2. Bryant University Sample

The sample from Bryant University is the student class of 2018, enrolled in different math classes based on their major and the scores in the math placement test taken before they started their first year at Bryant. The grades were recorded as 1 if it was an A or A-, 2 if B-, B, or B+, 3 if C-, C, or C+ and 4 if D or D+. In regards to the languages the students speak, the Office of Admissions at Bryant asked the freshman students what languages they speak at home and what country they are from. To follow the same format as the national study, I grouped the languages as English, Spanish, and Other. Most of the students who were classified as Other had multiple languages they spoke at home, including English. For the sake of this research, I classified those students as balanced bilinguals.

Method

1. National Longitudinal Study of Adolescent Health

The majority of my literature review sources use different math tests to evaluate the students' mathematical abilities. Since the students in this sample are in the 7th to 12th grade, the math topics they have covered in school are the same as the topics tested in the studies mentioned in my literature review. Therefore, the results would capture the students' ability in the same math topics. The analysis and comparisons were made using the statistical software, Minitab, with one-way ANOVA tests, and two-sample T- tests. The p-values were compared to a level of significance of 0.05. Comparative analysis was conducted between average math grades of non US born students, who speak either English, Spanish or Other at home. At the same time, their average English grades were compared, in order to draw conclusions about their level of bilingualism. These students were compared with the US born students, within their respective language groups. Lastly, all the samples were divided into male and female categories to see if there were any gender differences within the same samples.

2. Bryant University Sample

The analysis of the data was done the same way as on the national study, again using Minitab. The students' math scores were compared based on the language they speak at home and whether or not they were born in the US.

RESULTS

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Statistical Analysis

1. National Longitudinal Study of Adolescent Health

The global ANOVA test among the non US born students who speak English, Spanish or Other at home resulted with a p-value of 0.000, which means at least one of the means is different. Further t-tests showed that, the average math grade of non US born students who speak Other at home is significantly better than non US born students who speak English at home, with a p-value of 0.002. On the other hand, the average math grade of non US born students who speak English at home is significantly better than the average math grade of non US born students who speak Spanish at home, with a p-value of 0.007. Therefore, we can conclude that among students who were not born in the US, the ones who classify as speaking Other at home have an average math grade higher than those who speak English at home. Similarly, those speaking English at home have a higher math average than those who speak Spanish at home.

These results look promising in terms of the Other group compared to the English one, but seem a bit contradicting in terms of the Spanish group. To look a little deeper into these results, I compared the average English grades of non US born students who speak Spanish at home to those who speak English or Other at home. From two sample t-tests, the average English grade of students who speak English at home is significantly better than those who speak Spanish, with a p-value of 0.029. On the other hand, the average English grade of students who speak Other at home is significantly the same as those who speak English, with a p-value of 0.191. Since the proficiency in English of non US born students who classify themselves as speaking Other at home, is as proficient as those speak English, it is reasonable to classify this group as balanced bilinguals, speaking habitually and equally well both languages. Therefore, the non US born students who speak Spanish at home can be referred to as Spanish-English dominant bilinguals, able to speak both languages but being more proficient in Spanish. A possible explanation for this difference can be the fact that the Latino population in the US is big enough for these students to be able to get by with speaking Spanish even in school with their peers. As a result, they perform worse than their monolingual peers since the math is in English. These results are important because they support the theory that only balanced bilingualism enhances one's ability in mathematics.

Since the group of students classified as Other, resulted to have the highest average grades in mathematics, I looked into further breaking down this group. Even though the sample size of this group was only 74 students, I classified all their countries into four geographical groups: Latin America, Asia, Europe, and Middle East. From my literature review, the expected result would have been for the Asia group to perform better. However, with a p-value of 0.452, there was no significant difference between the four means and, therefore their average math grades were the same. As a result, I concluded that there is no difference in the mathematical grades among the students who speak Other at home, and their advantage can be attributed to their balanced bilingualism, rather than the school system they learned math in or the specific native language they speak.

Next, I looked into comparing these non US born groups of students with their respective US born groups. With a p-value of 0.296 there was no difference between the math grades of students who speak Spanish at home, independent of whether they were born in the US or not. The same results were true for students who speak Other at home, with a p-value of 0.121, and those who speak English at home with a p-value of 0.126. Therefore, there was no difference between the US born and the non US born groups. These results are important because the majority of students from the non US born groups, who speak either Spanish or Other at home, came to the US when they were between 10-14 years old. This means that they took their basic math education in the school systems in their home countries. Yet, this fact does not affect their math skills, and their bilingualism appears to give them an advantage either way.

Since the average math grade between US born and non US born students was the same within their language group, we can expect that the same comparisons between the languages to be true among the US born students. The average math grade of US born students who speak Other at home is higher than those US born students who speak English at home, with a p-value of 0.007. Consequently, the students who speak English at home have a higher math average than the US born students who speak Spanish at home with a p-value of .238. As a result, whether the students were born in the US or came to the US at a latter age, those who speak Other at home have higher math grades than those who speak English at home. Even though it is hard to isolate bilingualism as the only factor for this advantage, it is certainly a very determining factor.

Finally, we examined gender as an issue. Among the three groups of non US born populations, as well as the three groups of the US born populations, the male and female math grades were compared. Using two sample t-tests, only in the US born students who speak English at home, females outperform males with a p-value of 0.000. Even though I do not have an explanation for this difference, the results are interesting and new studies need to be conducted to explain the observation.

2. Bryant University Sample

After the results from the national study, we wondered if the Bryant University sample would produce the same conclusions. For the US born population, there was no significant difference in the math average of students who speak English at home, compared to those who speak Spanish and Other at home. However, for the non US born population, the math average of students who speak English at home is significantly higher than the average of students who speak Other at home. On the other hand, there is no difference between students who speak Spanish or Other at home. These results do not match up with the conclusions from the national study, and it is important to notice that the sample sizes for non US born students who speak English, Spanish or Other were 10, 13 and 29 respectively. If we consider under 30 students to be the threshold of a small sample, Bryant samples would fall under this category. The national sample, in return, is big enough to capture differences in math performance within different languages.

<u>Conclusions</u>

1. National Longitudinal Study of Adolescent Health

From the analysis of the National Longitudinal Study of Adolescent Health, there are several conclusions worth restating. First, the non US born students classified as Other had the highest average math grade followed by non US born who speak English and then Spanish. The students who speak Other perform equally well in English as the students who speak English at home, and can therefore be classified as balanced bilinguals. Also, there were no differences among the different countries these students were from, whether it was South

America, Europe or Asia. There was also no difference between the non US born students who speak Other at home and the US born ones who speak Other at home. This leads us to conclude that it is bilingualism that affects their mathematical abilities and not the school system in which they started learning math.

Second, the average math grade of students who were not born in the US and continued to speak Spanish at home is lower than of the non US born students who speak English or Other at home. Since the average English grade of these students is also lower than the other two groups, we can assume that their poor math performance is the result of other factors, such as problems with the math class being in English. At the same time, there is no difference in the math grades of students who speak Spanish at home, whether or not they were born in the US, concluding that the school system in which they started to learn mathematics was not a significant factor. However, if their English grades are not sufficient, they would be closer to monolingual Spanish speakers.

Lastly, gender differences were only observed in the US born students who speak English at home with females performing significantly higher than males. There were no gender differences in any other groups.

2. Bryant University Sample

Bryant University students did not show the same trends in terms of their bilingualism and mathematical ability. The US born students showed no difference in their math grades whether they spoke English, Spanish, or Other at home. Among the non US born students, those who speak English at home have a significantly higher mathematical grade than those who speak Spanish or Other at home. Also, there was no significant difference between non US born students who speak Spanish or Other at home.

DISCUSSION

As the results from the Bryant University sample do not match those from the National Longitudinal Study, I would like to discuss some hypothesis as to why this is the case.

First, we need to look at the differences between the students who classified as non US born who speak Other at home in the national study and those in the Bryant sample. The students in the national study have been in the US for a few years by the time the data was gathered and most likely came to the US with their families. Bryant non US born students who speak Other at home, are mostly international students. Even though the fact that they came to the US and were accepted to an American college testifies their English skills, it does not indicate that they have taken mathematics in English before. Therefore, the new terminology and different ways of teaching might prove to be challenging enough for the students to affect their mathematical grade. The fact that the non US born students who speak Other at home is equal to those who speak Spanish at home in the Bryant sample is not surprising. The main hypothetical reason why the Spanish speaking non US born students performed worse than those who speak Other or English at home in the national sample was because they are classified as one- dominant bilinguals and can get by with speaking Spanish in school. However, at Bryant, all the international students are in the same position, where they have come to the US for the first time most probably for college and have to take classes and communicate in English.

Second, we should focus on the students who were born in the US and either take a further look at their bilingualism, or hypothesize that the differences in mathematical performance disappear in the college level. If we look at the US born students who speak Other at home in the Bryant sample, we realize that there are multiple languages spoken at home, including English. We can assume that the parents of the students know English well, and therefore the amount of time they speak English at home is much higher than the amount of time the students in the national study speak English at home. If the amount of English spoken at home is constantly increasing and potentially substitutes the native language, the students can eventually fall in the one-dominant category instead of the balanced bilingual one.

Lastly, the math grades in the national study were self-reported by students, whereas the ones in the Bryant sample were taken from professors' records. Even though it is possible that the majority of students in the national database truthfully reported their mathematical grades, it is also possible that some students reported higher grades and therefore skewed the results.

FURTHER RESEARCH

One limitation in my study that can be captured by further research is the small sample from Bryant University. Future research can include data from similar schools to generate a big enough sample to capture the mathematical differences among students within different language categories. Second, the National Longitudinal study can be further analyzed with the income, and whether or not parents speak English variables kept constant. Since the national database captured students from 7^{th} to 12^{th} grade, further research can break down these grades and look if the overall results would change.

For the purpose of this study, balanced bilinguals have been defined as students who speak a different language at home and speak English at school. However, a broader range would include children of US citizens who have lived in a different country for a few years and attend school in a different country. A good sample would be children of US staff who work in US embassies around the world.

APPENDICES

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Appendix A – (National Longitudinal Study Minitab Results)

One-way ANOVA: Non US born speak English, Non US born speak Other, Non US born speak Spanish

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	25.68	12.839	12.15	0.000
Error	344	363.46	1.057		
Total	346	389.14			

Two-Sample T-Test and CI: Non US born speak English, Non US born speak Other

Two-sample T for Non US born speak English vs Non US born speak Other

	N	Mean	StDev	SE Mean
Non US born speak Englis	138	2.23	1.07	0.091
Non US born speak Other	74	1.81	1.00	0.12

```
Difference = μ (Non US born speak English) - μ (Non US born speak Other)
Estimate for difference:  0.421
95% lower bound for difference:  0.176
T-Test of difference = 0 (vs >): T-Value = 2.85  P-Value = 0.002  DF = 157
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Two-Sample T-Test and CI: Non US born speak English, Non US born speak Spanish

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Two-sample T for Non US born speak English vs Non US born speak Spanish

                            N   Mean  StDev  SE Mean
Non US born speak Englis  138   2.23   1.07    0.091
Non US born speak Spanis  135  2.541  0.998    0.086


Difference = μ (Non US born speak English) - μ (Non US born speak Spanish)
Estimate for difference:  -0.309
95% upper bound for difference:  -0.102
T-Test of difference = 0 (vs <): T-Value = -2.47  P-Value = 0.007  DF = 270
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Two-Sample T-Test and CI: Non US born speak Spanish, Non US born speak Other

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Two-sample T for Non US born speak Spanish vs Non US born speak Other

                            N   Mean  StDev  SE Mean
Non US born speak Spanis  135  2.541  0.998    0.086
Non US born speak Other    74   1.81   1.00     0.12


Difference = μ (Non US born speak Spanish) - μ (Non US born speak Other)
Estimate for difference:  0.730
95% lower bound for difference:  0.490
T-Test of difference = 0 (vs >): T-Value = 5.04  P-Value = 0.000  DF = 149
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One-way ANOVA: Latin America, Asia, Europe, Middle East

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Analysis of Variance

Source  DF  Adj SS  Adj MS  F-Value  P-Value
Factor   3   2.670  0.8899     0.89    0.452
Error   65  65.069  1.0011
Total   68  67.739
```

One-way ANOVA: Non US speak Spanish English grade, Non US speak English English grade, Non US speak Other English grade

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Analysis of Variance

Source   DF   Adj SS  Adj MS  F-Value  P-Value
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Factor    2    5.983  2.9915     3.48    0.032
Error   369  317.466  0.8603
Total   371  323.449
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Two-Sample T-Test and CI: Non US speak English English grade, Non US speak Spanish English grade

```
Two-sample T for Non US, speak English, English vs Non US, speak Spanish, English

                            N   Mean  StDev  SE Mean
Non US, speak English, E  147  2.088  0.898    0.074
Non US, speak Spanish, E  143  2.294  0.941    0.079


Difference = μ (Non US, speak English, English) - μ (Non US, speak Spanish,
English)
Estimate for difference:  -0.205
95% upper bound for difference:  -0.027
T-Test of difference = 0 (vs <): T-Value = -1.90  P-Value = 0.029  DF = 286
```

Two-Sample T-Test and CI: Non US, speak English, English, Non US, speak other, English

```
Two-sample T for Non US, speak English, English vs Non US, speak other, English

                            N   Mean  StDev  SE Mean
Non US, speak English, E  147  2.088  0.898    0.074
Non US, speak other, Eng   82  1.976  0.955     0.11


Difference = μ (Non US, speak English, English) - μ (Non US, speak other, English)
Estimate for difference:  0.113
95% lower bound for difference:  -0.101
T-Test of difference = 0 (vs >): T-Value = 0.88  P-Value = 0.191  DF = 159
```

Two-Sample T-Test and CI: Non US born speak Spanish, US born speak Spanish

```
Two-sample T for Non US born speak Spanish vs US born speak Spanish

                            N   Mean  StDev  SE Mean
Non US born speak Spanis  135  2.541  0.998    0.086
US born speak Spanish     111   2.61   1.08     0.10


Difference = μ (Non US born speak Spanish) - μ (US born speak Spanish)
Estimate for difference:  -0.072
95% upper bound for difference:  0.149
T-Test of difference = 0 (vs <): T-Value = -0.54  P-Value = 0.296  DF = 226
```

Two-Sample T-Test and CI: Non US born speak Other, US born speak Other

```
Two-sample T for Non US born speak Other vs US born speak Other

                         N  Mean  StDev  SE Mean
Non US born speak Other  74  1.81   1.00     0.12
US born speak Other      43  2.05   1.07     0.16


Difference = μ (Non US born speak Other) - μ (US born speak Other)
Estimate for difference:  -0.236
95% upper bound for difference:  0.097
T-Test of difference = 0 (vs <): T-Value = -1.18  P-Value = 0.121  DF = 83
```

Two-Sample T-Test and CI: Non US born speak English, US born speak English

```
Two-sample T for Non US born speak English vs US born speak English

                           N  Mean  StDev  SE Mean
Non US born speak Englis  138  2.23   1.07    0.091
US born speak English     138  2.51   1.08    0.092


Difference = μ (Non US born speak English) - μ (US born speak English)
Estimate for difference:  -0.283
95% upper bound for difference:  -0.070
T-Test of difference = 0 (vs <): T-Value = -2.19  P-Value = 0.015  DF = 273
```

Two-Sample T-Test and CI: Non US born, English, Male, Non US born, English, Female

```
Two-sample T for Non US born, English, Male vs Non US born, English, Female

                          N  Mean  StDev  SE Mean
Non US born, English, Ma  67  2.21   1.04     0.13
Non US born, English, Fe  71  2.25   1.10     0.13


Difference = μ (Non US born, English, Male) - μ (Non US born, English, Female)
Estimate for difference:  -0.045
95% lower bound for difference:  -0.347
T-Test of difference = 0 (vs >): T-Value = -0.24  P-Value = 0.596  DF = 135
```

One-way ANOVA: Non US born, English, Female, Non US born, English, Male

```
Analysis of Variance

Source   DF   Adj SS   Adj MS  F-Value  P-Value
Factor    1    0.068  0.06846     0.06    0.808
Error   136  156.511  1.15082
Total   137  156.580
```

One-way ANOVA: Non US born, Spanish, Female, Non US born, Spanish, Male

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.573	0.5732	0.57	0.450
Error	133	132.953	0.9996		
Total	134	133.526			

One-way ANOVA: Non US born, Other, Female, Non US born, Other, Male

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.0715	0.07153	0.07	0.792
Error	72	73.2798	1.01778		
Total	73	73.3514			

One-way ANOVA: US born, English, Male, US born, English, female

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	27.45	27.449	26.03	0.000
Error	4218	4448.68	1.055		
Total	4219	4476.13			

One-way ANOVA: US born, Spanish, Male, US born, Spanish, female

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.035	0.03523	0.03	0.863
Error	109	128.307	1.17713		
Total	110	128.342			

One-way ANOVA: US born, Other, Male, US born, Other, female

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.3483	0.3483	0.30	0.587
Error	41	47.5587	1.1600		
Total	42	47.9070			

One-way ANOVA: US born speak English, US born speak Spanish, US born speak Other

Method
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	10.19	5.097	4.40	0.013
Error	289	334.72	1.158		

```
Total   291  344.91
```

Two-Sample T-Test and CI: US born speak English, US born speak Spanish

```
Two-sample T for US born speak English vs US born speak Spanish

                         N  Mean  StDev  SE Mean
US born speak English  138  2.51   1.08    0.092
US born speak Spanish  111  2.61   1.08     0.10


Difference = μ (US born speak English) - μ (US born speak Spanish)
Estimate for difference:  -0.098
95% upper bound for difference:  0.129
T-Test of difference = 0 (vs <): T-Value = -0.71  P-Value = 0.238  DF = 235
```

Two-Sample T-Test and CI: US born speak English, US born speak Other

```
Two-sample T for US born speak English vs US born speak Other

                         N  Mean  StDev  SE Mean
US born speak English  138  2.51   1.08    0.092
US born speak Other     43  2.05   1.07     0.16


Difference = μ (US born speak English) - μ (US born speak Other)
Estimate for difference:  0.468
95% lower bound for difference:  0.157
T-Test of difference = 0 (vs >): T-Value = 2.50  P-Value = 0.007  DF = 70
```

Two-Sample T-Test and CI: US born speak Spanish, US born speak Other

```
Two-sample T for US born speak Spanish vs US born speak Other

                         N  Mean  StDev  SE Mean
US born speak Spanish  111  2.61   1.08     0.10
US born speak Other     43  2.05   1.07     0.16


Difference = μ (US born speak Spanish) - μ (US born speak Other)
Estimate for difference:  0.566
95% lower bound for difference:  0.246
T-Test of difference = 0 (vs >): T-Value = 2.94  P-Value = 0.002  DF = 77
```

<u>Appendix B – (Bryant University Minitab Results)</u>

One-way ANOVA: US born English, US born Spanish, US born Other

```
Analysis of Variance
```

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	0.112	0.05620	0.06	0.938
Error	669	587.959	0.87886		
Total	671	588.071			

One-way ANOVA: Non US born English, Non US born Spanish, Non US born Other

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	8.050	4.025	3.68	0.033
Error	49	53.642	1.095		
Total	51	61.692			

Two-Sample T-Test and CI: Non US born English, Non US born Spanish

Two-sample T for Non US born English vs Non US born Spanish

	N	Mean	StDev	SE Mean
Non US born English	10	1.200	0.422	0.13
Non US born Spanish	13	2.38	1.12	0.31

```
Difference = μ (Non US born English) - μ (Non US born Spanish)
Estimate for difference:  -1.185
95% upper bound for difference:  -0.594
T-Test of difference = 0 (vs <): T-Value = -3.50  P-Value = 0.001  DF = 16
```

Two-Sample T-Test and CI: Non US born English, Non US born Other

Two-sample T for Non US born English vs Non US born Other

	N	Mean	StDev	SE Mean
Non US born English	10	1.200	0.422	0.13
Non US born Other	29	1.97	1.15	0.21

```
Difference = μ (Non US born English) - μ (Non US born Other)
Estimate for difference:  -0.766
95% upper bound for difference:  -0.341
T-Test of difference = 0 (vs <): T-Value = -3.04  P-Value = 0.002  DF = 36
```

Two-Sample T-Test and CI: Non US born Spanish, Non US born Other

Two-sample T for Non US born Spanish vs Non US born Other

	N	Mean	StDev	SE Mean
Non US born Spanish	13	2.38	1.12	0.31
Non US born Other	29	1.97	1.15	0.21

```
Difference = μ (Non US born Spanish) - μ (Non US born Other)
Estimate for difference:  0.419
95% lower bound for difference:  -0.227
T-Test of difference = 0 (vs >): T-Value = 1.11  P-Value = 0.139  DF = 23
```

Two-Sample T-Test and CI: US born English Male, US born English Female

```
Two-sample T for US born English Male vs US born English Female

                          N   Mean  StDev  SE Mean
US born English Male    359  1.992  0.926    0.049
US born English Female  234  1.872  0.950    0.062


Difference = μ (US born English Male) - μ (US born English Female)
Estimate for difference:  0.1198
```

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Commented [OU4]: Instead of Annotated Bibliography, include a references list

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